DRAFT FINAL
VOLUME I OF II
(Revision 2)

# FEASIBILITY STUDY REPORT OPERABLE UNIT NO. 2 (GROUNDWATER) FORMER NEBRASKA ORDNANCE PLANT MEAD, NEBRASKA DACA 41-92-C-0023

Prepared for
Department of the Army
U.S. Army Engineers District
Kansas City District
Corps of Engineers
Kansas City, Missouri
May 1995

Woodward-Clyde

200-1e

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May 24, 1995
WCC Project 92KW030R

Commander
U.S. Army Engineer District, Kansas City
ATTN: CEMRK-EP-EC (Ms. Rosemary Gilbertson)
700 Federal Building
601 East 12th Street
Kansas City, Missouri 64106-2896

Re: Transmittal of Draft Final
Feasibility Study Report (Revision 2)
For Operable Unit No. 2 (Groundwater)
Former Nebraska Ordnance Plant, Mead, Nebraska
Contract No. DACA 41-92-C-0023

Dear Ms. Gilbertson:

We are hereby transmitting nine copies of the Draft Final Feasibility Study (FS) Report (Revision 2) for the former Nebraska Ordnance Plant near Mead, Nebraska. The FS Report (Revision 2) consists of a partial revision of the FS Report (Revision 1) transmitted in December 1994. We are transmitting the revised material which should be placed in the FS Report (Revision 1) binders according to the directions printed on the blue sheets of paper. The attached revision summary lists the material included in this transmittal. The remainder of the FS Report (Revision 2) consists of the unchanged FS Report (Revision 1) material. Distribution of the remaining copies of this document have been made in accordance with the attached distribution list.

Please contact us should you have any questions.

Very truly yours,

Douglas E. Fiscus. P.E.
FS Task Leader

Robert F. Skach
Project Manager

Enclosure

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## REVISION SUMMARY

## DRAFT FINAL FEASIBILITY STUDY REPORT (Revision 2)
## FOR FORMER NEBRASKA ORDNANCE PLANT
## MEAD, NEBRASKA
## CONTRACT NO. DACA 41-92-C-0023

## MAY 1995

| Volume I of II | |
|---|---|
| 1. | Letter of transmittal |
| 2. | Binder cover insert |
| 3. | Title pages, Table of Contents |
| 4. | List of Abbreviations, Acronyms, and Terms |
| 5. | Sections 1 through 7 |
| 6. | Table 2-1A |
| 7. | Table 2-1B |
| 8. | Table 4-1 |
| 9 | Table 4-2 |
| **Volume II of II** | |
| 1. | Binder cover insert |
| 2. | Appendix B (Table of Contents and Sections 1 through 4) |
| 3. | Appendix L (Table of Contents and Sections 1 through 4) |
| 4. | Appendix L (Table L-7) |

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| Natural Resource District<br>ATTN: Larry Angle | 1 |
| U.S. Army Center for Health Promotion and Preventative Medicine (Provisional)<br>ATTN: MCHB-ME-R (Andrew Maly) | 8 |

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
700 FEDERAL BUILDING
KANSAS CITY, MISSOURI 64106-2896

REPLY TO
ATTENTION OF:

December 29, 1994

Hazardous, Toxic and Radioactive
Waste Branch

Mr. Michael Sanderson
Environmental Protection Agency
Region VII
726 Minnesota
Kansas City, Kansas 66101

Dear Mr. Sanderson:

Please find enclosed the revised Draft Final Feasibility Study (FS) for Operable Unit 2 (OU2) for the former Nebraska Ordnance Plant.

As a result of extensive discussion and coordination among our staffs since the previous June 1994 submission, I believe this version reflects acceptable resolution of outstanding issues. However, because of the extensive changes in this version (as a result of issue resolution), this submission more closely resembles a draft document as opposed to a draft final. I am also concerned with two other aspects of this version with regard to evaluation of acceptability and ask that you consider my concerns during your review.

a. In the absence of timely receipt of clarification of State ARARs from the Nebraska Department of Environmental Quality (NDEQ), we prepared this FS based on our interpretation. We originally proposed the submittal date of December 30, 1994 conditioned on receipt of NDEQ ARAR's interpretation by October 14, 1994. We received this requested information on December 23 1994 which did not allow sufficient time for analysis and incorporation into this version of the FS. Thus, I do not expect that the standard of an "acceptable FS" include an evaluation of this information.

b. Because of the disapproval of our extension request for the submission of the Draft Final Proposed Plan 60 days <u>after</u> submission of this document, the Draft Final Feasibility Study, we submitted a Proposed Plan on October 30, 1994. This submission was out of the normal IAG and NCP sequence. Both the Feasibility Study and Proposed Plan may now require further revision to ensure consistency and mutual supportability.

In an effort to continue to focus efforts on remediation of this site, I have instructed my staff to discuss these topics as agenda items during the meeting here in Kansas City on January 19 1995. I am confident that our staffs will continue to attempt to resolve these and any other issues or concerns.

Please call me if you have any questions or concerns regarding this letter.

Sincerely,

Richard H. Goring
Colonel, Corps of Engineers
District Engineer

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
700 FEDERAL BUILDING
KANSAS CITY, MISSOURI 64106-2896

REPLY TO
ATTENTION OF:

December 29, 1994

Hazardous, Toxic and Radioactive
Waste Branch

Mr. Randall Wood
Director
Nebraska Department of Environmental Quality
The Atrium Building
1200 N Street, Suite 400
P.O. Box 98922
Lincoln, Nebraska 68509-8922

Dear Mr. Wood:

Please find enclosed the revised Draft Final Feasibility Study (FS) for Operable Unit 2 (OU2) for the former Nebraska Ordnance Plant.

As a result of extensive discussion and coordination among our staffs since the previous June 1994 submission, I believe this version reflects acceptable resolution of outstanding issues. However, because of the extensive changes in this version (as a result of issue resolution), this submission more closely resembles a draft document as opposed to a draft final. I am also concerned with two other aspects of this version with regard to evaluation of acceptability and ask that you consider my concerns during your review.

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Richard H. Goring
Colonel, Corps of Engineers
District Engineer

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Engineering & sciences applied to the earth & its environment

December 29, 1994
WCC Project 92KW030R

Commander
U.S. Army Engineer District, Kansas City
ATTN: CEMRK-ED-TD (Ms. Rosemary Gilbertson)
700 Federal Building
601 East 12th Street
Kansas City, Missouri 64106-2896

Re: Transmittal of Draft Final
Feasibility Study Report (Revision 1)
For Operable Unit No. 2 (Groundwater)
Former Nebraska Ordnance Plant, Mead, Nebraska
Contract No. DACA 41-92-C-0023

Dear Ms. Gilbertson:

We are hereby transmitting nine copies of the Draft Final Feasibility Study (FS) Report (Revision 1) for the former Nebraska Ordnance Plant near Mead, Nebraska. Distribution of the remaining copies of this document has been made in accordance with the attached distribution list.

Please do not hesitate to contact us should you have any questions.

Very truly yours,

Douglas E. Fiscus, P.E.
FS Task Leader

Robert F. Skach, P.E.
Project Manager

Enclosure

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DRAFT FINAL
VOLUME I OF II
(Revision 2)

# FEASIBILITY STUDY REPORT OPERABLE UNIT NO. 2 (GROUNDWATER) FORMER NEBRASKA ORDNANCE PLANT MEAD, NEBRASKA DACA 41-92-C-0023

Prepared for
Department of the Army
U.S. Army Engineers District
Kansas City District
Corps of Engineers
Kansas City, Missouri
May 1995

Woodward-Clyde Consultants
10975 El Monte, Suite 100
Overland Park, Kansas 66211

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## LIST OF ABBREVIATIONS, ACRONYMS, AND TERMS

The following abbreviations, acronyms, and terms are commonly used in environmental reports, work plans, and guidance documents. Not all of these abbreviations, acronyms, and terms have been used in this document. They are listed here as an aid to the reader because they are in common use in the industry or are specific to the subject of this document.

| **Term** | **Definition** |
|---|---|
| 2-ADNT | 2-Amino-4,6-dinitrotoluene |
| 4-ADNT | 4-Amino-2,6-dinitrotoluene |
| ARARs | Applicable or Relevant and Appropriate Requirements |
| ARDC | Agriculture Research and Development Center of the University of Nebraska, formerly the University of Nebraska Field Laboratory (UNFL) |
| ASTM | American Society for Testing and Materials |
| ATSDR | Agency of Toxic Substance and Disease Registry |
| bgs | below ground surface |
| BOD | Biochemical Oxygen Demand |
| BRA | Baseline Risk Assessment |
| CDAP | Chemical Data Acquisition Plan |
| CCL | CompuChem Laboratories, Research Triangle Park, North Carolina |
| CDI | Chronic Daily Intake |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| CFA | Continuous Flight Augers |
| CFR | Code of Federal Regulations. The CFR are published in numbered titles such as 40 CFR and numbered parts such as 40 CFR 280. |
| CHSO | Corporate Health and Safety Officer |
| CLP | Contract Laboratory Program. Protocol for chemical analysis and documentation promulgated by EPA for laboratories under contract to EPA or other laboratories used for CERCLA Sites. |
| COC | Chemical of Concern |
| CRP | Community Relations Plan |
| CTV | Critical Toxicity Value |

| Term | Definition |
|---|---|
| DCA | 1,1-Dichloroethane |
| DCE | cis-1,2-Dichloroethene |
| DERP | Defense Environmental Restoration Program |
| DNAPL | Dense, Non-Aqueous Phase Liquid |
| DNB | Dinitrobenzene |
| 2,4-DNT | 2,4-Dinitrotoluene |
| 2,6-DNT | 2,6-Dinitrotoluene |
| DoD | Department of Defense |
| DO | Dissolved Oxygen |
| Donohue | SEC Donohue, Inc. (formerly Donohue & Associates, now RUST Environmental and Infrastructure) |
| DQO | Data Quality Objectives |
| ECD | Electron Capture Detector |
| EP | Extraction Procedure |
| EPA or USEPA | U.S. Environmental Protection Agency |
| ER | Electrical Resistive Logging Device |
| ESE | Environmental Science and Engineering, Inc. |
| FID | Flame Ionization Detector |
| FP | Field Protocols (CDAP, Part II) |
| FS | Feasibility Study |
| FSP | Field Sampling Plan |
| FUDS | Formerly Used Defense Site |
| GC | Gas chromatograph |
| GPD | Gallons per day |
| GSA | General Services Administration |
| HI | Hazard Index |
| HMX | Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine |
| HNu | Portable organic vapor analyzer using a PID manufactured by HNu Corporation. |
| HQ | Hazard Quotient |
| HSA | Hollow-Stem Augers |
| HSO | Health and Safety Officer |
| HTW | Hazardous/Toxic Waste |
| IAG | Interagency Agreement |
| i.d. | inside diameter |
| IDW | Investigation - Derived Waste |

| Term | Definition |
|---|---|
| IF | Intake Factor |
| K | Hydraulic conductivity |
| $K_d$ | Distribution coefficient |
| $K_{oc}$ | Organic carbon partition coefficient |
| $K_{ow}$ | Octanol-water partition coefficient |
| Law | Law Environmental, Inc., Albuquerque, New Mexico |
| Load Line | Bomb Load Line (No. 1, 2, 3, and 4) |
| LOAEL | Lowest-Observed-Adverse-Effect-Level |
| MCL | Maximum Contaminant Level |
| mg/kg | Milligrams per kilogram (ppm by weight) equivalent to µg/g |
| mg/L | Milligrams per liter (ppm) |
| MRI | Midwest Research Institute, Kansas City, Missouri |
| MSL | Mean Sea Level |
| MTV | Mobility, Toxicity, and Volatility |
| MW | Monitoring Well (Groundwater) |
| NAPL | Non-Aqueous Phase Liquid |
| NCP | National Contingency Plan |
| NDEQ | Nebraska Department of Environmental Quality |
| NDOH | Nebraska Department of Health |
| NOAA | National Oceanic and Atmosphere Agency |
| NOAEL | No-Observed-Adverse-Effect-Level |
| NOP | Nebraska Ordnance Plant |
| NPL | National Priorities List |
| NRD | Lower Platte (North) Natural Resources District |
| OAC | Ordnance Ammunition Command |
| o.d. | outside diameter |
| ORP | Oxidation Reduction Potential |
| OSWER | Office of Solid Waste and Emergency Response |
| OU | Operable Unit |
| OU1 | Operable Unit 1 (Soils) |
| OU2 | Operable Unit 2 (Groundwater) |
| OU3 | Operable Unit 3 (Landfill and any currently unidentified disposal areas) |
| OVA | Organic Vapor Analyzer |
| OVM | Organic Vapor Monitor |
| Ortek | Ortek Environmental Laboratories |

| Term | Definition |
|---|---|
| PA | Preliminary assessment |
| PCB | Polychlorinated biphenyl |
| PCE | Tetrachloroethene (tetrachloroethylene) (also known as perchloroethylene) |
| PES | Plains Environmental Services, Inc., Salina, Kansas |
| PHSO | Project Health and Safety Officer |
| PID | Photo ionization detector |
| POTW | Publicly Owned Treatment Works |
| ppb | Parts per billion (μg/kg and μg/L) |
| PPE | Personal Protective Equipment |
| ppm | Parts per million (mg/kg and mg/L) |
| PVC | Polyvinyl Chloride |
| PWP | Project Work Plan |
| QA/QC | Quality Assurance/Quality Control |
| QAP | Quality Assurance Plan (CDAP, Part III) |
| QCRs | Quality Control Reports |
| RA | Remedial Action |
| RAO | Remedial Action Objective |
| RAGS | Risk Assessment Guidance for Superfund |
| RD | Remedial Design |
| RDA | Recommended Daily Allowance |
| RDX | Hexahydro-1,3,5-trinitro-1,3,5-triazine |
| Region VII | EPA Region VII |
| RfC | Reference Concentration |
| RfD | Reference Dose (Subchronic) |
| RI/FS | Remedial Investigation/Feasibility Study |
| RI | Remedial Investigation |
| RME | Reasonable Maximum Exposure |
| ROD | Record of Decision |
| RUST | Rust Environment and Infrastructure (formerly SEC Donohue) |
| SARA | Superfund Amendments and Reauthorization Act of 1986 |
| SCBA | Self Contained Breathing Apparatus |
| SEC Donohue | SEC Donohue, Inc. (formerly Donohue & Associates, now Rust Environment and Infrastructure) |
| SF | Slope Factor |
| SHERP | Safety, Health, and Emergency Response Plan document |

| Term | Definition |
|---|---|
| SI | Site Inspection |
| Site | Former Nebraska Ordnance Plant (NOP) NPL Site |
| SPO | Sampling Plans and Objectives (CDAP, Part I) |
| SPT | Standard Penetration Test |
| SSO | Site Safety Officer |
| SVOC | Semivolatile Organic Compound |
| T | Transmissivity |
| TAL | Target Analyte List. EPA's list of hazardous inorganic compounds (see CDAP Part III) |
| TBC | To Be Considered |
| TC | Toxicity Characteristics (Reference: 40 CFR 261.24) |
| TCA | Trichloroethane (all isomers) |
| 1,1,1-TCA | 1,1,1-Trichloroethane |
| TCE | Trichloroethene (trichloroethylene) |
| TCL | Target Compound List. EPA's list of hazardous organic compounds (see CDAP Part III) |
| TCLP | Toxicity Characteristic Leaching Procedure (Reference: 40 CFR 261-Appendix II, SW 846 Method 1311) |
| TCO | Total Chromatographable Organics |
| TCT | Twin City Testing |
| TDS | Total Dissolved Solids |
| THC | Total hydrocarbons (quantitated as diesel) |
| TKN | Total Kjeldahl Nitrogen |
| TNB | 1,3,5-Trinitrobenzene |
| TNT | 2,4,6-Trinitrotoluene |
| TOC | Total Organic Carbon |
| TOX | Total Organic Halides |
| TSS | Total Suspended Solids |
| UCL | Upper Confidence Limit |
| UN | University of Nebraska |
| USACE | United States Army Corps of Engineers |
| USATHMA | United States Army Toxic and Hazardous Materials Agency |
| USC | Unified Soil Classification System |
| USDA | United States Department of Agriculture |
| USDHHS | United States Department of Health and Human Services |
| USEPA or EPA | United States Environmental Protection Agency |

| Term | Definition |
|---|---|
| USFWS | United States Fish and Wildlife Service |
| UV | Ultraviolet |
| UXO | Unexploded Ordnance |
| VOA | Volatile Organic Analysis |
| VOC | Volatile Organic Compound |
| WC | Woodward-Clyde |
| WCC | Woodward-Clyde Consultants |
| WQ1 | First set of general water quality parameters collected during the RI |
| WQ2 | Second set of general water quality parameters collected during the February 1993 groundwater sampling event for the FS |
| μg/L | Micrograms per liter (ppb by volume) |
| μg/kg | Micrograms per kilogram (ppb by mass) |

# 1.0
# INTRODUCTION

## 1.1 PURPOSE AND ORGANIZATION OF REPORT

### 1.1.1 Purpose

This Feasibility Study (FS) Report for Operable Unit No. 2 (OU2) of the former Nebraska Ordnance Plant (NOP) near Mead, Nebraska, (Site) has been prepared by Woodward-Clyde Consultants (WCC) under Contract No. DACA 41-92-C-0023 for the U.S. Army Corps of Engineers (USACE), Kansas City District. This report was prepared in conformance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), amended by the Superfund Amendments and Reauthorization Act (SARA), and its governing regulations, the National Contingency Plan (NCP), 40 CFR Part 300. Under CERCLA, uncontrolled hazardous waste sites which may pose risks to public health or the environment due to contamination of environmental media (such as groundwater or soil) are studied through the Remedial Investigation/Feasibility Study (RI/FS) process. The purpose of the RI is to characterize the nature and extent of contamination. The purpose of the FS is to develop and evaluate remedial action alternatives that address potential risks and comply with regulatory requirements. The FS process is based on technical, environmental, public health, and economic considerations so that an informed risk management decision can be made concerning selection of the most appropriate remedial action for a site.

The scope of work for this FS is described in the Feasibility Study Work Plan (WCC, 1992b) prepared by WCC and approved by USACE, U.S. Environmental Protection Agency (EPA), and the Nebraska Department of Environmental Quality (NDEQ).

### 1.1.2 Interagency Agreement

According to an Interagency Agreement (EPA, 1991g) between the EPA, NDEQ, and USACE, the Site is divided into three operable units (OUs). Operable units are defined to streamline remedial activities for specific contaminated media. Remedial response actions at the Site will be based upon the assignment of contaminated media to these operable units. OU1 includes explosives-contaminated soil which pose an unacceptable risk to human health. OU2 includes contaminated groundwater, and OU3 includes the former landfill located near the Wastewater Treatment Plant and any other disposal areas not included in the first two OUs.

Although the intent of dividing the Site into three OUs was to streamline remedial activities, the OUs share some common contaminants and contaminated media which requires coordination between the activities associated with each OU. The specific investigations that correspond to each of the OUs are listed in the following table.

| Operable Unit | Media | Investigation Areas | Investigation Target Analytes |
|---|---|---|---|
| OU1 | soil | Administration Area | explosives, metals, polychlorinated biphenyls (PCBs) |
| | | Ammonium Nitrate Plant | PCBs |
| | | Bomb Booster Area | explosives, metals |
| | | Burning/Proving Grounds | explosives, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), PCBs/pesticides, metals/cyanide |
| | | Load Lines 1,2,3 and 4 | explosives, metals, PCBs |
| | | Atlas Missile Area | trichloroethene (TCE) |
| | surface water, sediment | Johnson Creek | explosives, metals, nitrates/nitrites, VOCs |
| OU2 | soil | Administration Area | VOCs, SVOCs, pesticides, metals/cyanide at locations not sampled during OU1 |
| | | Atlas Missile Area | VOCs |
| | | Load Line 1 | VOCs |
| | soil gas | Administration Area | VOCs |
| | | Atlas Missile Area | VOCs |
| | | Load Line 1 | VOCs |
| | groundwater | Administration Area | VOCs, SVOCs, explosives, pesticides/PCBs, metals/cyanide |
| | | Atlas Missile Area | VOCs, explosives |
| | | Bomb Booster Area | VOCs, explosives |

| Operable Unit | Media | Investigation Areas | Investigation Target Analytes |
|---|---|---|---|
| | | Landfill Area | VOCs, SVOCs, explosives, pesticides/PCBs, metals/cyanide, radionuclides |
| OU2 (Cont.) | groundwater (Cont.) | Load Lines 1,2,3 and 4 | VOCs, explosives |
| | | Platte River Alluvial Aquifer | VOCs, explosives |
| OU3 | soil | Waste Disposal Areas | VOCs, SVOCs, metals, PCBs, explosives, |
| | | Burning Grounds, Proving Grounds, Demolition Grounds, Demolition Areas | VOCs, SVOCs, metals, explosives |
| | groundwater | Landfill Area Ammonium Nitrate Plant, Load Lines 1, 2, 3, and 4 | thiodiglycol nitrates/nitrites metals |
| | soil and groundwater | Underground Storage Tanks | SVOCs; benzene, toluene, ethylbenzene, xylene (BTEX); total petroleum hydrocarbons (TPH) |
| | sediment | Johnson and Silver Creeks | VOCs, SVOCs, metals, explosives |
| | surface water | Johnson and Silver Creeks | VOCs, SVOCs, metals, explosives |
| | building surface materials | Load Lines and Igloo Storage Buildings | explosives and metals |

A Proposed Plan for OU1 was issued in May 1994 (RUST, 1994b). The potential remedial actions for OU1 have been identified as the following:

- Alternative 1: No Action
- Alternative 2: Biological Treatment
- Alternative 3: On-Site Thermal Treatment
- Alternative 4: On Site Landfill, Deed Restrictions and Groundwater Monitoring
- Alternative 5: Off-Site Landfill

The OU1 Proposed Plan identified incineration as the preferred alternative for explosives-contaminated soil which poses a risk to human health through ingestion. Explosives-contaminated soils will be excavated to a maximum depth of 4 feet as a part of OU1. The OU1 Record of Decision and Responsiveness Summary are currently being developed.

Potential remedial actions for OU2 are developed and evaluated in this FS Report.

Potential soil contamination by metals and cyanide is being evaluated under OU3. PCBs were addressed under a separate removal action which was completed in the fall of 1994. As a result of the coordination between OUs, further evaluations will be performed during the OU3 RI. Potential remedial actions for OU3 have not yet been identified.

### 1.1.3 FS Report Overview

The goal of an FS is to develop alternatives that provide a remedial action which is implementable, performance-oriented, cost-effective, and results in adequate protection of public health and the environment. There are three phases to an FS: the identification and screening of technologies, the development and screening of alternatives, and the detailed analysis of alternatives.

Section 1.0 summarizes the purpose and organization of this report and presents brief summaries of the site history, site background, nature and extent of contamination, and the fate and transport mechanisms. Section 2.0 presents the identification and screening of remediation technologies. The factors to be considered in the identification and screening of technologies are also discussed in Section 2.0, namely the remedial action objectives (RAOs), areas and volumes of contamination, and general response actions. Section 3.0 describes the development and screening of the remedial alternatives applicable to the affected media (soil and groundwater) at the Site. Section 4.0 analyzes the remedial alternatives according to criteria defined by EPA. Section 5.0 presents a cost-effectiveness analysis for the remedial alternatives described in Section 4.0. Section 6.0 briefly describes the next steps in the process: the acquisition of additional data, the remedial design/remedial action (RD/RA) process, and a generalized schedule for implementing RD/RA. Section 7.0 lists the references used in preparing this FS.

## 1.2 SITE BACKGROUND

### 1.2.1 Site Description

The Site is located approximately ½ mile south of Mead and 30 miles west of Omaha in Saunders County, Nebraska. Currently the land is owned by the University of Nebraska, Agricultural Research and Development Center (ARDC), U.S. Army, U.S. Department of

Commerce, and private interests. **Drawings 1-1** and **1-2** show the Site location and physical features, respectively.

### 1.2.2 Site History

This section is a summary of the Site History discussion from the RI Report (WCC, 1993c).

During World War II, the production facilities were operated from 1942 to 1945 by the Nebraska Defense Corporation, a Department of Defense (DoD) Contractor and subsidiary of Firestone Tire and Rubber Company. The former NOP was comprised of an Administration Area, an Ammonium Nitrate Plant, a Bomb Booster Assembly Plant, four Bomb Load Lines, Demolition Grounds, a sewage treatment plant, analytical laboratories, a laundry, vehicle and equipment maintenance shops, a landfill, Burning Grounds, Proving Range, and several square miles of bermed storage igloos and magazines located north and south of the load lines (**Drawing 1-2**).

Production was terminated and decontamination procedures were implemented during the interim period 1945 through 1949, and the NOP was placed on standby status. Decontamination procedures included cleaning, flushing, and sweeping of floors, rafters, pipes, and ventilation systems, flushing of contaminated ditches, and removal and burning of contaminated soils. At the North and South Burning Grounds near the Landfill Area, 340,000 pieces of ordnance were destroyed in 1946 (SEC Donohue, 1992). Tetryl boosters were destroyed at the Demolition Ground, which is located in the southwestern portion of the Site. The NOP was reactivated in 1950 in order to produce weapons for the Korean Conflict. In 1956, the NOP was again placed on standby status.

In 1959, approximately 960 acres were transferred to the U.S. Army Reserve for training grounds; 2,000 acres were granted to the U.S. Air Force for a missile site; and 40 acres were transferred to the Department of Commerce. From 1959 to 1960, the Offutt Air Force Base Missile Site S-1 launch area (Atlas Missile Area) was built on 1,185 acres north of Load Line 4. TCE was used during construction to degrease and clean pipelines used to carry liquid oxygen fuel for missiles. The missile silos were abandoned in 1964 and the Launcher Area and the Nike Area were transferred to the Nebraska National

Guard. U.S. Army activities included Nike missile maintenance at the former heavy equipment garage north of Load Line 1. The U.S. Air Force also occupied 34 acres of the northern portion of Load Line 1 for use as a "Tech Area" (ESE, 1983). The north end of Load Line 1 was also known as the Air Force Ballistic Missile Division (AFBMD) Tech Area.

In 1962, approximately 9,000 acres of the Site were purchased by the University of Nebraska for use as the ARDC. An additional 600 acres were purchased in 1964 for the ARDC. The remaining 5,000 acres were purchased by private individuals and corporations. A fireworks company operated for approximately 20 years at the former Bomb Booster Assembly Plant (Bomb Booster Area) until 1989. Two commercial enterprises currently manufacture insulation board and processed styrofoam packing material at the former administration buildings (Administration Area). The Site was placed on the National Priorities List (NPL) in August 1990.

### 1.2.3 Previous Investigations

Soil

The following discussion of investigations of contaminated soil at the Site is summarized primarily from the OU1 FS Report (RUST, 1994a).

In 1983, an Archives Search Report prepared by Environmental Science and Engineering (ESE) for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) concluded that the Site areas with the greatest potential for contamination were the four load lines, the Bomb Booster Area, and the Burning/Proving Grounds (ESE, 1983).

A Confirmation Study conducted by USACE in 1989 concluded that explosive residues are present in soil in some areas around Load Lines 1, 2, and 3. Additionally, VOCs were detected in soil samples from other areas, and a summary of previous investigations in the Confirmation Study Report showed that PCBs were detected in surface soil samples adjacent to locations of former electrical transformers. Refer to the Confirmation Study Report (USACE, 1989) for complete details.

A preliminary ordnance assessment conducted in 1991 concluded that TNT was visibly present, or present in soil at concentrations greater than two percent by weight at portions of Load Lines 1, 2, and 3 and the Burning/Proving Grounds (TCT, 1991).

USACE initiated the OU1 RI in 1991. Soil samples collected from the four load lines confirmed the presence of explosives contamination in Load Lines 1, 2, and 3 and PCB contamination at the locations of former electrical transformers in Load Lines 1, 3, and 4. Isolated locations of elevated metals concentrations were also detected. Refer to the Remedial Investigation Report (USACE, 1991) for a complete discussion of the investigation.

In 1992, a supplemental OU1 RI was conducted by SEC Donohue under contract to USACE. The purpose of the supplemental RI was to more completely characterize the horizontal and vertical extent of explosives-contaminated soil at the Site. The detailed results of the RI are presented in SEC Donohue (1992).

The results of the preliminary ordnance assessment, confirmation study, remedial investigation, and supplemental remedial investigation indicate that explosives contamination in soil is mostly limited to drainage ditches and sumps in the load lines. Explosives contamination in areas outside the ditches and sumps occur in isolated locations. In the load lines and the Bomb Booster Area, the contamination is believed to have originated from discharge of wash water from the ordnance manufacturing process. In the Burning/Proving Grounds, testing and burning activities probably contributed to soil contamination. No significant explosives contamination was identified in soils outside of the production areas or the Burning/Proving Grounds.

Ninety-one percent of the explosives-contaminated soil is found within 4 feet of the ground surface, but the maximum depth of contamination measured and detected in these studies is approximately 30 feet. Explosives compounds detected include:

- 2,4,6-Trinitrotoluene (TNT)
- Hexahydro-1,3,5-trintro-1,3,5-triazine (royal demolition explosive or RDX)
- 1,3-Dinitrobenzene (DNB)
- 2,4- and 2,6-Dinitrotoluenes (DNT)
- 1,3,5-Trinitrobenzene (TNB)

- Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (high melt explosive or HMX)
- n-2,4,6-Tetranitro-n-methylaniline (tetryl)
- o-Nitrotoluene
- m-Nitrotoluene
- p-Nitrotoluene

The OU1 Supplemental RI Report (SEC Donohue, 1992) included an evaluation of metals in soils. The nature and extent of metals contamination was assessed by identifying measured soil concentrations exceeding five times the mean measured background concentrations (or in some cases the reported average concentrations for U.S. soil). The majority of detected metals were not significantly above background. Two areas of elevated concentrations of chromium and silver/mercury were identified. These two areas do not appear to be co-located with explosives and will, therefore, be evaluated in OU3 as previously unidentified potential disposal areas. Twenty-three locations were identified where lead exceeded five times the background concentration. The EPA uptake-biokinetic model, used to evaluate the risks due to lead contamination in the soil, showed that two isolated areas may be of potential concern. However, the actual risk depends on the extent of the lead contamination, which will be investigated as part of OU3. It was also concluded that VOCs are not generally co-located with explosives. Endrin aldehyde was detected in one soil sample and ubiquitous phthalate semi-volatile organic compounds (SVOCs) were detected in some soil samples.

Groundwater

Groundwater sampling was initiated during the Confirmation Study (USACE, 1989). Samples were collected from 25 monitoring wells installed during the Confirmation Study and from water supply wells. These samples were analyzed for VOCs, explosives, metals (monitoring wells only), and pesticides/PCBs (water supply wells only). In a subsequent sampling event, additional water supply wells were sampled. RDX, TNT, and TCE were identified in groundwater samples from monitoring wells, and RDX and TCE were detected in water supply well samples. Some of the TCE concentrations exceeded the Maximum Contaminant Limit (MCL) of 5 micrograms per liter (μg/L), and some of the RDX concentrations exceeded the lifetime Health Advisory (2 μg/L). PCBs, pesticides, and petroleum hydrocarbons were not detected, and metals concentrations did not exceed MCLs. As a result of Confirmation Study, carbon filtration systems were installed at two residences and the ARDC Agronomy Building. Additionally, two ARDC water supply wells were removed from service.

In late 1989 and early 1990, a soil gas survey was conducted by Law Environmental under contract to USACE to evaluate areas of soil that may be contributing TCE contamination to groundwater (Law Environmental, 1990). Analysis for petroleum hydrocarbons was also performed. Approximately 10 areas were investigated during the survey, and while TCE and other VOCs and petroleum hydrocarbons were detected in the two intervals which were sampled, source areas were not definitively identified.

USACE installed and sampled 14 monitoring wells during the final stages of the OU1 RI but the results are not discussed in the RI Report (USACE, 1991). These wells were sampled during the OU2 RI, and the results are included in the OU2 RI Report (WCC, 1993c).

In 1992, an OU2 RI was conducted by WCC under contract to USACE. The primary purpose of the OU2 RI was to evaluate the nature and extent of potential chemicals of concern (COC) in the groundwater at the Site attributable to past DoD activities. The secondary objective was to evaluate the nature and extent of VOC contamination in soils at three areas (Administration Area, Atlas Missile Area, and the AFBMD Tech Area) to assess whether or not these contaminants are possible continuing sources of VOCs in the groundwater. The OU2 RI was conducted in two phases. Phase I included soil gas sampling, soil sampling, groundwater headspace analysis, Hydropunch® groundwater sampling, borehole geophysics, and groundwater monitoring well installation and sampling. The groundwater headspace screening for VOCs provided information which assisted in locating the 89 monitoring wells installed during the first phase. Phase II included soil and soil gas sampling at Load Line 1, and a second round of groundwater sampling.

Subsequent to the OU2 RI, an Additional Field Investigation (AFI) was conducted to confirm the extent of contamination along the leading edges of groundwater contamination in the Todd Valley and the Platte River Valley. Groundwater samples were collected for headspace gas analysis and eight monitoring wells were installed. The details of the AFI are in the AFI Technical Memorandum (WCC, 1993f).

Groundwater samples were collected from all of the 136 monitoring wells on a quarterly basis beginning during the RI (August 1992) and continuing for one year. The results are discussed in the Quarterly Groundwater Sampling Report (WCC, 1993b). The analytical parameters are tabulated in **Table 1-1**, the soil gas results are summarized in **Table 1-2**, and the groundwater results are summarized in **Table 1-3**. The locations of all monitoring wells is shown on **Drawing 1-3**, the soil gas results are presented on **Drawing 1-4** through **Drawing 1-6**, and the groundwater results are presented graphically on **Drawing 1-7** through **Drawing 1-21**. The estimated horizontal extent of TCE in shallow groundwater monitoring wells is shown on **Drawing 1-7**, the extent of TCE in intermediate wells is on **Drawing 1-8**, and the extent of TCE in deep wells is on **Drawing 1-9**. The estimated horizontal extent of RDX in groundwater monitoring wells is shown for shallow wells on **Drawing 1-10** and for intermediate wells on **Drawing 1-11**. The locations of the cross sections which define the vertical extent of TCE and RDX are depicted in **Drawing 1-12**. The vertical extent of TCE is shown on **Drawings 1-13, 1-18**, and **1-21**. The vertical extent of RDX is shown on **Drawings 1-10, 1-11, 1-14** through **1-17, 1-19** and **1-20**. Continued quarterly sampling of selected monitoring wells is ongoing as described in modifications to the Chemical Data Acquisition Plan (WCC, 1994e).

Outside of OU2 investigations, groundwater samples have been collected from water supply wells at, and in the vicinity of the Site. Those sampling results are summarized in **Table 1-4**.

### 1.2.4 Geology/Hydrogeology

The following discussion is a summary of Site geology/hydrogeology. Refer to the OU2 RI Report (WCC, 1993c) for complete details.

The Site is located in the Todd Valley, an abandoned alluvial valley of the ancestral Platte River. The thickness of unconsolidated material above bedrock at the Site ranges from approximately 81 feet to 157 feet. The unconsolidated material consists of topsoil, loess, sand, and gravel. The uppermost bedrock is the Omadi Shale in the northwest and the Omadi Sandstone in the southeast.

Three aquifers are present at the Site: the Omadi Sandstone aquifer, the Todd Valley aquifer, and the Platte River alluvial aquifer. Three aquitards are present: the Pennsylvanian shales, the Omadi Shale, and the Platte River aquitards. Where the Omadi Shale is absent, the Omadi Sandstone and Todd Valley aquifers are in hydraulic communication and behave as a single aquifer without hydraulic barriers.

The water-bearing portions of the unconsolidated material in the Todd Valley are divided into two units, an upper fine sand unit and a lower sand and gravel unit. During the OU2 RI, the sand and gravel unit was found to range from 17.5 to 72 feet thick and the fine sand unit was found to range from 12 to 77 feet thick. The upper fine sand unit is overlain by 4 to 23 feet of the Peoria Loess.

The sands and sandy gravels of the Platte River Valley, which range from 39 to 49 feet thick, were not deposited at the same time as the sands and gravels of Todd Valley. Overbank silts and clays ranging from 10 to 17 feet thick overlie the Platte River alluvial sands.

The water table surface of the Todd Valley slopes toward the south-southeast. A major zone of groundwater discharge is located along the western side of the Platte River Floodplain in the southeastern portion of the Site. East of Johnson Creek, the water table surface of the Platte River alluvial aquifer slopes to the south, paralleling the Platte River Valley.

### 1.2.5 Nature and Extent of Contamination

Results of soil investigations conducted by TCT (TCT, 1991), USACE (USACE 1989 and 1991), and RUST (RUST 1994a and 1994b) indicate that explosives contamination in soil is mostly limited to drainage ditches and wash water sumps in the load lines. Explosives contamination in areas outside the ditches and sumps occurs in localized areas. In the load lines, the contamination is believed to have originated from discharge of wash water from the ordnance manufacturing process. In the Bomb Booster Assembly Area, activities involved in the manufacture of boosters potentially caused contamination. In the Burning/Proving Grounds, testing and burning activities probably caused the soil contamination. No significant explosives contamination was identified in the

Administration Area. Most of the contaminated soil is found within 4 feet of the ground surface, but the maximum depth of contamination detected is approximately 30 feet.

The OU2 RI identified four areas of groundwater contamination or four groundwater contamination plumes. A separate source area has been identified for each plume. Two of the plumes consist of explosives contamination (primarily RDX) and two of the plumes consist of primarily TCE-contaminated groundwater.

Groundwater contamination was found more extensively and at higher concentrations in the upper fine sand units relative to the underlying sand and gravel units. Generally, the least contamination was found in the deepest of the three aquifers, the Omadi Sandstone aquifer.

Data collected during the OU1 RI and OU2 RI were used to characterize the potential for the Atlas Missile Area and the north end of Load Line 1 (AFBMD Tech Area) to be sources of TCE in the groundwater. The characterization of source areas was inconclusive with regard to active sources. An effective investigation methodology is not available to further evaluate the source potential. Therefore, remedial actions to address volatile organics in soil vapor are not currently warranted. A pilot-scale soil vapor extraction (SVE) study will be conducted, and the study will have two purposes:

- Characterize the potential of the two areas with respect to the recovery of TCE from soil gas.
- Evaluate the SVE performance for site specific conditions.

### 1.2.6 Environmental Fate and Transport

The fate and transport of the explosive compounds present in soil at the Site are determined primarily by adsorption, biodegradation, and photodegradation. Some biotransformation of TNT, RDX, DNT, and tetryl may occur, however, photolysis will only be potentially significant in surface waters. The explosive compounds at the Site, therefore, will likely persist in surface soil and slowly leach into the groundwater. Soil sample results from OU1 and groundwater data from OU2 support this. Refer to the OU1 FS (RUST, 1994a) for a discussion of the fate and transport analysis of explosives in soil at the Site.

The fate and transport of potential contaminants in groundwater were analyzed in the OU2 RI to identify off-site areas potentially affected by contamination and to estimate contaminant concentrations in those areas. The fate and transport analysis was a multiple step procedure which consisted of screening the potential routes of contamination, identifying the persistence of the contaminants in terms of their physicochemical properties, and quantitatively simulating contaminant migration for the predominant transport mechanisms identified during the screening process. The contaminant transport analysis was evaluated for the sand and gravel unit of the Pleistocene aquifer where the groundwater velocity was estimated to be higher relative to the overlying fine sand unit. The concentrations which were estimated using the analytical model were compared to concentrations measured in shallow, intermediate, and deep monitoring wells. Refer to the OU2 RI Report (WCC, 1993c) for a complete discussion of the fate and transport analysis performed for the Site.

### 1.2.7 Baseline Risk Assessments

The purpose of a Baseline Risk Assessment (BRA) is to evaluate potential human health hazards (both carcinogenic and non-carcinogenic effects) that may result from exposure to contaminated media at the Site.

A Site Conceptual Model was developed to identify potential exposure pathways. The OU1 BRA (SEC Donohue, 1993) evaluated pathways associated with explosives-contaminated soil, and the OU2 BRA (WCC, 1994c) evaluated pathways associated with contaminated groundwater. The cumulative cancer risks and Hazard Indices for soil and groundwater were also developed in the OU2 BRA.

#### 1.2.7.1 Site Conceptual Model

A site conceptual model was developed for the OU2 BRA (WCC, 1994c) based on the data collected during the OU2 RI. For purposes of evaluating potential exposure to contaminated groundwater, the OU2 BRA evaluated potential risk associated with the two most contaminated groundwater monitoring wells (MW-5B and MW-40B). These wells were chosen for evaluation because they contain the highest concentrations of RDX

(MW-5B) and TCE (MW-40B), the two potential chemicals of concern that contributed to the majority of Site risk.

As can be seen on the Site Conceptual Exposure Model **Drawing 1-22**, the primary source of contamination is surface wastes/spills. The release mechanisms are infiltration/leaching, mixing with surface soils, surface runoff, and wind erosion for surface wastes/spills. Additional (secondary) sources potentially resulting from releases from the primary sources include subsurface soils, surface soils, surface water/sediment, air particulates, and air VOCs. The corresponding release mechanisms for the secondary sources include infiltration, future intrusive action, bioaccumulation, and direct contact. The exposure routes associated with this direct contact include both dermal exposure and incidental ingestion. Additional (tertiary) sources include surface water seeps, groundwater, irrigation water/stock ponds, air VOCs, and food (typically vegetables and beef).

The exposure routes for all of the sources described above are ingestion, inhalation, and dermal contact. Three potential receptors were identified:

- On-site farm family
- On-site worker
- Construction worker

The complete exposure routes for all potential receptors for the groundwater pathway are ingestion, inhalation, and dermal contact (ingestion is considered a minor pathway for the construction worker). In addition to the groundwater pathways, the construction worker was assumed to have complete exposure pathways from dermal, oral and inhalation exposure to contaminants in subsurface soil. The remaining exposure pathways identified in the OU2 BRA are minor or incomplete.

Potential exposure to contaminants at the Site could also occur through ingestion of contaminated plants or animal life found on-site. Some of the food chain effects in vegetables or beef include bioconcentration, biomagnification, biotransformation and excretion. Because of the uncertainties inherent in the calculation of food chain effects, and because food chain effects have already been evaluated for soils in OU1, the exposure to chemicals through the food chain effects is not evaluated quantitatively in the OU2 BRA. To evaluate the extent of plant bioaccumulation under site-specific conditions, a plant uptake study will be included as part of the OU3 investigation. The plant uptake pathway will be re-evaluated after the planned plant uptake study is completed.

### 1.2.7.2 OU1 Baseline Risk Assessment

Potential cancer risks and non-carcinogenic health hazards were evaluated for surface soils in the OU1 BRA (SEC Donohue, 1993). Potential cancer risks and non-carcinogenic hazards for average and Reasonable Maximum Exposure (RME) exposures were found to be unacceptably high in the most contaminated portions of the Site for both workers and residential populations, with cancer risks as high as $2 \times 10^{-2}$ and Hazard Indices (HIs) as high as 300. EPA has defined RME as the highest exposure that can reasonably be expected to occur at a site. The regulatory (NCP) target cancer risk range is $10^{-6}$ to $10^{-4}$ and a hazard index value of 1 is considered a threshold for adverse non-cancer health effects. In order to address risks from multiple pathways, it is assumed that the risks/hazards that were reported for Site soils in the OU1 BRA are directly additive to the risks/hazards calculated for groundwater in the OU2 BRA. Cumulative risks for soil and groundwater pathways are discussed below.

### 1.2.7.3 OU2 Baseline Risk Assessment

As part of the OU2 studies, a BRA (WCC, 1994c) was performed to evaluate potential cancer risks and non-carcinogenic hazards posed by site-related chemicals. Additionally, risks/hazards were evaluated for VOCs in Site subsurface soils in the vicinity of Load Line 1 and the Atlas Missile Area.

An evaluation was performed of site-wide groundwater, and subsurface soils from the Atlas Missile Area and Load Line 1 to identify the potential COCs. Based on this evaluation, the following potential COCs were identified:

VOCs:

- Acetone
- 1,2-Dichloroethene (total)
- Methylene chloride
- Trichloroethene
- 1,1,1-Trichloroethane

Explosives:

- HMX
- RDX
- 1,3,5-Trinitrobenzene
- 2,4,6-Trinitrotoluene
- 2,4-dinitrotoluene

- 1,2-Dichloropropane
- Tetrachloroethene
- Chloroform

SVOCs:

- Diethyl phthalate
- Di-n-butylphthalate
- Phenol
- N-Nitrosodiphenylamine

Metals:

- Aluminum
- Lead
- Vanadium
- Nickel

The potential COCs identified in soils from the Atlas Missile Area and the AFBMD Tech Area consisted of three VOCs (acetone, benzene and trichloroethene). Other compounds in soils from these areas were evaluated in OU1.

Potential health risks (current and hypothetical future use scenarios) were estimated for a group of exposure scenarios believed to represent the most likely forms of human activities that might occur on or near the Site. The scenarios included residential and occupational exposure to groundwater and exposure of construction workers to VOCs in subsurface soils. Potential health risks were quantitatively evaluated for three potential exposure routes (ingestion, inhalation, and direct dermal contact) for both groundwater and soils.

The non-carcinogenic hazards and cancer risks associated with the two most contaminated monitoring wells, MW-58 and MW-40B, were evaluated using maximum exposure scenarios for all exposure scenarios. For well MW-5B, the HIs associated with the groundwater are 7 for child residents, 3 for adult residents, and 1 for Site workers. An HI value of 1 is considered a threshold for possible adverse non-cancer health effects. The potential total cancer risks associated with adult resident exposure to MW-5B groundwater are three in 10,000 ($3 \times 10^{-4}$) which exceeds the EPA advisory range of $10^{-6}$ to $10^{-4}$ for acceptable site risks. Virtually all of this risk is the result of RDX, the ingestion of which is estimated to result in $3 \times 10^{-4}$ risk. The cancer risk associated with the child resident exposed to MW-5B groundwater is $7 \times 10^{-5}$, and the cancer risk for the Site worker in the same scenario of $4 \times 10^{-5}$. Both of those cancer risks are within the advisory range of $10^{-6}$ to $10^{-4}$. For well MW-40B, the child HI is 13 and the adult resident HI is 3. Both of those values are in excess of the HI value of 1. For the same scenario, the Site worker is below the threshold of 0.9. The potential total cancer risk associated with adult resident exposure to MW-40B groundwater is 2 x $10^{-3}$, the risk associated with the child resident scenario is 7 x $10^{-4}$, and the risk associated with the Site worker is 2 x $10^{-4}$. All three potential total cancer risks exceed the advisory range result of $10^{-6}$ to $10^{-4}$. The majority of the risk is the result of exposure to TCE. For example, exposure to the TCE in groundwater from MW-40B results in 1 x $10^{-3}$ risk for adult residents.

A construction worker scenario was included in the OU2 BRA to evaluate the risks associated with the subsurface soils in the Atlas Missile Area and AFBMD Tech Area. Hazard Indices and cancer risks resulting from combined exposure to groundwater from MW-5B and subsurface soil from either the Atlas Missile Area or the AFBMD Tech Area are within or below the threshold value of 1. This indicates that exposure to chemicals in groundwater and subsurface soils in this area are not likely to result in unacceptable health effects to the construction workers. However, when it was assumed that construction workers were exposed to groundwater from MW-40B, the RME HIs for construction workers exposed to subsurface soils from either the Atlas Missile Area or the AFBMD Tech Area are at the threshold value of 1. Cancer risks are estimated to be 4 x $10^{-6}$ which is within the advisory range of $10^{-6}$ to $10^{-4}$. The majority of non-cancer hazard and cancer risk was associated with the groundwater pathways.

Cumulative cancer risks and HIs were summed for soil pathways evaluated in the OU1 BRA and groundwater pathways from the OU2 BRA. Cumulative soil/groundwater HIs were 5,000 for a child resident, 2,000 for an adult resident and 4 for a Site worker, indicating that portions of the Site may present a potential non-carcinogenic health hazard. These HIs were primarily a result of exposure to explosives in soils. The cumulative cancer risks for soil (OU1) and groundwater (OU2) were also driven by the soil exposures. Cumulative soil/groundwater cancer risks were estimated to be 6 x $10^{-2}$ for adult residents and 6 x $10^{-5}$ for Site workers, and were primarily due to exposures to explosives found in Site soils. Cancer risks are quantified only for adults exposed to soil.

The development of health-based Remedial Action Objectives (RAOs) is generally warranted when Site risks exceed some regulatory target risk (i.e., usually $10^{-6}$ to $10^{-4}$). Because risks associated with potential RME residential use of groundwater exceeds the

$10^{-6}$ to $10^{-4}$ range, RAOs need to be evaluated to ensure the health-protectiveness of any remedy selected for the Site. OU2 RAOs are presented in Section 2.2.1.

Risks associated with OU1 soils are presented in the OU1 BRA (SEC Donohue, 1993).

#### 1.2.7.4 Ecological Assessment

An ecological risk assessment was performed for OU1 which focused primarily on ecological exposures to contaminants in surface soils, sediment and surface water at the Site. Exposure of ecological receptors flora and fauna to contaminated groundwater was considered unlikely, except through crop irrigation, and was not addressed specifically in the OU1 BRA (SEC Donohue, 1993).

Although sediment and surface water samples have previously been collected from Johnson Creek and the NRD reservoir, additional samples will be collected during OU3.

According to U.S. Fish and Wildlife Service (WCC, 1993b), one species of fish in Saunders County, the Plains topminnow, is a candidate for threatened and endangered status. The Bald Eagle, Peregrin Falcon, Interior Least Tern, and Piping Plover are threatened and endangered, and the Ferruginous Hawk and Loggerhead Shrike are candidates for threatened and endangered status in Saunders County. The American Burying Beetle is also threatened and endangered.

#### 1.2.7.5 Data Limitations and Uncertainties

The results from the OU1 RI (USACE, 1991) and Supplementary OU1 RI (SEC Donohue, 1992) characterized the extent of soils contaminated with explosives resulting from past DoD activities at the Site. Treatability studies were conducted on Site soils to aid in the evaluation of the feasibility of remediating Site soils. Treatability studies were conducted for three soil treatment process options: rotary kiln incineration, vitrification, and slurry-phase biological treatment. The objectives and preliminary results of each study are discussed in the OU1 FS (RUST, 1994a) and the conclusions are summarized below:

- Contaminated soil from the Site can be treated using rotary kiln incineration to non-detect levels for explosives contaminants and treated soil would not be classified as Resource Conservation and Recovery Act (RCRA) hazardous waste by the toxicity characteristic.

- Contaminated soil from the Site can be treated using vitrification to non-detect levels for explosive contaminants and the vitrified mass would not be classified as RCRA hazardous waste by the toxicity characteristic.

- Under the conditions evaluated for the biological treatment study, limited treatment is achieved and biological treatment may not achieve the OU1 preliminary remediation goals (PRGs) calculated for the Site without further optimization.

The results from the OU2 RI (WCC, 1993c) characterized the general extent of groundwater contamination resulting from past DoD activities at the Site. Monitoring well clusters MW-60, MW-61, and MW-62 were installed after the OU2 RI. MW-60 was installed in the downgradient area between MW-20 and MW-37, and MW-61 was installed downgradient from MW-10 to refine the estimated extent of the explosives plumes. MW-62 was installed downgradient from MW-36, to refine the extent of the TCE plume.

Because OU2 RI was designed to characterize the Site, little data were collected that would directly apply to the feasibility of extraction and treatment of groundwater. Therefore, to provide adequate data for design and construction of the selected remedy, and to reduce the uncertainty inherent in a feasibility study, additional data collection will be necessary during the pre-design phase of the project. The following paragraphs and Section 6.0 briefly describe the type and benefit of the additional data collection.

A pumping test is required to evaluate the effectiveness of groundwater extraction or reinjection. Section 1.3.4 describes the pumping test currently being conducted the Site. Analysis of the impacts of injection of treated water may also be necessary. If treated water is discharged to surface water, the effects of this discharge on local streams must be analyzed.

Treatability studies to evaluate the effectiveness of carbon usage for carbon adsorption treatment are being conducted as described in Section 1.3.5. Treatability studies are being conducted to evaluate advanced oxidation treatment of groundwater as described in Section

1.3.5. Pilot testing may be necessary to evaluate vapor extraction and/or air sparging systems.

## 1.3 ONGOING AND INTERIM ACTIONS

### 1.3.1 Alternative Water Supply

Some of the domestic wells serving individual homes in the area have been contaminated by TCE and/or RDX to concentrations above the MCL of 5 $\mu$g/L for TCE and the Health Advisory Level of 2 $\mu$g/L for RDX. In these residences, the USACE has installed, and is maintaining, point-of-entry carbon adsorption treatment systems. These systems will be maintained as long as the groundwater contamination concentrations are above the MCL or Health Advisory at the supply well.

In addition, some of the water supply wells for the ARDC have been contaminated. The USACE has installed, and is maintaining, carbon adsorption point-of-entry treatment systems at each of the ARDC facilities which provide drinking water.

### 1.3.2 Removal Action

Currently, a Removal Action for contaminated groundwater at the Site is being designed. The specific objectives for the Removal Action are:

- Hydraulic containment of groundwater contamination to minimize expansion of the plumes prior to the initiation of the final remedy (the final remedy is the action that will be recommended in the Proposed Plan). The Removal Action is being conducted in two phases. Phase I addresses TCE-contaminated groundwater (including groundwater contaminated with both TCE and explosives). Phase II addresses groundwater that is contaminated with explosives only.

- Protection of unimpacted downgradient groundwater users

- Treatment and discharge of extracted groundwater to meet applicable standards

- Periodic monitoring of the effectiveness of the containment system

Because all of the proposed alternatives for the final remedy at the Site include the element of hydraulic containment, the Removal Action will be consistent with the final remedy.

The Hydraulic Containment Removal Action is being conducted with participation from EPA and NDEQ, and the public will be invited to participate during a future public meeting to be scheduled.

The Engineering Evaluation/Cost Analysis and Removal Action Design Documents are in the draft stage and are not currently available for public review.

### 1.3.3 Soil Vapor Extraction Pilot Study

As previously discussed, data does not conclusively indicate whether the Atlas Missile Area or the AFBMD Tech Area are continuing sources of TCE to groundwater. Therefore, remedial actions to address VOCs in soil vapor are not currently proposed. However, a pilot-scale soil vapor extraction (SVE) study is being conducted. The purpose of the study is to evaluate whether the study area unsaturated zone soils are continuing sources of TCE to groundwater. The evaluation will be based on the following:

- Determination of the presence or absence of a recoverable source of TCE from the unsaturated zone at the Atlas Missile Area or the AFBMD Tech Area
- The effectiveness of SVE in removing TCE from the unsaturated zone at the two locations

If the pilot study concludes that the study areas are continuing sources of TCE to groundwater, remedial action objectives may be established. Details of the SVE pilot study are presented in the Soil Vapor Extraction Pilot Study Work Plan (WCC, 1994h) and the results will be presented in a technical memorandum.

### 1.3.4 Pumping Tests

Currently, two pumping tests are being implemented at the Site, one south of Load Line 1 and one in the Platte River Valley. The specific objectives of the pumping tests are:

- Evaluate the performance of each test well in terms of its sustainable pumping rate, specific capacity, well loss, and well efficiency
- Estimate the transmissivity, hydraulic conductivity, and storativity of the Todd Valley aquifer and the Platte River Valley alluvial aquifer west of Johnson Creek in the vicinity of the pumping wells
- Evaluate and characterize the hydraulic communication between the Platte River Valley alluvial aquifer and the Omadi Sandstone
- Assess whether drawdowns will be affected by aquifer boundaries during extended continuous (72 hour) pumping
- Evaluate the radius of influence and zone of capture of each test well under steady-state conditions of continuous pumping
- Evaluate water quality during pumping
- Use well performance results in the final design phase of a containment system treatment facility

Subsequent to the completion of the pumping tests, the pumping test extraction wells may be used as the extraction wells as an element of the containment removal action. Details of the planned pumping tests are presented in the Pumping Test Work Plan (WCC, 1995b).

### 1.3.5 Treatability Studies

Bench scale treatability studies are currently being conducted to provide performance data needed to evaluate the potential feasibility of a given technology for treating the potential COCs. The treatability studies focus on two major Site contaminants, TCE and RDX. TCE and RDX are indicator chemicals that are used to define the extent of contamination as discussed in Section 2.2.2. The primary objectives of the studies are to:

- Develop Freundlich adsorption isotherm constants for the TCE and RDX using granular activated carbon (GAC)

- Assess the efficiency of selected Advanced Oxidation Process (AOP) technologies to treat the Site groundwater

The results of the GAC isotherm tests will be used to refine the literature-based GAC consumption rates presented in this FS Report. The AOP test results will be used to evaluate whether oxidation technologies are effective in removing contaminants detected in groundwater. If the AOP or the GAC process is successful, the results may be used to design on-site pilot studies. Details of the planned treatability studies are presented in the Groundwater Treatability Study Work Plan (WCC, 1994e) and the Chemical Data Acquisition Plan (WCC, 1994e).

### 1.3.6 Water Supply Monitoring

The objective of the water supply monitoring is to assess the quality of water from domestic, municipal, and irrigation wells located on or near the Site. Groundwater samples are currently being collected on a quarterly basis from irrigation wells, stock wells, ARDC supply wells, and residential wells which are used for domestic use. The samples are analyzed for VOCs and explosives, and the results are reported to the well owners, as well as the EPA, NDEQ, and Nebraska Department of Health (NDOH).

### 1.3.7 Monitoring Well Sampling

Groundwater samples are currently being collected on a quarterly basis from monitoring wells at the Site. The objectives of the groundwater sampling are as follows:

- Develop a historical record for comparison of future results
- Monitor and evaluate any changes in the extent of contamination with time
- Evaluate metals contamination and thiodiglycol contamination in support of OU3
- Support groundwater treatment design

Details of the quarterly groundwater sampling program are presented in modifications to the Chemical Data Acquisition Plan (WCC, 1994e).

**2.0**

# IDENTIFICATION AND SCREENING OF TECHNOLOGIES

## 2.1 INTRODUCTION

In this section, remedial technologies and process options are identified and screened based on site-specific information. This process involves the following steps:

- Develop remedial action objectives (RAOs) that address site-specific contaminants, contaminated media, and exposure pathways. OU1 and OU2 soil RAOs are discussed in Section 2.3.
- Identify areas and volumes of contamination (Section 2.4)
- Develop general response actions (GRAs) to satisfy the site-specific RAOs (Section 2.5)
- Identify and screen groundwater technologies and process options satisfying each GRA. The initial criterion for this screening is technical feasibility. Further screen the technically feasible technologies and process options based on effectiveness, implementability, and cost to select a representative process option for a given remedial technology type, where appropriate. Technologies retained after the second screening process (Section 2.6) are carried into Section 3.0 where they are assembled into alternatives.
- Identify and screen leaching soil technologies and process options (Section 2.7). Leaching soils are defined as (explosives) contaminated soils that are estimated to contribute to groundwater contamination for a given time period.
- Summarize the retained technologies and process options (Section 2.8).

## 2.2 OU2 REMEDIAL ACTION OBJECTIVES

RAOs consist of medium-specific or operable unit-specific goals for protecting human health and the environment; they specify the chemicals of concern, exposure routes, receptors, and acceptable contaminant levels for each exposure route. These objectives are based on available information, standards such as ARARs, and risk-based levels established in the BRA and therefore account for potential chemicals of concern. The three components of RAOs are: the Target Groundwater Cleanup Goals, the area of attainment; and the restoration time frame. The RAOs are developed in this section by taking the following actions:

- Defining sets of Preliminary Target Groundwater Cleanup Goals based on ARARs; or, in the absence of ARARs, either TBCs or human health-protective concentrations

- Defining the area within which remedial actions will be used to achieve the Target Groundwater Cleanup Goals for each set of Preliminary Target Groundwater Cleanup Goals

- Establishing the general restoration time frame for each set of Preliminary Target Groundwater Cleanup Goals

The following overall remedial action objectives have been established for OU2:

- Minimize the potential for ingestion of contaminated groundwater, or reduce concentrations to acceptable health-based levels

- Minimize the potential for dermal exposure to contaminated groundwater, or reduce concentrations to acceptable health-based levels

- Minimize the potential for inhalation of chemicals emanating from the use of contaminated groundwater, or reduce concentrations to acceptable health-based levels

RAOs which address contaminated soil have been established during OU1, and are discussed in Section 2.3.

The ultimate goal, inclusive of all of the OUs at the Site, is to provide protection so that simultaneous and cumulative exposures to all COCs will not result in unacceptable risk/hazard.

### 2.2.1 Preliminary Target Groundwater Cleanup Goals

A remedial action will be complete when the concentrations of the COCs in the area of attainment are reduced to the concentrations designated as the Final Target Groundwater Cleanup Goals. The Final Target Groundwater Cleanup Goals will be selected from the three sets of Preliminary Target Groundwater Cleanup Goals presented in this document. Extracted groundwater will meet disposal-dependent standards. The three sets of Preliminary Target Groundwater Cleanup Goals will be assembled from the levels which are ARARs, TBCs, or other health-based goals.

#### 2.2.1.1 ARARs

CERCLA, Section 121(d)(2)(A), requires that Superfund remedial actions meet any federal and/or state standards, requirements, criteria or limitations that are determined to be ARARs. Identification of ARARs must be conducted on a site-specific basis and involves a two-part analysis:

- A determination whether a given requirement is applicable
- If the requirement is not applicable, a determination whether the requirement is nevertheless relevant and appropriate

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address:

- A hazardous substance
- A pollutant
- A contaminant
- Remedial action
- Location
- Other circumstances at CERCLA sites

Relevant and appropriate requirements are cleanup standards and other environmental protection requirements that address similar problems or situations.

There are various types of requirements with which remedial actions may have to comply. The ARARs are grouped as follows:

- Ambient or chemical-specific ARARs: usually health- or risk-based numerical values or methodologies. (The application of these numerical values establishes the acceptable amount or concentration of a chemical that may exist in a media or discharged to the environment.)

- Performance, design or other action-specific ARARs: usually technology-or activity-based requirements or limitations on actions taken with respect to hazardous waste.

- Location-specific ARARs: restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in special locations.

**Tables 2-1A, B, C** summarize the three groups of potential ARARs for groundwater and subsurface soil for the Site. **Table 2-1A** presents the potential contaminant or chemical-specific ARARs. The maximum concentration levels (MCLs) and action levels are chemical-specific ARARs for groundwater. **Table 2-1B** presents those potential ARARs that are action-specific for the Site. **Table 2-1C** presents the potential location-specific ARARs applicable to the Site.

#### 2.2.1.2 TBCs

TBCs are non-promulgated advisories, criteria, or guidance issued by Federal or State government that are not legally binding and do not have the status of potential ARARs.

Lifetime Health Advisories (HAs) for diethyl phthalate (5,000 $\mu$g/L), phenol (4,000 $\mu$g/L), TNT (2 $\mu$g/L), RDX (2 $\mu$g/L) and HMX (400 $\mu$g/L) are TBC standards for the Site. The Drinking Water Equivalent Level (DWEL) for 2,4-DNT (100 $\mu$g/L) is also a TBC standard for the Site. The concentrations listed above are from EPA (1993b).

#### 2.2.1.3 Health-Based Cleanup Goals

The purpose of this section is to develop health-based cleanup goals for chemicals associated with DoD activities which are found in contaminated groundwater at the Site.

The establishment of health-based cleanup goals serves as an important means of guiding corrective actions. A health-based approach is warranted when cleanup standards are not promulgated by state or federal agencies for contaminants in the medium of concern (groundwater).

As identified in the OU2 BRA, use of maximum exposure assumptions indicates that the most-contaminated wells may potentially pose unacceptably high risk to exposed populations. To be protective of a potentially maximally exposed individual, health-based cleanup goals have been developed.

The methodology and rationale used to develop a set of health-based groundwater cleanup goals for Site contaminants include:

- Identification of Potential COCs (Section 2.2.1.3.1)
- Identification of potentially exposed receptor populations and potentially complete exposure pathways (Section 2.2.1.3.2)
- Identification of critical toxicity values for the chemicals requiring corrective action (Section 2.2.1.3.3)
- Calculation of health-based cleanup goals (Section 2.2.1.3.4)
- Identification of COCs (Section 2.2.1.3.5)

#### 2.2.1.3.1 Potential Chemicals of Concern

The purpose of this section is to develop a preliminary list of chemicals in the groundwater that may be of potential concern from a human health perspective. COCs are defined as those potentially toxic chemicals that may have been released to the environment in significant quantities as a result of site-related activities. As described in the OU2 BRA (WCC, 1994c), potential COCs are identified for site-wide groundwater using data from samples collected during the OU2 RI sampling activities. The selection criteria used to identify potential COCs are based on procedures outlined in Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual (EPA, 1989b). These criteria were developed by the EPA as a means of identifying those site-related chemicals most likely to contribute to potential health hazards.

Chemicals were excluded from the list of potential COCs using the following criteria:

- The chemical was not detected at the Site
- The chemical was a laboratory contaminant
- The chemical was present within background ranges
- The chemical was an essential nutrient and present at health-protective/beneficial levels

A subset of chemicals detected in groundwater was selected as the potential COCs (**Table 2-2**) as described above. This group of Site-related chemicals is believed to represent the greatest potential health risks associated with the Site. Health-based cleanup goals have been calculated for these compounds using exposure parameters and toxicity information developed in the OU2 BRA.

In Section 2.2.1.3.5, the concentrations of the potential COCs measured in monitoring well groundwater samples will be compared to the health-based cleanup goals calculated in Section 2.2.1.3.4. The final COCs (hereinafter referred to as "COCs") in groundwater will be the potential COCs which exceed the health-based cleanup goals.

#### 2.2.1.3.2 Exposure Assessment

The purpose of an exposure assessment is to estimate the magnitude of potential exposure among various receptor populations. The steps required to perform an exposure assessment include the following:

- Identification of potential receptor populations
- Evaluation of potential exposure pathways for completeness
- Evaluation of potential exposure parameters
- Estimation of daily intake factors

The exposure scenarios evaluated are identified in the OU2 BRA, and include both occupational and residential Site use. Exposure assumptions used to estimate contaminant intake by these populations are derived from a number of EPA and scientific sources.

including RAGS (EPA, 1989b), the Exposure Factors Handbook (EPA, 1989a), Standard Default Exposure Factors (EPA, 1991b), Dermal Exposure Assessment: Principles and Applications (EPA, 1992a), and site-specific information, when available.

The approach used to develop cleanup goals incorporates reasonable maximum exposure (RME) assumptions and reasonable Site use scenarios, so that residual risks posed by the Site after corrective action are within a health-protective range. It is important to note that the RME is meant to represent the most exposed individual in a population. Therefore, the estimates provided herein are conservative. Since cleanup goals developed using RME assumptions are health-protective for the most exposed individual in a population, the cleanup goals also would be health-protective for all potentially exposed individuals within that population.

Under current Site conditions, the populations of primary concern include both on-site workers and residents (see the discussion of the Conceptual Site Model, Section 1.2.7.1). As identified in the OU2 BRA, the greatest potential cancer risks were associated with adult resident receptors, while the largest hazard indices (i.e., non-carcinogenic effects) were associated with child resident receptors. Thus, to provide cleanup values that are protective of all potentially exposed individuals, cleanup goals for carcinogenic COCs are developed using adult resident exposure assumptions, while cleanup goals for non-carcinogenic COCs are developed using child resident exposure assumptions.

Among residential receptors, exposure to contaminants in groundwater is most likely to occur as a result of ingestion, dermal contact (showering), or inhalation (showering). In order to develop the chemical intake factors used to calculate cleanup goals, a number of exposure parameters that are used to characterize the receptor populations must first be quantified. Parameters typically evaluated include the following:

- Lifespan (days)
- Days per year (AT1; days)
- Averaging time (AT2; years)
- Exposure duration (ED; years)
- Exposure frequency (EF; days/year)
- Groundwater ingestion rate (IR; L/day)
- Body weight (BW; kg)

- Air inhalation rate (IH; $m^3$/day)
- Exposure time (ET; hours/day)
- Conversion Constant (Ks) from "shower" model (see **Appendix A**)
- Exposed body surface area (SA; $cm^2$)
- Permeability constant (PC; cm/hr)

These parameters are assigned numerical values following the precedence established by the OU1 FS. The exposure duration was assigned a value of 30 years, and the remainder of the parameters were assigned numerical values identified in the OU2 BRA (WCC, 1994c). (The BRA exposure duration was 70 years). The parameters were used as input to the exposure algorithms used to estimate the extent of chemical exposure.

Intake factors provide a means of estimating daily contaminant intake by exposed individuals. Equations used to calculate intake factors (IF) via ingestion ($IF_{ing}$), inhalation ($IF_{inh}$), and dermal ($IF_{der}$) contact (as determined in the OU2 BRA; WCC, 1994c) are as follows:

$$IF_{ing} = \frac{(IR * EF * ED)}{(BW * AT1 * AT2)}$$

$$IF_{inh} = \frac{(IH * ET * EF * ED * Ks)}{(BW * AT1 * AT2)}$$

$$IF_{der} = \frac{(SA * PC * ET * EF * ED)}{(BW * AT1 * AT2)}$$

For cancer causing chemicals, the intake factors (IFs) for adult residents are calculated for ingestion, dermal, and inhalation exposure to groundwater using exposure parameters developed and presented in **Table 2-3** (ingestion exposure), **Table 2-4** (dermal exposure), and **Table 2-5** (inhalation exposure). For non-cancer causing chemicals, the IFs for a 0-6 year old resident are calculated for ingestion, dermal, and inhalation exposure to groundwater using exposure parameters developed and presented in **Table 2-6** (ingestion exposure), **Table 2-7** (dermal exposure), and **Table 2-8** (inhalation exposure).

#### 2.2.1.3.3 Toxicity Assessment

As identified in the OU2 BRA, the potential COCs at the Site consist of a number of VOCs, SVOCs, explosives, and metals. Critical Toxicity Values (CTVs) for these chemicals are presented in this section. The CTVs are values established by the EPA that are used to quantify the potential carcinogenic and non-carcinogenic toxicity of the individual chemicals. Conversely, these values can also be used (in conjunction with intake factors) to calculate health-protective chemical concentrations that become the target cleanup goals.

Non-cancer effects are evaluated using a CTV known as a reference dose (RfD). The RfD can be considered a threshold dose. As long as the daily intake of a chemical by an exposed population is less than the RfD, no non-carcinogenic health hazard is believed to exist for that chemical (EPA, 1989b).

Cancer effects are evaluated using a CTV known as a slope factor (SF). The SF can be considered a measure of the potential carcinogenicity of a compound. In general, the larger the SF, the greater the potential carcinogenicity of the chemical and the lower the target cleanup goal. In addition to the SF, carcinogens are also evaluated based on the EPA "weight of evidence" system whereby chemicals are ranked as known, probable, or possible human carcinogens. Class A carcinogens are chemicals which are considered known human carcinogens (based on human epidemiological studies), class B carcinogens are considered probable human carcinogens (based on animal studies), and class C carcinogens are considered possible human carcinogens (based on limited data). The confidence level associated with class C carcinogens (including RDX) is considered to be low (i.e., it is uncertain whether RDX is a human carcinogen); therefore, the health-based cleanup goals developed for class C carcinogens are conservative.

The CTVs and associated weight of evidence criteria (carcinogens) for the potential COCs are presented in **Table 2-9**.

#### 2.2.1.3.4 Calculation of Health-Based Cleanup Goals

The purpose of this section is to calculate health-based cleanup goals for each potential COC identified in Section 2.2.1.3.1. As stated, the approach to developing health-based cleanup goals is derived from the risk assessment process. The methodology employed to develop target cleanup goals for the Site was based on multiple pathway exposure, and was derived from the Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual, Part B; RAGS Part B; EPA, 1991f). The risk assessment is a process whereby the magnitude of potential cancer risks and other health effects associated with Site contaminants can be quantitatively evaluated. A health-based cleanup goal is established by "back-calculating" a health protective contaminant concentration, given an acceptable target risk and using the intake factors discussed in Section 2.2.1.3.2 to represent potentially exposed populations.

Health-protective concentrations are those concentrations associated with potential risks in the range of $10^{-4}$ to $10^{-6}$ (or less) for carcinogens or a Hazard Index (HI) of 1.0 for non-carcinogens under RME conditions. At the Site, receptor populations potentially exposed to groundwater have been identified as residents and on-site workers (see Section 2.2.1.3.2). Cleanup goals were developed using the most sensitive population (i.e., residents). Major exposure pathways have been identified for these receptor groups, including:

- Ingestion of groundwater
- Dermal exposure to groundwater during showering
- Inhalation of volatile chemicals in groundwater during showering

Site-wide health-based cleanup concentrations are calculated using the RME IFs developed for these scenarios/pathways combined with the relevant exposure pathways into the cleanup calculations. The combined IFs are used in conjunction with RfDs and SFs presented in Section 2.2.1.3.3 and target risks that are thought to be health-protective. For carcinogens, $10^{-6}$, $10^{-5}$, and $10^{-4}$ target risks are used to calculate a range of target cleanup values. For non-carcinogens, 1.0 is considered an appropriate target hazard quotient value and is used to calculate the target values for non-carcinogenic effects.

The health-based cleanup goals, based on carcinogenic and non-carcinogenic effects, are presented in **Tables 2-10** and **2-11,** respectively. If health-based cleanup goals for a chemical are calculated for both carcinogenic and non-carcinogenic effects, the more protective (lower) concentration is established as the unique health-based cleanup goal for that chemical. As discussed in Section 2.2.1, the health-based cleanup goals will be considered along with ARARs and TBCs when assembling the Preliminary Target Groundwater Cleanup Goals.

#### 2.2.1.3.5 <u>Chemicals of Concern</u>

The concentrations of the potential COCs measured in monitoring well groundwater samples were compared to the health-based cleanup goals. The COCs in groundwater are the potential COCs which were detected at concentrations exceeding the lower of the health-based cleanup goals corresponding to $10^{-6}$ cancer risk or the HI of 1.0. The comparison was made using the most health-protective exposure scenario so that the selection of COCs would be health-protective for all scenarios.

Health-based cleanup goals could not be calculated for lead and aluminum because CTVs are not available for those metals. Therefore, lead and aluminum were evaluated as COCs according to other criteria described below.

The Safe Drinking Water Act action level for lead (15 $\mu$g/L) was identified as a potential contaminant-specific ARAR. Lead analyses have been performed for water samples collected from 15 monitoring wells at the Site. The lead concentration exceeded 15 $\mu$g/L at one well, and that frequency of occurrence (approximately 7 percent) is below the lead action level exceedance frequency (10 percent). Lead was rejected as a COC on this basis.

A potential contaminant-specific ARAR has not been identified for aluminum. A Secondary Maximum Contaminant Level (SMCL) range (5 to 200 $\mu$g/L) has been established for aluminum. An SMCL is an unenforceable Federal guideline established for non-health based aesthetic water quality. Aluminum is a naturally-occurring metal which has been detected in all of the wells that were sampled for metals. Both monitoring wells in the background (upgradient) cluster, MW-47, had maximum total aluminum concentrations of 416 μg/L, which exceeds the SMCL. Total aluminum concentrations exceeding 416 μg/L have been measured in only one other monitoring well, MW-54B. Aluminum has been rejected as a COC on the basis that it is a metal that occurs in background wells at high concentrations (relative to the SMCL).

The COCs are tabulated below.

| **Groundwater Chemicals of Concern** |
| --- |
| 1,2-Dichloropropane |
| Methylene Chloride |
| TCE |
| TNB |
| TNT |
| 2,4-DNT |
| RDX |

#### 2.2.1.4 Selection of Preliminary Target Groundwater Cleanup Goals

Three sets of Preliminary Target Groundwater Cleanup Goals have been assembled from the levels which are ARARs, TBCs, or health-based cleanup goals. The detailed analysis of alternatives presented in Section 4.0 will be conducted for each set of Preliminary Target Groundwater Cleanup Goals so that the risk managers may consider the benefits derived from each set of goals when selecting the final Target Groundwater Cleanup Goals.

The following tabulation summarizes the set of groundwater COC concentrations from which the Preliminary Target Groundwater Cleanup Goals were selected. The tabulation contains concentrations developed in previous sections which correspond to the following:

- ARARs (represented by MCLs)
- TBCs (represented by Health Advisories)
- Health-based cleanup goals (represented by the Carcinogenic Effects and Non-Cancer Effects)

| CHEMICAL OF CONCERN | CONCENTRATION (μg/L) | | | | | Health Advisory[c] |
|---|---|---|---|---|---|---|
| | Non-Cancer Effect[a] | Carcinogenic Effects | | | MCL[b] | |
| | | $10^{-6}$ Risk | $10^{-5}$ Risk | $10^{-4}$ Risk | | |
| 1,2-Dichloropropan e | 68.2 | 1.23 | 12.3 | 123 | 5.00 | - |
| Methylene chloride | 291 | 9.06 | 90.6 | 906 | 5.00 | - |
| TCE | - | 2.82 | 28.2 | 282 | 5.00 | - |
| TNB | 0.778 | - | - | - | - | - |
| TNT | 7.78 | 2.82 | 28.2 | 282 | - | 2.00 |
| 2,4-DNT | 31.1 | 0.124 | 1.24 | 12.4 | - | 100[d] |
| RDX | 46.9 | 0.774 | 7.74 | 77.4 | - | 2.00 |

Note:
a. The target Hazard Index for each chemical is set at 1.0.
b. Based on the value presented in the "Drinking Water Regulations and Health Advisories" (EPA, 1994).
c. Based on the Lifetime Health Advisory values presented in the "Drinking Water Regulations and Health Advisories" (EPA, 1994).
d. Based on the Drinking Water Equivalent Level values presented in the "Drinking Water Regulations and Health Advisories" (EPA, 1994).

The response to comments on the NCP proposed rule addressing the use of a risk range (§300.430(3)(2)(i)(A)(2)) provides the basis for considering different sets of Preliminary Target Groundwater Cleanup Goals (Federal Register, 1990, page 8717):

> "In the Superfund program, remediation decisions must be made at hundreds of diverse sites across the country. Therefore, as a practical matter, the remediation goal for a medium typically will be established by means of a two-step approach. First, EPA will use an individual lifetime excess cancer risk of $10^{-6}$ as a point of departure for establishing remediation goals for the risks from contaminants at specific sites. While the $10^{-6}$ starting point expresses EPA's preference for setting cleanup levels at the more protective end of the risk range, it is not a presumption that the final Superfund cleanup will attain that risk level.
>
> The second step involves consideration of a variety of site-specific or remedy-specific factors. Such factors will enter into the determination of where within the risk range of $10^{-4}$ to $10^{-6}$ the cleanup standard for a given contaminant will be established."

The risk associated with each COC (except TNB) for the three sets of Preliminary Target Groundwater Cleanup Goals are presented in the following sections. In addition, the aggregate risk for each Preliminary Target Groundwater Cleanup Goal is tabulated. The aggregate risk is the sum of the individual risks. The residual risk is the risk remaining in groundwater at the completion of remediation. At a maximum, the residual risk will be equal to the aggregate risk if all COCs are remediated to their respective cleanup goals. It is likely that the residual risk will be less than the aggregate risk because the concentration of the COCs will be reduced preferentially with the relative maximum concentration(s) equal to the cleanup goal(s).

#### 2.2.1.4.1 Preliminary Target Groundwater Cleanup Goal I

The Preliminary Target Groundwater Cleanup Goal I (Cleanup Goal I) is tabulated below.

| CLEANUP GOAL I | | |
|---|---|---|
| COC | Concentration ($\mu$g/L) | Cancer Risk |
| Methylene Chloride | 5 | 5.52E-07 |
| 1,2-Dichloropropane | 5 | 4.07E-06 |
| TCE | 5 | 2.19E-06 |
| TNB | 0.778 | --- |
| TNT | 7.78 | 2.76E-06 |
| 2,4-DNT | 1.24 | 1.00E-05 |
| RDX | 7.74 | 1.00E-05 |
| | Aggregate Risk | 2.96E-05 |

The rationale for developing Cleanup Goal I is described below.

- For those chemicals with MCLs established, the MCL is the target cleanup goal.
- For those chemicals that do not have MCLs, but have carcinogenic effects and non-carcinogenic effects, the target cleanup goal is the **lower** of either the value from the carcinogenic risk of $10^{-5}$ or the value calculated from the non-carcinogenic HI of 1.0.
- For those chemicals that do not have MCLs or carcinogenic effects, the target cleanup goal is calculated from the non-carcinogenic HI of 1.0.

- For those chemicals that do not have MCLs or non-carcinogenic effects, the target cleanup goal is calculated from the carcinogenic risk of $10^{-5}$.

#### 2.2.1.4.2 Preliminary Target Groundwater Cleanup Goal II

The Preliminary Target Groundwater Cleanup Goal II (Cleanup Goal II) is tabulated below.

| CLEANUP GOAL II | | |
|---|---|---|
| COC | Concentration (μg/L) | Cancer Risk |
| Methylene Chloride | 5 | 5.52E-07 |
| 1,2-Dichloropropane | 5 | 4.07E-06 |
| TCE | 5 | 2.19E-06 |
| TNB | 0.778 | --- |
| TNT | 2 | 7.09E-07 |
| 2,4-DNT | 1.24 | 1.00E-05 |
| RDX | 2 | 2.58E-06 |
| | Aggregate Risk | 2.01E-05 |

The rationale for developing Cleanup Goal II is described below.

- For those chemicals with MCLs established, the MCL is the target cleanup goal.

- For those chemicals that do not have MCLs, but have carcinogenic effects, non-carcinogenic effects, and Health Advisories, the target cleanup goal is the **lower** of either the value from the carcinogenic risk of $10^{-5}$, the value calculated from the non-carcinogenic HI of 1.0, or the Health Advisories.

- For those chemicals that do not have MCLs, carcinogenic effects, or Health Advisories, the target cleanup goal is calculated from the non-carcinogenic HI of 1.0.

- For those chemicals that do not have MCLs, non-carcinogenic effects, or Health Advisories, the target cleanup goal is calculated from the carcinogenic risk of $10^{-5}$.

#### 2.2.1.4.3 Preliminary Target Groundwater Cleanup Goal III

The Preliminary Target Groundwater Cleanup Goal III (Cleanup Goal III) is tabulated below.

| CLEANUP GOAL III | | |
|---|---|---|
| COC | Concentration (μg/L) | Cancer Risk |
| Methylene Chloride | 5 | 5.52E-07 |
| 1,2-Dichloropropane | 5 | 4.07E-06 |
| TCE | 5 | 2.19E-06 |
| TNB | 0.778 | --- |
| TNT | 2.82 | 1.00E-06 |
| 2,4-DNT | 0.124 | 1.00E-06 |
| RDX | 0.774 | 1.00E-06 |
| | Aggregate Risk | 9.81E-06 |

The rationale for developing Cleanup Goal III is described below.

- For those chemicals with MCLs established, the MCL is the target cleanup goal.
- For those chemicals that do not have MCLs, but have carcinogenic effects and non-carcinogenic effects, the target cleanup goal is the **lower** of either the value from the carcinogenic risk of $10^{-6}$ or the value calculated from the non-carcinogenic HI of 1.0.
- For those chemicals that do not have MCLs or carcinogenic effects, the target cleanup goal is calculated from the non-carcinogenic HI of 1.0.
- For those chemicals that do not have MCLs or non-carcinogenic effects, the target cleanup goal is calculated from the carcinogenic risk of $10^{-6}$.

#### 2.2.1.4.4 Comparison of Preliminary Target Groundwater Cleanup Goals

There is no difference between Preliminary Target Cleanup Goals I, II, or III for the following four chemicals because cleanup goals for these chemicals are MCLs or non-carcinogenic risk whose concentrations are common to all cleanup goals:

- Methylene chloride
- 1,2-Dichloropropane
- TCE
- TNB

The difference between Preliminary Target Groundwater Cleanup Goals I, II, and III are for the three explosive chemicals:

- TNT
- 2,4-DNT
- RDX

The Preliminary Target Groundwater Cleanup Goal varies for these three chemicals depending on which risk level is used and whether Health Advisories are considered.

### 2.2.2 Areas of Attainment

The area of attainment defines the area within which remedial actions will be used to achieve the Target Groundwater Cleanup Goal. Because there are three sets of Preliminary Target Groundwater Cleanup Goals, there are three corresponding areas of attainment.

The areas of attainment defined for each set of Preliminary Target Groundwater Cleanup Goals are based on the extent of contamination defined by the particular cleanup goals composited over the three general depth intervals in which monitoring wells are completed. TCE and RDX are used as indicator chemicals to define the areas of attainment. These areas of attainment are based on analyses of groundwater samples collected from monitoring wells during the following sampling events:

- August 1992 (RI)
- November 1992 (RI)
- February/March/April 1993 (WCC, 1993d)
- May/June 1993 (WCC, 1993e)
- July 1993 (AFI) (WCC, 1993f)
- December 1993 (off-site) (WCC, 1993g and 1994a; MRI, 1993 and 1994a)
- March 1994 (off-site) (WCC, 1994b; MRI, 1994b)
- June 1994 (off-site) (WCC, 1994d; MRI, 1994c)

TCE was measured more frequently and at higher concentrations in monitoring wells with respect to other VOC COCs. With the exception of wells containing methylene chloride and one well containing 1,-Dichloropropane, TCE was always detected in groundwater samples that contain a VOC COC. Methylene chloride appears to be ubiquitous as it appears in most of the samples with a VOC COC detected. However, out of 467 samples with methylene chloride detected, 93.8 percent were non-quantifiable (i.e., either methylene chloride was found in the blanks or the sample detections were below quantifiable limits). Additionally, only 45 percent of the quantifiable methylene chloride detections were above MCLs. For the explosive chemicals, RDX was encountered in groundwater monitoring wells at concentrations above Preliminary Target Groundwater Cleanup Goals more frequently (i.e., detected in a larger number of groundwater monitoring wells) than TNB, TNT, or 2,4-DNT. RDX is always present whenever concentrations of TNB, TNT, and 2,4-DNT exceed Preliminary Target Groundwater Cleanup Goals. Thus, the spatial distributions of TCE, RDX, and TCE co-located with RDX form the basis for the areas of attainment. Currently, RDX and TCE have the widest extent in the upper portion of the Todd Valley aquifer and the Platte River Valley aquifer. There are locations within the areas of attainment where RDX and TCE concentrations exceed or equal the cleanup goals in the Omadi sandstone aquifer but contaminant concentrations are below cleanup goals in the overlying unconsolidated aquifer. The vertical distribution of contamination may require that remedial actions focus on a specific depth interval rather than the entire saturated thickness of the aquifer.

The areas of attainment for Cleanup Goals I, II, and III are shown on **Drawing 2-1**, **Drawing 2-2**, and **Drawing 2-3**, respectively.

Once defined, an area of attainment remains constant although the location of RDX and TCE concentration contours which initially defined the area of attainment, may change. This consistency allows remedial actions to be developed and implemented.

### 2.2.3 Restoration Time Frame

The restoration time frame is the period of time required to achieve the Preliminary Target Groundwater Cleanup Goals at all locations within the areas of attainment. The rate at which the groundwater is cleaned up depends on the following factors:

- Technical limits to extracting contaminants
- The feasibility of providing an alternate water supply
- The potential use and value of the groundwater
- The effectiveness and reliability of institutional controls
- The ability to monitor and control contaminant movement

The technical restrictions associated with relatively large areas of attainment will govern the establishment of restoration time frames. The other factors listed above can be managed effectively through other institutional and engineering controls. For example, it has been relatively easy to install point-of-use carbon filtration units at impacted residences.

The method for calculating restoration time frame estimates is presented in **Appendix B**, and the restoration time frame estimates for specific alternatives are discussed in Section 4.0.

## 2.3 OU1 AND OU2 SOIL REMEDIAL ACTION OBJECTIVES

The OU1 RAOs have been identified in the OU1 FS Report (RUST, 1994a) as:

- Minimize risk to human health and the environment from ingestion of soil contaminated with DNB, TNB, 2,4-DNT, TNT, RDX, HMX, tetryl, and nitrotoluene (NT)

- Minimize risk to human health from ingestion of contaminated groundwater extracted from a residential well located within an exposure area, if a domestic well is installed prior to completion of OU2 activities, by providing point-of-use treatment if water from that well exceeds Lifetime Health Advisory or regulatory limits

- Minimize potential additional groundwater contamination from leaching of soil contaminants

OU1 excavation PRGs were developed to provide the basis to define the boundaries of an area to be excavated in OU1. The OU1 chemical-specific excavation PRGs are tabulated below. Soils will not be excavated below four feet which is the estimated depth of soil at which a person is unlikely to come into direct contact with contaminated soil based on Site uses and characteristics. The excavation PRGs correspond to a cancer risk of $3 \times 10^{-6}$ and a hazard index of 1.0 (RUST, 1994b).

| **OU1 Excavation PRGs** | |
|---|---|
| **Chemical** | **Concentration (mg/kg)** |
| HMX | 1715.2 |
| RDX | 5.8 |
| TNB | 1.7 |
| DNB | 3.4 |
| TNT | 17.2 |
| DNT (2,4 or 2,6) | 0.9 |
| NT | 343.0 |
| Tetryl | 343.0 |

It is estimated that an approximate surface area of 1.3 acres and volume of 8,400 cubic yards of soil require excavation to achieve the excavation PRGs.

OU1 soil treatment PRGs will be selected and based on results of OU1 treatability studies and other factors during the OU1 Remedial Design and will meet the total Site cancer risk goals between $10^{-4}$ and $10^{-6}$.

There are explosives-contaminated soils that do not contain concentrations greater than the excavation PRGs. Although these soils to are not a risk with respect to dermal contact or ingestion, a potential was identified for these soils to be a source of groundwater contamination. These soils are subsequently referred to as "leaching soils." The evaluation of the actions, soil cleanup, and infiltration control, are contained in **Appendix C**.

The remedial action objective for leaching soils is to remediate those soils to the degree that the groundwater remediation potentially benefits in terms of time, cost, or protectiveness. Any potential soil excavation and treatment associated with OU2 will be coordinated with OU1 soil excavation and treatment.

The volume of leaching soils was defined by soils satisfying the following criteria:

- TNB soil concentrations greater than, or equal to, 5 mg/kg in the depth interval from the ground surface to 9 feet
- TNB soil concentrations greater than, or equal to, 1 mg/kg in the depth interval from 9 feet to 12.5 feet

The basis for selection of the above criteria is presented in **Appendix B**.

VOC RAOs may be established at a later time based on the results of the ongoing SVE pilot study discussed in Section 1.3.3. Therefore, subsequent discussion of soils in this document refer to explosives-contaminated soil unless otherwise noted.

## 2.4 AREAS AND VOLUMES OF CONTAMINATION

**Appendix D** presents the calculations of the volume of the contaminated groundwater. **Table D-1** in **Appendix D** shows the average thickness of the saturated zone at different areas at the Site based on the RI Report. **Tables D-2, D-3**, and **D-4** present the calculations showing total estimated volumes of contaminated groundwater for the Preliminary Target Cleanup Goals I, II, and III, respectively. These estimates were calculated as follows:

- Obtain average saturated zone thickness values from **Table D-1** in **Appendix D**
- Assume a porosity of 0.25 (Freeze and Cherry, 1979)

- Calculate volume of contaminated groundwater in each of the shallow, intermediate, and deep zones by multiplying the combined TCE and RDX plume area of that zone by its average thickness and porosity

- Calculate the total volume of contaminated groundwater by summing up the volumes for each zone

The composite areal extent of the contaminated groundwater was measured using Microstation Version 4.03 and **Drawings 2-1, 2-2 and 2-3**.

The area and volume of contaminated groundwater are tabulated below.

| Areas and Volumes of Contaminated Groundwater | | | | |
|---|---|---|---|---|
| Preliminary Target Groundwater Cleanup Goals | Area | | Volume | |
| | ($ft^2$) | (acres) | (gallons) | (acre-feet) |
| Cleanup Goal I | 1.18E+8 | 2,720 | 1.19E+10 | 36,700 |
| Cleanup Goal II | 2.56E+8 | 5,880 | 2.26E+10 | 69,300 |
| Cleanup Goal III | 2.81E+8 | 6,450 | 2.70E+10 | 82,800 |

**Appendix E** contains the calculations of the volumes of contaminated soil as determined under OU1 (RUST, 1994c).

The volume of leaching soils was initially estimated at 2,600 cubic yards, and the estimate will be refined when data from the OU1 Predesign Investigation is available. The OU1 Predesign Investigation Report will be submitted in the Spring of 1995..

## 2.5 GENERAL RESPONSE ACTIONS

General response actions (GRAs) describe those broad classes of actions that will satisfy the RAOs. The subsequent sections describe the GRAs for OU2 (groundwater and leaching soils). The OU1 GRAs are discussed in the OU1 FS Report (RUST, 1994a).

### 2.5.1 Groundwater

The following GRAs have been identified for groundwater.

- No Action - This consists of leaving the Site "as is," with provisions only for monitoring the contamination. No active control or remediation would be included.

- Institutional Controls - This response action prevents exposure to contaminated groundwater which may include, but is not limited to, the following:

  - Access restrictions
  - Alternate water source
  - Point-of-entry controls

  Groundwater monitoring of the analytes listed in Table 1-1 which includes COCs and some of their degradation products is an institutional control.

- Containment - This involves physical restrictions on contaminant mobility and/or water infiltration.

- Removal - This involves the direct physical removal of the contamination or contaminant sources.

- Treatment - This consists of on-site and/or off-site measures to reduce toxicity, mobility, and volume of the contaminated materials.

- Disposal - This involves measures to relocate contaminants in such a way as to reduce their interaction with the public and the environment. Treatment will address the COCs and their potential degradation products.

### 2.5.2 Leaching Soil

The following GRAs have been identified for leaching soil. The GRAs are consistent with the GRAs developed for OU1 soils.

- No Action - This consists of leaving the Site "as is." No active control or remediation would be included.

- Institutional Controls - This involves the creation and implementation of responsibilities for restricting public and environmental contact with the contaminants.

- Containment - This involves physical restrictions on contaminant mobility and/or water infiltration.

- Removal - This involves the direct physical removal of the contamination or contaminant sources.

- Treatment - This involves on-site and/or off-site measures to reduce toxicity, mobility, and volume of the contaminated materials.

- Disposal - This involves measures to relocate contaminants in such a way as to reduce their interaction with the public and the environment.

- Residuals Management - This consists of treatment of any sidestreams, end products, and spent contaminated materials resulting from in-situ or on-site remediation. This response action may include on-site or off-site containment/treatment/disposal.

- Solids Processing - This consists of removing any subsurface debris followed by decontamination, separation from soil and decontamination, or management with soil. Debris not managed with soil could be disposed of on-site or off-site.

## 2.6 IDENTIFICATION, EVALUATION, AND SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

### 2.6.1 Introduction

This section describes three activities that follow identification of the response actions presented in Section 2.5.1.

- Identification of Remedial Technologies and Process Options

- Initial screening of Remedial Technologies and Process Options

- Evaluation and Screening of Technologies and Process Options Based on Effectiveness, Implementability, and Cost.

The term remedial technology refers to general categories of technology types such as biological treatment, chemical treatment, and thermal destruction. The term process option refers to specific processes within each technology category. For example, under the technology category of biological treatment, there may be aerobic and anaerobic treatment process options.

### 2.6.2 Identification of Groundwater Remedial Technologies and Process Options

As one of the initial steps in the FS process, groundwater remedial technologies and process options have been identified and presented in the table at the end of this section. The technologies and process options for groundwater were assembled after extensive review of:

- EPA documents
- EPA's Alternative Treatment Technology Information Center (ATTIC) database
- Dialogue Information Services, Inc. database search (including ATTIC, VISITT, NTIS, Enviroline, Inspec, Water Resources Abstracts, Federal Research in Progress, and PTS databases)
- Pertinent technical journals and seminar/conference proceedings
- Information provided by remediation contractors
- WCC's experience in hazardous waste remediation

Some of the EPA documents used in this review were:

- Remedial Action at Waste Disposal Sites Handbook (EPA, 1985)
- Technology Screening Guide for Treatment of CERCLA Soils and Sludges (EPA, 1988c)
- Compendium of Technologies Used in the Treatment of Hazardous Wastes (EPA, 1987)
- Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites (EPA, 1989c)

The groundwater remedial technologies and process options are tabulated below.

| General Response Actions | Remedial Technology | Process Options |
|---|---|---|
| No Action | None | None |
| Institutional Controls | Access Restrictions | Deed Restrictions |
| | Alternate Water Source | Bottled Water |
| | | Extension of Nearby Water Supply System |
| | Point-of-Entry Controls | Point-of-Entry Water Treatment Units |
| | Monitoring | Groundwater Monitoring |
| Containment | Hydraulic Controls | Extraction Wells |
| | Horizontal Barriers | Grout Injection<br>Liners |
| | Vertical Barriers | Concrete Diaphragm<br>Grout Curtain<br>Sheet Piling<br>Slurry Wall<br>Vibrating Beam |
| Removal | Extraction | Extraction Wells |
| | Interception | French Drains and<br>Drainage Galleries |
| Treatment | Biological | Aerobic<br>Anaerobic<br>Powder Activated Carbon Treatment -(PACT) |
| | In-Situ | Aeration (Air Sparging)<br>Bioremediation<br>Permeable Treatment Beds |
| | Off-Site | Publicly Owned Treatment Works (POTW) |
| | Physical/Chemical | Alkaline Hydrolysis<br>Coagulation/Flocculation<br>Dissolved Air Flotation<br>Distillation<br>Evaporative Ponds<br>Filtration<br>Freeze Crystallization<br>Granular Activated Carbon (GAC)<br>Adsorption<br>Ion Exchange<br>Liquid/Liquid Extraction<br>Oil-Water Separation<br>Reverse Osmosis<br>Sedimentation<br>Supercritical Extraction<br>Air/Steam Stripping<br>Supercritical Water Oxidation<br>Advanced Oxidation Process (AOP) |
| | Physical/Chemical<br>(air pollution control) | GAC<br>Catalytic Oxidation |
| | Thermal | Incineration<br>Wet Air Oxidation |

| General Response Actions | Remedial Technology | Process Options |
|---|---|---|
| Disposal | Discharge | Deep Well Injection<br>On-/Off-Site Stream<br>Off-Site POTW<br>Recharge Trench/Basin<br>Reinjection Wells |
| | Reuse | Agricultural<br>Industrial<br>Water Supply |

### 2.6.3 Evaluation and Screening of Groundwater Remedial Technologies and Process Options

The groundwater remedial technologies and process options identified in Section 2.6.2 are first screened on the basis of technical implementability in accordance with the RI/FS guidance document (EPA, 1988b).

The table below describes the groundwater technologies and process options, and presents initial screening comments. A brief description of each process option is included to provide an understanding of each option and to assist in the evaluation of its technical implementability. The screening comments address the technical feasibility and ability of a given process option to serve its intended purpose. The screening comments include a statement as to whether each process option is potentially applicable or rejected.

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| No Action | None | None | No action taken. | **Potentially applicable** |
| Institutional Controls | Access Restrictions | Deed Restrictions | Deeds for property in the area of influence would include restriction on wells. | **Potentially applicable** |
| | Alternate Water Source | Bottled Water | Bottled water in lieu of groundwater for public use. | **Potentially applicable** |
| | | Extension of Nearby Water Supply System | Extension of a nearby water distribution system to include users of groundwater at the Site. | **Potentially applicable** |
| | Point-of-Entry Controls | Point-of-Entry Water Treatment Units | Treatment of groundwater at-the-tap | **Potentially applicable** |
| | Monitoring | Groundwater Monitoring | Sampling/analysis of groundwater on a regimented time schedule. | **Potentially applicable** |

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| Containment | Hydraulic Controls | Extraction Wells | Series of wells to contain groundwater contamination plume | **Potentially applicable** |
| | Vertical Barriers | Concrete Diaphragm | Subsurface barrier of reinforced concrete panels, either cast-in-place or pre-cast. | Rejected: not feasible due to extensive length required to the bottom of contaminated aquifer. |
| | | Grout Curtain | Grout barrier pressure injected into the subsurface in unconsolidated materials. | Rejected: not feasible due to extensive length required to the bottom of contaminated aquifer and lack of key in lower unit. |
| | | Sheet Piling | Interlocked steel sheeting driven into soil. | Rejected: not feasible due to extensive length required to the bottom of contaminated aquifer. |
| | | Slurry Wall | Barrier of soil, water, and bentonite slurry backfilled into an excavated level trench. (Portland cement is also used.) | Rejected: not feasible due to extensive length required to the bottom of contaminated aquifer. |
| | | Vibrating Beam | Grout injection after vibrating a beam through the subsurface. | Rejected: not feasible due to extensive length required to the bottom of contaminated aquifer. |
| Removal | Extraction | Extraction Wells | Series of wells to remove contaminated groundwater. | **Potentially applicable** |

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| Removal (Continued) | Interception | French Drains and Drainage Galleries | Subsurface perforated pipe drains collect contaminated water. | Rejected; not feasible due to extensive length required to the bottom of contaminated aquifer. |
| Treatment | Biological | Aerobic | Degradation of organics using micro-organisms in an aerobic environment. | **Potentially applicable** |
| | Biological (Continued) | Anaerobic | Degradation of organics using micro-organisms in an anaerobic environment. | **Potentially applicable** |
| | | PACT | Activated sludge treatment combined with powdered activated carbon. | **Potentially applicable** |
| | In-Situ | Air Sparging | System of wells to inject air into groundwater to remove volatiles by air stripping. | **Potentially applicable** |
| | | Bioremediation | System of injection and extraction wells to introduce bacteria and necessary nutrients to contaminated areas. | **Potentially applicable** |
| | | Permeable Treatment Beds | Downgradient trenches backfilled with activated carbon to remove contaminants from water. | Rejected; not feasible due to extensive length required to the bottom of contaminated aquifer and lack of key in lower unit. |
| | Off-Site | POTW | Extracted water discharged to a POTW for treatment/disposal. | **Potentially applicable** |
| | Physical/Chemical | Alkaline Hydrolysis | Partial or complete oxidation of contaminants by addition of alkali. | Rejected; not effective for chemicals of concern. |
| | | Coagulation/ Flocculation | Destabilization and removal of suspended particles by chemical addition. | Rejected; not effective for chemicals of concern. |
| | | Dissolved Air Flotation | Separation of solids in a suspension by injecting pressurized air. | Rejected; not effective for chemicals of concern. |

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| Treatment (Continued) | Physical/Chemical (Continued) | Distillation | Evaporation followed by condensation. | Rejected; not effective for low contaminant concentrations. |
| | | Evaporative Ponds | Evaporation in open ponds. | Rejected; not effective for chemicals of concern. |
| | | Filtration | Separation of suspended solids by passing the liquid through a porous medium. | Rejected; not effective for low levels of contamination. |
| | | Freeze Crystallization | Separation of water from waste streams containing hazardous substances by cooling it until ice crystals begin to form. | Rejected; not effective for low levels of contamination. |
| | | GAC Adsorption | Adsorption of contaminants to carbon. Spent carbon can be regenerated by different means. | **Potentially applicable** |
| | | Ion Exchange | Contaminated water is passed through a resin bed where ions are exchanged between the resin and water. | Rejected; not effective for the chemicals of concern. |
| | | Liquid/Liquid Extraction | Two liquids which are mutually soluble may be separated by adding a third liquid which is a solvent for one of the original components but insoluble in and immiscible with the other. | Rejected; not effective for low levels of contamination. |
| | | Oil/Water Separation | Gravity force used to separate immiscible liquids with differing densities. | Rejected; not effective for low levels of contamination. |
| | | Reverse Osmosis | Transport of a contaminant from the contaminated medium to another liquid medium across a semi-permeable membrane. | Rejected; not effective for chemicals of concern. |
| | | Sedimentation | Settling of settleable solids through gravity forces and their subsequent removal. | Rejected; not effective for chemicals of concern. |
| | | Air/Steam Stripping | Mixing of large volumes of air or steam with contaminated water in a packed column to promote the transfer of VOCs to air. | **Potentially applicable** |

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| Treatment (Continued) | Physical/Chemical (Continued) | Supercritical Extraction | Use of supercritical carbon dioxide to extract organics from aqueous streams. | Rejected; not effective for chemicals of concern. |
| | | Supercritical Water Oxidation | Contaminated water pressurized and heated to supercritical conditions to oxidize organic constituents. | Rejected; not effective for chemicals of concern. |
| | | AOP | Oxidation by addition of chemicals (e.g., ozone, hydrogen peroxide) with or without ultraviolet light. | **Potentially applicable** |
| | Physical/Chemical (air pollution control) | GAC Adsorption | Adsorption of contaminants to carbon. Spent carbon can be regenerated by different means. | **Potentially applicable** |
| | | Catalytic Oxidation | Low temperature thermal destruction of organic compounds using a catalyst to promote the oxidation process. Catalyst may be poisoned by chlorinated compounds thus rendering the process ineffective for VOC treatment. | Rejected; not effective for treatment of chlorinated compounds. |
| | Thermal | Incineration | Combustion of organics at high temperatures. | Rejected; water content too high. |
| | | Wet Air Oxidation | Organic materials are broken down at high temperatures and pressures. | Rejected; not effective for chemicals of concern. |
| Disposal | Discharge | Deep Well Injection | Injection of extracted water (treated or untreated) into a deep well (on- or off-site). | **Potentially applicable** |
| | | Off-Site POTW | Treated water shipped to an off-site POTW. | **Potentially applicable** |
| | | On-/Off-Site Stream | Extracted/treated water discharged to a stream or such water body. | **Potentially applicable** |
| | | Recharge Trench Basin | Treated water recharged into the uppermost aquifer. | **Potentially applicable** |
| | | Reinjection Wells | Treated water reinjected into the same aquifer. | **Potentially applicable** |
| | Reuse | Agricultural | Treated water is applied on land for irrigation, supplied to livestock operations, or other use. | **Potentially applicable** |
| | | Industrial | Treated water is used for industrial application such as cooling waters. | Rejected; no major industry present. |

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| Disposal (Continued) | Reuse (Continued) | Water Supply | Treated water is supplied to a municipally or other water user. | **Potentially applicable** |

The groundwater technologies and process options that were retained after the initial screening are evaluated in greater detail and further screened below. In accordance with the RI/FS guidance document (EPA, 1988b), three criteria are used in evaluating the technologies and process options: effectiveness, implementability, and cost. These are briefly described below.

**Effectiveness:** Specific process options are evaluated on the basis of effectiveness in comparison to other processes within the same technology type. This effectiveness evaluation focuses on:

- The potential effectiveness of the process option in handling the estimated areas or volumes of media required to attain the remedial goals
- The potential impacts on human health and the environment of the process option during the construction and implementation phases
- The practicality and reliability of the technology process for the contaminants and conditions at the site

**Implementability:** Implementability encompasses both the technical and administrative feasibility of implementing a technology process. Because technical implementability is utilized as an initial screen of technology types and process options, this detailed evaluation of process options places greater emphasis on the administrative aspects of implementability. Aspects of implementability considered at this screening stage include the ability to obtain necessary permits for on- or off-site actions, the maturity of the technology, the availability of required treatment, storage, and disposal (TSD) services, and the availability of required equipment and skilled workers to implement the technology.

**Cost:** The greatest cost consequences in site remediation are associated with the selection of a technology type, whereas the costs of process options within a technology type typically vary less. Cost plays a limited role in the process option screening. Relative capital and operation and maintenance (O&M) costs between process options in the same technology type are used rather than detailed estimates of costs. The cost assessment at this stage of the screening procedure is made by engineering judgment. Costs are evaluated as high, moderate, or low. The cost levels are separated by order of magnitude estimates.

The effectiveness, implementability, and cost screening of the groundwater process options retained from the first screening is presented in the following table.

| Response Action/ Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Status |
|---|---|---|---|---|---|
| **No Action** | None | No action taken. | May require periodic monitoring of aquifer. | No capital and low O&M costs. | **Retain** |
| **Institutional Controls** | | | | | |
| Access Restrictions | Deed Restrictions | Effective means of limiting contact with contaminated groundwater. Also can restrict future land use. Does not lower contaminant levels or control future uses of the Site. | Legal means are not available for implementation. | Low capital and O&M costs. | Reject |
| Alternate Water Source | Bottled Water | Effective means of eliminating ingestion exposure. Does not lower exposure from dermal contact or inhalation. Does not lower contaminant levels or control future uses of the Site. However, bottled water may serve as an interim measure in combination with other alternative water supply options. | Easily implemented. | No capital and low annual costs. | Reject |
| | Extension of Nearby Water Supply System | Effective means of eliminating exposure. Does not lower contaminant levels or control future uses of the Site. | Technically implementable. Administratively infeasible. | High capital and moderate O&M costs. | Reject |

| Response Action/ Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Status |
|---|---|---|---|---|---|
| Point-of-Entry Controls | Point-of-Entry Water Treatment Units | Effective means of eliminating exposure. Does not lower contaminant levels or control future uses of the Site. | Easily implemented. | Low capital and O&M costs. | **Retain** |
| Monitoring | Groundwater Monitoring Wells | Does not lower contamination, but is an effective way of determining condition of the aquifer. | Easily implemented; wells already installed. | Low capital and low to moderate O&M costs. | **Retain** |
| **Containment** | | | | | |
| Hydraulic Controls | Extraction Wells | Effective and well-established technology. | Easily implemented. | Moderate capital and O&M costs. | **Retain** |
| **Removal** | | | | | |
| Extraction | Extraction Wells | Effective and well-established technology. | Easily implemented. | Moderate capital and O&M costs. | **Retain** |
| Treatment | | | | | |
| Biological | Aerobic | The technology has not been proven to achieve the required cleanup goals. | Easily implemented. Treatability studies would be required. | Low to moderate capital and O&M costs. | Reject |
| | Anaerobic | The technology has not been proven to achieve the required cleanup goals. | Easily implemented. Treatability studies would be required. | Low capital and O&M costs. | Reject |
| | PACT | The technology has not been proven to achieve the required cleanup goals. | Easily implemented. Treatability studies would be required. | Moderate capital and O&M costs. | Reject |

| Response Action/ Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Status |
|---|---|---|---|---|---|
| In-Situ | Air Sparging | Effective to remove VOCs but not explosives. | Emerging technology which is not commercially available. May require pilot testing. | High capital and O&M costs. | **Retain** |
| In-Situ (Continued) | **Bioremediation** | Potentially uses effective and well-established technologies. | Not feasible for the relatively large volume of contaminated groundwater at the Site. | Moderate capital and O&M costs. | Reject |
| Off-Site | POTW | The technology has not been proven to achieve the required cleanup goals. Potentially uses effective and well-established technologies. | Permitted facilities with adequate capacity are far from the Site; POTWs may not accept the groundwater from the Site. | High transportation and treatment costs. | Reject |
| Physical/ Chemical | GAC Adsorption | Effective for most organics. | Easily implemented. | Moderate capital and moderate to high O&M costs. | **Retain** |
| Physical/Chemical (Continued) | Air/Steam Stripping | Proven technology to remove VOCs. Can be accomplished by using air or steam. Not effective for treating explosives. | Commercially available. May require off-gas treatment. | Moderate capital and O&M costs. Steam stripping more costly than air stripping but has no added benefit over air stripping. | **Retain Air stripping; Reject steam stripping** |
| | AOP | Effective for treating most organics. | Easily implemented. May require bench- and pilot-scale testing. | High capital and moderate O&M costs. | **Retain** |
| Physical/Chemical (air pollution control) | GAC | GAC treatment is effective at removing VOCs from air stripping discharge. | Easily implemented. | Moderate capital and O&M costs. | **Retain** |

| Response Action/ Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Status |
|---|---|---|---|---|---|
| **Disposal** | | | | | |
| Discharge | Deep Well Injection | Effective, proven technology for disposal untreated water. | Off-Site facilities exist, but not close to the Site. | High transportation and disposal costs for an off-Site facility. High capital and low O&M costs for an on-Site facility. | Reject |
| | POTW | Effective means of disposing treated water. | Permitted facilities with adequate capacity are far from the Site. | High transportation and treatment costs. | Reject |
| | On-/Off-Site Stream | Effective means of disposing treated water. | Easily implemented. Regulatory permit requirements. | Low capital and O&M costs. | **Retain** |
| | Recharge Trench/ Basin | Moderately effective means of disposing treated water. | Implementable. | Capital and O&M costs are prohibitive | Reject |
| Reuse | Reinjection Wells | Moderately effective means of disposing treated water. | Implementable. | Moderate to high capital and O&M costs. | **Retain** |
| Reuse | Agricultural | Effective disposal means for treated water. | Demand may not be available for year-round operation. | Moderate capital and O&M costs. | **Retain** |
| | Water Supply | Effective disposal means for treated water. | Implementable. Water supply must be identified. | Moderate to high capital and low O&M costs. | **Retain** |

A description of the remedial technologies and related process options and the rationale for eliminating or retaining each is provided below.

### 2.6.3.1 No Action

The no action response is not a technology, but is required under the NCP as a baseline against which other remedial alternatives may be compared. Under no action, contaminated groundwater would be left undisturbed. The long-term human health and environmental risks would be the same baseline risk that exists if no remedial activity takes place. The no action response does not achieve RAOs at the Site, but is retained as required by the NCP.

#### 2.6.3.2 Institutional Controls

Institutional controls are actions which are implemented to protect human health until such time when the contaminants in the groundwater have been reduced to the Target Groundwater Cleanup Goals. Institutional controls which are considered at the Site include monitoring, restrictions imposed on access to property or uses of property, or the supply of potable water to on-Site users.

**Deed Restrictions - Reject**

There are no legal instruments available for implementation of deed restrictions at the Site. Deed restrictions have been rejected for further consideration based on input from the University of Nebraska.

**Bottled Water - Reject**

Establishing a supply of bottled water is technically feasible. Bottled water protects human health by preventing ingestion; however, it does not eliminate risk from dermal contact and inhalation pathways. Bottled water has been rejected for further consideration as a long-term, permanent water source. However, bottled water may serve as an interim measure in combination with other alternative water supply options.

**Extension of Nearby Water Supply System - Reject**

Replacing domestic water supply wells with an extension of an existing nearby water supply system is technically implementable. Lincoln Water System (LWS) is the only nearby system with sufficient capacity. However, it is against LWS policy to extend its distribution system beyond city limits. (WCC, 1994f). The process option was rejected due to the administrative infeasibility.

**Point-of-Entry Water Treatment Units - Retain**

Point-of-entry treatment units are currently being used for alternative water supply (See Section 1.3.1), and have proven to be technically feasible for treating the COCs and other analytes listed in **Table 1-1**. Therefore, point-of-entry treatment units have been retained for further consideration.

**Groundwater Monitoring - Retain**

Groundwater monitoring wells are currently being used to monitor groundwater conditions at the Site and are being retained for further consideration.

### 2.6.3.3 Containment

The principle of containment is to prevent or significantly reduce the expansion of existing contamination. As such, reduction in toxicity and volume of contamination is not emphasized.

**Extraction Wells - Retain**

Hydraulic containment involves extracting groundwater to create capture zones which prevent downgradient migration. Because hydraulic containment involves contaminated groundwater extraction, the volume of contaminated groundwater is inherently reduced over time. Hydraulic containment is technically feasible and has been retained for further consideration.

### 2.6.3.4 Removal

The principle of removal is to reduce the toxicity and volume of contaminated groundwater. Hydraulic containment is generally not considered a removal technology, although hydraulic containment involves the extraction (removal) of contaminated groundwater.

**Extraction - Retain**

The extraction of contaminated groundwater is technically feasible and has been retained for further consideration.

**2.6.3.5 Treatment**

Treatment is the reduction of toxicity. Groundwater can be treated using a number of physical, chemical, or biological process, or a combination of different types of processes. Some treatment processes operate on extracted groundwater, and other processes operate without extracting the groundwater (in-situ). The treatment processes will be evaluated for the COCs and potential degradation products which are included in **Table 1-1**.

**Biological Treatment - Reject**

Above-ground biological treatment of extracted groundwater may include aerobic, anaerobic, and PACT. The objective of biological treatment is to transform or destroy the hazardous contaminants into non-hazardous end-products. This is accomplished by treating the groundwater in bioreactors containing the appropriate microorganisms. These reactors are typically supplemented with nutrients (nitrogen and phosphorus) for biological growth.

Aerobic biological treatment involves biological transformations or destruction of contaminants using oxygen, where anaerobic treatment take place in the absence of oxygen. PACT involves a combination of aerobic treatment and carbon adsorption. Aerobic, anaerobic, and PACT biological treatment have been rejected because the treatments are not effective at achieving the cleanup goals.

**In-Situ Aeration - Retain**

In-situ aeration (air sparging) is a treatment which may be effective for removing VOCs, including TCE, from the groundwater but is not appropriate for treating explosives contamination. Air sparging consists of the injection of air into the saturated zone of the contaminated aquifer, and the subsequent collection and treatment of the resulting vapor in the unsaturated zone. VOCs are transferred from water to the air as the air moves through the aquifer. Air sparging is an emerging technology which has been retained for further consideration.

**In-Situ Bioremediation - Reject**

In-situ bioremediation uses microorganisms indigenous to the aquifer to treat the contaminated groundwater. Typically, nutrients and oxygen must be injected into the aquifer. In-situ bioremediation has been rejected because it is not effective at achieving the cleanup goals, and it is not feasible when applied to the relatively large area and volume of contaminated groundwater existing at the Site.

**Off-Site Publicly Owned Treatment Works (POTW) - Reject**

Treatment of nearby POTWs is not technically feasible because the POTWs do not have the capacity to treat the expected volume of extracted groundwater. It is also estimated that the cost of conveying the extracted groundwater to nearby POTWs will be relatively high. Therefore, POTWs have been rejected for further consideration.

**Granular Activated Carbon (GAC) - Retain**

GAC treatment involves passing the contaminated groundwater through a series of towers which contain packed beds of GAC. The dissolved chemicals adsorb to the GAC at different rates. As discussed in Section 1.3.5, a treatability study is currently being conducted to generate GAC performance data for the Site groundwater and COCs. GAC has been retained for further consideration. The GAC treatment will be evaluated for the COCs and potential degredation products.

**Air Stripping - Retain; Steam Stripping - Reject**

Air stripping involves transferring VOCs from water to air by passing the water through a packed tower against a forced air stream. Subsequent treatment of the air stream may be required to remove the VOCs. Air stripping is a proven technology to treat VOC contaminated water and is not effective for treating explosives contaminated groundwater.

Air stripping has been retained for further consideration. The air stripping process will be evaluated for the COCs and potential degredation products.

Steam stripping is similar to air stripping except that pressurized steam removes organic compound that have higher boiling points. This is not an important consideration for the COC VOCs at the Site. Because steam stripping is more costly than air stripping and has no increased benefit, it is rejected for further consideration.

**Advanced Oxidation Process (AOP) - Retain**

The Advanced Oxidation Process (AOP) is an emerging technology which uses oxidants such as hydrogen peroxide or ozone to treat extracted groundwater. Ultraviolet light may also be used in conjunction with the oxidants. AOPs have not been used on a full-scale basis, but bench- and pilot-scale systems have been successful in treating VOCs and explosives. As discussed in Section 1.3.5, a treatability study is currently being conducted to generate AOP gross performance data for Site groundwater COCs. AOP has been retained for further consideration.

**GAC Air Stream Polishing - Retain**

If air stripping or air sparging are implemented, it may be necessary to remove VOCs from the resultant air stream. Therefore, GAC air stream polishing has been retained for further consideration as a potential component of a treatment train which involves either air stripping or air sparging.

#### 2.6.3.6 Disposal

Subsequent to treatment of the extracted groundwater, the treated water must be disposed. The retained technologies discussed below may be grouped into two categories, either on-/off-site stream discharge or beneficial reuse. Beneficial reuse includes recharge trench, reinjection wells, agricultural reuse, and water supply reuse.

**Deep Well Injection - Reject**

Deep well injection involves the injection of treated water into an aquifer at a depth greater than the aquifer from which the groundwater was extracted. Deep well injection is technically feasible, however it may be administratively difficult to obtain the necessary regulatory approvals for on-site deep well injection. It is estimated that conveyance/transportation costs associated with off-site deep well injection are relatively very high. Therefore, deep well injection has been rejected for further consideration.

**On-/Off-Site Stream Discharge - Retain**

Discharge of treated groundwater to an on- or off-site stream is technically feasible. Administratively, procurement of approval to discharge will be required. On-/off-site stream discharge has been retained for further consideration.

**POTW Discharge - Reject**

Discharge of treated groundwater to nearby POTWs is not technically feasible because the POTWs do not have the capacity to handle the expected volume of treated groundwater. Discharge to POTW has been rejected for further consideration.

**Recharge Trench/Basin - Reject**

Recharge of treated groundwater in an infiltration impoundment or trench is technically feasible. A detailed analysis of infiltration as a disposal method during the Containment Removal Action (the Contaminated Removal Action is discussed in Section 1.3.2) indicated that the cost of infiltration was prohibitive, and recharge trenches/basins have been rejected for further consideration.

**Reinjection Wells - Retain**

Reinjection of treated groundwater is technically feasible according to analyses performed during the Containment Removal Action and reinjection wells have been retained as a potential reuse of treated groundwater (WCC, 1995a).

**Agricultural Reuse - Retain**

Agricultural reuse may include irrigation, livestock watering, or processing (i.e. soybean washing). Agricultural reuse is technically feasible and has been retained as a potential reuse of treated groundwater.

**Water Supply Reuse - Retain**

Water supply reuse may include providing the treated groundwater to a future rural water district, and existing municipal water supply system, or the ARDC. Water supply reuse is technically feasible and has been retained as a potential beneficial reuse for treated groundwater.

## 2.7 IDENTIFICATION, EVALUATION, AND SCREENING OF LEACHING SOIL REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

### 2.7.1 Introduction

Soil remedial technologies and process options have been identified, evaluated, and screened in the OU1 FS Report (RUST, 1994a). The technologies and process options which were retained form the basis for addressing the RAO for the leaching soils. The two-step evaluation process described in Section 2.6.1 was used to screen the remedial technologies and process options retained by the OU1 screening process.

### 2.7.2 Identification of Leaching Soil Remedial Technologies and Process Options

The soil remediation technologies and process options retained after screening in the OU1 FS Report and subsequently identified as potential leaching soil remedial technologies and process options are tabulated below.

| Response Actions | Remedial Technology | Process Options |
|---|---|---|
| No Action | None | None |
| Institutional Controls | Monitoring | Groundwater Monitoring |
| | Access Restrictions | Deed Restrictions<br>Fencing |
| Containment | Capping | Soil Cap |
| Removal | Excavation | Excavation<br>Consolidation |
| Treatment | Thermal Treatment | Rotary Kiln Incineration<br>Above-Ground Vitrification<br>Low-Temperature Thermal Desorption |
| | Biological Treatment | Composting<br>Slurry-Based Biological Treatment |
| Disposal Actions | Land Disposal | Off-Site Secure Landfill<br>On-Site Secure Landfill |
| Residuals Management Actions | Water Treatment | On-Site Treatment and Discharge<br>Off-Site Treatment and Discharge |
| | Solids Treatment | On-Site Treatment and Disposal |
| Debris Removal Actions | Removal | Removal/Separation/Disposal/Management With Soil |

### 2.7.3 Evaluation and Screening of Leaching Soil Remedial Technologies and Process Options

The technical feasibility screening of leaching soil remedial technologies and process options is presented below.

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| No Action | None | None | No Action taken. | **Potentially applicable** |
| Institutional Controls | Monitoring | Groundwater Monitoring | Institute groundwater monitoring program. | **Potentially applicable** |
| Containment | Capping | Soil Cap | Cap covering waste materials to minimize infiltration of precipitation and reduce potential for groundwater contamination. | **Potentially applicable.** |
| Removal | Excavation | Excavation | Soil removal using standard earthwork equipment, shoring, and common construction practices. | **Potentially applicable** |

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| Removal (Continued) | Excavation (Continued) | Consolidation | Stockpiling and sampling contaminated soil near excavated areas or in a single centralized area prior to containment or treatment actions. | **Potentially applicable** |
| Treatment | Thermal Treatment | Rotary Kiln Incineration | A cylindrical, refractory-lined shell with a slightly inclined axis that rotates to provide mixing of wastes and combustion air while heating wastes to combustion temperatures. Combustibles are incinerated in an afterburner. | **Potentially applicable** |
| | | Above-Ground Vitrification | Hazardous waste is consolidated above-ground and heated with electrodes to reduce organic compounds to elemental gas and carbon under anoxic conditions. Inorganic contaminants remain entrained in the glass and siliceous melts. | **Potentially applicable** |
| | | Low Temperature Thermal Desorption | This includes a soil aeration system consisting of a thermal dryer, a bag house for control of particulate material, and an after-burner for off-gases. Variations of this process may include a scrubber to remove water soluble gases and a vapor phase carbon treatment system. | **Potentially applicable** |
| | Biological Treatment | Composting | Degradation of organic compounds in soil using microorganisms and compost amendments. | **Potentially applicable** |
| | | Slurry-Based Biological Treatment | Aerobic or anaerobic biological treatment of soil in a water-based slurry. Treatment may be accomplished in tanks or pits. | **Potentially applicable** |
| Disposal Actions | Land Disposal | Off-Site Secure Landfill | Excavated contaminated soil disposed of in an off-site secure landfill. | **Potentially applicable.** |
| | | On-Site Secure Landfill | Excavated contaminated soil disposed of in an on-site secure landfill. | **Potentially applicable.** |

| Response Action | Remedial Technology | Process Option | Process Option Description | Screening Comments |
|---|---|---|---|---|
| Residuals Management Action | Solids Treatment | On-Site Treatment and Disposal | Solids residuals from on-site treatment are treated/disposed on-site. | **Potentially applicable** |
| Debris Removal Actions | Removal | Removal/Separation/ Disposal/Management With Soil | Surface and subsurface debris such as concrete, brick, boulders, wood, metal, plastic, and glass are removed from the surface or separated from excavated soil, and decontaminated, if necessary, and disposed. | **Potentially applicable** |

The effectiveness, implementability, and cost screening of the leaching soil process options retained from the first screening is presented below.

| Response Action/ Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Status |
|---|---|---|---|---|---|
| No Action | None | No Action Taken | No Action Taken | None | **Retain** |
| Institutional Controls<br>Monitoring | Groundwater Monitoring | Does not achieve RAOs, but is an effective indicator of migration of contaminants. | Implementable | No capital costs and low O&M costs | **Retain** |
| Containment<br>Capping | Soil Cap | Effective for reducing the rate/concentration of contaminants entering the groundwater. | Not implementable. The integrity of the cap cannot be assured without land use restrictions facilitated using deed restrictions. | Low capital costs and low O&M costs. | Reject. |
| Removal<br>Excavation | Excavation | Effective for removal of contaminant source. Migration potential is eliminated after source is removed. | Implementable with standard construction equipment. | Low capital costs and no O&M costs | **Retain** |

| Response Action/ Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Status |
|---|---|---|---|---|---|
| Removal Excavation (Continued) | Consolidation | Facilitates implementation of treatment actions. | Implementable with standard construction equipment. | Low capital costs and no O&M costs | **Retain** |
| Treatment Thermal | Rotary Kiln Incineration | Extensive full-scale demonstrated success, including explosives treatment. | Full-scale units commercially available from many vendors. Residuals may require further treatment/disposal. | High capital costs and no O&M costs | **Retain** |
| | Above-Ground Vitrification | Immobilizes both organic and inorganic contaminants in a stable vitreous solid. No demonstrated success with explosives. | Available from a limited number of vendors. Energy intensive. Would require a treatability study. | High | Reject |
| | Low Temperature Thermal Desorption | Some vendors claim explosives may be removed. Effectiveness uncertain due to waste and soil type. No demonstrated success with explosives. | Would require treatability studies. Easily implemented. Residuals may require further treatment/disposal. | Moderate to high capital costs and no O&M costs | Reject |
| Biological | Composting | There is evidence of detoxification and polymerization, but incomplete mineralization. Estimated to not be effective at reducing explosives concentrations below the concentrations that define leaching soils. | Commercially available from several vendors. Treatability study and process scale-up required before implementation. | Moderate capital costs and no O&M costs | Reject |

| **Response Action/ Remedial Technology** | **Process Options** | **Effectiveness** | **Implementability** | **Cost** | **Status** |
|---|---|---|---|---|---|
| Biological (Continued) | Slurry-Based Biological Treatment | Laboratory studies have shown high levels of detoxification at fairly rapid rates (30 days). Estimated to not be effective at reducing explosives concentrations below the concentrations that define leaching soils. | Commercially available from several vendors. Treatability study and process scale-up required before implementation. | Moderate to high capital costs and no O&M costs | Reject |
| Disposal Actions Land Disposal | Off-Site Secure Landfill | Effective for reducing the rate/ concentration of contaminants entering the groundwater. | Least preferred option under the NCP. | Low capital costs and low O&M costs. | Reject. |
| Disposal Actions Land Disposal (Continued) | On-Site Secure Landfill | Effective for reducing the rate/ concentration of contaminants entering the groundwater. | Not implementable. The integrity of the landfill cannot be assured without land use restrictions facilitated using deed restrictions. | Low capital costs and low O&M costs. | Reject. |
| Residuals Management Action | | | | | |
| Solids Treatment | On-Site Treatment and Disposal | Effectiveness varies with processes. Generally, reliable processes are utilized for secondary waste streams. | Technically implementable. Agency approval for backfilling with treated soil on-site is required. | Low capital costs and no O&M costs | **Retain** |

| Response Action/ Remedial Technology | Process Options | Effectiveness | Implementability | Cost | Status |
|---|---|---|---|---|---|
| Debris Removal Action | | | | | |
| Removal | Removal/ Separation/ Disposal/ Management With Soil | Removal, separation, and disposal actions would be very effective in managing debris; because contaminated soil is non-hazardous, debris decontamination may not be required. Very large debris may require size reduction prior to disposal. | Technically implementable by standard construction techniques. | Low capital costs and no O&M costs | **Retain** |

A description of the remedial technologies and related process options and the rationale for eliminating or retaining each is provided below.

### 2.7.3.1 No Action

The no action response may be appropriate if it is determined that there is no benefit associated with remediating leaching soils within the context of the groundwater remediation (i.e., does the groundwater remediation benefit in terms of time, cost, or protectiveness if the leaching soils are remediated).

### 2.7.3.2 Institutional Controls

**Groundwater Monitoring Wells - Retain**

Groundwater monitoring wells are currently being used to monitor groundwater conditions at the Site and have been retained as a groundwater institutional control process option in Section 2.6.3.2.

### 2.7.3.3 Containment

**Soil Cap - Reject**

A soil cap would be constructed over the leaching soil areas. The cap would reduce the infiltration of water from the ground surface through the leaching soils. The rate and concentration of contaminants reaching the groundwater would be reduced. A soil cap is not implementable because deed restrictions cannot be used to limit land use. Land use restrictions are required to assure the integrity of the soil cap. Soil cap is rejected for further consideration.

### 2.7.3.4 Removal

**Excavation - Retain**

Leaching soils would be removed to predetermined cut lines using primarily standard excavation equipment. The contaminated soil could then be consolidated and treated. Excavation is an effective means of reducing the potential for leaching soils to contribute to groundwater contamination and has been retained for further consideration. It is anticipated that leaching soils would be excavated in conjunction with OU1 excavation activities.

**Consolidation - Retain**

Consolidation of excavated material will be necessary to optimize any treatment process. Consolidation has been retained for further consideration.

### 2.7.3.5 Treatment

Treatment is the reduction of toxicity. Thermal and biological treatment processes were retained by the technical feasibility screening.

**Rotary Kiln Incineration - Retain**

Rotary kiln incineration is an element in the treatment included as a part of the preferred alternative identified in the OU1 Proposed Plan (RUST, 1994b).

The rotary kiln incinerator is a cylindrical refractory-lined shell mounted on a slight incline and in a manner such that it can be slowly rotated. Wastes and fuels are introduced into the high end of the kiln. The kiln's rotation constantly agitates the material to expose the solids to oxygen and to improve heat transfer. Because the solids are agitated, particulates entrained in the gas stream require post-combustion control. Ash residues from the combustion process are discharged and collected at the low end of the kiln. Exhaust gases typically pass to a secondary combustion chamber or afterburner for further oxidation. These gases usually require acid gas or particulate removal. The ash and the aqueous pollution control process residues from the incinerator may require further treatment (e.g., solidification) prior to disposal. Rotary kilns have successfully destroyed refractory compounds at destruction and removal efficiencies (DRE) in excess of 99.9999 percent.

Rotary kilns can process solid particle sizes of up to 2 to 4 inches. Rotary kiln incineration has demonstrated performance in destroying explosives in soil (IT 1987a, 1989). Due to the destruction of contaminants, no long-term management is associated with rotary kiln treatment. The availability of many commercial vendors who use rotary kilns makes this process option readily implementable. Large quantities (10 percent of treated volume) of fly ash are expected due to the high clay content of the soil (Chemical Waste Management, 1992c). However, service providers contacted consider this to be an operational factor which can be addressed through proper system design and operational control. This process option is retained for further consideration.

**Above-Ground Vitrification - Reject**

Vitrification of wastes involves electrical melting of contaminated solids to destroy, remove, and/or immobilize contaminants. Soils are either consolidated into piles (above-ground) or left in-place (in-situ), and electrodes are placed in an array in the soil. The electrodes heat the soil to temperatures of 1,600 degrees to 2,000 degrees Celsius to destroy or remove organic contaminants and entrain the inorganic contaminants. The organic constituents are reduces to elemental gas and carbon either within the soil or after removal. Because of the destruction of contaminants, no long-term management is associated with vitrification. Inorganic contaminants remain entrained in a siliceous melt which forms a stable vitreous solid when cooled.

Above-ground vitrification is a modified in-situ technology that relies on the adequate characterization of contaminant concentrations for its ensured success. This process has an organic concentration loading limit of 5 to 10 percent (Geosafe, 1992). Also, vitrification adds heat to soil within the melt area and thus, could present a hazard when applied to high concentrations of explosive compounds. The possible presence of detonation hazards and the organic concentration loading limit would make necessary the excavation, consolidation, and blending of site soil. The vitrification process has been implemented at full scale on only a few sites; however, it has been demonstrated for explosives-contaminated soil at the bench scale as described in the OU 1 FS Report (RUST, 1994a). Because this treatment technology has not been previously used successfully at full-scale for explosives-contaminated soil, this process option is rejected for further consideration.

**Low Temperature Thermal Desorption - Reject**

Two types of low-temperature thermal desorption (LTTD) systems are currently in use. One is directly fired, where heated air is forced countercurrent to soil flow, and the other is indirectly fired, where soil is heated in an oxygen-free atmosphere. Both use rotary shells to ensure uniform heat transfer and to remove organic compounds at temperatures less than about 1,000 degrees Fahrenheit. Organic compounds are vaporized, then removed from the vapor phase by condensation, carbon adsorption, or combustion. If vapors are condensed, they are separated into organic and aqueous phases by an oil-water separation unit. The gas stream is then discharged through a stack. Process residuals may include processed soil, a condensed organic liquid phase, an aqueous liquid stream, ash from an afterburner, spent carbon, and air emissions.

LTTD systems are generally used to remove volatile and semi-volatile organic compounds from soil. Clayey soil may require longer residence times than looser, larger-grained soils. This reduction of process rate will cause increases in cost (Chemical Waste Management, 1992b). Although this technology was deemed not effective for explosives-contaminated soil at one site in a study conducted for the U.S. Army Toxic and Hazardous Materials Agency (IT, 1987b), several technology vendors interviewed (Chemical Waste Management, 1992a; Canonie, 1992) believed that their process units could treat explosive compounds. These firms recommended the use of an afterburner to treat desorbed organic compounds. Because this treatment technology has not been previously used successfully at full-scale for explosives-contaminated soil, this process option is rejected for further evaluation.

**Composting - Reject**

Composting is an aerobic biological treatment process in which contaminated soil is mixed with organic amendments such as sewage sludge, vegetable wastes, or animal manure, and bulking agents, such as sawdust, bark, straw, or wood chips, to produce an environment in which thermophilic (active at relatively high temperatures) microorganisms flourish. Bulking agents create void volume in the compost, allowing for sufficient aeration. The enhanced biological activity tends to speed the degradation process. Organic contaminants are transformed along with the organic amendments, which serve as the main carbon source for the microorganisms.

A literature survey of bioremediation for degradation of explosive chemicals in soils was conducted. Bioremediation has been accomplished via both composting and slurry-based biological treatment processes. Information for both processes from known publicly available references is summarized and the references listed in **Appendix F**.

Success with composting explosives has been demonstrated at a number of test sites using aerated static pile methods, windrowing, and a mechanically agitated vessel method (Roy F. Weston, Inc., 1988, 1989a, 1989b; USAEC, 1993). TNT has been degraded from 3,800 mg/kg to 40 mg/kg, RDX from 600 mg/kg to 46 mg/kg, and HMX from 300 mg/kg to 60 mg/kg in an aerated static pile system (Roy F. Weston, 1991). Agitated vessel experiments have resulted in reduction of TNT concentrations from 3,000 mg/kg to

6 mg/kg, RDX from 575 mg/kg to 4 mg/kg, and HMX from 120 mg/kg to 6 mg/kg (Roy F. Weston, 1991). However, experiments using radio-labeled TNT indicated mineralization of less than 1 percent by the conversion to carbon dioxide, water, and inorganic nitrogen compounds (Isbister, et al., 1982). In windrow composting demonstrations, concentrations of TNT, RDX, and HMX were reduced by over 99 percent, over 99 percent, and over 96 percent, respectively. Leachate toxicity and extractable mutagenicity test showed significant reductions of toxicity (USAEC, 1993).

Development of this technology is still in progress. Explosives compounds do not appear to be mineralized, but are transformed to unknown compounds and immobilized in the compost matrix. Detailed composting treatability information is not available to date for all explosives at the Site. Excavation, composting, and on-site disposal has been recommended as the preferred remedial alternative for explosives-contaminated soil at the Umatilla Army Depot in Hermiston, Oregon (EPA, 1992b). Although research is being conducted to obtain Site-specific composting treatment information, it is not estimated that composting will reduce explosives concentrations below the concentrations which define leaching soils. Composting is rejected for further consideration.

**Slurry-Based Biological Treatment - Reject**

Slurry-based biological treatment can be accomplished either in mechanically agitated vessels or in a lined pit or "biopad". Nutrients (e.g., phosphorus and nitrogen) and water are added to soil to create a slurry of 20 to 50 percent solids (Treatek, 1992). In some cases, organic substrates and/or a population of microorganisms specifically acclimated to site contaminants (an inoculum) may be added. Proper conditions of pH, temperature, and redox potential are necessary for transformation of organic contaminants into less hazardous compounds. Conditions may be manipulated such that either aerobic or anaerobic biodegradation takes place at a given time during treatment.

A literature survey of bioremediation for degradation of explosive chemicals in soils was conducted. Bioremediation has been accomplished via both composting and slurry-based biological treatment processes. Information for both processes from known publicly available references is summarized and the references listed in **Appendix F.**

Recent bench scale experiments conducted at the U.S. Army Engineer Waterways Experiment Station (WES, 1992) on mixed tank, aerobic slurry biodegradation indicate that TNT can be reduced from 10,000 mg/kg to below 5 mg/kg. In separate studies with radioactive-labeled TNT, approximately 15 percent of the TNT was completely mineralized.

An anaerobic slurry-based biotreatment system has been accepted into USEPA's Superfund Innovative Technology Evaluation (SITE) Program and is undergoing pilot-scale testing at the former Weldon Springs Ordnance Works near St. Louis, Missouri. This is the largest scale test which has been conducted for anaerobic bioslurry treatment of explosives-contaminated soil. Slurry-reactor bioremediation has several advantages over composting:

- Superior mixing and nutrient transfer for the contaminant-microbe interface
- Better control of environmental parameters which effect biotreatment including temperature, dissolved oxygen (where appropriate), pH, and nutrient concentration
- More uniform conditions throughout the reactor resulting in more uniform treatment
- Residual volume of treated soil is not increased through the addition of bulking agents. In spite of the above advantages, composting would appear to be a more economical process

Although research is being conducted to obtain Site-specific slurry-based biological treatment information, it is not estimated that this treatment will reduce explosives concentrations to below concentrations which define leaching soils. Slurry-based biological treatment is rejected for further consideration.

### 2.7.3.6 Disposal Actions

**Off-Site Secure Landfill - Reject**

Leaching soils would be excavated, consolidated, and transported to an off-site secure landfill. This action would transfer the potential for leaching soils to contribute to groundwater contamination at the Site to the groundwater beneath the landfill. This is the least preferred option under the NCP. Off-site secure landfill is rejected from further consideration.

**On-Site Secure Landfill - Reject**

Leaching soils would be excavated, consolidated, and placed in a secure landfill constructed on-site. This option would transfer a (reduced) potential for leaching soils to contribute to groundwater contamination between geographic areas at the Site. Land use restrictions are required to assure the integrity of the landfill. Because deed restrictions cannot be used to obtain land use restrictions, on-site secure landfill is rejected for further consideration.

#### 2.7.3.7 Residuals Management Actions

**On-Site Treatment and Disposal - Retain**

The treatment technologies discussed previously produce residual wastewater and decontamination wastewater. Liquid residuals may not require treatment if contaminant levels are acceptable as defined by the ARARs, including the Clean Water Act (CWA) and associated state requirements. Various physical, chemical, and biological treatment processes are appropriate for different types of wastewater streams which would be produced by different soil treatment technologies. Water could be discharged to Clear Creek or possibly to other streams or drainage ditches on-site. This process option is retained for further consideration in conjunction with groundwater treatment technologies.

#### 2.7.3.8 Debris Removal Actions

**Removal/Separation/Disposal/Management with Soil - Retain**

Surface and subsurface debris removal will be required at many contaminant source areas before removal actions for soil may be implemented. Debris removal may include:

- Removal and treatment/disposal of surface debris such as wood, metal scrap and concrete structures.

- Removal, separation from soil and treatment/disposal of bucket trap sumps, associated concrete aprons, and inlet and outlet piping/structures.

- Removal and disposal of tree and brush cover.

- Removal and relocation (on-site) of large structures such as escape chutes.

Surface debris containment or disposal procedures may include the following options:

- Haul to an off-site authorized landfill.

- Place in on-site capped area (if implemented for explosives-contaminated soil).

- Place in on-site landfill (if implemented for explosives-contaminated soil).

Subsurface debris may be removed/disposed depending on size. Large subsurface debris may be separated from soil during excavation/consolidation and disposed with surface debris. Small subsurface debris may be managed with excavated soil; however, it may be removed by subsequent pre-process screening. In the latter case, the contaminated debris will be taken to an off-site disposal facility. In the OU1 FS Report (Rust, 1994a), subsurface debris are assumed to be non-hazardous under RCRA because the Site soil is unlikely to be hazardous under RCRA. The same assumption was used during OU1 (SEC Donohue, 1992).

Debris removal may pose potential physical hazards to workers; however, these risks can be controlled by safe work practices. Dust generated during debris removal would be managed by standard practices. This action uses standard construction techniques and equipment, and is therefore considered reliable and implementable. Debris removal is retained for use in conjunction with on-site treatment actions.

## 2.8 SUMMARY OF RETAINED REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

### 2.8.1 Groundwater

The retained groundwater technologies and process options are tabulated below.

| Retained Groundwater Remedial Technologies and Process Options | | |
|---|---|---|
| **General Response Actions** | **Remedial Technologies** | **Process Options** |
| No Action | None | None |
| Institutional Controls | Alternate Water Supply | Point-of-Entry Treatment Units |
| | Monitoring | Groundwater Monitoring Wells |
| Containment | Hydraulic Controls | Extraction Wells |
| Removal | Extraction | Extraction Wells |
| Treatment | In-Situ | Air Sparging |
| | Physical/Chemical | GAC Adsorption |
| | | Air Stripping |
| | | AOP |
| | Physical/Chemical (air pollution control) | GAC |
| Disposal | Discharge | On-/Off-Site Stream Discharge |
| | Beneficial Reuse | Reinjection Wells |
| | | Agricultural |
| | | Water Supply |

### 2.8.2 Leaching Soils

The retained leaching soils technologies and process options are tabulated below:

| Retained Leaching Soils Remedial Technologies and Process Options | | |
|---|---|---|
| **General Response Actions** | **Remedial Technologies** | **Process Options** |
| No Action | None | None |
| Institutional Controls | Monitoring | Groundwater Monitoring |
| Removal | Excavation | Excavation |
| | | Consolidation |
| Treatment Actions | Thermal | Rotary Kiln Incineration |
| Residuals Management Actions | Treatment | On-Site Treatment and Disposal |
| Debris Removal Actions | Removal | Removal/Separation/Disposal /Management with Soil |

3

# DEVELOPMENT AND SCREENING OF ALTERNATIVES

## 3.1 INTRODUCTION

In this section, the retained technologies and related process options summarized in Section 2.8 are developed into preliminary remedial alternatives to address contaminated groundwater at the Site. These preliminary alternatives are then screened based on the three criteria (effectiveness, implementability, and cost) to reduce the number of alternatives which will undergo detailed analysis. These criteria are the same used in the second screening evaluation presented in Section 2.0, but they are applied to alternatives as a whole rather than to process options or technologies. The nine evaluation criteria which are used during the detailed analysis of alternatives in Section 4.0 (with the exception of state acceptance and community acceptance) form the components for the three screening criteria, as listed below.

Effectiveness

- Overall Protection of Human Health and Environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)
- Minimizes residual risks and affords long-term effectiveness and permanence
- Reductions in toxicity, mobility, and volume through treatment
- Minimizes short-term impacts and how quickly it achieves protection

Implementability

- Implementability

Cost

- Cost

## 3.2 ASSEMBLE PRELIMINARY ALTERNATIVES

Preliminary alternatives are assembled by combining different remedial technology types and/or process options to form preliminary remedial alternatives that can attain the RAOs for OU2. The following rationale were used in assembling the alternatives:

- The No Action alternative includes groundwater monitoring of the analytes listed in Table 1-1 and is included to provide a baseline against which other alternatives may be compared

- All alternatives except for the No Action alternative will include point-of-entry treatment systems for impacted residential supply wells within the area of attainment, and that treatment will reduce exposure associated with unacceptable human health risks

- All alternatives except for the No Action alternative protect groundwater users outside the area of attainment by reducing the potential for additional continuing areal expansion of contamination through hydraulic containment

- All groundwater which is extracted as a part of the remedial alternative will be treated to applicable water quality standards, and the treatment option will be selected during the remedial design

- All treated groundwater will be disposed through either stream discharge or beneficial reuse, and if beneficial reuse is selected, a study will be conducted at a later time to select the specific beneficial reuse

- All potential treatment will be evaluated for the COCs and the water will be monitored for the analytes listed in Table 1-1

- All leaching soils which are excavated as a part of the remedial alternative will be treated by incineration and subject to residuals management and debris removal

Eleven preliminary alternatives for OU2 were developed using the rationale above. The preliminary alternatives are illustrated below:

| General Response Action | | 1<br>No Action | 2<br>Hydr. Contain. | 3<br>Hydr. Contain. w/Soil Exca. | 4<br>Hydr. Contain. w/Air Sparging | 5<br>Hydr. Contain. w/Air Sparging and Soil Exca. | 6<br>Focused Extrac. | 7<br>Focused Extrac. and Soil Exca. | 8<br>Focused Extrac. w/Air Sparging | 9<br>Focused Extrac. w/Air Sparging and Soil Exca. | 10<br>Groundw. Extrac. | 11<br>Groundw. Extrac. and Soil Exca. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Medium | Technology Type or Process Option | | | | | | | | | | | |
| Ground-water | Monitoring | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | Point-of-Entry Treatment | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | Hydraulic Containment | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | Supplemental Focused Extraction | | | | | | ● | ● | ● | ● | | |
| | Supplemental Broad Extraction | | | | | | | | | | ● | ● |
| | Air Sparging | | | | ● | ● | | | ● | ● | | |
| | Ex-Situ Treatment | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| | Disposal | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Leaching Soils | Excavation | | | ● | | ● | | ● | | ● | | ● |
| | Incineration | | | ● | | ● | | ● | | ● | | ● |
| | Residuals Management | | | ● | | ● | | ● | | ● | | ● |
| | Debris Removal | | | ● | | ● | | ● | | ● | | ● |

The preliminary alternatives are described below:

Alternative 1 - No action: Alternative 1 consists of only groundwater monitoring. Evaluation of the no action alternative is required by the NCP to provide a baseline for comparison with other alternatives.

Alternative 2 - Hydraulic Containment: Alternative 2 consists of the hydraulic containment of the contaminated groundwater at the downgradient edge of the area of attainment, point-of-entry treatment systems supplying potable water (potable water supply), and groundwater monitoring.

Alternative 3 - Hydraulic Containment with Soil Excavation: Alternative 3 consists of all of the elements of Alternative 2 plus the excavation and incineration of the leaching soils.

Alternative 4 - Hydraulic Containment with Air Sparging: Alternative 4 consists of all of the elements of Alternative 2 plus air sparging in the Atlas Missile Area where there are relatively high concentrations of TCE in the groundwater without the presence of explosives.

Alternative 5 - Hydraulic Containment with Air Sparging and Soil Excavation: Alternative 5 consists of all of the elements of Alternative 2, air sparging in the Atlas Missile Area, and the excavation and incineration of leaching soils.

Alternative 6 - Focused Extraction: Alternative 6 consists of all of the elements of Alternative 2 plus additional groundwater wells which focus groundwater extraction in areas with relatively high TCE and/or RDX concentrations.

Alternative 7 - Focused Extraction and Soil Excavation: Alternative 7 consists of all of the elements of Alternative 6, plus excavation and incineration of leaching soils.

Alternative 8 - Focused Extraction with Air Sparging: Alternative 8 consists of all of the elements of Alternative 2, additional extraction wells in areas with relatively high RDX and/or TCE concentrations (except for the Atlas Missile Area where TCE are present and explosives are not), and air sparging in the Atlas Missile Area to address the TCE-only groundwater contamination.

Alternative 9 - Focused Extraction with Air Sparging and Soil Excavation: Alternative 9 consists of all of the elements of Alternative 8 plus excavation and incineration of the leaching soils.

Alternative 10 - Groundwater Extraction: Alternative 10 consists of all of the elements of Alternative 2 plus additional groundwater wells to extract contaminated groundwater throughout the area of attainment.

Alternative 11 Groundwater Extraction and Soil Excavation: Alternative 11 consists of all of the elements of Alternative 10 plus the excavation and incineration of leaching soils.

## 3.3 SCREENING OF ALTERNATIVES

The three screening criteria, effectiveness, implementability, and cost, are applied to the preliminary remedial alternatives. The preliminary alternatives that are retained by the screening process will undergo a more thorough evaluation in the detailed analysis phase of the FS.

### 3.3.1 Effectiveness

Preliminary Alternative 1 does not provide an immediate reduction in human health risk for existing or potential future groundwater users. There is no environmental protection because Preliminary Alternative 1 allows the continued migration of contaminated groundwater. Because Preliminary Alternative 1 is not protective of human health and the environment, it is not considered further in the screening analysis. However, Preliminary Alternative 1 is retained as a baseline for comparison of other alternatives.

The remaining preliminary alternatives use point-of-entry treatment systems and groundwater extraction to protect current and potential future groundwater users. These preliminary alternatives provide environmental protection by containing contaminated groundwater and minimizing its potential for migration past the downgradient edge of the area of attainment. Preliminary Alternatives 4 and 5 preferentially extract or in-situ treat TCE-contaminated groundwater with air sparging. Preliminary Alternatives 8 and 9 also include in-situ treatment of TCE-contaminated groundwater with air sparging as well as focused extraction of groundwater with relatively high concentrations of RDX or RDX and TCE combined. Therefore, there is no additional incremental benefit associated with Preliminary Alternatives 4 and 5 relative to Preliminary Alternatives 8 and 9. Preliminary Alternatives 4 and 5 are rejected on that basis and are not considered further.

The potential for contaminated soils to be a continuing source of groundwater contamination will be reduced by soil excavation and treatment in Preliminary Alternatives 3, 7, 9, and 11, providing additional protection of human health and the environment.

Preliminary Alternatives 2, 3, and 6 through 11 can be designed to comply with chemical-specific, location-specific, and action-specific ARARs.

Preliminary Alternatives 2, 3, and 6 through 11 control residual risk by point-of-entry groundwater treatment systems at impacted residences, and downgradient groundwater users are protected by the element of hydraulic containment. Residual risk is further reduced in Preliminary Alternatives 6 through 11 by either groundwater extraction wells (in addition to the containment systems), or the air sparging systems, or a combination of both. Soil treatment associated with Preliminary Alternatives 3, 7, 9, and 11 reduces the potential for residual risk associated with the transfer of contaminants from the soil to the groundwater.

The point-of-entry treatment systems associated with Preliminary Alternatives 2, 3, and 6 through 11 are reliable and adequate to treat the contaminants of concern over the long-term. Hydraulic containment and the other extraction systems which are a part of Preliminary Alternatives 2, 3, and 6 through 11 are reliable when the adequacy of the systems are monitored. Air sparging (Preliminary Alternatives 8 and 9) is an emerging technology whose reliability and adequacy must also be monitored. Long-term engineering controls are not necessary for the soil treatment included as a part of Preliminary Alternatives 3, 7, 9, and 11.

Proven and effective technologies (GAC and air stripping) and the emerging technology AOP, which is considered implementable and for which treatability studies are being conducted, are being considered for the treatment of COCs in extracted groundwater. The air sparging element of Preliminary Alternatives 8 and 9 is an emerging technology. Incineration of leaching soils (Preliminary Alternatives 3, 7, 9, and 11) is a proven and effective treatment process.

Preliminary Alternatives 2, 3, and 6 through 11 will eventually destroy all COCs in groundwater above the Target Groundwater Cleanup Goals. The destruction of COCs and their associated degradation products will be monitored by analyzing groundwater samples for the analytes listed in Table 1-1. Explosives contamination in approximately 2,600 cubic yards of leaching soil will be destroyed as part of Preliminary Alternatives 3, 7, 9, and 11.

For Preliminary Alternatives 2, 3, and 6 through 11, the groundwater contaminants remain mobile but the mobility is managed through hydraulic containment. Those preliminary alternatives reduce the volume of contaminated groundwater through extraction, and the toxicity is reduced through treatment. The thermal treatment of soils (Preliminary Alternatives 3, 7, 9, and 11) reduces toxicity, mobility, and volume of contaminated soils, and reduces the potential contribution to groundwater contamination.

The treatment process options included for soil and groundwater as a part of Preliminary Alternatives 2, 3, and 6 through 11 destroy the contaminants or transfer them to another media and are therefore irreversible.

Residual materials resulting from the treatment of groundwater and leaching soils are manageable and do not pose residual risk when properly managed.

The objective of hydraulic containment is to prevent the further downgradient migration of contamination, rather than the clean up of the aquifer. As such, the restoration time frame estimate using hydraulic containment of groundwater within the area of attainment is essentially perpetuity. Therefore, the cleanup of leaching soils included in Preliminary Alternative 3 does not realize a benefit in terms of time, yet the cost will be higher than hydraulic containment alone (Preliminary Alternative 2), without a significant increase in the degree of human-health protectiveness. On that basis, Preliminary Alternative 3 does not provide any benefit and is rejected and not considered further.

The objective of the other remedial technologies which involve supplemental extraction or in-situ treatment is to clean up groundwater contamination (as opposed to containment), and the restoration time frame estimates will be time periods less than perpetuity. Preliminary alternatives which do not include soil excavation and treatment (Preliminary Alternatives 2, 6, 8, and 10) will have restoration time frames estimates which account for continuing contamination from leaching soils. These restoration time frame estimates will be longer than restoration time frames which are estimated based on cleanup of currently existing groundwater contamination alone because the leaching soils would have been remediated (Preliminary Alternatives 7, 9, and 11).

Risk to the community is not significantly increased by the implementation of groundwater remedial technologies which are included as elements of Preliminary Alternatives 2 and 6 through 11, and any additional risk can be managed by engineering controls. For Preliminary Alternatives 7, 9, and 11, there is potential for exposure due to airborne emissions during excavation and treatment of contaminated soils. All such risks are manageable.

Preliminary Alternatives 3, 4, and 5 were rejected for further consideration on the basis of effectiveness.

### 3.3.2 Implementability

Preliminary Alternatives 2 and 6 through 11 possess the same degree of implementability with the exception of Preliminary Alternatives 8 and 9 which rely on air sparging, an emerging technology. The emerging technology status means that the alternatives may be more difficult to implement.

No preliminary alternatives were rejected on the basis of implementability.

### 3.3.3 Cost

Comparative cost rankings for preliminary alternative capital costs and O&M costs are presented in this section. The comparative cost ranking categories are "low", "medium", and "high". A "low" cost is estimated to be less than one-half of the cost of the median (by ranking) alternative. The "medium" cost is estimated to be more than one-half, but less than two times the median cost, and the "high" cost is estimated to be more than two times the median cost. Section 4.0 will present quantified cost estimates as a part of detailed analysis of the retained alternatives.

No preliminary alternatives were rejected on the basis of cost.

#### 3.3.3.1 Capital Cost Categorization

The groundwater remedial technologies components of the remaining preliminary alternatives include the point-of-entry treatment systems, the groundwater extraction wells, the groundwater treatment systems, the piping to convey the extracted water from the wells to the treatment plant, and the discharge works. The remaining preliminary alternatives are ranked below in order of increasing total extraction flowrate:

- Preliminary Alternative 2
- Preliminary Alternatives 8 and 9

- Preliminary Alternatives 6 and 7
- Preliminary Alternatives 10 and 11

Using the flowrate ranking to assign the preliminary alternatives to the general cost categories, Preliminary Alternatives 2, and 6 through 9 are categorized as medium cost, and Preliminary Alternatives 10 and 11 are assigned to the high cost category.

It is estimated that air sparging capital costs normalized per unit area of contaminated aquifer will be greater than the corresponding capital cost for groundwater extraction and treatment plant capacity. Based on the estimated cost differential of air sparging, Preliminary Alternatives 8 and 9 are re-categorized as high cost.

One-time costs associated with soil excavation and incineration are included in the capital cost of the alternatives. These one-time costs include excavation, consolidation, incineration debris removal, and residuals management of the leaching soils. It is assumed that all capital costs of the incinerator will be accounted for as OU1 costs. Therefore, it is estimated that the inclusion of leaching soils excavation and incineration costs are low enough that there is no change to the preliminary alternatives cost categorizations.

The categorization of preliminary alternative capital cost is tabulated below:

| Preliminary Alternative | Capital Cost Category |
|---|---|
| 2 | Medium |
| 6 | |
| 7 | |
| 8 | High |
| 9 | |
| 10 | |
| 11 | |

The capital cost categorization indicates that Preliminary Alternatives 2 and 6 through 11 be retained for further consideration.

### 3.3.3.2 <u>Annual Operation and Maintenance Cost Ranking</u>

In a manner similar to capital costs, it is estimated that annual O&M costs will increase with increasing total extraction flowrate. However, it is estimated that the annual O&M costs associated with the different flowrates will be similar enough to be categorized in a single group. Based on total extraction flowrates, the annual O&M costs for all of the remaining flowrates are categorized as medium.

It is estimated that the annual O&M costs associated with air sparging and groundwater extraction (Preliminary Alternatives 8 and 9) are not significantly different from the costs associated with extraction wells only (Preliminary Alternatives 6 and 7).

The estimated annual O&M costs associated with soil excavation and incineration are estimated to be low. The addition of these low (soil) O&M costs to the estimated medium (groundwater) O&M costs results in estimated costs below the high cost categorization. Therefore, the remaining annual O&M costs for preliminary alternatives are all categorized as medium.

The annual O&M cost categorization indicates that Preliminary Alternatives 2 and 6 through 11 be retained for further consideration.

## 3.4 SUMMARY OF THE RETAINED ALTERNATIVES

Preliminary Alternatives 1, 2, and 6 through 11 were retained during the screening evaluations. The alternatives have been redesignated as shown on the summary table below.

| General Response Action | | 1<br>No Action | 2<br>Hydraulic Containment | 3<br>Focused Extraction | 4<br>Focused Extraction and Soil Excavation | 5<br>Focused Extraction with Air Sparging | 6<br>Focused Extraction with Air Sparging and Soil Excavation | 7<br>Groundwater Extraction | 8<br>Groundwater Extraction and Soil Excavation |
|---|---|---|---|---|---|---|---|---|---|
| **Medium** | **Technology Type or Process Option** | | | | | | | | |
| Groundwater | Monitoring | ● | ● | ● | ● | ● | ● | ● | ● |
| | Point-of-entry treatment | | ● | ● | ● | ● | ● | ● | ● |
| | Hydraulic Containment | | ● | ● | ● | ● | ● | ● | ● |
| | Supplemental Focused Extraction | | | ● | ● | ● | ● | | |
| | Supplemental Broad Extraction | | | | | | | ● | ● |
| | Air Sparging | | | | | ● | ● | | |
| | Ex-Situ Treatment | | ● | ● | ● | ● | ● | ● | ● |
| | Disposal | | ● | ● | ● | ● | ● | ● | ● |
| Leaching Soils | Excavation | | | | ● | | ● | | ● |
| | Incineration | | | | ● | | ● | | ● |
| | Residuals Management | | | | ● | | ● | | ● |
| | Debris Removal | | | | ● | | ● | | ● |

4

# 4.0
# DETAILED ANALYSIS OF ALTERNATIVES

The detailed analysis of alternatives for the FS is designed to provide sufficient information concerning each potential remedial alternative for selecting an appropriate remedy for the Site. The analysis presented herein is in accordance with the procedure used to evaluate CERCLA sites. As such, the detailed analysis evaluates each alternative with respect to the nine criteria detailed in the RI/FS guidance (EPA, 1988b) and the NCP. The detailed analysis concludes with a comparative analysis of the alternatives.

The evaluation criteria are discussed in Section 4.1. In Section 4.2, general site elements (i.e., elements common to all the alternatives) are described. In Section 4.3, the remedial alternatives developed in Section 3.0 are fully described and analyzed using the nine evaluation criteria. Section 4.4 presents the comparative analysis of alternatives and the cost sensitivity analysis.

## 4.1 DESCRIPTION OF EVALUATION CRITERIA

During the detailed analyses, each alternative is presented in sufficient detail so that its performance can be evaluated with respect to the following seven criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. Following completion of the public comment period, two additional criteria; state and community acceptance, are evaluated, making a total of nine criteria.

Revisions to the NCP in 1990 (Federal Register, 1990) suggested the separation of the nine criteria into three categories:

Threshold Criteria:

- Overall protection of human health and the environment
- Compliance with ARARs

Balancing Criteria

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility or volume
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

- Community acceptance
- State acceptance

An alternative must meet the threshold criteria to be eligible for selection. The balancing criteria are then applied. These balancing criteria are the primary technical criteria upon which the detailed analysis is based. They are used to assess the positive and negative aspects of performance, implementability, and cost. In the case of a CERCLA site, the modifying criteria do not impact the comparison of alternatives until the Record of Decision (ROD) for a site is prepared. At the time of the ROD, the modifying criteria can be used to adjust the components of a given alternative or change the preferred alternative.

The following paragraphs describe each of the nine criteria.

### 4.1.1 Threshold Criteria

Threshold criteria focus on how risks posed through each exposure pathway are reduced, controlled, or eliminated through institutional controls, engineering controls, or treatment. There are two threshold criteria: 1) overall protection of human health and the environment; and 2) compliance with ARARs. According to the RI/FS guidance (EPA, 1988b), assessments against these criteria relate directly to statutory findings that must ultimately be made in the remedy selection. Therefore, these are categorized as threshold criteria that each alternative must meet.

The criterion of overall protection of human health and the environment assesses the adequacy of short-term and long-term protection from unacceptable risks associated with hazardous substances, pollutants, or contaminants at a site. Each risk and each pathway identified in the baseline risk assessment for a site must be addressed. An alternative that does not provide overall protection of human health and the environment cannot be considered for selection as the remedy for a site.

Assessing compliance with ARARs involves evaluating whether or not an alternative willmeet all pertinent chemical-specific, location-specific, and action-specific ARARs. The regulations which are applicable or relevant and appropriate to an alternative will be described in the detailed analysis. In the event an ARAR cannot be complied with, discussion will be provided as to whether or not a waiver can be justified (EPA, 1988b). In addition to complying with ARARs, compliance with TBC standards may be considered in the analysis.

### 4.1.2 Balancing Criteria

Balancing criteria are utilized to further evaluate the alternatives which satisfy the two threshold criteria. These balancing criteria include:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

The criterion of long-term effectiveness and permanence involves the assessment of the ability of a remedial alternative to maintain protection of human health over time. The level of risk associated with residual contaminants left on the Site and the effectiveness of the reliability of controls used to manage untreated wastes are also considered and evaluated. A preference for permanent solutions and alternative treatment technologies that do more than divert the risk was expressed in SARA.

The stated goal of SARA not only included a preference for permanent solutions and alternative treatment, including innovative technology, but also for reduction of toxicity, mobility, or volume. The detailed analysis will consider how treatment reduces the toxicity, mobility, or volume of the waste and, if possible, to what extent. Achievement of 90 to 99 percent reductions in concentrations or mobility of individual contaminants of concern is a goal stated in the RI/FS guidance (EPA, 1988b). The degree to which the alternative is irreversible is a consideration in the evaluation of the reduction of toxicity, mobility, and volume.

Short-term effectiveness addresses the impact to the community and workers during the implementation of the remedy and until remedial action objectives are met. Protecting human health and the environment during the remedy's implementation is the key goal of the short-term effectiveness criterion. Any risk resulting from the implementation of the remedial action will be assessed to establish short-term effectiveness.

Implementability refers to the technical and administrative feasibility of executing an alternative. Technical feasibility encompasses construction and operation considerations and the reliability of the technology. Other considerations relative to the technical implementability of an alternative include the reliability of the technology, the ease of undertaking additional remedial actions should they become necessary, the ability to monitor the effectiveness of the remedy, and the availability of prospective technologies not yet demonstrated. Included in the evaluation of technical implementability will be a determination of the availability of resources necessary to implement the alternative as well as the assessment of the capabilities of various vendors.

The ability to coordinate implementation of an alternative with other involved agencies is the primary consideration in the assessment of administrative feasibility.

Estimates of the cost of implementing an alternative will include direct capital costs, indirect capital costs, and annual O&M costs. Direct capital items include equipment, land and site development, and buildings and utilities. Indirect capital costs include construction, engineering expenses, license or permit fees, start-up and shakedown costs, and contingency allowances. Operating labor, maintenance labor, energy, disposal of residues, purchased services such as sampling, administrative costs, insurance, taxes, maintenance reserve and contingency funds, rehabilitation or replacement, and 5-year reviews are typical elements of O&M cost estimates. As a final step, the present worth of all associated costs will be calculated so that the alternatives can be compared in today's dollars. The RI/FS guidance recommends a 30-year time frame for the development of present worth costs. However, for the analysis contained herein, an

80-year time frame was used to develop present worth costs because it approaches the shortest estimated restoration time frame and provides a more realistic estimate of costs than would be provided by a 30-year time frame.

### 4.1.3 Modifying Criteria

The modifying criteria consist of community and state acceptance. These criteria will be evaluated in the Record of Decision, following a review of the public comments received on the RI/FS reports and the Proposed Plan. State acceptance will indicate whether the State agrees with the preferred alternative presented in the Proposed Plan.

## 4.2 GENERAL SITE ELEMENTS AND COMMON ESTIMATING PROCEDURES

Eight alternatives summarized in Section 3.4 were retained subsequent to screening. General site elements common to the alternatives are described in Section 4.2.1. Section 4.2.2 contains the descriptions of the estimating procedures common to the detailed analysis of Alternatives 2 through 8.

Details presented for the general site elements (i.e., well locations and flowrates) were developed for cost estimating purposes only and so that the various alternatives could be compared to each other. Well locations and flowrates will be refined during the remedial design.

### 4.2.1 General Site Elements

General site elements are those portions of the individual remedial action alternatives which are common to specific groups of alternatives. Groundwater monitoring is common to all eight alternatives. Additional elements which are common to Alternatives 2 through 8 are:

- Point-of-entry treatment
- Hydraulic containment
- Groundwater treatment
- Disposal of treated groundwater
- Groundwater treatment standards

#### 4.2.1.1 Groundwater Monitoring

The groundwater monitoring program for all eight Alternatives was assumed to be quarterly for 5 years and annually thereafter. Although the exact number and location of monitoring wells has not been established, for cost estimating purposes the monitoring network during the first 5 years was estimated to include approximately 97 monitoring wells in place at the Site. Monitoring wells were selected to represent upgradient conditions (approximately 17 wells), locations where COCs have been detected (approximately 60 wells), and areas of the Site downgradient of the contamination (approximately 20 wells). The monitoring network would be reduced to monitoring wells located primarily in contaminated areas (approximately 31 wells) and downgradient of contaminated areas (approximately 17 wells) for the annual sampling. For cost estimating, it is assumed that each well will be sampled for VOCs, explosives, and general water quality parameters throughout the monitoring period. The exact location, number of monitoring wells and monitoring frequency will be selected during the remedial design.

#### 4.2.1.2 Point-of-Entry Treatment

Groundwater treatment at the point-of-entry is included as a part of Alternatives 2 through 8. Point-of-entry treatment will provide potable water to those households with water supply wells which contain COCs at concentrations unacceptable to the Nebraska Department of Health (NDOH). To date, those concentrations have been MCLs or HAs. There are currently three domestic water supply wells which have point-of-entry treatment systems in place as a result of explosives and/or TCE contamination. Domestic wells which exhibit unacceptable COC concentrations in the future will be provided with point-of-entry treatment. For cost estimating purposes only, it was assumed in Alternatives 2 through 8 that ten domestic wells would require point-of-entry treatment. Residences requiring point-of-entry treatment systems would be identified during the remedial design. The point-of-entry treatment systems use granular activated carbon to remove contaminants from the groundwater prior to potable use (i.e., drinking, cooking, bathing). Existing and future systems will be maintained and monitored for effectiveness until the Target Groundwater Cleanup Goal has been met. Spent carbon is changed out as necessary and sent off-site for regeneration or disposal. Selected water supply wells on, and in the vicinity of the Site are currently sampled and analyzed on a quarterly basis as described in Section 1.3.6.

#### 4.2.1.3 Hydraulic Containment

The hydraulic containment component of Alternatives 2 through 8 consists of hydraulic controls to prevent continued migration of groundwater to the south and southeast of the Site (i.e., downgradient). Hydraulic control will consist of the installation and pumping of groundwater from a series of extraction wells. These wells will be located in the vicinity of the downgradient boundary of the area of attainment defined by the Target Groundwater Cleanup Goal (Target Groundwater Cleanup Goals are discussed in Section 2.2.1.4). For cost estimating and comparative purposes potential hydraulic containment system(s) based on the various Preliminary Target Groundwater Cleanup Goals were developed. Final well locations and flowrates will be developed during the remedial design. A summary of the system developed for cost estimating is presented below:

| Target Groundwater Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) |
| I | 1 | 110 | 3 | 620 | 1 | 240 | 5 | 970 |
| II | 1 | 160 | 7 | 1,580 | 1 | 360 | 9 | 2,100 |
| III | 1 | 160 | 7 | 1,810 | 1 | 360 | 9 | 2,330 |

The proposed locations and pumping rates of the hydraulic control wells for Cleanup Goals I, II and III are shown on **Drawings 4-1A, 4-1B**, and **4-1C** respectively. For cost estimating purposes, the drawings show the location of the wells with respect to the area of attainment and other site features. The methods used to calculate estimated capture zone widths, description of groundwater capture zone and aquifer drawdown calculations are discussed in Section 4.2.2 and **Appendix G**.

The goal of hydraulic containment is to prevent, or significantly reduce, the expansion of existing contamination. This is accomplished by extracting groundwater to create capture zones which prevent COCs at concentrations exceeding the Target Groundwater Cleanup Goals from migrating past the downgradient boundary of the area of attainment. The pumping rate should be low enough so as to minimize the impact to the groundwater flow direction and gradient. Based on the analysis provided in **Appendix G**, the estimated pumping rate of the hydraulic control wells is between 160 and 360 gallons per minute (gpm) per well. The individual rates were selected based on the expected yields and estimated capture zones at the Site. The estimated total groundwater extraction rate for the hydraulic control system ranges from 970 gpm to 2,330 gpm.

As discussed in Section 1.2.5, groundwater contamination was found more extensively and at higher concentrations in the upper fine sand units relative to the underlying sand and gravel units. Generally, the least contamination was found in the deepest of the three aquifers, the Omadi Sandstone aquifer. The containment system extraction wells will initially be completed in the Todd Valley aquifer and the Platte River alluvial aquifer so that water is extracted directly from those aquifers. The leading edge of contamination in the underlying Omadi Sandstone aquifer is upgradient from the downgradient edges of the Cleanup Goal I, II, and III Areas of Attainment. If COC concentrations measured in Omadi monitoring wells located near the downgradient edges of the areas of attainment equal or exceed the respective cleanup goal concentrations, additional remedial actions will be taken to contain groundwater in the upper portion of the Omadi Sandstone aquifer. The actions might include, but would not be limited to:

- Increasing the flow rate in existing extraction wells to induce upward vertical flow from the Omadi Sandstone aquifer to the extraction wells completed in the Todd Valley aquifer and/or Platte River alluvial aquifer

- Installing and operating extraction wells which are designed to selectively extract water from the Omadi Sandstone aquifer along the downgradient edge of the respective areas of attainment

- Installation and sampling of additional monitoring wells completed in the Omadi Sandstone aquifer in conjunction with one or both of the above actions

The capital costs associated with any potential additional remedial actions are estimated to be of the same order of magnitude as costs associated with similar initial remedial actions which focus on the Todd Valley aquifer and the Platte River alluvial aquifer.

Hydraulic containment may be impacted by agricultural irrigation. Groundwater modeling prior to, or as part of the remedial design, will be necessary to more fully assess the relationship between hydraulic containment and irrigation.

#### 4.2.1.4 Groundwater Treatment

Extracted groundwater will be pumped to a central location and treated using one of, or a combination of, three potential treatment process options. These include:

- GAC adsorption
- Advanced Oxidation Process (AOP)
- Air stripping

The three potential technologies are briefly described below. GAC, AOP and air stripping will be compared before final selection of the treatment process. This selection will be made in the design analysis of the remedial design after completion of the treatability studies. Selection will be made based on the following factors:

- Nature and disposition of any degradation products created during treatment
- Total present worth cost
- Schedule to implement technology
- Reliability

GAC will be assumed to be the selected process option for groundwater treatment duringthe cost analysis for Alternatives 2 through 8. GAC is a well-established, commercially available technology. Other, less well-established technologies will not be considered unless they offer a cost advantage to GAC and can be shown through treatability studies to have no degradation products in the effluent above acceptable limits. Because it is commercially available, a GAC system can be constructed and made operational at the Site on a predictable schedule. Less well established technologies may have more uncertainties in the time required to construct a system at the Site and to make the system operational, including start-up time. Cost savings will be balanced against any potential increases in the time required to have an operational system. Because GAC is a well-established technology, O&M requirements are well known. Questions and uncertainties concerning the O&M reliability of other technologies will be balanced against any cost savings. In summary, GAC is the standard for a recommended extracted groundwater treatment technology. Other technologies must be proven superior to GAC through treatability tests and engineering analysis, including cost analysis, before they would be recommended. References to specific vendors of treatment technologies are made for example only. No treatment processes or treatment technologies have been selected.

**GAC Adsorption**

GAC adsorption is a proven technology for removing organic contaminants from water. Adsorption by activated carbon involves the accumulation or concentration of substances at a surface or interface. Organic matter is extracted from one phase and concentrated at the surface of another phase in the adsorption process; therefore, adsorption is termed a surface phenomenon. GAC has an affinity for organic compounds and, because of this selectivity, is particularly effective in removing organic compounds from aqueous solution (EPA, 1973).

For cost estimating purposes, it is estimated that a typical system may include multiple GAC units, each unit consisting of two in-series GAC columns containing 20,000 pounds (lbs) of GAC per column. Calgon Carbon Corporation (Calgon) proposes the use of their Model 10 adsorber system (see **Appendix H**). Each column vessel would contain 20,000 lbs of Calgon Filtrasorb 300, 8 mesh X 30 mesh GAC. The advantages of using multiple in-series units are: 1) short-circuiting is minimized; 2) breakthrough of target compounds in the final effluent can be prevented by monitoring the effluent from the first column and replacing the spent carbon as necessary; and 3) carbon is most efficiently utilized through more complete saturation of the first unit in the series. GAC adsorption is a well-established technology for the removal of the Site COCs. No further treatment of the groundwater would be necessary prior to disposal. A typical GAC system process flow diagram is shown on **Drawing 4-2**.

On-going treatability studies for GAC adsorption are discussed in Section 1.3.5.

**AOP**

Advanced Oxidation Process (AOP) treatment is another potential technology. The major advantage of AOP over GAC adsorption is that AOP destroy the contaminants by oxidation and there are generally no residual end products. Any end products are typically non-hazardous and innocuous but, in some cases, incomplete oxidation may result in intermediate compounds which are more toxic than the parent compound. In the case of carbon adsorption, however, contaminants are transferred from one medium to another, (i.e., from groundwater to carbon), and complete destruction is not achieved.

AOPs use one or more oxidizing agents, such as ozone and hydrogen peroxide, to destroy organic contaminants. The oxidation potential of these chemicals may be enhanced by conducting the process in the presence of ultraviolet (UV) light. UV light enhances production of hydroxyl radicals, which have a high oxidation potential. The current research (Mark Zappi, 1994) indicates that combination of ozone and hydrogen peroxide (without the UV light) is extremely effective in treating relatively low levels of nitroaromatics and other COCs observed at the Site. However at high concentrations (greater than approximately 100 mg/L), UV light may enhance the process effectiveness.

Complete oxidation of organics results in formation of carbon dioxide, inorganic salts, and water. However, partial oxidation may result in organic intermediates such as carboxylic acids, which are non-toxic. As stated above, in some instances intermediate compounds are formed which may be more toxic than the parent compound itself. For example, incomplete oxidation of some of the chlorinated solvents (TCE) may result in the formation of vinyl chloride, which is more toxic than the parent compounds.

It is believed that the low concentrations of COCs at the Site can be treated by combination of ozone and peroxide without UV light. This treatment is frequently referred to as "Peroxone". Until the results of the treatability study are available, the need for UV light is uncertain.

Although the oxidation chemistry of many of the Site groundwater COCs is not completely understood, two compounds are of significance: partial oxidation of TCE and TNT may result in formation of vinyl chloride and TNB, respectively, which are more toxic than the parent compounds. (It should be noted that TNT concentrations are expected to be low based on the groundwater data collected to date). Complete oxidation of contaminants can be achieved by providing sufficient retention time in the oxidation reactor and adding adequate amounts of chemicals. As an added protection, GAC adsorption can be added following AOP treatment as a polishing step. This would ensure removal of any residual organics in the oxidation treatment effluent.

A typical AOP system, based on preliminary information provided by Solarchem Environmental Systems, Inc. (Solarchem), may include the use of two parallel units, each consisting of six 30-kW Rayox®-O reactor towers, to handle the anticipated flowrates. The modularized system reportedly has adequate capacity to destroy the concentration of organic compounds present to the desired treatment levels. The Solarchem system uses ozone coupled with ultraviolet radiation to produce hydroxyl radicals for the direct oxidation of organics. The use of an ozone generator increases the capital costs, but decreases the energy requirement needed for organic destruction. Solarchem's completed response is included in **Appendix I**.

An AOP flow diagram is shown on **Drawing 4-3**. Although AOPs have not been used on a full-scale basis, bench- and pilot-scale systems have been successful in treating VOCs and explosives. Treatability studies are described in Section 1.3.5.

**Air Stripping**

Air stripping and treatment of vapor emissions from the air stripper by GAC adsorption is also a proven treatment technology for VOCs. Air stripping involves transferring VOCs from water to air by passing the water through a packed tower against a forced air stream. Air stripping provides a contact between the dissolved-phase VOCs in groundwater with atmospheric air such that the VOCs partition to the vapor-phase as a result of the contact. A counter-current flow, packed tower air stripper is commonly used for this purpose. This technology is not effective at removing the less volatile explosive contaminants, such as RDX, but is extremely effective at removing TCE because of its high vapor pressure.

A typical air stripping system may include an air stripping tower or towers having the capacity to treat the maximum total extraction flow. The stripping tower would be designed to remove VOCs to the levels presented in Section 4.2.1.6. GAC polishing would then be used to remove the less volatile contaminants (explosives) from the groundwater.

No pretreatment has been included in this alternative, either to remove any soluble iron or hardness. Scaling in the packed tower is not anticipated to be a problem under normal maintenance.

At the request of WCC, Century Plastics Inc. (Century) solicited estimates from two suppliers of air stripping towers: Carbonair Environmental Systems, Inc. (Carbonair) and Hydro Group, Inc., (see **Appendix J**). The conceptual design included herein is based on Carbonair's response. A typical tower would have a diameter of 8 feet and a packed height of 30 feet. An air stripping system process flow diagram is shown on **Drawing 4-4**.

It is assumed that the vapor emissions from the top of the tower will be treated by carbon adsorption. Based on the air stripping model predictions for the amount of VOC air emissions, Century proposes the use of a Carbonair Model GPC 120 adsorber. The vessel would contain 13,600 pounds of activated carbon.

**Cost Basis For Feasibility Study**

GAC adsorption was assumed to be the selected process option for groundwater treatment during the cost analysis for Alternatives 2 through 8. GAC was selected for costing purposes because it is commercially available, will treat the COCs, and provides a common element in the evaluation of the alternatives. Also, for cost estimating purpose only, effluent concentrations of the carbon treatment system were assumed to be the groundwater disposal standards tabulated in Section 4.2.1.6. The use of GAC and the disposal standards for cost estimating does not preclude the implementation of one of the other treatment processes (AOP or air stripping) or a different disposal standard. Disposal standards will be finalized with the State of Nebraska during remedial design. Cost/benefit analysis of all three treatment options (GAC, AOP, and air stripping) will be performed during the remedial design analysis as a part of the treatment selection process.

#### 4.2.1.5 Disposal

All treated groundwater will be disposed through either on-/off-site stream discharge or beneficial reuse. The selection of the disposal option will be made during the remedial design analysis and will be based on the following criteria:

- Cost/benefit analysis
- Technical feasibility
- Public acceptance

If beneficial reuse is selected, on/off-site stream discharge will be used initially until the final beneficial reuse option can be designed. The detailed cost analysis of alternatives assumed the only cost associated with disposal (either on-/off-site stream discharge or beneficial reuse) was one mile of discharge piping. The options associated with disposal and beneficial reuse are described below.

**On-/Off-Site Stream Discharge**

On-/off-site stream discharge is a feasible option for final disposal of treated groundwater and a viable option prior to development of beneficial reuse systems or during periods when end user water demand is less than the amount discharged. Treated groundwater could be discharged directly to Clear Creek. The discharge water would be sediment free and contain contaminant concentrations at or below those presented in Section 4.2.1.6 posing minimal environmental impact. Potential physical impacts from surface discharge may include erosion and flooding. To control flooding potential restrictions on discharge flows during peak flow periods may be a condition of the authorization to discharge. The discharge flowrate will be dependent upon the alternative and Target Groundwater Cleanup Goal selected, which govern the discharge volume. The following potential impacts of surface water discharge will be evaluated during the remedial design if stream discharge is selected as a disposal option:

- Elevated water levels in Clear Creek near the discharge point
- Elevated groundwater levels in the vicinity of the discharge point
- Increased sediment transport in Clear Creek near the discharge point

Since this action falls under CERCLA, a discharge permit will not be required, but an authorization to discharge must be obtained from the State. This authorization may include water quality monitoring requirements.

The beneficial reuse options identified in Section 2.0; reinjection wells, agricultural, and water supply, are described below.

**Reinjection Wells**

Reinjection of treated groundwater is a technically feasible disposal method. However, reinjection well tests and groundwater modeling would be required as a part of the predesign investigations before the system could be designed. Technical problems have been encountered with injection systems at some sites. Problems with reinjection include plugging of the aquifer around the screened interval by fines, bacteria, air bubbles or chemical precipitates, thereby reducing the capacity of the aquifer to receive water. These plugging problems require periodic redevelopment of the wells to maintain the necessary injection rates. The analysis of reinjection can be refined and optimized during design if reinjection is selected.

The injection wells could potentially be located downgradient of the area of attainment to augment the hydraulic containment system. In this area, groundwater mounding caused by injection of treated water may supplement the hydraulic barrier created by extraction. Final well locations and flowrates would be developed as part of the remedial design, if this disposal alternative is selected.

## Agricultural

Agricultural reuse of treated groundwater may include (but is not limited to) irrigation, livestock watering, or processing (i.e. soybean washing). Irrigation demand is seasonal and during the non-irrigation season the treated water would require an alternative discharge option. Livestock watering may include water for livestock consumption and the demand may be more constant relative to irrigation demand. A demand for processing water may also exist within the agricultural community near the Site.

## Water Supply

Water supply reuse may include providing the treated groundwater to a future rural water district, an existing municipal water supply system, or the ARDC. Since the water would be used for domestic purposes when implementing one of these disposal alternatives it would require treatment to potable water quality.

Currently, rural residences rely on individual groundwater wells for water supply. Exceptions include anyone connected to the former NOP distribution systems including those connected to the ARDC water distribution system and the former Administration area distribution system. Distributing treated groundwater to rural residences would require the development of a rural water district.

Memphis, Mead, Ashland, Wahoo, Yutan, Omaha and Lincoln are nearby municipalities to which treated groundwater could be supplied. This option would require the evaluation of the water demand of the municipalities and the cost associated with piping the water from the treatment plant to the municipal water distribution system.

The University of Nebraska ARDC Water System is an extension of the former NOP water distribution system built approximately fifty years ago. The ARDC utilizes a common distribution system for domestic uses, irrigation and other agricultural activities. The total usage of the ARDC Water System is normally 600 gpm, peaking to 4,500 gpm during irrigation season. During irrigation season, depending on the alternative selected, all of the water from the treatment system could potentially be used by the ARDC. During the non-irrigation season, only a portion of the treated water could be used by the

ARDC, with the remaining portion requiring an alternate disposal option. Discharge to the ARDC Water System would require the construction of an underground transmission main from the treatment plant to the ARDC Water System near the load lines.

#### 4.2.1.6 <u>Groundwater Disposal Standards</u>

Groundwater which is extracted will meet disposal-dependent standards (which may varyfor different disposal options) prior to disposal. For cost estimating purposes it was assumed that the groundwater disposal standards are defined by the MCL or HA where available. In the case of TNB and 2,4-DNT the non-carcinogenic health-based cleanup goal and the drinking water equivalent (DWEL), respectively were assumed. The final disposal standards will be established with the State during remedial design. The groundwater disposal standards used for cost estimating purposes are tabulated below:

| GROUNDWATER DISPOSAL STANDARDS | | |
|---|---|---|
| **COC** | **Concentration (μg/L)** | **Basis For Disposal Standard** |
| Methylene Chloride | 5 | MCL |
| 1,2-Dichloropropane | 5 | MCL |
| TCE | 5 | MCL |
| TNB | 0.778 | Health-based cleanup goal calculated for non-cancer effects |
| TNT | 2 | Health Advisory |
| 2,4-DNT | 100 | Drinking Water Equivalent Level |
| RDX | 2 | Health Advisory |

### 4.2.2 Common Cost Estimating Elements

Three elements of the detailed analysis are evaluated for Alternatives 2 through 8:

- Restoration time frames
- Extraction well locations and flowrates
- Treatment plant COC influent concentrations

#### 4.2.2.1 <u>Restoration Time Frames</u>

The restoration time frame is the period of time required to achieve the Target Groundwater Cleanup Goals at all locations within the area of attainment. Guidance on Remedial Actions for Contaminated Groundwater (EPA, 1988a) presents the following methodology to estimate restoration time frames:

1) Calculate the number of batch flushes. A batch flush consists of enough clean water to fill the pore space in a given volume of the aquifer. Values of contaminant concentration for both soil and water following each batch flush are considered. Zheng, et. al. (1991) presents a method for calculating the number of batch flushes that are required to lower the maximum concentration of a particular COC assumed to be present in the aquifer prior to remediation to the Target Groundwater Cleanup Goal concentration.

2) Calculate the volume of groundwater which must be extracted by multiplying the number of batch flushes by the volume of contaminated groundwater (as defined by the Target Groundwater Cleanup Goals).

3) Calculate the restoration time frame by dividing the volume of water calculated in Step 2 by the total extraction flowrate for a particular alternative.

The detailed development of the restoration time frame estimates is presented in **Appendix B**.

The restoration time frame estimates to be used for the comparative cost estimates for Alternative 2 through 8 are assumed to be the longest of the time frame estimates for the individual plumes. For example, the following restoration time frame estimates were developed for Alternative 4 using the Cleanup Goal II Area of Attainment:

- Load Line 1: 31 years
- Load Lines 2 and 3: 77 years
- Atlas Missile Area: 130 years

Based on these estimates, the part of the remedial system which extracts groundwater from the Load Line 1 plume could be turned off approximately 99 years earlier than the Atlas Missile Area extraction system. The conceptual extraction well locations and flow rates were used to develop the restoration time frame estimates as a basis for estimating costs. The actual extraction well locations and flow rates will be determined during remedial design. The restoration time frame assumption may potentially result in overestimation of the cost of the alternative because extraction wells associated with the plumes that require shorter periods of time to clean up will not operate for the entire time periods tabulated in **Appendix B**.

As a part of the detailed analysis of each alternative, the present worth costs are calculated for an 80-year period using a 6 percent discount rate. The 80-year period was selected because it provides a more realistic estimate of costs compared to the 30-year period suggested by EPA RI/FS guidance (EPA, 1988b).

#### 4.2.2.2 Extraction Well Locations and Flowrates

For cost estimating and comparative purposes well locations and flowrates were estimated. Capture zone analysis (Keely and Tsang, 1983; and Javandel and Tsang, 1986) was used to locate groundwater extraction wells and estimate the extraction flowrates as a basis for cost estimating. The resulting aquifer drawdown was estimated using the Theis non-equilibrium equation (Driscoll, 1986). The methods used to calculate capture zone widths, description of groundwater capture zone analysis, and calculation of aquifer drawdowns are contained in **Appendix K**. Final well locations and flowrates will be selected during the remedial design.

A two-dimensional computer model (Quickflow ®) was used to simulate hydraulic containment as a part of the Removal Action discussed in Section 1.3.2. The results of the computer model are in the Remedial Action Groundwater Modeling Technical Memorandum (WCC, 1994j). The computer modeling may be revisited on the basis of the analysis of the data generated during the pumping test described in Section 1.3.4. Computer modeling was performed for hydraulic containment only. To maintain consistency, the Keeley and Tsang (1983) and Javandel and Tsang (1986) methodologies were used to estimate all well locations and flowrates including the hydraulic containment extraction wells.

The potential aquifer drawdown at existing water supply wells (primarily domestic, irrigation, and stock wells) which may result from groundwater extraction cannot be quantified during the FS because the extraction well locations will be selected during the remedial design. The remedial design will evaluate strategies for mitigating impacts on existing water supply wells which may include, but are not limited to, selection of extraction well locations and flow rates, and developing a groundwater extraction management plan. The remedial design will balance the mitigation of extraction impacts with the other design criteria which relate to effectiveness and technical feasibility.

#### 4.2.2.3 Treatment Plant COC Influent Concentrations and GAC Usage

Treatment plant influent concentrations were estimated so that GAC use rates for carbon treatment could be estimated for the detailed cost analysis of each alternative. Since extracted groundwater would be conveyed to the treatment plant via a common piping and transfer pumping system, the waters from the various wells would be co-mingled before entering the treatment plant. The net result is that the influent concentration would be the concentration of this co-mingled water. Since the frequency of detection and concentration of COCs was low, except TCE and RDX, the contribution of all other COCs to the influent and carbon use is negligible. As a result, only TCE and RDX concentrations impact the influent concentrations and carbon use rate estimates.

The following steps were followed in estimating the influent concentrations of TCE and RDX. A complete description is contained in **Appendix K**.

- Monitoring wells located upgradient from, and within, the zone of influence of an extraction well were identified as contributors of RDX and TCE concentrations to that particular extraction well
- Each of the identified monitoring wells were allocated a weight factor **(Wi)** calculated as the fraction of pumpage contributed by each extraction well with respect to the total pumpage of that alternative
- A summary of the concentrations of RDX and TCE for each monitoring well, sampling event and screen interval was compiled. Average concentrations of RDX and TCE were calculated for each monitoring well, sampling event, and alternative. A weighted average concentration was calculated as a product of the average concentration **(Ci)** and the weight factor **(Wi)**

- The sum of the weighted average concentrations of each chemical by alternative and by quarter was calculated

- The estimated influent concentrations for TCE and RDX are summarized in the description of each alternative

GAC usage rates for the treatment of groundwater containing TCE and RDX were then estimated using a Freundlich adsorption isotherm model. The isotherm equation and calculations are provided in **Appendix K**. The numerical values of the parameters used in the isotherm equation for RDX and TCE were provided by a literature review. A conservative scaleup factor of 2 was used to estimate the GAC usage rate of the treatment system in the absence of treatability study data.

## 4.3 ANALYSIS OF ALTERNATIVES

### 4.3.1 Summary of Retained Alternatives

This section describes the eight alternatives retained from the screening process completed in Section 3.0. The alternatives are evaluated against seven of the nine evaluation criteria previously discussed. Initially, each alternative is evaluated with respect to the two threshold criteria: overall protection of human health and the environment, and compliance with ARARs. Alternatives which meet the threshold criteria are then further evaluated against the balancing criteria: long-term effectiveness; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost. The remaining criteria, the modifying criteria of Agency and community acceptance, will be addressed in the responsiveness summary of the ROD.

The eight alternatives are briefly described below with differentiating features shown in bold:

Alternative 1: **No Action**: includes only **groundwater monitoring**

Alternative 2: **Groundwater Containment**: includes groundwater monitoring, **point-of-entry treatment for domestic water supply, hydraulic containment, groundwater treatment, and disposal.**

Alternative 3: **Focused Extraction:** includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, **groundwater extraction focused in areas with high concentrations of TCE or RDX, groundwater treatment, and disposal.**

Alternative 4: **Focused Extraction and Soil Excavation**: includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, groundwater extraction focused in areas with high concentrations of TCE or RDX, groundwater treatment and disposal, and **soil excavation and thermal treatment**.

Alternative 5: **Focused Extraction with Air Sparging:** includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, groundwater extraction focused in areas with high concentrations of TCE and RDX together and RDX only, groundwater treatment and disposal, and **air sparging of TCE-only portion of groundwater plume**.

Alternative 6: **Focused Extraction with Air Sparging and Soil Excavation:** includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, groundwater extraction focused in areas with high concentrations of TCE and RDX together and RDX only, groundwater treatment and disposal, air sparging of the volatiles only groundwater plume, and **soil excavation and thermal treatment**.

Alternative 7: **Groundwater Extraction:** includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, **groundwater extraction throughout the area of attainment**, treatment, and disposal.

Alternative 8: **Groundwater Extraction and Soil Excavation:** includes groundwater monitoring, point-of-entry treatment for domesticwater supply, hydraulic containment, groundwater extraction throughout the area of attainment, treatment, and disposal, and **soil excavation and thermal treatment.**

### 4.3.2 Alternative 1 - No Action

#### 4.3.2.1 Description

Alternative 1 is the No Action alternative. This alternative will allow Site conditions to remain as they currently exist. No reduction in risks associated with potential groundwater exposure to the COCs is achieved, nor is migration of contaminants controlled. Groundwater monitoring, as described in Section 4.2.1, is included to allow for ongoing evaluation of contaminant migration in the absence of remedial action. Evaluation of theno action alternative is required by the NCP and provides a baseline for comparison with other alternatives.

Alternative 1 does not provide protection of human health and the environment and does not comply with ARARs. Since Alternative 1 does not meet the threshold criteria, it is not evaluated further.

### 4.3.3 Alternative 2 - Hydraulic Containment

#### 4.3.3.1 Description

Alternative 2 combines groundwater monitoring, point-of-entry treatment for domestic water supply, and hydraulic containment of the contaminated groundwater. Containment wells will be located in the vicinity of the downgradient edge of the area of attainment defined by the Target Groundwater Cleanup Goals. Extracted groundwater will then be treated and disposed.

For cost estimating and comparative purposes extraction well locations and pumping rates were estimated. **Drawings 4-1A, 4-1B**, and **4-1C** show the extraction well locations, pumping rates, and the discharge piping schematics for Target Cleanup Goals I, II, and III, respectively which were used for cost estimating purposes. Influent contaminant concentrations were estimated based on the proposed well locations and pumping rates, the methodology presented in Section 4.2.2.3, and the information contained in **Appendix K**. As discussed in **Appendix K**, extracted water is collected by a common piping and transfer pumping network which delivers the extracted groundwater to the central treatment facility. The net result is that all extracted groundwater is co-mingled prior to treatment and the estimated influent concentration is the concentration of those co-mingled waters. Therefore, since the frequency of detection and concentration of all COCs except TCE and RDX was low, contribution from other Site COCs to the treatment plant influent would be negligible. A summary of the estimated Alternative 2 well locations, pumping rates, and influent concentrations is presented below. The final well locations and flowrates will be developed during the remedial design.

| COST ESTIMATING ASSUMPTIONS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Target Ground-water Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | | Estimated Influent Concentration (µg/L) | |
| | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | TCE | RDX |
| I | 1 | 110 | 3 | 620 | 1 | 240 | 5 | 970 | 21 | 53 |
| II | 1 | 160 | 7 | 1,580 | 1 | 360 | 9 | 2,100 | 14 | 5 |
| III | 1 | 160 | 7 | 1,810 | 1 | 360 | 9 | 2,330 | 13 | 5 |

Based on the influent concentrations presented above, GAC consumption rates were estimated using the Freundlich adsorption model, including a conservative scaleup factor of 2, discussed in **Appendix K**. For Alternative 2 the GAC usage rate is estimated to be 100,000 to 104,000 lbs/year (274 to 285 lbs/day) for all Cleanup Goals. The decreasing concentration of TCE and RDX with increasing extracted groundwater flow rate results in GAC usage remaining relatively constant between Cleanup Goals. Considering the uncertainties present in making GAC usage rate estimates, there is no significant difference between 100,000 and 104,000 lbs/year (4 percent).

Groundwater treatment and discharge are discussed in Sections 4.2.1.4 and 4.2.1.5.

#### 4.3.3.2 Overall Protection of Human Health and the Environment

Alternative 2 provides environmental protection by containing groundwater contaminated at concentrations above the Target Groundwater Cleanup Goals minimizing its potential for migration. Groundwater containment is also protective of human health and the environment because contaminant concentrations are reduced by groundwater treatment and expansion of the plume is controlled, protecting downgradient groundwater users. Point-of-entry treatment systems protect currently impacted and future users by eliminating the potential for exposure to groundwater with unacceptable COC concentrations.

#### 4.3.3.3 Compliance with ARARs

Target Groundwater Cleanup Goals are met in the vicinity of the downgradient edge of the area of attainment as soon as the alternative becomes operational. Eventually, the entire volume of contaminated groundwater would be remediated and Target Groundwater Cleanup Goals would be met within the area of attainment. The alternative can be designed to meet the ARARs relevant to OU2 activities as listed in **Table 4-1**.

#### 4.3.3.4 Long-Term Effectiveness and Permanence

Residual risk to current and future groundwater users is controlled within the plume by point-of-entry treatment and downgradient by containment. Point-of-entry treatment is adequate to protect currently impacted users and those who may be impacted prior to reaching the Target Groundwater Cleanup Goals. The containment and treatment systems are proven and reliable and GAC adsorption is presently in use at the Site for point-of-entry treatment. Containment is effective in controlling long-term residual risk by minimizing the migration of contamination to currently unimpacted users.

Groundwater monitoring and a 5-year review will evaluate the effectiveness of the point-of-entry treatment systems and the containment system.

#### 4.3.3.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

The groundwater treatment technologies being considered include the proven and effective treatment technologies of GAC and air stripping and the emerging technology, AOP, which is considered implementable and for which treatability studies are being conducted for Site groundwater. By implementing one of these technologies, all groundwater contamination above Target Groundwater Cleanup Goals will eventually be destroyed.

The toxicity and volume of contaminants in groundwater will be reduced by extraction and treatment, and the mobility (i.e. migration) will be managed. With regard to groundwater, this alternative satisfies the statutory preference for treatment.

#### 4.3.3.6 Short-Term Effectiveness

Risks to the community are not increased by implementation of this alternative and environmental risks to workers involved in the Site remediation are minimal. Adverse environmental impacts during implementation would be minimal. However, aquifer drawdown during groundwater extraction would result, which may impact irrigation activities. The groundwater containment system would operate for perpetuity. Restoration time frame estimates are discussed in **Appendix B**.

#### 4.3.3.7 Implementability

A hydraulic containment system uses conventional technologies and is implementable and relatively simple to construct and operate. Point-of-entry treatment systems are available immediately. Additional point-of-entry treatment systems and containment wells could be added without difficulty if monitoring indicates a need for these components. The treatment system for extracted groundwater will be designed in a modular fashion to accommodate varying volumes and influent concentrations. Monitoring the effectiveness of the groundwater containment and treatment systems uses common sampling and analysis techniques, is easily implemented, and reliable.

#### 4.3.3.8 Cost

Conceptual cost estimates for Alternative 2 are based on the system described in Section 4.3.3.1 and assumes that GAC adsorption is the selected treatment technology. The conceptual cost estimate also assumes one mile of discharge piping and discharge at the concentrations presented in Section 4.2.1.6. The total estimated capital and present worth O&M costs for the three Target Groundwater Cleanup Goals are summarized below:

| Target Groundwater Cleanup Goal | Capital Cost (Million $) | Present Worth O&M Cost (Million $) | Total Capital & Present Worth Cost (Million $) |
|---|---|---|---|
| I | $6.4 | $23.2 | $29.6 |
| II | $8.2 | $27.1 | $35.3 |
| III | $7.9 | $27.2 | $35.2 |

The detailed cost estimates for Alternative 2 are presented in **Appendix L.**

### 4.3.4 Groundwater Alternative 3 - Focused Extraction

#### 4.3.4.1 Description

Alternative 3 includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, groundwater treatment, and disposal as previously described for Alternative 2. In addition, this alternative also includes focused groundwater extraction followed by groundwater treatment at locations with high concentrations of TCE or RDX. As previously described, groundwater treatment options include GAC adsorption, advanced oxidation and/or air stripping. In addition to the containment wells, Alternative 3 includes five additional extraction wells for Target Groundwater Cleanup Goal I and six additional extraction wells for Target Groundwater Cleanup Goals II and III. The number, location, and flowrates of these wells were developed for cost estimating and comparative purposes. Final well locations, and flowrates will be developed during the remedial design.

**Drawings 4-5A, 4-5B**, and **4-5C** show the estimated well locations, pumping rates, and discharge piping schematics for the three Target Groundwater Cleanup Goals for Alternative 3. Total estimated flows, well numbers, and influent concentrations for Alternative 3 are summarized below, for cost comparison purposes only.

| COST ESTIMATING ASSUMPTIONS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Target Ground-water Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | | Estimated Influent Concentration (μg/L) | |
| | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM ) | TCE | RDX |
| I | 6 | 1120 | 3 | 620 | 1 | 240 | 10 | 1,980 | 350 | 27 |
| II | 6 | 1170 | 8 | 1,770 | 1 | 360 | 15 | 3,300 | 209 | 18 |
| III | 6 | 1170 | 8 | 2,000 | 1 | 360 | 15 | 3,530 | 196 | 18 |

As with Alternative 2, the estimated influent concentrations are based on estimated well locations and flowrates and the methodology discussed in Section 4.2.2.3. The co-mingling of extracted water makes the influent contribution of Site COCs other than TCE and RDX insignificant. Therefore, GAC consumption rates are based on the influent concentrations of TCE and RDX using the Freundlich adsorption model discussed in **Appendix K.** For Alternative 3 the GAC usage rate is estimated to be approximately 472,000 lbs/year (1,293 lbs/day) for Cleanup Goal I; 635,000 lbs/year (1,740 lbs/day) for Cleanup Goal II; and 663,000 lbs/year (1,816 lbs/day) for Cleanup Goal III. A conservative scaleup factor of 2 is included in these estimates in the absence of treatability study data.

#### 4.3.4.2 Overall Protection of Human Health and the Environment

Alternative 3 provides protection of human health and the environment. Point-of-entry systems protect currently impact and future users by eliminating the potential for exposure to groundwater with unacceptable COC concentrations. Containment/extraction systems protect future users because groundwater is extracted, and migration of groundwater contaminated at concentrations above the Target Groundwater Cleanup Goals is controlled. Contaminant concentrations are reduced by extraction and treatment providing protection of human health and the environment.

#### 4.3.4.3 <u>Compliance with ARARs</u>

Target Groundwater Cleanup Goals are met in the vicinity of the downgradient edge of the plume as soon as the alternative becomes operational. Eventually, the entire volume of contaminated groundwater would be remediated and Target Groundwater Cleanup Goals would be met within the area of attainment. The alternative can be designed to meet the ARARs listed in **Table 4-1**.

#### 4.3.4.4 <u>Long-Term Effectiveness and Permanence</u>

Residual risk is controlled within the plume by point-of-entry treatment and focused extraction and treatment, and downgradient by containment and treatment. Point-of-entry treatment is adequate to protect currently impacted users and those who may be impacted prior to reaching the Target Groundwater Cleanup Goals. Contaminant/extraction systems are proven and reliable. Point-of-entry GAC adsorption is presently in use at the Site. Containment controls long-term residual risk by controlling the spread of contamination to currently unimpacted users and currently unimpacted groundwater.

Groundwater monitoring and a 5-year review will evaluate the effectiveness of the point-of-entry treatment systems, extraction system, and containment system.

#### 4.3.4.5 <u>Reduction of Toxicity, Mobility, or Volume Through Treatment</u>

The groundwater treatment technologies being considered include the proven and effective treatment technologies of GAC and air stripping and the emerging technology, AOP, which is considered implementable and for which treatability studies are being conducted for Site groundwater. By implementing one or a combination of these technologies, all groundwater contamination above the Target Groundwater Cleanup Goals will eventually be destroyed. The toxicity and volume of contaminants in groundwater will be reduced by focused extraction and treatment, and the mobility (i.e. migration) will be managed. With regard to groundwater, this alternative satisfies the statutory preference for treatment.

#### 4.3.4.6 Short-Term Effectiveness

Risks to the community are not increased by this alternative and environmental risks to workers involved in the Site remediation are minimal outside of general construction safety issues. Adverse environmental impacts during implementation would be minimal, however, aquifer drawdown during groundwater extraction would result which may impact irrigation activities. The groundwater extraction and containment system for the Target Groundwater Cleanup Goals would operate for greater than 140 years. Restoration time frames are discussed in **Appendix B**.

#### 4.3.4.7 Implementability

Groundwater extraction and hydraulic containment systems use conventional technologies and are relatively simple to construct and operate. Point-of-entry treatment systems are simple to install and available immediately. Additional point-of-entry treatment systems and extraction containment wells can easily be added. The treatment system for extracted groundwater will be designed in a modular fashion to accommodate varying volumes and influent concentrations. Monitoring the effectiveness of the groundwater extraction/containment and treatment systems uses common sampling and analysis techniques, is easily implemented, and reliable.

#### 4.3.4.8 Cost

Conceptual cost estimates for Alternative 3 are based on the system described in Section 4.3.4.1 and assume GAC adsorption is the selected treatment technology. The conceptual cost estimate also assumes one mile of discharge piping and discharge at the concentrations presented in Section 4.2.1.6. The total estimated capital and present worth O&M costs for the three Target Cleanup Goals are summarized below:

| Target Groundwater Cleanup Goal | Capital Cost (Million $) | Present Worth O&M Cost (Million $) | Total Capital & Present Worth Cost (Million $) |
|---|---|---|---|
| I | $11.0 | $35.8 | $46.8 |
| II | $12.8 | $44.2 | $57.0 |
| III | $12.8 | $44.3 | $57.1 |

The detailed cost estimates for Alternative 3 are presented in **Appendix L**.

### 4.3.5 Groundwater Alternative 4 - Focused Extraction and Soil Excavation

#### 4.3.5.1 Description

Alternative 4 includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, focused extraction, groundwater treatment and disposal as previously described in Alternative 3. The proposed well locations, pumping rates, and discharge piping schematics for Alternative 4 are presented on **Drawings 4-5A, 4-5B**, and **4-5C**. Estimated influent concentrations and GAC consumption rates are discussed in Section 4.3.4.1. The number, location, and flow rates of the wells (see Section 4.3.4.1) were developed for cost estimating and comparative evaluation purposes. Final well locations and flowrates will be developed during the remedial design.

In addition, this alternative includes soil excavation and treatment of explosives contaminated soils to reduce potential leaching. The components of the soil excavation and thermal treatment include excavation, consolidation, solids processing, thermal treatment and residual management. The contaminated soil will be removed from the ground by excavation and thermally treated by rotary kiln incineration. Soil treatment residuals will then be tested to verify they are not toxicity characteristic leaching procedure (TCLP) hazardous waste. The non-hazardous residuals will be blended with clean soil and backfilled into the open excavation. It is estimated that approximately 2,600 cubic yards of soil will be excavated and treated. Soil requiring excavation is located in Load Lines 1, 2, and 3. Explosives concentrations in soil at Load Line 4 do not meet the leaching soils definition presented in Section 2.3. **Drawings 4-6A, 4-6B, 4-6C** and **4-6D** show the approximate locations of the excavations and typical details used for cost estimating purposes only. The 2,600 cubic yards volume estimate will be refined when data from the OU1 Preliminary Design Investigation is available. The OU1

Predesign Investigation will be submitted in the Spring of 1995. Soil volume calculations and assumptions are presented in **Appendix E.**

Soil excavation and thermal treatment is proposed as the preferred remedial action for OU1 contaminated soils. Excavating and incinerating OU1 and OU2 soils together will realize a savings in terms of time and money. Detailed analysis of alternatives 4, 6, and 8 has been performed assuming that the OU1 and OU2 soils are excavated and incinerated together. However, if one of those alternatives is presented as the preferred alternative in the Proposed Plan, all elements of the alternative, including the timing of soil excavation and incineration will be subject to public comment.

#### 4.3.5.2 Overall Protection of Human Health and the Environment

Alternative 4 protects human health and the environment because the potential for exposure to groundwater with unacceptable concentrations of COCs is minimized by point-of-entry and containment/extraction systems. Containment/extraction systems protect both current and future groundwater users by controlling the potential for migration beyond the area of attainment. Contaminated groundwater is contained at the Target Groundwater Cleanup Goal and extracted in areas of high concentration of TCE or RDX to minimize migration above the Target Groundwater Cleanup Goal. Soil is excavated and treated to remove explosive contaminants and minimize the potential for future leaching, therefore, providing additional environmental protection.

#### 4.3.5.3 Compliance with ARARs

Target Groundwater Cleanup Goals are met in the vicinity of the downgradient edge of the plume as soon as the alternative becomes operational. Eventually, the entire volume of contaminated groundwater would be remediated and Target Groundwater Cleanup Goals would be met within the entire area of attainment. Particulate emissions during excavation, materials handling and thermal treatment must be controlled to meet Clean Air Act and Nebraska Air Pollution Control regulations. Residuals from the thermal treatment may be considered hazardous if they fail the TCLP making RCRA Land Disposal Restrictions applicable to this alternative. Air pollution control systems and stabilization/solidification of treatment residuals can be designed to address these ARARs. The alternative can be designed to meet the ARARs listed in **Table 4-1**.

#### 4.3.5.4 Long-Term Effectiveness and Permanence

Residual risk is controlled within the plume by point-of-entry treatment and focused extraction and treatment, and downgradient by containment and treatment. Soil excavation and treatment further reduces long-term residual risk by minimizing the potential for continued leaching of explosives from the soil to the groundwater. Point-of-entry treatment is currently in use at the Site, is reliable, and can adequately protect currently impacted and future users. Containment/extraction systems control long-term residual risk by controlling the spread of contamination to currently unimpacted users and currently unimpacted groundwater. System reliability is high but adequacy will be monitored. Soil treatment reduces potential leaching of explosive contaminants to groundwater and long-term residual risk is minimized.

Groundwater monitoring and a 5-year review will evaluate the effectiveness of the point-of-entry treatment system, extraction system, and containment system.

#### 4.3.5.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

The groundwater treatment technologies being considered include the proven and effective treatment technologies of GAC and air stripping and the emerging technology, AOP, which is considered implementable and for which treatability studies are being conducted for Site groundwater. Thermal treatment of explosives contaminated soil by rotary kiln incineration is also proven and effective and has demonstrated effectiveness. All groundwater contamination above Target Groundwater Cleanup Goal will eventually be destroyed. Toxicity and volume of contaminated groundwater are reduced by extraction and treatment. Contaminants in groundwater remain mobile but mobility is managed.

Approximately 2,600 cubic yards of soil will be treated and the contaminants destroyed. Thermal treatment of soils reduces toxicity, mobility, and volume and minimizes volume associated with potential leaching.

The treatment of soil and groundwater would be irreversible. Groundwater treatment residuals potentially include spent carbon from groundwater treatment and off-gas treatment. Residuals from thermal treatment may include scrubber water and ash. Quantities are manageable and do not pose residual risk when properly managed. With regard to soil and groundwater, this alternative satisfies the statutory preference for treatment.

#### 4.3.5.6 Short-Term Effectiveness

Risk to the community is not increased by implementation of the alternative which includes soil excavation and thermal treatment. There is a potential for exposure (ingestion or inhalation) to airborne emissions during excavation and treatment of contaminated soils but exposures can be easily and adequately controlled. There is minimal risk to workers involved in the Site remediation outside of general construction safety issues during implementation of the alternative remedy. Care must be exercised to avoid incidents related to high-temperature activities resulting from the thermal treatment of contaminated soil.

Adverse environmental impacts during implementation are minimal, but aquifer drawdown may impact irrigation activities. Excavation and treatment of contaminated subsurface soils has a beneficial environmental impact due to reduced leaching potential. The groundwater containment/extraction system would operate for an estimated 140 years. Restoration time frames are discussed in **Appendix B**.

Soil treatment would be combined with OU1 and could be completed in approximately 15 months (RUST, 1994c).

#### 4.3.5.7 Implementability

The groundwater management system including point-of-entry treatment systems and containment/extraction systems use conventional technologies and are relatively simple to construct and operate. Thermal treatment of soils involves processes which are commonly used and have demonstrated effectiveness. Additional point-of-entry treatment systems and containment/extraction wells can be easily added. The treatment system for extracted groundwater would be designed in a modular fashion to accommodate varying volumes and influent concentrations. The proposed soil treatment system will be an expansion of the OU1 system and there is not an anticipated need to expand the system.

No difficulty is expected in gaining approvals for the proposed groundwater treatment system. The thermal treatment system trial burn will be conducted as a part of OU1 activities.

No difficulties are anticipated for monitoring the system. Groundwater monitoring will be used to ensure the site cleanup goals are met and that the contamination is contained. Groundwater and soil treatment require monitoring during implementation to ensure effective operation and that discharge standards are met.

All services, technologies, and components for Alternative 4 are available.

**4.3.5.8 Cost**

Alternative 4 conceptual cost estimates are based on the system described in Section 4.3.5.1 and assume GAC adsorption is the selected treatment technology. The conceptual cost estimate also assumes one mile of discharge piping and discharge at the concentrations presented in Section 4.2.1.6. The capital costs for the thermal treatment systems are included within OU1. The total estimated capital and present worth O&M costs for the three Target Cleanup Goals are summarized below:

| Target Groundwater Cleanup Goal | Capital Cost (Million $) | Present Worth O&M Cost (Million $) | Total Capital & Present Worth Costs (Million $) |
|---|---|---|---|
| I | $15.2 | $35.9 | $51.1 |
| II | $17.0 | $44.3 | $61.3 |
| III | $17.0 | $44.4 | $61.4 |

The detailed cost estimates for Alternative 4 are presented in **Appendix L**.

### 4.3.6 Groundwater Alternative 5 - Focused Extraction with Air Sparging

#### 4.3.6.1 Description

Alternative 5 combines air sparging and focused groundwater extraction with the general site elements of groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, groundwater treatment, and disposal. Focused extraction will occur at locations with high concentrations of TCE or RDX, except at the Atlas Missile area where an air sparging system will be installed for remediation of the volatiles-only contaminant plume. Two of the groundwater extraction wells sited nearest the Atlas Missile area for Alternative 4 will be replaced by the air sparging unit. Contaminated vapor extracted via air sparging will be treated at the ground surface using vapor phase GAC.

Therefore, in addition to the hydraulic containment wells described for Alternative 2, three extraction wells will be installed for Target Cleanup Goal I and four extraction wells will be installed for Target Cleanup Goals II and III.

The number, location, and flowrates of these wells and air sparging system were developed for cost estimating and comparative purposes. Final well locations and flowrates will be developed during the remedial design. **Drawings 4-7A, 4-7B**, and **4-7C** show the estimated well locations, pumping rates, discharge piping schematics, and the location of the air sparging system for Target Cleanup Goals I, II, and III, respectively for Alternative 5. Total flows, well numbers and influent concentrations for Alternative 5 are summarized below.

| COST ESTIMATING ASSUMPTIONS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Target Ground-water Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | | Estimated Influent Concentration (μg/L) | |
| | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | Wells | Flow-Rate (GPM) | TCE | RDX |
| I | 4 | 590 | 3 | 620 | 1 | 240 | 8 | 1,450 | 51 | 36 |
| II | 4 | 640 | 8 | 1,770 | 1 | 360 | 13 | 2,770 | 30 | 23 |
| III | 4 | 640 | 8 | 2,000 | 1 | 360 | 13 | 3,000 | 23 | 21 |

As with the previous alternatives, the estimated influent concentrations are based on estimated well locations and flow rates and the methodology discussed in Section 4.2.2.3. The co-mingling of extracted groundwater makes the influent contribution of COCs, other than TCE and RDX, insignificant. Based on the influent concentrations presented above, GAC consumption rates were estimated using the Freundlich adsorption model, including a conservative scaleup factor of 2, discussed in **Appendix K**. For Alternative 5 the GAC usage rate is estimated to be 188,000 lbs/year (515 lbs/day) for Cleanup Goal I and 255,000 and 269,000 lbs/year (699 and 737 lbs/day) for Cleanup Goals II and III, respectively. The decreasing concentration of TCE and RDX with increasing extracted groundwater flow rate results in GAC usage remaining relative constant for Cleanup Goals II and III. Considering the uncertainties present in making GAC usage rate estimates, there is no significant difference between 255,000 and 269,000 lbs/year (5 percent difference).

The air sparging system will be located in the Atlas Missile Area where there are relatively high concentrations of TCE without any explosives. Air sparging is an emerging technology which removes VOCs, such as TCE, from the groundwater without extracting the groundwater. This is accomplished by drilling horizontal and/or vertical wells below the water table, and using the wells to inject air into the contaminated groundwater. The air migrates upward through the groundwater, and the organic vapors are collected above the water table by a soil vapor extraction system and treated if necessary. This technology is not effective for removing explosives, and is not proposed for areas of explosives- contaminated groundwater.

Emerging technologies, while demonstrated at a pilot scale, remain unproven and additional pilot scale testing at the Site may be necessary.

The major components of the air sparging and vapor extraction system include:

- Horizontal air injection wells
- Air vacuum pumps/blowers
- Vertical vapor extraction wells
- Air/water separators
- Vapor treatment systems (GAC adsorption)
- Piping and valves
- Instrumentation

Monitoring of the air sparging process is necessary to ensure proper system performance. Parameters which would be monitored during the operation of the system include:

- Contaminant concentration in extracted air
- Dissolved oxygen in groundwater
- Radius of influence for both vacuum and sparging wells
- Air flowrates
- Vacuum and sparging pressure

The design of the air sparging system is based on parameters including:

- Contaminants present
- Site stratigraphy
- Geochemical and hydrogeologic properties of the contaminated media

The air sparging and vapor extraction system were assumed to be operated in a pulsed manner. The shutdown time allows the soil, groundwater, and soil vapor to equilibrate, increasing the vapor concentration for subsequent operation periods. Spent carbon from the vapor treatment system would be sent off-site for regeneration. Water generated from the vapor treatment system would also be treated with activated carbon and discharged on-site or taken off-site for disposal.

Initial assumptions and calculations related to specifics of the conceptual air sparging system including well location, length, area of influence, and estimated VOC extraction rates are presented in **Appendix M**. The final parameters will be established in the remedial design if Alterative 5 is selected as the remedy. A schematic of an air sparging system is shown in **Drawing 4-8**.

#### 4.3.6.2 Overall Protection of Human Health and the Environment

Alternative 5 provides human health and environmental protection by containing contaminated groundwater and minimizing its potential for migration beyond the area of attainment. The potential for exposure to contaminated groundwater is minimized by point-of-entry treatment systems and containment/extraction systems. Point-of-entry treatment systems protect both currently impacted and future groundwater users and are presently in use at the Site. Containment/extraction systems contain groundwater at the Target Groundwater Cleanup Goal controlling migration and extract groundwater in areas of high concentration.. Alternative 5 also reduces VOC contaminant concentrations by in-situ air sparging, providing additional environmental protection.

#### 4.3.6.3 Compliance with ARARs

Target Groundwater Cleanup Goals are met in the vicinity of the downgradient edge of the plume as soon as the alternative becomes operational. Eventually, the entire volume of contaminated groundwater would be remediated and Target Groundwater Cleanup Goals would be met within the entire area of attainment. Air pollution control systems for the air sparging system can be designed to meet State air pollution regulations and Clean Air Act requirements. The alternative can be designed to meet the ARARs listed in **Table 4-1**.

#### 4.3.6.4 Long-Term Effectiveness and Permanence

Residual risk is controlled within the plume by point-of-entry treatment, air sparging, and focused extraction and treatment. Residual risk is controlled downgradient by containment and treatment. Point-of-entry treatment systems are adequate and reliable in the protection of currently impacted and future groundwater users. Containment/extraction systems protect future groundwater users by controlling migration of contaminated groundwater beyond the area of attainment. Although system reliability is high, the adequacy will be monitored. Air sparging is an emerging technology and reliability and adequacy must be carefully monitored. The treatment is permanent and irreversible.

Groundwater monitoring, off-gas monitoring, and a 5-year review will evaluate the effectiveness of the point-of-entry treatment system, the air sparging system, and the containment/extraction system.

#### 4.3.6.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Proven and effective treatment technologies are considered including; GAC adsorption, air stripping, and advanced oxidation. All groundwater contamination above Target Groundwater Cleanup Goals will eventually be destroyed. Toxicity and volume of contaminated groundwater are reduced by air sparging and groundwater extraction and treatment. Contaminants remain mobile but mobility (i.e. migration) is managed. Treatment residuals would include spent carbon from groundwater treatment and off-gas treatment. Quantities of treatment residuals would be manageable and do not pose residual risk when properly managed. With regard to groundwater, this alternative satisfies the statutory preference for treatment.

#### 4.3.6.6 Short-Term Effectiveness

Overall risk to the community is not increased by implementation of this alternative. There is minimal environmental risks to workers involved in the Site remediation. Adverse environmental impacts during implementation are minimal but aquifer drawdown would occur and may impact irrigation activities.

The components of this alternative are immediately available. The containment/extraction system would operate for greater than 110 years. Restoration time frame estimates are presented in **Appendix B**.

#### 4.3.6.7 Implementability

The proposed groundwater management system components of point-of-entry treatment and containment/extraction use conventional technology and are relatively simple to construct/operate. Air sparging is an emerging technology which may require horizontal drilling which can be complicated. Additional point-of-entry treatment systems and containment/extraction wells can be added. Additional air sparging capacity can also be added. The groundwater treatment system will be designed in a modular fashion to accommodate varying volumes and influent concentrations.

No difficulties for monitoring of effectiveness of the alternative are anticipated. Groundwater monitoring will be used to ensure cleanup goals will be met. The groundwater treatment system will require monitoring during implementation to ensure effective operation and that discharge standards are met.

#### 4.3.6.8 Cost

Alternative 5 conceptual cost estimates are based on the system described in Section 4.3.6.1 and assume GAC adsorption is the selected treatment technology. The conceptual cost estimate also assumes one mile of discharge piping and discharge at the concentrations presented in Section 4.2.1.6. The total estimated capital and present worth O&M costs for the three Target Cleanup Goals are summarized below:

| Target Groundwater Cleanup Goal | Capital Cost (Million $) | Present Worth O&M Cost (Million $) | Total Capital & Present Worth Cost (Million $) |
|---|---|---|---|
| I | $29.6 | $37.9 | $67.5 |
| II | $31.7 | $44.6 | $76.3 |
| III | $31.4 | $43.8 | $75.2 |

The detailed cost estimates for Alternative 5 are presented in **Appendix L**.

### 4.3.7 Groundwater Alternative 6 - Focused Extraction with Air Sparging and Soil Excavation

#### 4.3.7.1 Description

Alternative 6 combines air sparging, focused groundwater extraction, and soil excavation with the general site elements of groundwater monitoring, point-of-entry treatment, hydraulic containment, groundwater treatment and disposal. The general site elements are those described for Alternative 2. The air sparging/soil excavation and treatment are the same as those described in Alternative 5 and Alternative 4, respectively.

Total flows, well numbers, influent concentrations and GAC consumption rates are the same as those described for Alternative 5 in Section 4.3.6.1 and were developed for cost estimating and comparative purposes only. Final well locations and flowrates will be developed during the remedial design. **Drawings 4-7A**, **4-7B**, and **4-7C** show the proposed well locations and discharge piping schematics for Target Cleanup Goal I, II, and III, respectively for Alternative 6. These drawings also show the location of the air sparging system. **Drawings 4-6A**, **4-6B**, **4-6C** and **4-6D** show the soil excavation areas.

#### 4.3.7.2 Overall Protection of Human Health and the Environment

Alternative 6 protects human health and the environment because the potential for exposure to groundwater with unacceptable concentrations of COCs is minimized by point-of-entry treatment systems and containment/extraction systems. The containment/extraction system control the potential for continued migration beyond the area of attainment, protecting the environment. Groundwater is extracted in areas of the high RDX concentration providing additional environmental protection.

Alternative 6 is also protective of the environment by excavating and treating soil, thereby minimizing the potential for leaching of explosive contaminants. In-situ air sparging reduces the VOC contaminant concentrations in groundwater, providing environmental protection.

#### 4.3.7.3 Compliance with ARARs

Target Groundwater Cleanup Goals are met in the vicinity of the downgradient edge of the plume as soon as the alternative becomes operational. Eventually, the entire volume of contaminated groundwater would be remediated and the Target Groundwater Cleanup Goals would be met within the area of attainment. Particulate emissions during excavation, materials handling, and thermal treatment must be controlled to meet Clean Air Act and Nebraska Air Pollution Control Regulations. Residuals from the thermal treatment may be considered hazardous if they fail the TCLP making RCRA Land Disposal Restrictions applicable to this alternative. Air pollution control systems and stabilization/solidification of treatment residuals can be designed to address these ARARs. Air pollution control systems for the air sparging system can be designed to meet State air pollution regulations and Clean Air Act requirements. The alternative can be designed and constructed to meet the ARARs listed in **Table 4-1**.

#### 4.3.7.4 Long-Term Effectiveness and Permanence

Residual risk is controlled within the plume by point-of-entry treatment, air sparging, and extraction and treatment. Soil excavation and treatment further reduces long-term residual risk by minimizing the potential for continued leaching of explosives contaminants from soil to groundwater resulting in contaminant concentrations above the Target Groundwater Cleanup Goal. Downgradient residual risk is managed through containment of contaminated groundwater at the Target Groundwater Cleanup Goal. Point-of-entry treatment systems exhibit long-term reliability and are adequate to protect currently impacted and future users. Containment and extraction system reliability is high but adequacy will be monitored.

Groundwater monitoring, off-gas monitoring, and a 5-year review will evaluate the effectiveness of the point-of-entry systems, the air sparging system, the extraction system, and the containment system. Soil excavation and treatment permanently removes the leaching potential and long-term controls and monitoring are not required.

#### 4.3.7.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

The groundwater treatment technologies being considered include the proven and effective treatment technologies of GAC and air stripping and the emerging technology, AOP, which is considered implementable and for which treatability studies are being conducted for Site groundwater. Air sparging is an emerging technology but can be effective at reducing contaminant concentrations. Thermal treatment of explosives contaminated soil by rotary kiln incineration is proven and effective, and has been implemented at similar sites. Thermal treatment permanently destroys the explosive contaminants. All groundwater contamination above the Target Groundwater Cleanup Goal will eventually be destroyed. This reduces the toxicity, mobility, and volume of groundwater contamination via treatment. It is estimated that 2,600 cubic yards of soil will be treated, satisfying the statutory preference for treatment, and reducing toxicity, mobility and volume. The treatment processes considered are irreversible. Potential groundwater treatment residuals include spent carbon from groundwater treatment and off-gas treatment. Residuals from thermal treatment of soil may include scrubber water and ash, which are easily managed and do not pose a residual risk when properly managed. With regard to soil and groundwater, this alternative satisfies the statutory preference for treatment.

#### 4.3.7.6 Short-Term Effectiveness

Overall risk to the community is not increased by implementation of Alternative 6, which includes soil excavation and treatment. There is a potential for exposure (ingestion or inhalation) to airborne emissions during excavation and treatment of contaminated soil, but potential exposure can be easily and adequately controlled. There is only minimal environmental risk to workers involved in the Site remediation outside of general construction safety issues during implementation of this alternative. Ingestion and/or inhalation of airborne particulates by workers during excavation and treatment of contaminated soil is possible but potential exposures are easily managed. Care must be taken to avoid incidents related to high-temperature activities resulting from the thermal treatment of contaminated soil. Potential adverse environmental impacts during implementation are minimal given the low levels of contaminants, but aquifer drawdown may impact irrigation activities.

The excavation and treatment of contaminated soils has an immediate short-term beneficial impact on the environment since the potential for leaching of explosive contamination is removed. Point-of-entry treatment systems and containment/extraction systems are immediately available. Air sparging is an emerging technology which may require horizontal drilling, but the systems are available and relatively easy to construct. The groundwater containment/extraction and air sparging system would operate for approximately 110 years. Restoration time frames are presented in **Appendix B**.

Soil treatment could be completed in approximately 15 months (RUST, 1994c).

#### 4.3.7.7 Implementability

The groundwater management system components including point-of-entry treatment, and containment/extraction followed by treatment are relatively simple to construct and operate. Air sparging may require horizontal drilling which can be complicated. Thermal treatment of soils involves processes which are commonly used and have demonstrated effectiveness. Additional point-of-entry systems and containment/extraction wells can easily be added if they become necessary. The treatment system would be designed to accommodate varying volumes and influent concentrations and could be expanded in a modular fashion. There is not an anticipated need to expand the air sparging system or thermal soil treatment system which will be undertaken concurrently with OU1. No difficulties are anticipated with system monitoring, which employs conventional sampling and analysis techniques.

Groundwater monitoring will be used to ensure that progress toward the final Target Groundwater Cleanup Goal and discharge standards are being met. During operation the soil treatment system will be monitored to ensure effective operations in compliance with the operating parameters. No difficulty in gaining approval for the groundwater treatment system is anticipated. The thermal treatment system trial burn will be conducted as part of the OU1 activities. All required services, technologies, and components for implementation of this alternative are readily available.

#### 4.3.7.8 Cost

The conceptual cost estimates for Alternative 6 are based on the system described in Section 4.3.7.1 and assume GAC adsorption is the selected treatment technology. The conceptual cost estimate also assumes one mile of discharge piping and discharge at the concentrations presented in Section 4.2.1.6. The capital costs for the thermal treatment system are included within OU1. The total estimated capital and present worth O&M costs for the three Target Cleanup Goals are summarized below:

| Target Groundwater Cleanup Goal | Capital Cost (Million $) | Present Worth O&M Cost (Million $) | Total Capital & Present Worth Cost (Million $) |
|---|---|---|---|
| I | $33.9 | $38.0 | $71.8 |
| II | $36.0 | $44.7 | $80.6 |
| III | $35.7 | $43.9 | $79.5 |

The detailed cost estimates for Alternative 6 are presented in **Appendix L.**

### 4.3.8 Groundwater Alternative 7 - Groundwater Extraction

#### 4.3.8.1 Description

Alternative 7 includes groundwater monitoring, point-of-entry treatment for domestic water supply, hydraulic containment, groundwater extraction throughout the area of attainment, treatment, and disposal. The containment/extraction system in Alternative 7 consists of a total of 9 to 17 wells, depending on the Target Groundwater Cleanup Goal. The number, location, and flowrates of these wells were developed for cost estimating and comparative purposes. Final well locations and flowrates will be developed during the remedial design.

The estimated groundwater extraction well locations and discharge piping schematics for Target Cleanup Goals I, II, and III are shown on **Drawings 4-9A**, **4-9B**, and **4-9C**, respectively. The schematics show the location of the wells with respect to groundwater contamination and other Site features. The extraction wells are located within and on the downgradient edge of the shallow and intermediate groundwater contamination plumes. Well location information is summarized below:

| COST ESTIMATE ASSUMPTIONS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Target Groundwater Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | | Estimated Influent Concentration (µg/L) | |
| | Wells | Total Flow-(GPM) | Wells | Total Flow-(GPM) | Wells | Total Flow-(GPM) | Wells | Total Flow-(GPM) | TCE | RDX |
| I | 5 | 1,630 | 3 | 620 | 1 | 240 | 9 | 2,490 | 338 | 18 |
| II | 5 | 1,680 | 9 | 2,160 | 1 | 360 | 15 | 4,200 | 205 | 23 |
| III | 5 | 1,680 | 11 | 2,870 | 1 | 360 | 17 | 4,910 | 173 | 21 |

As with the previous alternatives, the estimated influent concentrations are based on estimated well locations and flowrates, and the methodology discussed in Section 4.2.2.3. The co-mingling of extracted water makes the influent contribution of Site COCs other than TCE and RDX insignificant. Therefore, GAC consumption rates are based on the influent concentrations of TCE and RDX using the Freundlich adsorption model discussed in **Appendix K.** For Alternative 7 the GAC usage rate is estimated to be approximately 568,000 lbs/year (1,556 lbs/day) for Cleanup Goal I; 819,000 lbs/year (2,244 lbs/day) for Cleanup Goal II; and 896,000 lbs/year (2,455 lbs/day) for Cleanup Goal III. A conservative scaleup factor of 2 is included in these estimates in the absence of treatability study data.

#### 4.3.8.2 Overall Protection of Human Health and the Environment

Point-of-entry systems protect currently impacted and future users by eliminating the potential for exposure to groundwater with unacceptable concentrations of COCs. Point-of-entry treatment systems are currently in use at the Site. Containment/extraction systems protect future users because groundwater is contained and extracted, and migration above the Target Groundwater Cleanup Goal is controlled. Contaminant concentrations are reduced by extraction and treatment providing protection of human health and the environment.

#### 4.3.8.3 Compliance with ARARs

Target Groundwater Cleanup Goals are met in the vicinity of the downgradient edge of the plume as soon as the alternative becomes operational. Eventually, the entire volume of contaminated groundwater would be remediated and the Target Groundwater Cleanup Goal would be met within the area of attainment. The alternative can be designed to meet ARARs listed in **Table 4-1**.

#### 4.3.8.4 Long-Term Effectiveness and Permanence

Residual risk is controlled within the plume by point-of-entry treatment, and extraction and treatment, and downgradient by containment and treatment. Point-of-entry treatment is adequate to protect current and future users and the systems are proven and reliable. The containment/extraction systems are proven and reliable. Point-of-entry GAC adsorption is presently in use at the Site Containment controls long-term residual risk by controlling the spread of contamination.

Groundwater monitoring and a 5-year review will evaluate the effectiveness of point-of-entry treatment systems, extraction system, and containment system.

#### 4.3.8.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Proven and effective treatment technologies including; GAC adsorption, air stripping, and advanced oxidation are being considered for treatment of extracted groundwater. By implementing one of these technologies, all groundwater contamination above the Target Groundwater Cleanup Goal will eventually be destroyed. The toxicity and volume of contaminants in groundwater will be reduced and the mobility (i.e. migration) will be managed. With regard to groundwater, this alternative satisfies the statutory preference for treatment.

#### 4.3.8.6 Short-Term Effectiveness

Risks to the community are not increased by implementation of this alternative. Environmental risks to workers involved in the Site remediation are minimal. Adverse environmental impacts during implementation would be minimal but extraction will result in aquifer drawdown which may impact irrigation. The groundwater extraction and containment system for the three Target Groundwater Cleanup Goals would operate for greater than 90 years. Restoration time frames are discussed in **Appendix B**.

#### 4.3.8.7 Implementability

Groundwater extraction and hydraulic containment systems use conventional technology and are relatively simple to construct and operate. Point-of-entry treatment systems are simple to install and available immediately. Additional point-of-entry treatment systems and extraction/containment wells can easily be added. The treatment system for extracted groundwater will be designed in a modular fashion to accommodate varying volumes and influent concentrations. Monitoring the effectiveness of the groundwater extraction/containment and treatment systems uses common sampling and analysis techniques, is easily implemented, and reliable.

#### 4.3.8.8 Cost

The conceptual cost estimates for Alternative 7 are based on the system described in Section 4.3.8.1 and assume GAC adsorption is the selected treatment technology. The conceptual cost estimate also assumes one mile of discharge piping and discharge at the concentrations presented in Section 4.2.1.6. The total estimated capital and present worth O&M costs for the three Target Cleanup Goals are summarized below.

| Target Groundwater Cleanup Goal | Capital Cost (Million $) | Present Worth O&M Cost (Million $) | Total Capital & Present Worth Cost (Million $) |
|---|---|---|---|
| I | $10.3 | $36.8 | $47.1 |
| II | $14.8 | $47.4 | $62.2 |
| III | $15.2 | $51.0 | $66.2 |

The detailed cost estimates for Alternative 7 are presented in **Appendix L**.

### 4.3.9 Groundwater Alternative 8 - Groundwater Extraction with Soil Excavation

#### 4.3.9.1 Description

Alternative 8 includes all of the groundwater elements of Alternative 7 with the addition of soil excavation and thermal treatment. Total flows, well numbers, influent concentrations, and GAC consumption rates are presented in Section 4.3.8.1. **Drawings 4-9A**, **4-9B**, and **4-9C** show the proposed well locations, pumping rates, and discharge piping schematics for Target Cleanup Goal I, II, and III, respectively. The number, location, and flowrates of the wells were developed for cost estimating and computative purposes. Final well locations and flowrates will be developed during remedial design.

Alternative 8 also incorporates soil excavation and treatment of explosives contaminated soils to reduce potential leaching. The soil excavation and treatment elements are the same as those described in Alternative 4 (Section 4.3.5.1). **Drawings 4-6A, 4-6B, 4-6C** and **4-6D** show the soil excavation areas. Soil volume calculations are presented in **Appendix E**.

#### 4.3.9.2 Overall Protection of Human Health and the Environment

Alternative 8 protects human health and the environment because the potential for exposure to groundwater with unacceptable concentrations of COCs is minimized by point-of-entry systems and containment/extraction systems. These systems protect both current and future users. Contaminated groundwater is contained at the Target Groundwater Cleanup Goal and extracted, thus migration above the Target Groundwater Cleanup Goal is minimized. Soil is excavated and treated to remove explosives contaminants and minimize the potential for future leaching, therefore, providing additional environmental protection.

#### 4.3.9.3 Compliance with ARARs

Target Groundwater Cleanup Goals are met in the vicinity of the downgradient edge of the plume as soon as the alternative becomes operational. Eventually, the entire volume of contaminated groundwater would be remediated and the Target Groundwater Cleanup Goal would be met within the area of attainment. The alternative can be designed to meet the ARARs listed in **Table 4-1**.

#### 4.3.9.4 Long-Term Effectiveness and Permanence

Residual risk is controlled within the plume by point-of-entry treatment and extraction, and downgradient by containment and treatment. Soil excavation and treatment reduces long-term residual risk by minimizing the potential for continued leaching of explosives contaminants from soil to groundwater resulting in contaminant concentrations above the Target Groundwater Cleanup Goal. Point-of-entry treatment is reliable and adequate and currently in use at the Site. The extraction system reliability is high but adequacy will be monitored.

Groundwater monitoring and a 5-year review will evaluate the effectiveness of point-of-entry treatment systems, extraction system, and containment system. Soil treatment permanently removes leaching potential and long-term monitoring and controls are not required.

#### 4.3.9.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

Proven and effective treatment technologies for groundwater, including GAC adsorption, air stripping, and advanced oxidation, are being considered for treatment of groundwater. Thermal treatment of explosives-contaminated soil by rotary kiln incineration is also proven and effective. All groundwater contamination above the Target Groundwater Cleanup Goal will eventually be destroyed. Toxicity and volume of contaminated groundwater are reduced. Contaminants remain mobile but mobility is managed.

It is estimated that 2.600 cubic yards of soil will be treated and the contaminants destroyed.

Thermal treatment of soils reduces toxicity, mobility, and volume and minimizes volumeassociated with potential leaching.

The treatment of soil and groundwater would be irreversible. Groundwater treatment residuals potentially include spent carbon from groundwater treatment and off-gas treatment. Residuals from thermal treatment may include scrubber water and ash. Quantities are manageable and do not pose residual risk when properly managed. With regard to soil and groundwater, this alternative satisfies the statutory preference for treatment.

#### 4.3.9.6 Short-Term Effectiveness

Risk to the community is not increased by implementation of the alternative which includes soil extraction and thermal treatment. There is a potential for particulate exposure (ingestion or inhalation) due to airborne emissions during excavation and treatment of contaminated soils but exposures can be adequately controlled. There is only minimal environmental risk to workers involved in the Site remediation. Care must be taken to avoid incidents related to high-temperature activities resulting from the thermal treatment of soil.

Adverse environmental impacts during implementation are minimal, but aquifer drawdown may impact irrigation activities. Excavation and treatment of contaminated subsurface soils has a beneficial environmental impact due to reduced leaching potential. Point-of-entry treatment is immediately available. The groundwater containment/extraction system would operate for an estimated 90 years. Soil treatment could be completed within 15 months (RUST, 1994).

#### 4.3.9.7 Implementability

The groundwater treatment system including point-of-entry and containment/extraction systems use conventional technology and are relatively simple to construct and operate. Thermal treatment of soils involves processes which are commonly used and have demonstrated effectiveness. Additional point-of-entry treatment systems and containment/extraction wells can be easily added. The groundwater treatment system would be designed in a modular fashion to accommodate varying volumes and influent concentrations. The proposed soil treatment system will be an expansion of the OU1 system and there is not an anticipated need for the expansion of the system. No difficulty is expected in gaining approvals for the proposed groundwater treatment system. The thermal treatment system trial burn will be conducted as a part of OU1 activities.

No difficulties are anticipated for monitoring the system. Groundwater monitoring will be used to ensure the site cleanup goals are met and that contamination is contained. Groundwater and soil treatment require monitoring during implementation to ensure effective operation and that discharge standards are met. All services, technologies, and components for implementation of this alternative are available.

#### 4.3.9.8 Cost

Alternative 8 conceptual cost estimates are based on the system described in Section 4.3.9.1 and assume GAC adsorption is the selected treatment technology. The conceptual cost estimate also assumes one mile of discharge piping and discharge at the concentrations presented in Section 4.2.1.6. The total estimated capital and present worth O&M costs of the three Target Cleanup Goals are summarized below:

| Groundwater Target Cleanup Goal | Capital Cost (Million $) | Present Worth O&M Cost (Million $) | Total Capital & Present Worth Cost (Million $) |
|---|---|---|---|
| I | $14.6 | $36.9 | $51.5 |
| II | $19.0 | $47.5 | $66.5 |
| III | $19.4 | $51.1 | $70.5 |

The detailed cost estimates for Alternative 8 are presented in **Appendix L.**

## 4.4 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section presents a comparative analysis of the eight alternatives retained above. **Table 4-2** summarizes the detailed analysis of each alternative and is included here to assist in comparing and contrasting the eight alternatives. The comparative analysis presented below evaluates the performance of the various alternatives against the nine evaluation criteria previously described.

### 4.4.1 Overall Protection of Human Health and Environment

Alternative 1 does not satisfy the requirement to protect human health or the environment. Overall risk is not reduced by implementation of this alternative.

Alternatives 4, 6, and 8 are the most protective of the environment because they not only contain contaminated groundwater at the Target Groundwater Cleanup Goal, they also remove and treat leaching soils, which provides further protection to the environment. Of these three alternatives, Alternative 8 is the most protective because it extracts groundwater at the highest flowrate thus removing the largest mass of contamination in the shortest time. Alternative 6 which utilizes air sparging and Alternative 4 which includes focused groundwater extraction provide approximately the same level of environmental protection.

The remaining four alternatives: Alternatives 2, 3, 5, and 7 are also protective of the environment. All of these alternatives include the element of containment at the Target Groundwater Cleanup Goal. The levels of protection between Alternatives 3 and 5 are approximately the same, since both aggressively treat the VOC plume but utilize different methods (i.e., air sparging vs. focused extraction). Therefore, the level of protection generally increases between 2 and 3, and 5 and 7.

With the exception of Alternative 1, the remaining seven alternatives are protective of human health through point-of-entry treatment and containment of groundwater contamination at the Target Groundwater Cleanup Goal. Containment protects currently unimpacted users from being exposed to groundwater with unacceptable levels of Site COCs.

### 4.4.2 Compliance with ARARs

Alternative 1 does not comply with ARARs. The remaining alternatives can be designed to meet the ARARs and the TBC standards where pertinent. **Table 4-1** presents the ARARs and indicates which ARARs are pertinent to a given alternative.

### 4.4.3 Long-Term Effectiveness and Permanence

Alternative 1 does not provide any long-term effectiveness as contaminated groundwater will continue to migrate and impact currently unimpacted areas. The remaining seven alternatives are all effective in the long-term and control residual risk by point-of-entry treatment and containment at the Target Groundwater Cleanup Goals and treatment. Alternatives 4, 6, and 8 also control long-term residual environmental risk from leaching since the leachable soils are excavated and thermally treated thereby removing the potential for continued leaching of contaminants to groundwater resulting in concentration above the Target Groundwater Cleanup Goals.

The containment/extraction systems and treatment systems proposed all use conventional technology and can be easily constructed. Once operational, the systems are reliable, but monitoring will be employed to evaluate adequacy of the containment/extraction and treatment systems.

Alternatives 5 and 6 employ air sparging, which is an emerging technology and reliability at full scale implementation is not known. Air sparging may use horizontal drilling, which can be complicated.

Alternatives 4, 6, and 8 involve the excavation and thermal treatment of leachable soils. Removal (excavation) of the identified soils is easily accomplished by conventional construction techniques. Thermal treatment is a well-established technology which has been successfully demonstrated on explosives-contaminated soils.

All alternatives would require a 5-year review to ensure that contaminant migration is being controlled and that the containment/extraction and treatment systems are meeting the remedial action objectives.

### 4.4.4 Reduction of Toxicity, Mobility, or Volume

This criterion addresses the use of treatment technologies to significantly reduce toxicity, mobility, and volume. According to CERCLA Section 121(b), preference should be given to those alternatives which employ treatment. With the exception of Alternative 1, all the alternatives use treatment in combination with containment and/or extraction. The groundwater treatment technologies being considered include the proven and effective treatment technologies of GAC and air stripping and the emerging technology, AOP, which is considered implementable and for which treatability studies are being conducted for site groundwater. An emerging treatment technology, advanced oxidation, is also being considered for groundwater treatment. Treatability testing to evaluate this technology is currently underway. Another emerging technology, air sparging, is also being considered for Alternative 5 and Alternative 6. In addition, Alternatives 4, 6, and 8 include thermal treatment, which will eliminate the toxicity, mobility, and volume of contaminants associated with the leaching soils.

All treatment processes being considered are irreversible.

Treatment residuals will be associated with all the alternatives. These primarily include spent GAC from direct treatment of groundwater or treatment of the off-gas stream associated with air stripping and/or air sparging. The alternatives which employ thermal treatment of soils will also generate residuals in the form of ash and scrubber water, and treated soil which can be returned to the excavation if it passes TCLP. The residuals generated are easily managed and do not posses residual risk when managed properly.

### 4.4.5 Short-Term Effectiveness

Short-term effectiveness evaluates potential impacts on human health and the environment during construction and implementation of the various alternatives. Implementation of Alternative 1 does not impact human health or the environment as no action is taken beyond groundwater monitoring which will have little or no impact on the surrounding community. The remaining seven alternatives will include drilling, trenching, and construction of the treatment plant. All of these activities will result in the generation of dust and noise and an increase in traffic around the Site. Alternatives 4, 6, and 8 which involve excavation and transport of leachable soils prior to thermal treatment will result in the largest potential for dust generation. However, dust generation is easily controlled and should not increase risk to the local community. Short-term environmental risk to workers are not significant beyond those associated with general construction activities. Care must be taken with Alternatives 4, 6, and 8 to avoid incidents related to high temperature activities from thermal treatment of soil. The remaining alternatives all present similar levels of short-term risk because extraction well drilling, trenching, and treatment building construction are required for each alternative.

Implementation of Alternatives 2 through 8 will result in the drawdown of the water level in the aquifer. The drawdown will vary spatially depending on proximity to containment/extraction wells, the containment/extraction well flowrate, the physical dimensions of theaquifer, and the hydraulic properties of the aquifer. Alternative 2 has the lowest total extraction flowrate which results in the lowest overall potential of adverse impacts due to aquifer drawdown. Alternatives 7 and 8 have the highest total extraction flowrates, which result in a correspondingly high potential for adverse impacts from drawdown. The following list ranks the alternatives in terms of increasing total extraction flow rate. Thelist also ranks the potential for adverse effects from drawdown from lowest to highest potential effect.

- Alternative 2
- Alternatives 5 and 6
- Alternatives 3 and 4
- Alternatives 7 and 8

Time estimates until the Target Groundwater Cleanup Goals are achieved are presented in **Appendix B.**

### 4.4.6 Implementability

All of the alternatives are implementable with Alternative 2 being the easiest to implement because it requires the fewest number of containment wells. Alternatives 5 and 6 employ air sparging which is an emerging technology which may require horizontal drilling making them the most difficult to implement. All the alternatives (except Alternative 1) employ conventional construction technologies and the associated equipment, operators and specialists are readily available. Alternatives 2 through 7 could be easily expanded if necessary by adding additional point-of-entry treatment systems and or additional containment/extraction wells. The treatment plant will be designed in a modular fashion to allow for expansion if additional flow is added to the system. The groundwater treatment technologies being considered include GAC, AOP, and air stripping. AOP is an emerging technology but considered implementable. GAC and air stripping are established and easily implementable.

Excavation and thermal treatment of soil included as part of Alternatives 4, 6 and 8 is easily implementable. Soil excavation and thermal treatment is proposed as the preferred remedial action for OU1 contaminated soils. Implementation of excavation and thermal treatment of additional contaminated soils identified as part of an OU2 remedy could be accomplished during the OU1 Remedial Action.

The ability to monitor the effectiveness of the systems is relatively simple as groundwater sampling and analysis and off-gas sampling and analysis are well established.

### 4.4.7 Costs

#### 4.4.7.1 <u>Cost Summary</u>

Alternatives are evaluated in terms of estimated capital costs, annual O&M costs, and present worth costs. The following tabulation summarizes the estimated costs for each alternative based on the Target Groundwater Cleanup Goals.

| Conceptual Cost Summary | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Capital Cost | | | Present Worth O&M Cost | | | Total Present Worth Cost | | |
| Alternative | Cleanup Goal I (Million $) | Cleanup Goal II (Million $) | Cleanup Goal III (Million $) | Cleanup Goal I (Million $) | Cleanup Goal II (Million $) | Cleanup Goal III (Million $) | Cleanup Goal I (Million $) | Cleanup Goal II (Million $) | Cleanup Goal III (Million $) |
| 1 | 0 | 0 | 0 | $11.1 | $11.1 | $11.1 | $11.1 | $11.1 | $11.1 |
| 2 | $6.4 | $8.2 | $7.9 | $23.2 | $27.1 | $27.2 | $29.6 | $35.3 | $35.2 |
| 3 | $11.0 | $12.8 | $12.8 | $35.8 | $44.2 | $44.3 | $46.8 | $57.0 | $57.1 |
| 4 | $15.2 | $17.0 | $17.0 | $35.9 | $44.3 | $44.4 | $51.1 | $61.3 | $61.4 |
| 5 | $29.6 | $31.7 | $31.4 | $37.9 | $44.6 | $43.8 | $67.5 | $76.3 | $75.2 |
| 6 | $33.9 | $36.0 | $35.7 | $38.0 | $44.7 | $43.9 | $71.8 | $80.6 | $79.5 |
| 7 | $10.3 | $14.8 | $15.2 | $36.8 | $47.4 | $51.0 | $47.2 | $62.2 | $66.2 |
| 8 | $14.6 | $19.0 | $19.4 | $36.9 | $47.5 | $51.1 | $51.5 | $66.5 | $70.5 |

The estimated present worth costs constitute the present worth of all of the annual cost elements assuming a project life of 80 years. The present worth cost components for each alternative are:

- Quarterly groundwater monitoring costs for years 1 through 5
- Annual groundwater monitoring costs for years 6 through 80
- Annual operation and maintenance costs for years 1 through 80
- Periodic costs incurred every five years for selected equipment replacement
- Major equipment replacement costs incurred at 20-year intervals

The present worth costs are calculated for an 80-year period using a 6 percent discount rate. The 80-year period was selected because it approaches the shortest restoration time frame estimate of approximately 90 years. The 80-year period was selected because it provides a realistic estimate of costs and provides a common cost estimating basis between alternatives.

Three major assumptions are common to the cost estimates for Alternatives 2 through 8:

- Extracted groundwater is treated using GAC adsorption
- There is no cost to any alternative for disposal (either on-/off-site stream discharge or beneficial reuse) except for one mile of discharge piping
- All capital costs associated with the construction, installation and startup of the thermal treatment system (Alternatives 4, 6, and 8) are accounted for as OU1 costs

Capital costs are not proportional to pumping rates (i.e. extracted groundwater flow rates), and sometimes costs associated with attaining Cleanup Goal II are higher relative to Cleanup Goal III (which has a larger volume of water). Capital costs are primarily dependent on:

- The number of containment/extraction wells
- The length of piping and number of pumps required to transfer extracted groundwater to a fixed treatment location

For example, the number and location of containment/extraction wells is determined by the geometry of the individual plumes. As requirements for total groundwater extraction rate increases, the number of wells may not necessarily increase proportionally. In some cases, a specific well can capture a larger plume by only increasing the flow rate instead of adding a proportional number of wells. In other cases additional wells may be required with higher flow rate per well. For example, Alternative 5, Cleanup Goal I has 8 wells with a total flow rate of 1,450 GPM while Alternative 7, Cleanup Goal I has 9 wells with a total flow rate of 2,490 GPM. The increase in number of wells is 13 percent versus a 72 percent increase in flow rate.

As another example, a 6-inch pipeline will carry more than twice the flow of a 4-inch pipeline, yet installation costs for the 6-inch pipeline are much less than twice the costs associated with a 4-inch pipeline. Also, the construction costs for a 200 gpm well are only minimally greater than for a 400 gpm well. Both wells would use the same size casing, filter packs, well screens, and surface structures. The size of the pumps would differ between the wells.

However the cost of the treatment plant is proportional to the extracted groundwater flow rate.

Detailed cost assumptions and cost calculation sheets are presented in **Appendix L**.

#### 4.4.7.2 Cost Sensitivity Analysis

Some of the factors used to estimate costs may have a significant level of uncertainty. To address these uncertainties, cost sensitivity analyses were performed for Alternatives 2 through 8. It was assumed that the monitoring costs associated with all eight alternatives are known with a relatively high degree of certainty, therefore, no cost sensitivity analysis was performed. The sensitivity analysis consisted of the following:

- Identifying major cost components for each alternative that have a significant degree of uncertainty and estimating the reasonable minimum and maximum values for each component
- Varying the values assumed for these components

- Evaluating the relative change (sensitivity) of the present worth cost (tabulated in the preceding section) to these variations

If the variation results in a significant (20 percent or greater) change in the present worthcost, then the present worth cost will be considered sensitive to the varied component.

The major cost components can be classified into the following categories:

- Physical components which determine the volume of groundwater extracted to satisfy the general response action for the alternative (hydraulic containment, focused extraction, and extraction throughout the area of attainment), or in the case of air sparging, the capacity of the air sparging system

- Treatment components which impact the ability of the alternatives to reduce the COC concentrations in the extracted groundwater to the required Discharge Standards

- Financial components which are used to estimate the costs of the alternatives

**Restoration Time**

At this site, the shortest of the restoration time frame estimates for the alternatives is approximately 90 years. Present worth calculations are relatively insensitive to variations in project lifetimes which are initially on the order of 100 years or greater. The restoration time frames for the remainder of the alternatives are in excess of 100 years. For this reason, an analysis of present worth cost sensitivity to variations in restoration time frame estimates will not be performed.

**Area of Attainment**

The size of the area of attainment is dependent on the Target Groundwater Cleanup Goal selected. The areas of attainment defined for each set of Preliminary Target Groundwater Cleanup Goals are based on the extent of contamination defined by the particular cleanupgoals. The contaminant concentrations are highest near the source areas, and generally decrease away from the source areas. For this reason, as the Target Groundwater Cleanup Goals concentrations decrease, the corresponding areas of attainment increases. An analysis was performed to provide information concerning cost sensitivity relative to the different areas of attainment. The base for the analysis is the area of attainment corresponding to Target Groundwater Cleanup Goal I. The sizes of Cleanup Goal II (5,880 acres) and Cleanup Goal III (6,450 acres) areas of attainment are approximately 116 percent and 137 percent, respectively, larger than the size of Cleanup Goal I (2,720 acres). The following tabulation shows the present worth cost sensitivity relative to the areas of attainment defined by the three sets of Preliminary Target Groundwater Cleanup Goals.

| Cost Sensitivity to Area of Attainment as Defined by Preliminary Target Groundwater Cleanup Goals | | | | | |
|---|---|---|---|---|---|
| Alternative | Cleanup Goal I Cost (2,720 acres) (Million $) | Cleanup Goal II (5,880 acres) | | Cleanup Goal III (6,450 acres) | |
| | | Cost (Million $) | Cost % Diff. | Cost (Million $) | Cost % Diff. |
| 2 | 29.6 | 35.3 | 19.3 | 35.1 | 18.6 |
| 3 | 46.8 | 57.0 | 21.8 | 57.1 | 22.0 |
| 4 | 51.1 | 61.3 | 20.0 | 61.4 | 20.2 |
| 5 | 67.5 | 76.3 | 13.0 | 75.2 | 11.4 |
| 6 | 71.8 | 80.6 | 12.3 | 79.5 | 10.7 |
| 7 | 47.1 | 62.2 | 32.1 | 66.2 | 40.6 |
| 8 | 51.5 | 66.5 | 29.1 | 70.5 | 36.9 |

The data show that the overall costs are higher for Cleanup Goals II and III with respect to Cleanup Goal I. Alternatives 3, 4, 7 and 8 costs show a significant increase (greater than 20 percent) in cost when Cleanup Goals II and III are compared with Cleanup Goal I. Alternatives 7 and 8 (groundwater extraction and groundwater extraction with soil excavation) appear to be most sensitive to changes in the area of attainment. Increases for these alternatives range from 29 to 41 percent when Cleanup Goals II and III are compared with Cleanup Goal I.

The remaining sensitivity analyses will be performed using the area of attainment definedby Cleanup Goal I only.

## Groundwater Extraction Flowrate

There is uncertainty associated with the number of groundwater extraction wells and the rate at which those wells will be pumped. For the sensitivity analysis, it will be assumed that the number of wells does not change for each alternative, and costs will be varied based on varying flowrates. The total extraction flowrates estimated for Alternative 2 through 8 earlier in Section 4.0 are based on the hydraulic conductivity of the sand and gravel unit of the Pleistocene aquifer. During the OU2 RI, the hydraulic conductivity of the overlying fine sand unit was estimated to be lower relative to the sand and gravel hydraulic conductivity. Hydraulic containment was simulated using both values of hydraulic conductivity as a part of the Removal Action groundwater modeling (WCC, 1994a). The groundwater modeling showed that the ratio of the total extraction flowrate simulated using the lower (fine sand unit) hydraulic conductivity to the flowrate simulated using the higher (sand and gravel unit) hydraulic conductivity was approximately 0.41. For the sensitivity analysis the reasonable minimum total extraction flowrate was calculated as 41 percent of the reasonable maximum flowrate and the reasonable maximum total extraction flowrate was assumed to be the total extraction flowrates estimated using the sand and gravel unit hydraulic conductivity. The reasonable maximum and minimum estimated flowrates are tabulated below.

| Alternative | Reasonable Maximum Total Extraction Flowrate (gpm) | Reasonable Minimum Total Extraction Flowrate (gpm) |
|---|---|---|
| 2 | 970 | 400 |
| 3 | 1,980 | 810 |
| 4 | 1,980 | 810 |
| 5 | 1,450 | 595 |
| 6 | 1,450 | 595 |
| 7 | 2,490 | 1,020 |
| 8 | 2,490 | 1,020 |

The flowrates tabulated above were estimated for performing the sensitivity analysis. The flowrate estimate will be refined during remedial design.

For the sensitivity analysis, the costs were varied by making the following changes to thecost estimates of Alternatives 2 through 8 (Cleanup Goal I):

- The direct capital cost for the treatment system decreased to 41% of the cost for the reasonable maximum flowrate assuming that flowrate and treatment system capital costs are linearly dependent

- Adjustments were made to the indirect capital costs which were based on a percentage of the direct capital costs

- Carbon usage rates were recalculated using the reasonable minimum flowrates

- The power requirements for the groundwater extraction pumps were adjusted based on the reasonable minimum flowrates and the corresponding electricity usage rates were recalculated

- The groundwater monitoring costs were not altered

The following tabulation shows the present worth cost sensitivity relative to a reduction in total extraction flowrate.

| Cost Sensitivity to a Reduction in Total Extraction Flowrate | | | |
|---|---|---|---|
| | **Base (Cleanup Goal I)** | **41% Reduction in Flowrate** | |
| **Alternative** | **Cost at Maximum Flowrate (Million $)** | **Cost (Million $)** | **% Diff.** |
| 2 | 29.6 | 25.7 | ( - 13.2 ) |
| 3 | 46.8 | 34.9 | ( - 25.4 ) |
| 4 | 51.1 | 39.2 | ( - 23.3 ) |
| 5 | 67.5 | 59.8 | ( - 11.4 ) |
| 6 | 71.8 | 64.1 | ( - 10.7 ) |
| 7 | 47.1 | 34.6 | ( - 26.5 ) |
| 8 | 51.5 | 38.9 | ( - 24.5 ) |

Similar to the results for the area of attainment analysis, Alternatives 3, 4, 7 and 8 costs are sensitive to changes in the groundwater extraction flowrate. The decrease in costs associated with the 41 percent decrease in flowrate ranges from approximately 23 to 27 percent for these alternatives.

## Groundwater Treatment Costs

There is uncertainty associated with the contaminant concentration in the groundwater entering the treatment system. A change in concentration would impact the costs associated with treatment (for example, the carbon use rate would increase with increasing influent concentration). The reasonable minimum treatment costs are the base treatment costs (Cleanup Goal I) reduced by 30 percent, and the reasonable maximum treatment costs are the base costs increased by 50 percent. These minimum and maximum variances were chosen to correspond to the -30 percent to +50 percent accuracy of the overall cost estimates, as suggested in the guidance document (EPA, 1986).

The direct and indirect capital costs associated with the treatment system were not altered.

The sensitivity analysis was performed using estimated GAC treatment costs for Cleanup Goal I. It is assumed that cost sensitivity to GAC treatment costs will be approximately similar for Cleanup Goals II and III. For the sensitivity analysis, the costs were varied by making the following changes to the cost estimates of Alternatives 2 through 8 (Cleanup Goal I):

- The influent concentrations used in the granular activated carbon usage rate calculations were increased by 50 percent and decreased by 30 percent

- The estimated costs for granular activated carbon (based on the adjusted usage rates) were recalculated.

- The groundwater monitoring costs were not altered

The following tabulation shows the present worth cost sensitivity relative to changes in the cost of GAC treatment.

| Cost Sensitivity to Changes in GAC Treatment Costs | | | | | |
|---|---|---|---|---|---|
| | Base (Cleanup Goal I) | Influent Concentration Reduced by 30 percent | | Influent Concentration Increased by 50 percent | |
| Alternative | Cost (Million $) | Cost (Million $) | % Diff. | Cost (Million $) | % Diff. |
| 2 | 29.6 | 29.1 | ( - 1.7) | 30.2 | 2.0 |
| 3 | 46.8 | 45.5 | ( - 2.8) | 48.7 | 4.1 |
| 4 | 51.1 | 49.8 | ( - 2.5) | 53.0 | 3.7 |
| 5 | 67.5 | 66.8 | ( - 1.0) | 68.4 | 1.3 |
| 6 | 71.8 | 71.1 | ( - 1.0) | 72.7 | 1.3 |
| 7 | 47.1 | 45.5 | ( - 3.4) | 49.4 | 4.9 |
| 8 | 51.5 | 49.8 | ( - 3.3) | 53.7 | 4.3 |

The data indicate that Alternatives 2 through 8 are not sensitive to changes in influent concentrations.

The present worth costs were calculated using a discount rate (before taxes and after inflation) of 6 percent. The value of the discount rate is uncertain due to dependence on factors such as the long term interest and the inflation rates. The reasonable minimum and maximum disccent and 8 percent (reflecting a ±33 percent change in the discount rate.

The following tabulation shows the present worth cost sensitivity relative to changes in the discount rate.

| Cost Sensitivity to Changes in Discount Rate | | | | | |
|---|---|---|---|---|---|
| | Base (Cleanup Goal I) | Costs Calculated Using 4 percent Discount Rate | | Costs Calculated Using 8 percent Discount Rate | |
| Alternative | Cost (Million $) | Cost (Million $) | % Diff. | Cost (Million $) | % Diff. |
| 2 | 29.6 | 37.5 | 26.7 | 25.2 | ( - 14.9) |
| 3 | 46.8 | 60.5 | 29.3 | 39.3 | ( - 16.0) |
| 4 | 51.1 | 64.8 | 26.8 | 43.6 | ( - 14.7) |
| 5 | 67.5 | 82.1 | 21.6 | 59.5 | ( - 11.9) |
| 6 | 71.8 | 86.4 | 20.3 | 63.8 | ( - 11.1) |
| 7 | 47.1 | 61.2 | 29.9 | 39.4 | ( - 16.3) |
| 8 | 51.5 | 65.5 | 27.2 | 43.7 | ( - 15.1) |

Alternatives 2 through 8 are sensitive to a decrease in the discount rate from 6 percent to4 percent. The relative change in cost ranges from approximately 20 to 30 percent. None of the alternatives display a significant change in the estimated cost when the discount rate is increased from 6 to 8 percent. The relative change in costs range from 11 to 16 percent.

The estimated costs for Alternatives 3, 4, 7 and 8 are sensitive to variations in the size of the area of attainment and the groundwater extraction flowrate. The sensitivity analysis results indicate that of the five cost components analyzed, changes in the influent concentrations (and the associated treatment costs) have the least overall impact on the estimated costs. A change in the discount rate from 6 percent to 4 percent has the greatest impact on the remediation costs. None of the alternatives are sensitive to a change in the discount rate from 6 to 8 percent.

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# 5.0 COST-EFFECTIVENESS ANALYSIS

This cost-effectiveness analysis is not part of the detailed analysis of alternatives, but is an ancillary evaluation that is used to provide a better understanding of the alternatives. This section presents a general qualitative cost-effectiveness analysis of each of the alternatives with respect to their benefit in achieving the remediation goals. Estimated costs for each remedial alternative and Target Groundwater Cleanup Goal is developed in **Appendix L** and is listed in **Table 5-1** for this analysis. The description of Target Groundwater Cleanup Goals is contained in **Table 5-2**.

In addition to the benefits resulting from achieving the cleanup goals, potential disadvantages related to potential aquifer drawdown are also evaluated for each alternative. Groundwater is an important Site resource for agricultural irrigation and as a water supply for domestic and livestock uses. All of the alternatives, except the No Action Alternative, withdraw groundwater from the aquifer and this may potentially have an adverse impact on local groundwater uses by lowering the water table. The groundwater extraction rates which were assumed for cost estimating purposes (Section 4) are listed in **Table 5-3**. The potential disadvantage of aquifer drawdown is included in the cost-effectiveness comparison of alternatives discussed in this section.

Logical cost-effectiveness comparisons of alternatives made to show the cost of an added benefit are listed below and the evaluation is summarized in **Table 5-4**.

| Comparison | Evaluation |
|---|---|
| Alternative 2 - Hydraulic Containment<br>to<br>Alternative 1 - No Action | Cost increment to contain groundwater contaminant plume. |
| Alternative 3 - Focused Extraction<br>to<br>Alternative 2 - Hydraulic Containment | Cost increment to extract and treat groundwater within the contaminant plume. |
| Alternative 4 - Focused Extraction and Soil Excavation<br>to<br>Alternative 3 - Focused Extraction | Cost increment and to extract and treat contaminated soil in addition to groundwater. |

| Comparison | Evaluation |
|---|---|
| Alternative 5 - Focused Extraction with Air Sparging<br>to<br>Alternative 3 - Focused Extraction | Cost increment to treat volatiles- only contaminated groundwater using air sparging. |
| Alternative 6 - Focused Extraction with Air Sparging and Soil Excavation<br>to<br>Alternative 5 - Focused Extraction with Air Sparging | Cost increment to extract and treat contaminated soil in addition to groundwater. |
| Alternative 7 - Groundwater Extraction<br>to<br>Alternative 3 - Focused Extraction | Cost increment to increase volume of groundwater extracted and treated. |
| Alternative 8 - Groundwater Extraction and Soil Excavation<br>to<br>Alternative 4 - Focused Extraction and Soil Excavation | Cost increment to increase volume of groundwater extracted and treated. |

Alternative 1 is the No Action Alternative, with a total present worth cost of $11 million. This cost is incurred through groundwater monitoring over the assumed 80-year project life. No benefit in terms of overall protection of human health and the environment is recognized by Alternative 1.

All of the other alternatives (Alternatives 2, 3, 4, 5, 6, 7 and 8) provide:

- Groundwater monitoring as in Alternative 1
- Potable water supplies for groundwater users within the contaminated areas
- Hydraulic containment of the contaminant plume through extraction wells and treatment of groundwater

Thus all of these alternatives reduce exposure potential to contaminated groundwater by providing potable water supplies and remove potential downgradient exposure by hydraulic containment of the plume. The additional cost associated with this protection is $19 to $24 million, depending on the selected Target Groundwater Cleanup Goal (I, II, or III). This additional cost is for Alternative 2 as compared to Alternative 1, which also includes the potable point-of-entry water supply treatment systems and the hydraulic containment and treatment systems for the groundwater.

Alternative 3 adds groundwater extraction to Alternative 2 at an additional cost of $17 to $22 million, depending on the Target Groundwater Cleanup Goal. This additional cost is for the total present worth cost of installing and operating additional groundwater extraction wells and expanding the pump and piping network and treatment system. The benefit of Alternative 3 over Alternative 2 is that groundwater is remediated at a higher rate in areas of higher RDX or TCE contamination. As shown in **Table 5-1**, Alternatives 1 and 2 have estimated restoration times of perpetuity because contaminated groundwater is not extracted from within the plume. There is no groundwater extraction in Alternative 1 and groundwater is extracted and treated in Alternative 2 only at the leading edge of the groundwater contaminant plumes. Continued leaching from soils, plus the time necessary for migration through the plume, may require the Alternative 2 hydraulic containment system to operate longer than can be estimated (i.e. perpetuity). Although the restoration time period estimates do not provide a specific time estimate, the groundwater restoration time is estimated to be greater than 140 years for Alternative 3. A disadvantage of Alternative 3 compared to Alternative 2 is the potential aquifer drawdown caused by the incremental increase in the groundwater extraction flowrate of 1,010 to 1,200 gpm depending on the Target Groundwater Cleanup Goal.

Alternative 4 is similar to Alternative 3, except that contaminated soils are removed and treated in Alternative 4 for an additional cost of $4 million. Treatment will be accomplished at an on-site treatment facility mobilized for OU1. The additional $4 million total present worth cost for excavation, transportation to the OU1 on-site soil treatment system, operation of the system for the OU2 soils and transportation and placement of the treated soil. No cost is incurred for equipment, permits, construction and start-up of the treatment system because these cost are part of the OU1 remediation. The benefit of Alternative 4 is the reduced potential for leaching of contaminants from soils that cause Target Groundwater Cleanup Goals to be exceeded. Since leaching is reduced, the estimated restoration time can be estimated to be approximately 140 years.

Alternative 5 is similar to Alternative 3 except that air sparging is added at locations where only volatile contaminants need to be removed from groundwater to meet Target Groundwater Cleanup Goals. The air sparging system reduces both the number of groundwater extraction wells and the volume of groundwater treated. This results in reduced total present worth costs for groundwater extraction and treatment, however capital and

O&M costs are incurred for installation and operation of the air sparging system. The net cost increase from Alternative 3 to Alternative 5 is $18 to $21 million in total present worth cost, depending on the Target Groundwater Cleanup Goal. Alternative 5 treats some of the groundwater by air sparging instead of extraction and also includes above ground treatment, but at additional cost. There may be a reduction in restoration time if the volatiles-only portion of the groundwater contaminant plume achieves the Target Groundwater Cleanup Goals sooner via air sparging than by extraction, but because this reduction is not certain, the reduction in restoration time cannot be estimated. Restoration time for Alternative 3 is estimated to be greater than 140 years and restoration time for Alternative 5 is estimated to be greater than 110 years. However, because a statement cannot be made that the restoration time for Alternative 5 is less than 140 years, there is no apparent restoration time benefit for Alternative 5 over Alternative 3. Alternative 5 does have a benefit of a smaller extracted groundwater flowrate compared to Alternative 3, of 530 gpm.

Alternative 6 adds soil excavation and treatment to Alternative 5 for an additional total present worth cost of $4 to $5 million. As was the case for Alternative 4, the cost for soils is the capital and present worth O&M costs of excavation, transportation, treatment using the OU1 soils treatment system and replacement of treated soil. The additional benefit of Alternative 6 is that groundwater restoration time may be reduced by reducing the potential leaching of explosives from soils that cause Target Groundwater Cleanup Goals to be exceeded. Because leaching of contaminants from soils is reduced, restoration time is estimated to be approximately 110 years.

Alternative 7 is similar to Alternative 3, except that the groundwater extraction system is expanded. The cost increase compared to Alternative 3 includes the total and present worth costs for installation and operation of additional groundwater extraction wells, expansion of the pump and piping network and expansion of the groundwater treatment system. Because of the size and location of the groundwater contaminant plumes are unchanged, there is no significant difference in cost estimates between Alternative 3 and Alternative 7 for Target Groundwater Cleanup Goal I, and the additional cost is $5 to $9 million for the Target Groundwater Cleanup Goal II and III, respectively. Therefore, there is no clear benefit for Alternative 7 over Alternative 3. In theory, Alternative 7 should reach Target Groundwater Cleanup Goals in a shorter time period than Alternative 3 because groundwater is extracted and treated at a higher rate than for Alternative 3. However, because leaching of contaminants from soil into the groundwater is still occurring, a quantitative estimate of restoration time cannot be made. Restoration time for Alternative 7 is estimated to be greater than 90 years, but because a statement cannot be made that restoration time is less than an estimated number of years, Alternative 7 offers no additional benefit over Alternatives 3, 4, 5 or 6. Alternative 7 compared to Alternative 3 also has a disadvantage of higher groundwater extraction flowrates and thus a greater potential for aquifer drawdown. Compared to Alternative 3, the increase in aquifer drawdown is 510 to 1,380 gpm for Alternative 7, depending on the Target Groundwater Cleanup Goal.

Alternative 8 is Alternative 7 plus removal and treatment of soils, which is the same as Alternative 4 with expanded groundwater extraction. Compared to Alternative 4, the cost increase for Alternative 8 is for total present worth cost for installation and operation of additional wells and expansion of the pump and piping network and the groundwater treatment system. Because of the size and location of the groundwater contaminant plumes are unchanged, there is no significant cost difference between Alternatives 4 and 8 for Target Groundwater Cleanup Goal I, and the additional cost is $5 to $10 million for the Target Groundwater Cleanup Goals II and III, respectively. Soil excavation and treatment reduces the potential leaching of explosives into the groundwater that cause groundwater to exceed Target Groundwater Cleanup Goals, which in turn allows an estimated restoration time to be calculated for Alternative 8. The added benefit for Alternative 8 is that the estimated restoration time is reduced from 140 years for Alternative 4 to 90 years for Alternative 8. A disadvantage of Alternative 8 compared to Alternative 4 is a higher potential aquifer drawdown because of a higher groundwater extraction flowrate. Compared to Alternative 4, the increase in groundwater extraction rate for Alternative 8 is 510 to 1,380 gpm depending on the Target Groundwater Cleanup Goal.

A quantitative estimate of restoration time can be made only for Alternatives 4, 6, and 8, which employ soil excavation. While there are benefits added by all of the other alternatives, it is difficult to quantify cost-effectiveness for alternatives other than Alternatives 4, 6, and 8. Alternative 4 may possibly be more cost-effective than Alternative 3 because restoration time can be estimated for Alternative 4. For Alternatives 4, 6, and 8, comparative summary for these three alternatives with respect to the estimated restoration time, total present worth cost, and groundwater extraction flowrate and resultant aquifer drawdown is listed below:

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# 6.0 ADDITIONAL DATA NEEDS FOR REMEDIAL DESIGN/REMEDIAL ACTION

Additional data will be required prior to implementing any remedial action. Currently, two pumping tests are being conducted to evaluate aquifer response to pumping at the Site. Refer to Section 1.3.4 for a discussion of the pumping tests. Aquifer response data are necessary to design Alternatives 2 through 8. Groundwater modeling may be required prior to design to assess the relationship between groundwater extraction associated with Alternatives 2 through 8 and agricultural irrigation.

Bench scale treatability studies are currently being conducted to evaluate the potential feasibility of GAC or AOP to treat the Site groundwater. As discussed in Section 1.3.5, GAC or AOP pilot-scale studies may also be necessary if one of those two process options are selected as the means of groundwater treatment.

In the event that either Alternative 5 or 6 is selected, a field demonstration of air sparging would be required to evaluate system parameters. These parameters may include, but are not limited to: injection well parameters, vapor extraction well placement, and required system vacuum.

The additional data can be gathered concurrently with preliminary design activities in a Remedial Design Investigation program. The data collection program should be scoped by the design team to maximize the benefit obtained from the additional information. Other preliminary design activities required prior to preparation of remedial design plans and specifications include: completion of Design Requirement Checklists, preparation of a Project Management Plan, and development of the Basis of Design document.

Design Requirement Checklists ensure preparation of a design that meets all the requirements of the project and consist of a series of questions to be answered prior to proceeding with the design. The checklists are to assess the project needs relative to the system to be designed. For example, any applicable standard specifications are listed. The need for access roads or other site modifications are discussed and factored into the design for the remedial action. Preferred safety factors are discussed with the format for presenting design calculations.

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## 7.0
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TABLES

## TABLE 1-1

## ANALYTICAL PARAMETERS

### Target Compound List (TCL) VOCs

Chloromethane
Bromomethane
Vinyl Chloride
Chloroethane
Methylene Chloride
Acetone
Carbon Disulfide
1,1-Dichloroethene
1,1-Dichloroethane
cis-1,2-Dichloroethene[2]
trans-1,2-Dichloroethene[2]
1,2-Dichloroethene (total)[1]
Chloroform
1,2-Dichloroethane
2-Butanone
Bromochloromethane
1,1,1-Trichloroethane
Carbon Tetrachloride
Bromodichloromethane[2]
1,2-Dichloropropane
cis-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
trans-1,3-Dichloropropene
Bromoform
1,2-Dibromoethane[2]
4-Methyl-2-Pentanone
2-Hexanone
Tetrachloroethene
Toluene
1,1,2,2-Tetrachloroethane
Chlorobenzene
Ethylbenzene
Styrene
Xylenes (Total)
1,2-Dibromo-3-chloropropane[2]
1,3-Dichlorobenzene[2]
1,4-Dichlorobenzene[2]
1,2-Dichlorobenzene[2]

Notes:

1 Not on compound list for CLP-SOW (6-91) method for low level analysis.
2 Not on compound list for CLP-SOW (3-90)-REVS for high level analysis.

**TABLE 1-1**

**ANALYTICAL PARAMETERS**
**(Continued)**

**Target Compound List (TCL) SVOCs**

Phenol
Bis(2-chloroethyl)ether
2-chlorophenol
1,3-dichlorobenzene
1,4-dichlorobenzene
1,2-dichlorobenzene
2-methylphenol
2,2'-oxybis(1-chloropropane)
4-methylphenol
N-nitrosodi-*n*-propylamine
Hexachloroethane
Nitrobenzene
Isophorone
2-nitrophenol
2,4-dimethylphenol
bis(2-chloroethoxy)methane
2,4-dichlorophenol
1,2,4-trichlorobenzene
Naphthalene
4-chloroaniline
Hexachlorobutadiene
4-chloro-3-methylphenol
2-methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-trichlorophenol
2,4,5-trichlorophenol
2-chloronaphthalene
2-nitroaniline
Dimethylphthalate
Acenaphthylene
2,6-dinitrotoluene
3-nitroaniline
Acenaphthene
2,4-dinitrophenol
4-nitrophenol
Dibenzofuran
2,4-dinitrotoluene
Diethylphthalate
4-chlorophenyl-phenylether
Fluorene
4-nitroaniline
4,6-dinitro-2-methylphenol
N-nitrosodiphenylamine
4-bromophenyl-phenylether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene
Anthracene
Carbazole
Di-*n*-butylphthalate

**TABLE 1-1**

**ANALYTICAL PARAMETERS**
**(Continued)**

**Target Compound List (TCL) SVOCs**
**(Continued)**

| | |
|---|---|
| Fluoranthene | Di-*n*-octylphthalate |
| Pyrene | Benzo(b)fluoranthene |
| Benzylbutylphthalate | Benzo(k)fluoranthene |
| 3,3-dichlorobenzidine | Benzo(a)pyrene |
| Benzo(a)anthracene | Indeno(1,2,3-cd)pyrene |
| Chrysene | Dibenzo(a,h)anthracene |
| bis(2-ethylhexyl)phthalate | Benzo(ghi)perylene |

**Target Compound List (TCL) Pesticides/PCB**

| | |
|---|---|
| α-BHC | Methoxychlor |
| ß-BHC | Endrin ketone |
| δ-BHC | Endrin aldehyde |
| γ-BHC (Lindane) | α-Chlordane |
| Heptachlor | γ-Chlordane |
| Aldrin | Toxaphene |
| Heptachlor epoxide | Aroclor 1016 |
| Endosulfan I | Aroclor 1221 |
| Dieldrin | Aroclor 1232 |
| 4,4'-DDE | Aroclor 1242 |
| Endrin | Aroclor 1248 |
| Endosulfan II | Aroclor 1254 |
| 4,4'-DDD | Aroclor 1260 |
| Endosulfan sulfate | |
| 4,4'-DDT | |

**TABLE 1-1**

**ANALYTICAL PARAMETERS**
**(Continued)**

**Inorganic Target Analyte List (TAL)**

| | |
|---|---|
| Aluminum | Magnesium |
| Antimony | Manganese |
| Arsenic | Mercury |
| Barium | Nickel |
| Beryllium | Potassium |
| Cadmium | Selenium |
| Calcium | Silver |
| Chromium | Sodium |
| Cobalt | Thallium |
| Copper | Vanadium |
| Iron | Zinc |
| Lead | Cyanide |

**Explosive Compounds**

| | |
|---|---|
| Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) | 2,4,6-trinitrotoluene (TNT) |
| Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) | 2,4-dinitrotoluene (2,4-DNT) |
| 1,3,5-trinitrobenzene (TNB) | 2,6-dinitrotoluene (2,6-DNT) |
| 1,3-dinitrobenzene (DNB) | *o*-nitrotoluene |
| Methyl-2,4,6-trinitro-phenylnitramine (tetryl) | *m*-nitrotoluene |
| Nitrobenzene (NB) | *p*-nitrotoluene |

**TABLE 1-1**

**ANALYTICAL PARAMETERS**
**(Continued)**

**General Water Quality Parameters (WQ1)**

Total Suspended Solids (TSS)
Total Dissolved Solids (TDS)
Alkalinity
Hardness
$BOD_5$
$NO_3/NO_2$ (as Nitrogen)

General Water Quality Parameters (WQ2)

Total Organic Halides (TOX)
Total Chlorides
Total Organic Carbon (TOC)
Total Kjeldahl Nitrogen (TKN)
Total microbial count
Oxidation Reduction Potential (ORP)
Dissolved Oxygen (DO)
Total Sulfates

**Soil Gas/Water Headspace Analytes**

BTEX:
- Benzene
- Toluene
- Ethylbenzene
- Xylenes (total)

1,2-dichloroethane (total)
Total Hydrocarbons (THCs):
- Diesel
- Chlorinated Hydrocarbons (ClHs):
- Tetrachloroethene
- Trichloroethene
- 1,1,1-trichloroethane
- 1,1,2-trichloroethane
- 1,1-dichloroethane
- 1,2-dichloroethane

**Radioactivity**

Gross alpha
Gross beta

# TABLE 1-2
# SUMMARY OF SOIL GAS DATA (RESULTS IN µg/L)

| Analyte | Area | Number of Samples | Number of Detections | Minimum | Maximum | Average Concentration | Median | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane (1,1,1-TCA) | Admininistration | 66 | 1 | 0.5 | 0.5 | 0.5 | 0.5 | - |
| | Load Lines | 130 | 2 | 0.1 | 0.7 | 0.4 | 0.4 | 0.3 |
| 1,1-Dichloroethane (1,1-DCA) | Admininistration | 66 | 1 | 0.2 | 0.2 | 0.2 | 0.2 | - |
| | Load Lines | 130 | 0 | - | - | - | - | - |
| Tetrachloroethene (PCE) | Administration | 66 | 6 | 0.01 | 0.27 | 0.1 | 0.075 | 0.1 |
| | Load Lines | 130 | 3 | 0.01 | 0.2 | 0.1 | 0.06 | 0.1 |
| Toluene | Administration | 66 | 1 | 0.2 | 0.2 | 0.2 | 0.2 | - |
| | Load Lines | 130 | 5 | 0.2 | 3.5 | 0.9 | 0.2 | 1.3 |
| Trichloroethene (TCE) | Administration | 66 | 12 | 0.02 | 74.5 | 6.6 | 0.105 | 20 |
| | Load Lines | 219 | 147 | 0.01 | 707 | 51 | 1.21 | 110 |
| cis-1,2-Dichloroethene (c-1,2-DCE) | Administration | 66 | 2 | 0.1 | 0.4 | 0.3 | 0.25 | 0.2 |
| | Load Lines | 130 | 7 | 0.1 | 1.7 | 0.5 | 0.3 | 0.5 |

Notes:
1. *For complete data, refer to OU2 Remedial Investigation Report (WCC, 1993c)*
2. Results are indicated in µg/L.
3. Data qualifiers and quantitation limits are not included. Refer to the OU2 Remedial Investigation Report (WCC, 1993c)
4. Standard deviation is not calculated for one detection.

# TABLE 1-3
# SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **DISSOLVED METALS (ug/l)** | | | | | | |
| Aluminum | Aug/92 | 15 | 13 | 45.5 | 148 | 108 |
| | Nov/92 | 15 | 15 | 108 | 155 | 131 |
| | Feb/93 | 15 | 12 | 89.5 | 187 | 120 |
| | May/93 | 15 | 15 | 50.9 | 112 | 81.51 |
| Arsenic | Aug/92 | 15 | 12 | 4 | 20.6 | 9.07 |
| | Nov/92 | 15 | 7 | 5.1 | 22.7 | 11.0 |
| | Feb/93 | 15 | 8 | 3.2 | 20.6 | 11.3 |
| | May/93 | 15 | 14 | 3.2 | 40.1 | 11.33 |
| Barium | Aug/92 | 15 | 15 | 122 | 483 | 210 |
| | Nov/92 | 15 | 15 | 136 | 699 | 225 |
| | Feb/93 | 15 | 15 | 129 | 688 | 230 |
| | May/93 | 15 | 15 | 121 | 618 | 230.87 |
| Calcium | Aug/92 | 15 | 15 | 28300 | 111000 | 63400 |
| | Nov/92 | 15 | 15 | 35300 | 126000 | 65000 |
| | Feb/93 | 15 | 15 | 44800 | 129000 | 68200 |
| | May/93 | 15 | 15 | 42800 | 115000 | 66453.33 |
| Iron | Aug/92 | 15 | 4 | 1020 | 1770 | 1390 |
| | Nov/92 | 15 | 4 | 1210 | 1650 | 1430 |
| | Feb/93 | 15 | 7 | 22 | 1570 | 800 |
| | May/93 | 15 | 4 | 728 | 1500 | 1239.5 |
| Lead | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 1 | 2.4 | 2.4 | 2.4 |
| Magnesium | Aug/92 | 15 | 15 | 8520 | 33900 | 15100 |
| | Nov/92 | 15 | 15 | 10400 | 40800 | 15500 |
| | Feb/93 | 15 | 15 | 11100 | 40700 | 16200 |
| | May/93 | 15 | 15 | 10900 | 36400 | 15960 |
| Manganese | Aug/92 | 15 | 15 | 2.9 | 1010 | 182 |
| | Nov/92 | 15 | 13 | 2.3 | 456 | 135 |
| | Feb/93 | 15 | 12 | 1.2 | 1040 | 240 |
| | May/93 | 15 | 12 | 1.2 | 465 | 181.83 |

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# TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **DISSOLVED METALS [illegible]** | | | | | | |
| Potassium | Aug/92 | 15 | 15 | 5720 | 11200 | 8860 |
| | Nov/92 | 15 | 15 | 6760 | 11900 | 9390 |
| | Feb/93 | 15 | 15 | 5580 | 12500 | 9220 |
| | May/93 | 15 | 15 | 5070 | 13300 | 9062 67 |
| Selenium | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 1 | 47 4 | 47 4 | 47 4 |
| | May/93 | 15 | 0 | - | - | - |
| Sodium | Aug/92 | 15 | 15 | 11600 | 48200 | 21400 |
| | Nov/92 | 15 | 15 | 11500 | 48000 | 21800 |
| | Feb/93 | 15 | 15 | 12500 | 41100 | 22200 |
| | May/93 | 15 | 15 | 13000 | 42600 | 21286.67 |
| Vanadium | Aug/92 | 15 | 1 | 11 7 | 11 7 | 11 7 |
| | Nov/92 | 15 | 2 | 5 8 | 13 2 | 9 5 |
| | Feb/93 | 15 | 3 | 4 1 | 12 | 7 7 |
| | May/93 | 15 | 2 | 6 7 | 13 1 | 9 9 |
| Zinc | Aug/92 | 15 | 15 | 4 5 | 50 4 | 9 87 |
| | Nov/92 | 15 | 8 | 4 8 | 11 8 | 7 01 |
| | Feb/93 | 15 | 4 | 5 8 | 10 3 | 8 03 |
| | May/93 | 15 | 12 | 4 4 | 20 9 | 9 64 |
| **TOTAL METALS / CYANIDE [illegible]** | | | | | | |
| Aluminum | Aug/92 | 15 | 15 | 120 | 1820 | 326 |
| | Nov/92 | 15 | 8 | 51 4 | 19700 | 2590 |
| | Feb/93 | 15 | 15 | 99 | 16000 | 1220 |
| | May/93 | 15 | 15 | 51 7 | 687 | 126 29 |
| Arsenic | Aug/92 | 15 | 7 | 5 | 19 8 | 12 5 |
| | Nov/92 | 15 | 7 | 7 | 24 | 15 3 |
| | Feb/93 | 15 | 12 | 3 2 | 24 8 | 11 8 |
| | May/93 | 15 | 11 | 3 4 | 22 6 | 11 48 |

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## TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| TOTAL METALS / [illegible] - OU2 | | | | | | |
| Barium | Aug/92 | 15 | 15 | 116 | 450 | 199 |
| | Nov/92 | 15 | 15 | 126 | 632 | 224 |
| | Feb/93 | 15 | 15 | 121 | 691 | 229 |
| | May/93 | 15 | 15 | 110 | 597 | 221.67 |
| Beryllium | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 1 | 1 | 1 | 1 |
| | May/93 | 15 | 0 | - | - | - |
| Calcium | Aug/92 | 15 | 15 | 27100 | 99600 | 59800 |
| | Nov/92 | 15 | 15 | 35100 | 125000 | 65400 |
| | Feb/93 | 15 | 15 | 43000 | 127000 | 64900 |
| | May/93 | 15 | 15 | 41300 | 108000 | 62646.67 |
| Chromium | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 1 | 16.4 | 16.4 | 16.4 |
| | Feb/93 | 15 | 4 | 6.8 | 25.2 | 11.5 |
| | May/93 | 15 | 0 | - | - | - |
| Cobalt | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 1 | 12.8 | 12.8 | 12.8 |
| | Feb/93 | 15 | 1 | 12.7 | 12.7 | 12.7 |
| | May/93 | 15 | 0 | - | - | - |
| Copper | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 1 | 24 | 24 | 24 |
| | Feb/93 | 15 | 2 | 4.6 | 16.5 | 10.6 |
| | May/93 | 15 | 2 | 4.6 | 13.2 | 8.9 |
| Iron | Aug/92 | 15 | 11 | 58 | 1840 | 675 |
| | Nov/92 | 15 | 14 | 41.1 | 16100 | 1670 |
| | Feb/93 | 15 | 15 | 16.5 | 13400 | 1350 |
| | May/93 | 15 | 5 | 473 | 1540 | 1104.4 |
| Lead | Aug/92 | 15 | 1 | 2.6 | 2.6 | 2.6 |
| | Nov/92 | 15 | 4 | 3.7 | 33.2 | 13.5 |
| | Feb/93 | 15 | 1 | 10.9 | 10.9 | 10.9 |
| | May/93 | 15 | 0 | - | - | - |

# TABLE 1-3
# SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) Minimum | Maximum | Average |
|---|---|---|---|---|---|---|
| TOTAL METALS / CYANIDE (ug/l) | | | | | | |
| Magnesium | Aug/92 | 15 | 15 | 8050 | 31200 | 14300 |
| | Nov/92 | 15 | 15 | 10300 | 39700 | 15900 |
| | Feb/93 | 15 | 15 | 10700 | 40100 | 15600 |
| | May/93 | 15 | 15 | 10300 | 34700 | 15153 33 |
| Manganese | Aug/92 | 15 | 15 | 7 | 1090 | 184 |
| | Nov/92 | 15 | 15 | 2 5 | 1190 | 196 |
| | Feb/93 | 15 | 14 | 1 1 | 1270 | 214 |
| | May/93 | 15 | 12 | 1 4 | 651 | 189 98 |
| Mercury | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 1 | 0 33 | 0 33 | 0 33 |
| | May/93 | 15 | 0 | - | - | - |
| Nickel | Aug/92 | 15 | 1 | 11 1 | 11 1 | 11 1 |
| | Nov/92 | 15 | 1 | 24 9 | 24 9 | 24 9 |
| | Feb/93 | 15 | 2 | 15 6 | 30 1 | 22 9 |
| | May/93 | 15 | 0 | - | - | - |
| Potassium | Aug/92 | 15 | 15 | 5280 | 10900 | 8340 |
| | Nov/92 | 15 | 15 | 5770 | 11900 | 8910 |
| | Feb/93 | 15 | 15 | 6120 | 11800 | 8970 |
| | May/93 | 15 | 15 | 4740 | 12800 | 8814.67 |
| | Aug/92 | 15 | 0 | - | - | - |
| Selenium | Nov/92 | 15 | 1 | 23.8 | 23 8 | 23 8 |
| | Feb/93 | 15 | 1 | 53 | 53 | 53 |
| | May/93 | 15 | 0 | - | - | - |
| Sodium | Aug/92 | 15 | 15 | 10800 | 46700 | 20500 |
| | Nov/92 | 15 | 15 | 10800 | 45700 | 21100 |
| | Feb/93 | 15 | 15 | 11800 | 40100 | 21500 |
| | May/93 | 15 | 15 | 12000 | 41000 | 20286 67 |
| Thallium | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 1 | 2 4 | 2 4 | 2 4 |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 0 | - | - | - |

# TABLE 1-3
# SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **TOTAL METALS / CYANIDE (ug/l)** | | | | | | |
| Vanadium | Aug/92 | 15 | 2 | 5 5 | 11 3 | 8 4 |
| | Nov/92 | 15 | 2 | 10 8 | 53 7 | 32 2 |
| | Feb/93 | 15 | 3 | 4 1 | 43 9 | 20 0 |
| | May/93 | 15 | 2 | 7 1 | 13 2 | 10 15 |
| Zinc | Aug/92 | 15 | 14 | 4 1 | 47 1 | 10 8 |
| | Nov/92 | 15 | 15 | 4 8 | 92 3 | 13 4 |
| | Feb/93 | 15 | 7 | 5 2 | 62 5 | 13 9 |
| | May/93 | 15 | 13 | 4 3 | 22 6 | 11 56 |
| **EXPLOSIVES (ug/l)** | | | | | | |
| 1,3,5-Trinitrobenzene (TNB) | Aug/92 | 128 | 5 | 0 32 | 2 2 | 1 10 |
| | Nov/92 | 128 | 4 | 0 45 | 4 | 2 16 |
| | Feb/93 | 128 | 5 | 0 1 | 2 3 | 0 97 |
| | May/93 | 128 | 4 | 0 43 | 2 8 | 1 56 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 2,4,6-Trinitrotoluene (TNT) | Aug/92 | 128 | 3 | 6 5 | 20 | 11 3 |
| | Nov/92 | 128 | 6 | 0 1 | 31 | 7 18 |
| | Feb/93 | 128 | 7 | 0.12 | 39 | 8 12 |
| | May/93 | 128 | 4 | 0.53 | 35 | 12 01 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 2,4-Dinitrotoluene (24DNT) | Aug/92 | 128 | 1 | 0 97 | 0 97 | 0 97 |
| | Nov/92 | 128 | 2 | 0.15 | 1 3 | 0 72 |
| | Feb/93 | 128 | 3 | 0 23 | 1 6 | 0 73 |
| | May/93 | 128 | 3 | 0.24 | 1 9 | 0 81 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 4-Nitrotoluene (4NT) | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 2 | 0.38 | 0 4 | 0 39 |
| | Feb/93 | 128 | 1 | 0 92 | 0 92 | 0 92 |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |

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## TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **EXPLOSIVES (ug/l)** | | | | | | |
| HMX | Aug/92 | 128 | 12 | 0.26 | 45 | 5.05 |
| | Nov/92 | 128 | 14 | 0.082 | 54 | 4.75 |
| | Feb/93 | 128 | 19 | 0.1 | 47 | 3.35 |
| | May/93 | 128 | 17 | 0.11 | 57 | 4.11 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| RDX | Aug/92 | 128 | 44 | 0.16 | 98 | 5.23 |
| | Nov/92 | 128 | 46 | 0.08 | 320 | 11.1 |
| | Feb/93 | 128 | 44 | 0.14 | 320 | 12.7 |
| | May/93 | 128 | 46 | 0.13 | 534 | 16.12 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| Tetryl | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 1 | 5.1 | 5.1 | 5.1 |
| | Feb/93 | 128 | 1 | 0.89 | 0.89 | 0.89 |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| **GROSS Alpha/Beta (pCi/l)** | | | | | | |
| Gross Alpha | Aug/92 | 10 | 2 | 1.38 | 5.12 | 3.25 |
| | Nov/92 | 10 | 8 | 1.99 | 8.27 | 3.46 |
| | Feb/93 | 10 | 6 | 1.9 | 5.5 | 3.24 |
| | May/93 | 10 | 0 | - | - | - |
| Gross Beta | Aug/92 | 10 | 10 | 2.36 | 10.21 | 6.37 |
| | Nov/92 | 10 | 10 | 4.65 | 17.32 | 9.11 |
| | Feb/93 | 10 | 10 | 2.1 | 14.2 | 8.05 |
| | May/93 | 10 | 10 | 7.66 | 32.59 | 14.26 |
| **SEMIVOLATILES (ug/l)** | | | | | | |
| bis(2-Ethylhexyl)phthalate | Aug/92 | 15 | 15 | 2 | 20 | 6.4 |
| | Nov/92 | 15 | 12 | 1 | 12 | 3.91 |
| | Feb/93 | 15 | 11 | 1 | 8 | 2.91 |
| | May/93 | 15 | 12 | 1 | 11 | 2.83 |

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# TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) Minimum | Maximum | Average |
|---|---|---|---|---|---|---|
| **SEMIVOLATILES (ug/l)** | | | | | | |
| Butyl benzyl phthalate | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 1 | 1 | 1 | 1 |
| | May/93 | 15 | 0 | - | - | - |
| Di-n-butyl phthalate | Aug/92 | 15 | 4 | 1 | 1 | 1 |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 1 | 1 | 1 | 1 |
| Diethyl phthalate | Aug/92 | 15 | 7 | 1 | 2 | 1.43 |
| | Nov/92 | 15 | 2 | 1 | 1 | 1 |
| | Feb/93 | 15 | 4 | 1 | 2 | 1.25 |
| | May/93 | 15 | 2 | 2 | 3 | 2.5 |
| N-Nitrosodiphenylamine(1) | Aug/92 | 15 | 1 | 1 | 1 | 1 |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 0 | - | - | - |
| Phenol | Aug/92 | 15 | 8 | 1 | 4 | 2.25 |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 2 | 5 | 9 | 7 |
| **PESTICIDES/PCB (ug/l)** | | | | | | |
| 4,4'-DDT | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 2 | 0.014 | 0.018 | 0.02 |
| | Feb/93 | 15 | 1 | 0.0038 | 0.0038 | 0.0038 |
| | May/93 | 15 | 3 | 0.0043 | 0.0057 | 0.005 |
| Aldrin | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 1 | 0.0017 | 0.0017 | 0.0017 |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 0 | - | - | - |

## TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **PESTICIDES/PCB (ug/l)** | | | | | | |
| Alpha chlordane | Aug/92 | 15 | 3 | 0.0028 | 0.014 | 0.01 |
| | Nov/92 | 15 | 1 | 0.0064 | 0.0064 | 0.01 |
| | Feb/93 | 15 | 1 | 0.0025 | 0.0025 | 0.0025 |
| | May/93 | 15 | 4 | 0.0025 | 0.015 | 0.0065 |
| Alpha-BHC | Aug/92 | 15 | 1 | 0.0024 | 0.0024 | 0.0024 |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 1 | 0.0018 | 0.0018 | 0.0018 |
| | May/93 | 15 | 0 | - | - | - |
| Delta-BHC | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 3 | 0.0023 | 0.004 | 0.0032 |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 1 | 0.0017 | 0.0017 | 0.0017 |
| Dieldrin | Aug/92 | 15 | 1 | 0.0033 | 0.0033 | 0.0033 |
| | Nov/92 | 15 | 3 | 0.002 | 0.034 | 0.01 |
| | Feb/93 | 15 | 1 | 0.017 | 0.017 | 0.017 |
| | May/93 | 15 | 1 | 0.0062 | 0.0062 | 0.0062 |
| Endrin | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 1 | 0.0038 | 0.0038 | 0.0038 |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 0 | - | - | - |
| Gamma chlordane | Aug/92 | 15 | 2 | 0.0071 | 0.0075 | 0.01 |
| | Nov/92 | 15 | 3 | 0.002 | 0.0067 | 0.0039 |
| | Feb/93 | 15 | 3 | 0.0038 | 0.0079 | 0.0057 |
| | May/93 | 15 | 3 | 0.0027 | 0.015 | 0.0071 |
| Heptachlor | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 3 | 0.0017 | 0.0039 | 0.0018 |
| | Feb/93 | 15 | 8 | 0.0012 | 0.0075 | 0.0048 |
| | May/93 | 15 | 1 | 0.0013 | 0.0013 | 0.0013 |

# TABLE 1-3
# SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **PESTICIDES/PCB (ug/l)** | | | | | | |
| Heptachlor epoxide | Aug/92 | 15 | 0 | - | - | - |
| | Nov/92 | 15 | 0 | - | - | - |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 1 | 0.0018 | 0.0018 | 0.0018 |
| p,p'-Methoxychlor | Aug/92 | 15 | 1 | 0.0098 | 0.0098 | 0.01 |
| | Nov/92 | 15 | 2 | 0.11 | 0.12 | 0.11 |
| | Feb/93 | 15 | 0 | - | - | - |
| | May/93 | 15 | 0 | - | - | - |
| **VOLATILES (ug/l)** | | | | | | |
| 1,1,1-Trichloroethane | Aug/92 | 128 | 2 | 1 | 2 | 1.5 |
| | Nov/92 | 128 | 3 | 0.6 | 2 | 1.53 |
| | Feb/93 | 128 | 1 | 2 | 2 | 2 |
| | May/93 | 128 | 2 | 2 | 2 | 2 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 1,1-Dichloroethane | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 0 | - | - | - |
| | Feb/93 | 128 | 0 | - | - | - |
| | May/93 | 128 | 1 | 4 | 4 | 4 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 1,2-Dichloroethane | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 0 | - | - | - |
| | Feb/93 | 128 | 1 | 0.5 | 0.5 | 0.5 |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 1,2-Dichloroethene(Total) | Aug/92 | 20 | 9 | 1 | 10 | 2.44 |
| | Nov/92 | 16 | 9 | 1 | 6 | 2.11 |
| | Feb/93 | 21 | 7 | 1 | 7 | 2.43 |
| | May/93 | 20 | 7 | 1 | 8 | 2.71 |
| | AFI Jul/93 | 0 | | - | - | - |

# TABLE 1-3
# SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **VOLATILES (ug/l)** | | | | | | |
| 1,2-Dichloropropane | Aug/92 | 128 | 1 | 25 | 25 | 25 |
| | Nov/92 | 128 | 1 | 19 | 19 | 19 |
| | Feb/93 | 128 | 2 | 0.7 | 22 | 11.4 |
| | May/93 | 128 | 1 | 9 | 9 | 9 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 1,4-Dichlorobenzene | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 112 | 1 | 1 | 1 | 1 |
| | Feb/93 | 128 | 0 | - | - | - |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| 2-Butanone | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 0 | - | - | - |
| | Feb/93 | 128 | 0 | - | - | - |
| | May/93 | 128 | 28 | 1 | 39 | 16.61 |
| | AFI Jul/93 | 8 | 2 | 4 | 16 | 10 |
| Acetone | Aug/92 | 128 | 10 | 2 | 16 | 6 |
| | Nov/92 | 128 | 21 | 6 | 28 | 12.8 |
| | Feb/93 | 128 | 3 | 2 | 12 | 7 |
| | May/93 | 128 | 16 | 1 | 24 | 7.06 |
| | AFI Jul/93 | 8 | 1 | 5 | 5 | 5 |
| Carbon disulfide | Aug/92 | 128 | 32 | 0.6 | 25 | 4.74 |
| | Nov/92 | 128 | 24 | 0.5 | 4 | 1.27 |
| | Feb/93 | 128 | 0 | - | - | - |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| Carbon tetrachloride | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 0 | - | - | - |
| | Feb/93 | 128 | 1 | 1 | 1 | 1 |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |

## TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| VOLATILES (ug/l) | | | | | | |
| Chloroform | Aug/92 | 128 | 5 | 3 | 26 | 10 6 |
| | Nov/92 | 128 | 6 | 0.5 | 14 | 6 58 |
| | Feb/93 | 128 | 5 | 1 | 20 | 8 2 |
| | May/93 | 128 | 5 | 1 | 18 | 9 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| Cis-1,2-Dichloroethene | Aug/92 | 108 | 3 | 2 | 2 | 2 |
| | Nov/92 | 112 | 4 | 0.5 | 2 | 1 62 |
| | Feb/93 | 107 | 4 | 0 6 | 5 | 2 9 |
| | May/93 | 108 | 4 | 0 8 | 23 | 8 95 |
| | AFI Jul/93 | 8 | 0 | | | |
| Ethylbenzene | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 0 | - | - | - |
| | Feb/93 | 128 | 1 | 1 | 1 | 1 |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| Methylene chloride | Aug/92 | 128 | 117 | 0 5 | 43 | 2 37 |
| | Nov/92 | 128 | 96 | 0 5 | 35 | 3 16 |
| | Feb/93 | 128 | 95 | 0 5 | 35 | 2 24 |
| | May/93 | 128 | 117 | 0 5 | 610 | 7 11 |
| | AFI Jul/93 | 8 | 8 | 2 | 5 | 2 5 |
| Tetrachloroethene | Aug/92 | 128 | 1 | 3 | 3 | 3 |
| | Nov/92 | 128 | 0 | - | - | - |
| | Feb/93 | 128 | 0 | - | - | - |
| | May/93 | 128 | 0 | - | - | - |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| Toluene | Aug/92 | 128 | 39 | 0 5 | 30 | 1 50 |
| | Nov/92 | 128 | 3 | 0 5 | 0 9 | 0 73 |
| | Feb/93 | 128 | 1 | 0 6 | 0 6 | 0 6 |
| | May/93 | 128 | 29 | 0 5 | 5 | 1 02 |
| | AFI Jul/93 | 8 | 2 | 1 | 2 | 1 5 |

# TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **VOLATILES [illegible]** | | | | | | |
| Trichloroethene (TCE) | Aug/92 | 128 | 28 | 0 9 | 1800 | 128 |
| | Nov/92 | 128 | 32 | 0 7 | 3100 | 148 |
| | Feb/93 | 128 | 29 | 0 7 | 4800 | 227 |
| | May/93 | 128 | 29 | 1 | 3900 | 190 34 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| Xylenes (Total) | Aug/92 | 128 | 0 | - | - | - |
| | Nov/92 | 128 | 0 | - | - | - |
| | Feb/93 | 128 | 1 | 4 | 4 | 4 |
| | May/93 | 128 | 1 | 1 | 1 | 1 |
| | AFI Jul/93 | 8 | 0 | - | - | - |
| **WATER QUALITY [illegible]** | | | | | | |
| Alkalinity as Calcium Carbonate | Aug/92 | 128 | 128 | 56 | 300 | 199 |
| | Nov/92 | 128 | 128 | 70 | 310 | 196 |
| | Feb/93 | 128 | 126 | 75 | 310 | 195 |
| | May/93 | 128 | 128 | 79 | 530 | 200 34 |
| | AFI Jul/93 | 8 | 8 | 110 | 250 | 183 75 |
| Biochemical Oxygen Demand (BOD) | Aug/92 | 128 | 7 | 4 | 10 | 5 3 |
| | Nov/92 | 128 | 17 | 3 2 | 17 | 6 01 |
| | Feb/93 | 128 | 3 | 4 1 | 15 | 9 1 |
| | May/93 | 128 | 19 | 3 | 15 | 5 09 |
| | AFI Jul/93 | 8 | 3 | 3 | 3 1 | 3 0713 |
| Hardness as Calcium Carbonate | Aug/92 | 128 | 128 | 110 | 680 | 248 |
| | Nov/92 | 128 | 128 | 112 | 640 | 238 |
| | Feb/93 | 128 | 128 | 130 | 730 | 252 |
| | May/93 | 128 | 128 | 94 | 560 | 226 59 |
| | AFI Jul/93 | 8 | 8 | 97 | 450 | 202 3 |
| Nitrate-Nitrite-N | Aug/92 | 128 | 90 | 0 63 | 660 | 71 8 |
| | Nov/92 | 128 | 79 | 0 3 | 500 | 22 5 |
| | Feb/93 | 128 | 82 | 0 34 | 80 | 10 9 |
| | May/93 | 128 | 82 | 0 2 | 60 | 8 57 |
| | AFI Jul/93 | 8 | 2 | 9.5 | 15 | 12 25 |

## TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) Minimum | Maximum | Average |
|---|---|---|---|---|---|---|
| **WATER QUALITY (mg/l)** | | | | | | |
| Total Chlorides | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 18 | 14 | 3 1 | 24 | 10 9 |
| | May/93 | 18 | 18 | 3 | 270 | 25 44 |
| | AFI Jul/93 | 0 | | - | - | - |
| Total Dissolved Solids (TDS) | Aug/92 | 128 | 128 | 180 | 1900 | 425 |
| | Nov/92 | 128 | 128 | 190 | 1800 | 387 |
| | Feb/93 | 128 | 128 | 190 | 1800 | 397 |
| | May/93 | 128 | 128 | 160 | 10000 | 548 13 |
| | AFI Jul/93 | 8 | 8 | 310 | 1100 | 486 25 |
| Total Kjeldahl Nitrogen (TKN) | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 18 | 7 | 0.22 | 1 1 | 0 45 |
| | May/93 | 18 | 5 | 0 1 | 0 87 | 0 38 |
| | AFI Jul/93 | 0 | | - | - | - |
| Total Microbial Count (cells/ml) | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 18 | 3 | 9100 | 31000 | 22500 |
| | May/93 | 18 | 7 | 5300 | 63000 | 22800 |
| | AFI Jul/93 | 0 | | - | - | - |
| Total Organic Carbon (TOC) | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 18 | 16 | 1 1 | 4 2 | 2 |
| | May/93 | 18 | 9 | 1 2 | 7 1 | 2 98 |
| | AFI Jul/93 | 0 | | - | - | - |
| Total Organic Halides (TOX) (ug/L) | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 18 | 12 | 3 3 | 2600 | 242 |
| | May/93 | 18 | 18 | 4 5 | 3100 | 212 64 |
| | AFI Jul/93 | 0 | | - | - | - |

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## TABLE 1-3
## SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **WATER QUALITY (mg/l)** | | | | | | |
| Total Sulfates | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 18 | 18 | 13 | 760 | 88 9 |
| | May/93 | 18 | 17 | 24 | 730 | 87 |
| | AFI Jul/93 | 0 | | - | - | - |
| Total Suspended Solids (TSS) | Aug/92 | 128 | 85 | 5 | 2600 | 117 |
| | Nov/92 | 128 | 62 | 0 | 331 | 25 0 |
| | Feb/93 | 128 | 46 | 5 | 460 | 46.1 |
| | May/93 | 128 | 49 | 5 | 110 | 19 41 |
| | AFI Jul/93 | 8 | 3 | 6 3 | 60 | 24 67 |
| **FIELD PARAMETERS** | | | | | | |
| Dissolved Oxygen (mg/L) | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 18 | 18 | 0 3 | 6 4 | 2 08 |
| | May/93 | 18 | 18 | 4 | 9 9 | 6 81 |
| | AFI Jul/93 | 0 | | - | - | - |
| Oxidation Reduction Potential (mV) | Aug/92 | 0 | | - | - | - |
| | Nov/92 | 0 | | - | - | - |
| | Feb/93 | 16 | 16 | -175 | 209 | 67 0 |
| | May/93 | 18 | 18 | -48 | 213 | 78 89 |
| | AFI Jul/93 | 0 | | - | - | - |
| pH | Aug/92 | 124 | 124 | 6 13 | 7 38 | 6 76 |
| | Nov/92 | 108 | 108 | 5.79 | 7 34 | 6 76 |
| | Feb/93 | 126 | 126 | 5 97 | 7 25 | 6 75 |
| | May/93 | 128 | 128 | 4 73 | 7 26 | 6 65 |
| | AFI Jul/93 | 8 | 8 | 5 96 | 7 2 | 6 84 |

# TABLE 1-3
# SUMMARY OF OU2 GROUNDWATER MONITORING WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) Minimum | Maximum | Average |
|---|---|---|---|---|---|---|
| **FIELD PARAMETERS** | | | | | | |
| Specific Conductance (umhos/cm) | Aug/92 | 124 | 124 | 203 | 1894 | 451 |
| | Nov/92 | 128 | 128 | 189 | 1744 | 432 |
| | Feb/93 | 125 | 125 | 7.65 | 1498 | 396 |
| | May/93 | 128 | 128 | 23 | 1850 | 520.90 |
| | AFI Jul/93 | 8 | 8 | 229 | 1106 | 487.25 |
| Temperature (Celsius) | Aug/92 | 123 | 123 | 4.9 | 16 | 12.1 |
| | Nov/92 | 128 | 128 | 9.8 | 14.1 | 11.9 |
| | Feb/93 | 126 | 126 | 7.3 | 13.2 | 11.6 |
| | May/93 | 128 | 128 | 9.9 | 16.1 | 12.06 |
| | AFI Jul/93 | 8 | 8 | 11.2 | 12.8 | 12.63 |

Notes

1. The sampling events occured during the following time periods
   - Aug/92 - August 1992 groundwater sampling event during the OU2 Remedial Investigation (WCC, 1993c)
   - Nov/92 - November 1992 groundwater sampling event during the OU2 Remedial Investigation (WCC, 1993c)
   - Feb/93 - February/March/April 1993 quarterly groundwater sampling event (WCC, 1993d)
   - May/93 - May/June 1993 quarterly groundwater sampling event (WCC, 1993e)
   - AFI Jul/93 - Additional Field Investigation groundwater sampling event in July 1993 (WCC, 1993f)
2. When a re-extracted sample was analyzed, results of the original sample were neglected in the calculations

## TABLE 1-4
## SUMMARY OF WATER SUPPLY WELL SAMPLING RESULTS

| | Sampling Event (1) | Number of Samples (2) | Number of Detections (2) | Detected Concentrations (µg/L) (2) | | |
|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | Average |
| **Explosives (µg/L)** | | | | | | |
| 1,3,5-Trinitrobenzene (TNB) | Dec/93 QGW | 25 | 2 | 0.15 | 0.38 | 0.27 |
| | March/94 QGW | 12 | 2 | 0.15 | 0.18 | 0.17 |
| | June/94 QGW | 26 | 0 | - | - | - |
| | Sept/94 QGW | 16 | 0 | - | - | - |
| RDX | Dec/93 QGW | 25 | 8 | 0.31 | 8.9 | 2.55 |
| | March/94 QGW | 12 | 6 | 0.29 | 5.3 | 1.58 |
| | June/94 QGW | 26 | 8 | 0.23 | 70 | 10.49 |
| | Sept/94 QGW | 16 | 4 | 0.15 | 1.7 | 0.86 |
| HMX | Dec/93 QGW | 25 | 1 | 0.47 | 0.47 | 0.47 |
| | March/94 QGW | 12 | 0 | - | - | - |
| | June/94 QGW | 26 | 2 | 0.44 | 7.7 | 4.07 |
| | Sept/94 QGW | 16 | 0 | - | - | - |
| **VOC (µg/L)** | | | | | | |
| 1,1,1-Trichloroethane | Dec/93 QGW | 21 | 1 | 2 | 2 | 2 |
| | March/94 QGW | 10 | 0 | - | - | - |
| | June/94 QGW | 21 | 0 | - | - | - |
| | Sept/94 QGW | 13 | 0 | - | - | - |
| 1,2-Dichloroethene(Total) | Dec/93 QGW | 2 | 1 | 3 | 3 | 3 |
| | March/94 QGW | 1 | 0 | - | - | - |
| | June/94 QGW | 2 | 0 | - | - | - |
| | Sept/94 QGW | 10 | 0 | - | - | - |
| Acetone | Dec/93 QGW | 21 | 0 | - | - | - |
| | March/94 QGW | 10 | 8 | 3 | 14 | 5.7 |
| | June/94 QGW | 21 | 0 | - | - | - |
| | Sept/94 QGW | 13 | 4 | 5 | 9 | 6.5 |
| Chloroform | Dec/93 QGW | 21 | 0 | - | - | - |
| | March/94 QGW | 10 | 0 | - | - | - |
| | June/94 QGW | 21 | 0 | - | - | - |
| | Sept/94 QGW | 13 | 1 | 1 | 1 | 1 |
| Methylene chloride | Dec/93 QGW | 21 | 0 | - | - | - |
| | March/94 QGW | 10 | 0 | - | - | - |
| | June/94 QGW | 21 | 1 | 0.9 | 0.9 | 0.9 |
| | Sept/94 QGW | 13 | 1 | 2 | 2 | 2 |
| Trichloroethene | Dec/93 QGW | 21 | 2 | 2 | 40 | 21 |
| | March/94 QGW | 10 | 2 | 0.6 | 410 | 205.3 |
| | June/94 QGW | 21 | 3 | 4 | 64 | 42.3 |
| | Sept/94 QGW | 13 | 2 | 50 | 370 | 210 |

Note 1 The sampling events occured during the following dates
Dec/93 QGW December 1993 Water Supply Well Sampling Event (WCC, 1993g and 1994a, MRI 1993 and 1994a)
March/94 QGW March 1994 Water Supply Well Sampling Event (WCC, 1994b and MRI 1994b)
June/94 QGW June 1994 Water Supply Well Sampling Event (WCC, 1994c and MRI 1994c)
Sept/94 QGW September 1994 Water Supply Well Sampling Event (WCC, 1994d and MRI 1994d)
2 When a reextracted sample was analyzed, results of the original sample were neglected in the calculations

## TABL… 2-1A

## POTENTIAL CONTAMINANT-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| **FEDERAL** | | | |
| **Safe Drinking Water Act** | 40 USC Sect. 300 | | |
| National Primary Drinking Water Standards | 40 CFR Part 141 | Establishes maximum contaminant levels (MCLs) which are health-based standards for public water systems. Establish action levels for lead and copper. | The MCLs for organic and inorganic contaminants and action levels may be relevant and appropriate. The lead action level is exceeded if the concentration of lead in more than 10 percent of tap water collected during any one monitoring period exceed 0.015 mg/L. The exceedance of the copper action level is evaluated in a similar manner. |
| National Secondary Drinking Water Standards | 40 CFR Part 143 | Establishes secondary maximum contaminant levels (SMCLs) which are non-enforceable guidelines for public water systems to ensure the aesthetic quality of the water. | SMCLs may be relevant and appropriate if treated groundwater is used as a source of drinking water. |
| Maximum Contaminant Level Goals (MCLGs) | PL No. 99-339 100 Stat. 642 (1986) | Establishes drinking water quality goals set at levels of no known or anticipated adverse health effects with an adequate margin of safety. | MCLGs for organic and inorganic contaminants may be relevant and appropriate if a more stringent standard is required to protect human health or the environment. The MCL is the controlling ARAR. |
| **Clean Water Act** | 33 USC Sect. 1251-1376 | | |
| Ambient Water Quality Criteria | 40 CFR Part 131 Quality Criteria for Water, 1976, 1980, 1986 | Requires the states to set ambient water quality criteria (AWQC) for water quality based on use classifications and the criteria developed under Section 304(a) of the Clean Water Act. | May be relevant and appropriate if contaminated or treated groundwater is discharged to surface water during a remedial action. |
| National Pollutant Discharge Elimination System Permit Regulations (NPDES) | 40 CFR Parts 122, 125 | Requires permits for the discharge of pollutants from any point source into waters of the United States. | A permit is not required for on-site CERCLA response actions, but the substantive requirements would apply if an alternative developed would discharge into a creek or other surface water. A permit would be required if the discharge is to a creek or surface water located off-site. |
| Guidelines Establishing Test Procedures for the Analysis of Pollutants | 40 CFR 136.1-5 and Appendices A-C | Specific analytical procedures for NPDES applications and reports. | |

**TAB... 2-1A**
**(Continued)**

## POTENTIAL CONTAMINANT-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| Underground Injection Control Regulations | 40 CFR Parts 144-147 | Provides for protection of underground sources of drinking water. | If an alternative developed would involve underground injection, this part is applicable. |
| National Pretreatment Standards | 40 CFR Part 403 | Sets standards to control pollutants which pass through or interfere with treatment processes in publicly-owned treatment works (POTW) or which may contaminate sewage sludge. | If an alternative developed involves discharge to publicly-owned treatments works, these standards would be applicable. |
| **Clean Air Act** | 42 USC Sect. 7401-7642 | | |
| Title III - Hazardous Air Pollutants | Not applicable (proposed) | Maximum achievable control technology (MACT) emission controls required for remediation sites emitting one of the 189 listed Hazardous Air Pollutants. | Schedule for proposal of regulation lists November 15, 2000. Assuming 1 year to promulgate and 3 years to implement, regulations would be enforceable in 2004. |
| **State** | | | |
| **Nebraska Environmental Protection Act** | Chapter 81 | Establishes state's policy on environmental control. | |
| Water Quality Standards for Surface Waters of the State | Title 117 | Establishes environmental quality standards for the surface waters of the state. | May be applicable if contaminated groundwater is discharged into a surface water body. |
| Groundwater Quality Standards and Use Classification | Title 118 | Establishes standards and use classifications for groundwater sources of drinking water. | Nebraska MCLs are applicable if they are more stringent than any of the federal ARARs. |
| Nebraska Air Pollution Control Rules and Regulations | Title 129, Chapter 3 | Establishes State primary and secondary ambient air quality standards for particulate matter (< = 10 μm and > = 10 μm/< = 100 μm), sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and lead. | |
| | Title 129, Chapter 7 | Adopts 40 CFR 52 regarding Prevention of Significant Deterioration of Air Quality. | |
| | Title 129, Chapter 6, Section 002-007 | Establishes criteria for obtaining a permit to construct a source of potential toxic emissions. | May be applicable if contaminants exceed threshold quantities. |

# TABLE 2-1B

## POTENTIAL ACTION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| **FEDERAL** | | | |
| **Solid Waste Disposal Act (SWDA)** | 42 USC Section 6901-6987 | | |
| Guidelines for the Land Disposal of Solid Wastes | 40 CFR Part 241.100-213 | Establishes minimum levels of performance for the design, construction and operation of any solid waste landfill. | |
| Criteria for Classification of Solid Waste Disposal Facilities and Practices | 40 CFR Part 257 | Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health, and thereby constitute prohibited open dumps. | Only if an alternative developed would involve the land disposal of solid waste would this part be applicable. |
| Criteria for Hazardous Waste Landfills | 40 CFR Part 267 | Establishes minimum national standards that define acceptable management of hazardous waste for new land disposal facilities. | Remedies should be consistent with the more stringent Part 264 standards as these represent the ultimate RCRA compliance standards and are consistent with CERCLA's goal of long-term protection of public health and welfare and the environment. |
| Criteria for Municipal Solid Waste Landfills | 40 CFR Part 258.1-61 | Establishes minimum national criteria for municipal solid waste landfills, including location, design, operation, monitoring, and closure. | |
| **Resource Conservation and Recovery Act (RCRA)** | USC Section 6901 | | |
| Hazardous Waste Management Systems General | 40 CFR Part 260 | Establishes procedure and criteria for modification or revocation of any provision in 40 CFR Parts 260-265. | May be applicable if a substance at the Site was to be from the list of hazardous wastes. |
| Identification and Listing of Hazardous Wastes | 40 CFR Part 261 | Defines those solid wastes which are subject to regulation as hazardous wastes under 40 CFR Parts 263-265 and Parts 124, 270, and 271. | Identifies those wastes considered to be hazardous wastes at the Site. Any wastes considered as hazardous would be required to be handled as such. |
| Standards Applicable to Generators of Hazardous Waste | 40 CFR Part 262 | Establishes standards for generators of hazardous waste. | If an alternative developed would involve on-site storage or off-site disposal or treatment of hazardous wastes, these standards would be applicable. |
| Standards Applicable to Transporters of Hazardous Waste | 40 CFR Part 263 | Establishes standards which apply to persons transporting hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262. | If an alternative developed would involve off-site transportation of hazardous wastes, these standards would be applicable. |

## POTENTIAL ACTION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| **RCRA (cont.)** | | | |
| Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities | 40 CFR Part 264 | Establishes minimum national standards which define the acceptable management of hazardous waste for owners and operators of facilities which treat, store, or dispose hazardous waste. | Subparts B through X may be applicable or relevant and appropriate to on-site and off-site remedial actions. |
| Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities | 40 CFR Part 265 | Establishes minimum national standards that define the acceptable management of hazardous waste during the period of interim status and until certification of final closure or if the facility is subject to post-closure requirements, until post-closure responsibilities are fulfilled. | Remedies should be consistent with the more stringent Part 264 standards as these represent the ultimate RCRA compliance standards and are consistent with CERCLA's goal of long-term protection of public health and welfare and the environment. |
| Interim Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities | 40 CFR 267 | Establishes minimum national standards that define acceptable management of hazardous waste for new land disposal facilities. | Remedies should be consistent with the more stringent Part 264 standards as these represent the ultimate RCRA compliance standards and are consistent with CERCLA's goal of long-term protection of public health and welfare and the environment. |
| Land Disposal Restrictions | 40 CFR 268 | Establishes a timetable for restriction of land disposal of wastes and other hazardous materials. | If an alternative involves land disposal of any restricted waste, this part may be applicable. |
| Hazardous Waste Permit Program | 40 CFR Part 270 | Establishes provisions covering basic EPA permitting requirements. | A permit is not required for on-site CERCLA response actions; however, a permit is required for off-site actions. Substantive requirements are addressed in 40 CFR Part 264. Under 40 CFR Section 300.38, requirements of the Act apply to all response activities under the NCP. |
| **Clean Air Act** | 42 USC Section 7401-7642 | | |
| National Ambient Air Quality Standards | 40 CFR Part 50 | Establishes standards from ambient air quality to protect public health and welfare. | May be applicable if criteria pollutants are discharged to air during a treatment process. |
| **Hazardous Materials Transportation Act** | 49 USC Section 1801-1813 | | |
| Hazardous Materials Transportation Regulations | 49 CFR Parts 107, 171-177 | Regulates transportation of hazardous materials. | If an alternative developed would involve transportation of hazardous materials, these requirements are applicable. |

## TABLE 2-1B (Continued)

## POTENTIAL ACTION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| **STATE** | | | |
| **Nebraska Environmental Protection Act** | Chapter 81 Article 15 | | |
| Nebraska Pretreatment Regulations | Title 127 | Establishes limitations on types of wastes which can be discharged to a POTW and requires a permit when a discharge may interfere with, pass through, or be incompatible with a POTW's treatment processes. | Any alternatives which discharge contaminated groundwater to a POTW will have to meet the substantive requirements of this regulation. Permit may be required. |
| Nebraska General NPDES Rules for New and Existing Sources | Title 121 | Establishes point source effluent standards. | May be applicable to any discharge of treated effluent to a surface water body. |
| Rules and Regulations Pertaining to Solid Waste Management | Title 132 | Establishes policy for licensing, locations, construction, and operation of solid waste management facilities. | May be applied if landfilling is used as a means of disposal of contaminated materials. |
| Rules and Regulations Governing Hazardous Waste Management in Nebraska | Title 128 | Establishes procedures for notification of hazardous waste activity, identification and listing of hazardous wastes, generators, and operators of treatment, storage, and disposal facilities. | Treatment, storage, or disposal facilities built on-site would be required to meet the substantive requirements of this regulation. Off-site treatment, storage, or disposal facilities would be required to meet all requirements. |
| Rules and Regulations Pertaining to the Management of Wastes | Title 126 | Requires permits or licenses for various state management activities and establishes policy for releases of oil or hazardous substances. | Permits or licenses would not be required for on-site activities; however, the substantive requirements would need to be met. |
| National Pollutant Discharge Elimination Systems (NPDES) | Title 119 | Requires permit for discharging pollutants from a point source into the waters of the state. | May be applicable if an effluent is discharged into an off-site surface water. |
| Rules and Regulations for Injection Wells and Mineral Production Wells | Title 122 | Establishes procedures for permitting underground injection of hazardous wastes into or above an underground supply of drinking water. | May be applicable if treated groundwater is injected into aquifer. Will require permit if reinjection wells are located off-site. Reinjected water would have to comply with drinking water standards. |
| Nebraska Air Pollution Control Rules and Regulations | Title 129, Chapter 6 Section D02-007 | Establishes criteria for obtaining a permit to construct a source of air pollution. | May be applicable if emissions from treatment processes exceed threshold quantities. |
| | Title 129, Chapter 5 | Requires good engineering practice in design of the stack height. | |

## TABLE 2-1B (Continued)

## POTENTIAL ACTION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| **Nebraska Environmental Protection Act (cont.)** | Title 129, Chapter 17 | Prohibits visible dust beyond the limits of the property line where handling, transportation, or construction is taking place. | |
| | Title 129, Chapter 24 | Limits visible emissions from diesel-powered construction or transportation equipment. | |
| Nebraska Regulation of Disposal Sites Act | Chapter 81 Article 19 | Provides criteria that must be analyzed and considered by a city prior to the construction of any disposal site. | May be relevant and appropriate if on-site disposal is considered for remediation of the surface soils. |

# TABLE 2-1C

## POTENTIAL LOCATION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| **Federal** | | | |
| Flood Plain Management | Executive Order No. 11988<br>16 USC 661 et seq<br>40 CFR Part 6, Appendix A and<br>40 CFR 6.302 | Action that will occur in a floodplain and relatively flat areas adjoining inland and coastal waters and other floodplain areas to avoid adverse effects. | Site is not located within a floodplain. |
| 100-Year Floodplain Management | 40 CFR 264.18(b) | RCRA treatment, storage, or disposal facility must be designed, constructed, operated, and maintained to avoid washout within 100-year floodplain. | Site is not located within a 100-year floodplain. |
| Protection of Wetlands | Executive Order No. 11990<br>40 CFR Part 6, Appendix A | Action involving construction of facilities or management of property in wetlands to avoid adverse effects, minimize potential harm, and preserve and enhance wetlands, to the extent possible. | May be relevant and appropriate for on-site remediations if wetlands are located near the Site. |
| Protection of Wetlands | CWA Section 404;<br>40 CFR Part 230<br>33 CFR Part 320-330 | Action to prohibit discharge of dredged or fill materials into wetlands (as defined in USACE regulations) without permit. | No dredged or fill material will be discharged into a wetland. |
| Wilderness Act | 16 USC 1311 et seq<br>50 CFR 53.1 et seq | Federally-owned area designated as wilderness area must be administered in such a manner that will leave it unimpaired as wilderness and preserve its wilderness. | No federally-owned wilderness area is located on-site or in the vicinity of the Site. |
| Wildlife Refuge | 16 USC 668dd et seq<br>50 CFR Part 27 | Only actions allowed under the provisions of 16 USC 668dd(c) may be undertaken in areas designed as part of National Wildlife Refuge System. | Site and immediate area do not contain areas designated as part of National Wildlife Refuge System |
| Standards for Owners and Operators of hazardous Waste Treatment, Storage, and Disposal Facilities | 40 CFR 264.18(a) | New RCRA treatment, storage, or disposal of hazardous waste prohibited within 61 meters of a fault displaced in Holocene time. | No treatment, storage, or disposal facilities located on-site will be within 61 meters of a Holocene-Age fault. |
| Endangered Species Act | 16 USC 1531 et seq<br>50 CFR Part 200<br>50 CFR Part 402 | Action to conserve endangered species within critical habitats upon which endangered species depend, including consultation with the Department of Interior. | Critical habitats for endangered species have not been identified at the Site. |
| Fish and Wildlife Coordination Act | 16 USC 661 et seq<br>33 CFR Parts 320-330<br>40 CFR 6.302 | Action to protect fish or wildlife for diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife. | No action at Site should modify a stream or river |

# TABLE 2-1C (Continued)

## POTENTIAL LOCATION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| Coastal Zone Management Act | 16 USC Section 1451 et seq | Conduct activities affecting the coastal zone, including lands therein and thereunder and adjacent shorelands in a manner consistent with approved state management programs. | Site is not located within a coastal zone |
| Wild and Scenic Rivers Act | 16 USC 1271 et seq Section 7<br>40 CFR 6.302(e) | Avoid taking or assisting an action that will have direct adverse effect on scenic river specified in 16 USC 1276(a). | Actions at Site will not affect a scenic river. |
| Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities | 40 CFR 264.18(c) | Placement of non-containerized or bulk liquid RCRA hazardous waste prohibited within salt dome formation, underground mine, or cave. | None of the formations are present on or in the vicinity of the Site. |
| National Historic Preservation Act | 16 USC Section 469<br>36 CFR Part 65 | Action to recover and preserve artifacts in area where alteration of terrain threatens significant scientific, prehistorical, historical, or archaeological data. | From available information, Site contains no area which provides significant, prehistorical, historical, or archaeological data. |
| National Historic Preservation Act | 16 USC 470 et seq<br>36 CFR Part 800<br>40 CFR Section 6.301 | Action to preserve property in or eligible for National Register of Historic Places; planning of action to minimize harm to National Historic Landmarks. | No properties on the Site are eligible for National Register of Historic Places or are National Historic Landmarks. |
| Farmland Protection Policy Act | 40 CFR Part 658 | Requires Federal agencies to identify and take into account adverse effects of their programs on the preservation of farmland. Federal agencies are to consider alternative actions and ensure Federal programs are compatible with State and local government and private programs and policies to protect farmland. | Not relevant because Site remediation improves the Site rather than have an adverse impact. |
| Stormwater Discharge | 40 CFR Part 122.26 | Permit required for stormwater runoff discharge. | Permit required during construction of groundwater treatment plant. No permit required for operation of Groundwater treatment plant because any groundwater containment, extraction and treatment will be within closed systems not exposed to stormwater. Any treated groundwater discharge will not contain stormwater runoff. All soils treatment permits are part of OU1 |
| **State** | | | |

## TABLE 2-1C (Continued)

## POTENTIAL LOCATION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Comment |
|---|---|---|---|
| Nebraska Hazardous Waste Rules | Title 128, Chapter 121 | Adapts and incorporates all of Title 40 CFR Part 264 pertaining to standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities. | Discussed in previous sections containing 40 CFR 264 standards, requirements, criteria, or limitations. |
| Nebraska Air Pollution Control Rules and Regulations | Title 129, Chapter 2 | Establishes air quality control regions. | |
| Nebraska Regulation of Disposal Sites Act | Section 19-4107 | A disposal site shall be located at least 1,000 feet from the nearest edge of the right-of-way of any state, interstate, or federal highway unless the working area is screened so as not to be visible from such highway. | Might be relevant and appropriate for on-site disposal of solid waste. |
| Nebraska Solid Waste Rules | Title 132, Chapter 4 | No solid waste area shall be located within 10,000 feet of a runway intended for use by turbject-driven aircraft or 5,000 feet of a runway intended for use by piston-driven aircraft. | Site is not located within 10,000 feet of an aircraft runway. Potential waste does not attract birds so as to pose a threat to aircraft. |
| Nebraska Safe Drinking Water Act | Title 179, Chapter 2 | Establishes MCLs for public water systems, criteria for public water system design, and training and certification requirements for public water system operators. | Not applicable because treated water would not be used directly as drinking water. Treated water would potentially be used only as infeed water to a public system which would further treat the treat water to public system standards. Therefore, the Mead Site would not design and operate a public treatment system. |

## TABLE 2-2

## POTENTIAL GROUNDWATER CHEMICALS OF CONCERN

| PARAMETER GROUP | Parameter |
|---|---|
| VOCs | 1,1,1-Trichloroethane |
| | 1,2-Dichloroethene (total) |
| | 1,2-Dichloropropane |
| | Acetone |
| | Chloroform |
| | Methylene chloride |
| | Tetrachloroethene |
| | Trichloroethene |
| SVOCs | Diethyl phthalate |
| | Di-n-butyl phthalate |
| | N-Nitrosodiphenylamine |
| | Phenol |
| EXPLOSIVES | 1,3,5-Trinitrobenzene (TNB) |
| | 2,4,6-Trinitrotoluene (TNT) |
| | 2,4-Dinitrotoluene (2,4-DNT) |
| | Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) |
| | Octahydro-1,3,5,7-tetranitro-1,3,5,7-trazocine (HMX) |
| METALS | Aluminum |
| | Lead |
| | Nickel |
| | Vanadium |

Note: Tetryl was not identified in the OU2 BRA as a potential contaminant of concern, thus a site-specific health-based cleanup goal was not calculated. Comparison of the maximum tetryl concentration detected in Site groundwater, 5.1 ug/L, to generic health-based value of 370 ug/L indicates that tetryl is not a contaminant of concern. The generic health-based value is from Region 9 PRG tables, based on residential exposure to groundwater.

## TABLE 2-3

## GROUNDWATER INGESTION EXPOSURE INTAKE FACTORS
## CARCINOGENIC EFFECTS

Equation: IFing = (IR x EF x ED)/(BW x AT1 x AT2)

Where:
IFing = Ingestion Intake Factor
IR = Ingestion Rate (liters/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT1 = Days Per Year
AT2 = For carcinogenic effects the averaging time is based on a 70 year life span.

**For Adult Residents, For All Chemicals**

| IR (L/day) | EF (days/year) | ED (year) | BW (kg) | AT1 (days/yr) | AT2 (yrs) | IFing |
|---|---|---|---|---|---|---|
| 2.0 | 350 | 30 | 70 | 365 | 70 | 1.17E-02 |

Note: Adult resident is considered the worst scenario for carcinogenic effects.

# TABLE 2-4

## GROUNDWATER DERMAL EXPOSURE INTAKE FACTORS
## CARCINOGENIC EFFECTS

**Equation:** IFder = (SA x PC x ET x EF x ED x CF)/(BW x AT1 x AT2)

**Where:**
IFder = Dermal Exposure Intake Factor
SA = Skin Surface Area Available for Contact (c (cm²)
PC = Chemical Specific Dermal Permeability Constant (cm/hr)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor for Water (1 liter/1000cm³)
BW = Body Weight (Kg)
AT1 = Days Per Year
AT2 = For carcinogenic effects the averaging time is based on a 70 year life span

**For Adult Residents**

| CHEMICAL | SA (cm²) | PC (cm/hr) | ET (hr/dy) | EF (dy/year) | ED (year) | CF (L/cm³) | BW (kg) | AT1 (days/yr) | AT2 (yrs) | IFder |
|---|---|---|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 1.94E+04 | 1.70E-02 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 3.87E-04 |
| 1,2-Dichloroethene (total) | 1.94E+04 | 1.28E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 2.92E-05 |
| 1,2-Dichloropropane | 1.94E+04 | 1.00E-02 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 2.28E-04 |
| Acetone | 1.94E+04 | 5.70E-04 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 1.30E-05 |
| Chloroform | 1.94E+04 | 8.90E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 2.03E-04 |
| Methylene chloride | 1.94E+04 | 4.60E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 1.05E-04 |
| Tetrachloroethene | 1.94E+04 | 4.80E-02 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 1.09E-03 |
| Trichloroethene | 1.94E+04 | 1.48E-02 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 3.37E-04 |
| Diethyl phthalate | 1.94E+04 | 5.02E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 1.14E-04 |
| Di-n-butyl phthalate | 1.94E+04 | 3.63E-01 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 8.27E-03 |
| N-Nitrosodiphenylamine | 1.94E+04 | 3.60E-02 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 8.20E-04 |
| Phenol | 1.94E+04 | 5.54E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 1.26E-04 |
| TNB | 1.94E+04 | 3.80E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 8.66E-05 |
| TNT | 1.94E+04 | 3.80E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 8.66E-05 |
| 2,4-DNT | 1.94E+04 | 3.80E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 8.66E-05 |
| RDX | 1.94E+04 | 3.48E-04 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 7.93E-06 |
| HMX | 1.94E+04 | 3.48E-04 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 7.93E-06 |
| Aluminum | 1.94E+04 | 1.00E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 2.28E-05 |
| Lead | 1.94E+04 | 1.00E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 2.28E-05 |
| Nickel | 1.94E+04 | 1.00E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 2.28E-05 |
| Vanadium | 1.94E+04 | 1.00E-03 | 0.2 | 350 | 30 | 0.001 | 70 | 365 | 70 | 2.28E-05 |

Note: Adult resident is considered the worst scenario for carcinogenic effects

## TABLE 2-5

## GROUNDWATER INHALATION EXPOSURE INTAKE FACTORS
## CARCINOGENIC EFFECTS

**Equation:** **IFinh = (IH x ET x EF x ED x Ks)/(BW x AT1 x AT2)**

**Where:**
IFinh = Inhalation Exposure Intake Factor
IH = Inhalation Rate
ET = Exposure Time
EF = Exposure Frequency
ED = Exposure Duration
KS = Conversion Constant (Shower Model)
BW = Body Weight
AT1 = Days Per Year
AT2 = For carcinogenic effects the averaging time is based on a 70 year life span.

**For Adult Residents (a)**

| CHEMICAL | IH ($m^3$/hour) | ET (hour/day) | EF (dy/year) | ED (year) | KS (unitless) | BW (kg) | AT1 (dy/yr) | AT2 (yr) | IFinh |
|---|---|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| 1,2-Dichloroethene (total) | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| 1,2-Dichloropropane | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| Acetone | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| Chloroform | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| Methylene chloride | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| Tetrachloroethene | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| Trichloroethene | 0.83 | 0.2 | 350 | 30 | 13.34 | 70 | 365 | 70 | 1.31E-02 |
| Diethyl phthalate | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| Di-n-butyl phthalate | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| N-Nitrosodiphenylamine | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| Phenol | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| TNB | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| TNT | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| 2,4-DNT | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| RDX | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| HMX | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| Aluminum | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| Lead | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| Nickel | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |
| Vanadium | 0.83 | 0.2 | 350 | 30 | 0.00 (b) | 70 | 365 | 70 | 0.00E+00 |

Note: (a). Adult resident is considered the worst scenario for carcinogenic effects.
(b). Chemicals with low volatility.

## TABLE 2-6

## GROUNDWATER INGESTION EXPOSURE INTAKE FACTORS
## NON-CARCINOGENIC EFFECTS

**Equation:** **IFing = (IR x EF x ED)/(BW x AT1 x AT2)**

**Where:**
IFing = Ingestion Intake Factor
IR = Ingestion Rate (liters/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT1 = Days Per Year
AT2 = Averaging Time (Period over which exposure is averaged)

**For Child Residents, For All Chemicals**

| IR (L/day) | EF (days/year) | ED (year) | BW (kg) | AT1 (days/yr) | AT2 (yrs) | IFing |
|---|---|---|---|---|---|---|
| 1.0 | 350 | 6 | 15 | 365 | 6 | 6.39E-02 |

Note: Child resident is considered the worst scenario for non-carcinogenic effects.

## TABLE 2-7

## GROUNDWATER DERMAL EXPOSURE INTAKE FACTORS
## NON-CARCINOGENIC EFFECTS

Equation: IFder = (SA x PC x ET x EF x ED x CF)/(BW x AT1 x AT2)

Where: IFder = Dermal Exposure Intake Factor
SA = Skin Surface Area Available for Contact ($cm^2$/day)
PC = Chemical Specific Dermal Permeability Constant (cm/hr)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor for Water (1 liter/1000$cm^3$)
BW = Body Weight (Kg)
AT1 = Days Per Year
AT2 = Averaging Time (Period over which exposure is averaged)

For Child Resident

| CHEMICAL | SA ($cm^2$) | PC (cm/hr) | ET (hr/dy) | EF (dy/year) | ED (year) | CF ($L/cm^3$) | BW (kg) | AT1 (days/yr) | AT2 (yrs) | IFder |
|---|---|---|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 6.67E+03 | 1.70E-02 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 1.45E-03 |
| 1,2-Dichloroethene (total) | 6.67E+03 | 1.28E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 1.09E-04 |
| 1,2-Dichloropropane | 6.67E+03 | 1.00E-02 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 8.53E-04 |
| Acetone | 6.67E+03 | 5.70E-04 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 4.86E-05 |
| Chloroform | 6.67E+03 | 8.90E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 7.59E-04 |
| Methylene chloride | 6.67E+03 | 4.46E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 3.80E-04 |
| Tetrachloroethene | 6.67E+03 | 4.80E-02 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 4.09E-03 |
| Trichloroethene | 6.67E+03 | 1.48E-02 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 1.26E-03 |
| Diethyl phthalate | 6.67E+03 | 5.02E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 4.28E-04 |
| Di-n-butyl phthalate | 6.67E+03 | 3.63E-01 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 3.10E-02 |
| N-Nitrosodiphenylamine | 6.67E+03 | 3.60E-02 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 3.07E-03 |
| Phenol | 6.67E+03 | 5.54E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 4.72E-04 |
| TNB | 6.67E+03 | 3.80E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 3.24E-04 |
| TNT | 6.67E+03 | 3.80E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 3.24E-04 |
| 2,4-DNT | 6.67E+03 | 3.80E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 3.24E-04 |
| RDX | 6.67E+03 | 3.48E-04 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 2.97E-05 |
| HMX | 6.67E+03 | 3.48E-04 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 2.97E-05 |
| Aluminum | 6.67E+03 | 1.00E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 8.53E-05 |
| Lead | 6.67E+03 | 1.00E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 8.53E-05 |
| Nickel | 6.67E+03 | 1.00E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 8.53E-05 |
| Vanadium | 6.67E+03 | 1.00E-03 | 0.2 | 350 | 6 | 0.001 | 15 | 365 | 6 | 8.53E-05 |

Note: Child resident is considered the worst scenario for non-carcinogenic effects.

# TABLE 2-8

## GROUNDWATER INHALATION EXPOSURE INTAKE FACTORS
## NON-CARCINOGENIC EFFECTS

Equation: IFinh = (IH x ET x EF x ED x Ks)/(BW x AT1 x AT2)

Where:
IFinh = Inhalation Exposure Intake Factor
IH = Inhalation Rate
ET = Exposure Time
EF = Exposure Frequency
ED = Exposure Duration
KS = Conversion Constant (Shower Model)
BW = Body Weight
AT1 = Days Per Year
AT2 = Averaging Time (Period over which exposure is averaged)

**For Child Residents**

| CHEMICAL | IH ($m^3$/hour) | ET (hour/day) | EF (dy/year) | ED (year) | KS (unitless) | BW (kg) | AT1 (dy/yr) | AT2 (yr) | IFinh |
|---|---|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| 1,2-Dichloroethene (total) | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| 1,2-Dichloropropane | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| Acetone | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| Chloroform | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| Methylene chloride | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| Tetrachloroethene | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| Trichloroethene | 0.83 | 0.2 | 350 | 6 | 13.34 | 15 | 365 | 6 | 1.42E-01 |
| Diethyl phthalate | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| Di-n-butyl phthalate | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| N-Nitrosodiphenylamine | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| Phenol | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| TNB | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| TNT | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| 2,4-DNT | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| RDX | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| HMX | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| Aluminum | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| Lead | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| Nickel | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |
| Vanadium | 0.83 | 0.2 | 350 | 6 | 0.00 (b) | 15 | 365 | 6 | 0.00E+00 |

Note: (a). Child resident is considered the worst scenario for non-carcinogenic effects.
(b) Chemicals with low volatility.

**TABLE 2-9**

**CRITICAL TOXICITY VALUES FOR POTENTIAL CHEMICALS OF CONCERN**

| Chemical | Reference Doses (mg/kg-day) Oral Chronic | Slope Factor (mg/kg-day)-1 Oral | Slope Factor (mg/kg-day)-1 Inhalation | EPA Weight of Evidence |
|---|---|---|---|---|
| 1,1,1-Trichloroethane | 9.00E-02 [c] | - | - | |
| 1,2-Dichloroethene (total) | 9.00E-03 [a] | - | - | |
| 1,2-Dichloropropane | - | 6.80E-02 [d] | - | B2 [a] |
| Acetone | 1.00E-01 [c] | - | - | |
| Chloroform | 1.00E-02 [a] | 6.10E-03 [a] | 8.10E-02 [a,f] | B2 [a] |
| Methylene chloride | 6.00E-02 [c] | 7.50E-03 [a] | 1.65E-03 [c] | B2 [a] |
| Tetrachloroethene | 1.00E-02 [a] | 0.052 [b] | 2.00E-03 [b,f] | B2 [c] |
| Trichloroethene | - | 1.10E-02 [b] | 1.70E-02 [b] | B2 [a] |
| Diethyl phthalate | 8.00E-01 [a] | - | - | |
| Di-n-butyl phthalate | 1.00E-01 [a] | - | - | |
| N-Nitrosodiphenylamine | - | 4.90E-03 [a] | - | B2 [a] |
| Phenol | 6.00E-01 [a] | - | - | |
| TNB | 5.00E-05 [a] | - | - | |
| TNT | 5.00E-04 [a] | 3.00E-02 [a] | - | C [c] |
| 2,4-DNT | 2.00E-03 [a] | 6.80E-01 [a] | - | B2 [a] |
| RDX | 3.00E-03 [a] | 1.10E-01 [a] | - | C [a] |
| HMX | 5.00E-02 [a] | - | - | |
| Aluminum | - | - | - | - |
| Lead | - | - | - | B2 [a] |
| Nickel | 2.00E-02 [d] | - | - | |
| Vanadium | 7.00E-03 [d] | - | - | |

## CRITICAL TOXICITY VALUES FOR POTENTIAL CHEMICALS OF CONCERN

| EPA WEIGHT-OF-EVIDENCE CARCINOGENIC CLASSIFICATION OF CHEMICALS | | |
|---|---|---|
| Group | Description | Description of Evidence |
| A | Human carcinogen | Sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer. |
| B1 or B2[e] | Probable human carcinogen | B1 indicates that limited human data are available from epidemiologic studies. B2 indicates sufficient evidence in animals and inadequate or no evidence in humans of carcinogencity. |
| C[e] | Possible human carcinogen | Limited evidence of carcingenicity in animals. |
| D | Not classified as to human | Inadequate evidence of carcinogenicity in animals |
| E | No evidence of carcinogenicity in humans | No evidence of carcinogenicity in at least two adequate animal tests or in both epidemiologic and animal studies |

**Notes:**

a. EPA Integrated Risk Information System (IRIS) database.
b. Health Effects Assessment Summary Tables (HEAST; EPA, 1991)
c. Health Effects Assessment Summary Tables (HEAST; EPA, 1992)
d. Health Effects Assessment Summary Tables (HEAST; EPA, 1993)
e. Substances in groups B and C are considered potential carcinogens
f. Slope factor was calculated from Unit Risk Value

**TABLE 2-10**

**HEALTH-BASED GROUNDWATER CLEANUP GOALS**
**(CARCINOGENIC EFFECTS)**
**Based on the Adult Resident Scenario**

Equation: Cgw = Risk / [((IFing +IFder) x SF oral)+ (IFinh x SF inh)]

Where: Cgw = Health-Based Cleanup Goals
Risk = Target cancer risk level
SF oral = Slope Factor for oral route
SF inh = Slope Factor for inhalation exposure route
IFing = Ingestion Intake Factor
IFder = Dermal Exposure Intake Factor
IFinh = Inhalation Exposure Intake Factor.

Based on Adult Residents (a)

| Potential COCs | IFder | IFing | IFinh | SF oral (mg/kg-day)-1 | SF inh (mg/kg-day)-1 | Risk = 1.00E-06 Health-Based Cleanup Goals (Cgw) (mg/L) | Risk = 1.00E-05 Health-Based Cleanup Goals (Cgw) (mg/L) | Risk = 1.00E-04 Health-Based Cleanup Goals (Cgw) (mg/L) |
|---|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 3.87E-04 | 1.17E-02 | 1.31E-02 | - | - | NA | NA (b) | NA |
| 1,2-Dichloroethene (total) | 2.92E-05 | 1.17E-02 | 1.31E-02 | - | - | NA | NA | NA |
| 1,2-Dichloropropane | 2.28E-04 | 1.17E-02 | 1.31E-02 | 6.80E-02 | - | 1.23E-03 | 1.23E-02 | 1.23E-01 |
| Acetone | 1.30E-05 | 1.17E-02 | 1.31E-02 | - | - | NA | NA | NA |
| Chloroform | 2.03E-04 | 1.17E-02 | 1.31E-02 | 6.10E-03 | 8.10E-02 | 8.85E-04 | 8.85E-03 | 8.85E-02 |
| Methylene chloride | 1.05E-04 | 1.17E-02 | 1.31E-02 | 7.50E-03 | 1.65E-03 | 9.06E-03 | 9.06E-02 | 9.06E-01 |
| Tetrachloroethene | 1.09E-03 | 1.17E-02 | 1.31E-02 | 5.20E-02 | 2.00E-03 | 1.44E-03 | 1.44E-02 | 1.44E-01 |
| Trichloroethene | 3.37E-04 | 1.17E-02 | 1.31E-02 | 1.10E-02 | 1.70E-02 | 2.82E-03 | 2.82E-02 | 2.82E-01 |
| Diethyl phthalate | 1.14E-04 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| Di-n-butyl phthalate | 8.27E-03 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| N-Nitrosodiphenylamine | 8.20E-04 | 1.17E-02 | 0.00E+00 | 4.90E-03 | - | 1.62E-02 | 1.62E-01 | 1.62E+00 |
| Phenol | 1.26E-04 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| TNB | 8.66E-05 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| TNT | 8.66E-05 | 1.17E-02 | 0.00E+00 | 3.00E-02 | - | 2.82E-03 | 2.82E-02 | 2.82E-01 |
| 2,4-DNT | 8.66E-05 | 1.17E-02 | 0.00E+00 | 6.80E-01 | - | 1.24E-04 | 1.24E-03 | 1.24E-02 |
| RDX | 7.93E-06 | 1.17E-02 | 0.00E+00 | 1.10E-01 | - | 7.74E-04 | 7.74E-03 | 7.74E-02 |
| HMX | 7.93E-06 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| Aluminum | 2.28E-05 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| Lead | 2.28E-05 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| Nickel | 2.28E-05 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |
| Vanadium | 2.28E-05 | 1.17E-02 | 0.00E+00 | - | - | NA | NA | NA |

Note: (a). Adult resident is considered the worst scenario for carcinogenic effects.
(b). NA = Not applicable. Quantitative toxicity data is not available to calculate health-based cleanup goals.

**TABLE 2-11**

**HEALTH-BASED GROUNDWATER CLEANUP GOALS**
**(NON-CARCINOGENIC EFFECTS)**
**Based on the 0- to 6- year old child scenario**

**Equation:** Cgw = (HI x RfD) / (IFing + IFder + IFinh)
**Where:**
Cgw = Health-Based Cleanup Goals
HI = Target Hazard Index
IFing = Ingestion Intake Factor
IFder = Dermal Exposure Intake Factor
IFinh = Inhalation Exposure Intake Factor

| Potential COCs | IFder | IFing | IFinh | RfD (b) (CHRONIC) | Health-Based Cleanup Goals (Cgw) (mg/L) |
|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 1.45E-03 | 6.39E-02 | 1.42E-01 | 9.00E-02 | 4.34E-01 |
| 1,2-Dichloroethene (total) | 1.09E-04 | 6.39E-02 | 1.42E-01 | 9.00E-03 | 4.37E-02 |
| 1,2-Dichloropropane | 8.53E-04 | 6.39E-02 | 1.42E-01 | 1.30E-02 (c) | 6.28E-02 |
| Acetone | 4.86E-05 | 6.39E-02 | 1.42E-01 | 1.00E-01 | 4.85E-01 |
| Chloroform | 7.59E-04 | 6.39E-02 | 1.42E-01 | 1.00E-02 | 4.84E-02 |
| Methylene chloride | 3.80E-04 | 6.39E-02 | 1.42E-01 | 6.00E-02 | 2.91E-01 |
| Tetrachloroethene | 4.09E-03 | 6.39E-02 | 1.42E-01 | 1.00E-02 | 4.76E-02 |
| Trichloroethene | 1.26E-03 | 6.39E-02 | 1.42E-01 | - | NA |
| Diethyl phthalate | 4.28E-04 | 6.39E-02 | 0.00E+00 | 8.00E-01 | 1.24E+01 |
| Di-n-butyl phthalate | 3.10E-02 | 6.39E-02 | 0.00E+00 | 1.00E-01 | 1.05E+00 |
| N-Nitrosodiphenylamine | 3.07E-03 | 6.39E-02 | 0.00E+00 | - | NA |
| Phenol | 4.72E-04 | 6.39E-02 | 0.00E+00 | 6.00E-01 | 9.32E+00 |
| TNB | 3.24E-04 | 6.39E-02 | 0.00E+00 | 5.00E-05 | 7.78E-04 |
| TNT | 3.24E-04 | 6.39E-02 | 0.00E+00 | 5.00E-04 | 7.78E-03 |
| 2,4-DNT | 3.24E-04 | 6.39E-02 | 0.00E+00 | 2.00E-03 | 3.11E-02 |
| RDX | 2.97E-05 | 6.39E-02 | 0.00E+00 | 3.00E-03 | 4.69E-02 |
| HMX | 2.97E-05 | 6.39E-02 | 0.00E+00 | 5.00E-02 | 7.82E-01 |
| Aluminum | 8.53E-05 | 6.39E-02 | 0.00E+00 | - | NA |
| Lead | 8.53E-05 | 6.39E-02 | 0.00E+00 | - | NA |
| Nickel | 8.53E-05 | 6.39E-02 | 0.00E+00 | 2.00E-02 | 3.12E-01 |
| Vanadium | 8.53E-05 | 6.39E-02 | 0.00E+00 | 7.00E-03 | 1.09E-01 |

Note: (a). The Target Hazard Quotient for each chemical is set at 1.0.
(b). RfD values were used for evaluation of exposure via oral, dermal and inhalation routes. The use of RfD values to evaluate inhalation exposures assmues similar mechanisms of toxicity for both oral and inhalation exposure. This conversion approach was taken to cover the inhalation route for chemicals without inhalation RfC values.
(c) There is no chronic RfD for 1,2-dichloropropane. The cleanup goal were calculated using the subchronic RfD.
(d) Based on the recommendation of ECAO (April 19, 1993), dermal exposure was evaluated using oral toxicity values.
(e) NA = Not applicable. Quantitative toxicity data is not available to calculate health-based cleanup goals.

## TABLE 4-1

## ARARs

**CONTAMINANT-SPECIFIC ARARs**

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Type | Alternatives |
|---|---|---|---|---|
| **Federal** | | | | |
| **Resource Conservation and Recovery Act (RCRA) of 1976, as amended** | 42 U.S.C. §6901 et seq. | | | |
| Identification and Listing of Hazardous Waste | 40 CFR 261 | Defines characteristics of hazardous wastes and provides lists of hazardous wastes. Identifies wastes under 40 CFR Parts 124, 262-265, 268, 270, and 271. | A | 2, 3, 4, 5, 6, 7, 8 |
| Releases from Solid Waste Management Units | 40 CFR Part 264.94 | Subpart F (264.94) gives concentration limits in groundwater for hazardous constituents from a regulated unit. | R | 2, 3, 4, 5, 6, 7, 8 |
| **Safe Drinking Water Act** | 40 U.S.C. §300 | | | |
| National Primary Drinking Water Standards | 40 CFR Part 141 | Establishes maximum contaminant levels (MCLs) which are health-based standards for public water systems. | R | 2, 3, 4, 5, 6, 7, 8 |
| Maximum Contaminant Level Goals (MCLGs) | 40 CFR 141.50 | Establishes drinking water quality goals set at levels of no known or anticipated adverse health effects with an adequate margin of safety. | TBC | 2, 3, 4, 5, 6, 7, 8 |
| National Secondary Drinking Water Standards | 40 CFR Part 143 | Establishes secondary maximum contaminant levels (SMCLs) which are non-enforceable guidelines for public water systems to ensure the aesthetic quality of the water. | TBC | 2, 3, 4, 5, 6, 7, 8 |
| **Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977** | 33 U.S.C. §§1251-1376 | | | |
| National Pollutant Discharge Elimination System Permit Regulations (NPDES) | 40 CFR Parts 122, 125 | Requires permits for the discharge of pollutants from any point source into waters of the United States. | A | 2, 3, 4, 5, 6, 7, 8 |
| Ambient Water Quality Criteria | 40 CFR Part 131 Quality Criteria for Water, 1976, 1980, 1986 | Requires states to establish ambient water quality criteria for protection of surface water based on use classifications and the criteria stated under Section 304(a) of the Clean Water Act. Establishes use designation and antidegradation policy. | A | 2, 3, 4, 5, 6, 7, 8 |
| Guidelines Establishing Test Procedures for the Analysis of Pollutants | 40 CFR 136.1-5 and Appendices 1-C | Specific analytical procedures for NPDES applications and reports. | A | 2, 3, 4, 5, 6, 7, 8 |
| Explosives Manufacturing Point Source Category | 40 CFR 457 | Establishes limitations for discharges resulting from the production of explosives. | R | 2, 3, 4, 5, 6, 7, 8 |

## TABLE 4-1
## (Continued)
## ARARS

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Type | Alternatives |
|---|---|---|---|---|
| **Clean Air Act (CAA)** | 42 U.S.C. §§7401-7642 | | | |
| National Primary and Secondary Ambient Air Quality Standards and National Emission Standards for Hazardous Air Pollutants | 40 CFR Parts 50, 61 | Establishes ambient air quality standards for certain "criteria pollutants" to protect public health and welfare and emission standards for certain industrial pollutants and sources. | A | 2, 3, 4, 5, 6, 7, 8 |
| **State** | | | | |
| **Nebraska Environmental Protection Act** | Revised Statutes of Nebraska, Chapter 81 | Establishes state's policy on environmental control. | | |
| Water Quality Standards for Surface Waters of the State | Title 117, Nebraska Department of Environmental Quality (NDEQ) | Establishes environmental quality standards for the surface waters of the state. | A | 2, 3, 4, 5, 6, 7, 8 |
| Groundwater Quality Standards and Use Classification | Title 118, NDEQ | Establishes standards and use classifications for groundwater sources of drinking water. Used to determine priorities for groundwater remedial actions. | A | 2, 3, 4, 5, 6, 7, 8 |
| Nebraska Drinking Water Standards | Nebraska Administrative Code, Title 179, Department of Health | Establishes MCLs for drinking water supplies. | R | 2, 3, 4, 5, 6, 7, 8 |
| Nebraska Air Pollution Control Rules and Regulations | Title 129, Chapter 4 | Establishes sate primary and secondary ambient air quality standards for particulate matter (≤ 10 μm and ≥ 10 μm/≤ 100 μm), sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and lead. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 129, Chapter 19 | Adopts 40 CFR 52.21 regarding Prevention of Significant Deterioration of Air Quality. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 129, Chapter 5 | Establishes criteria for obtaining a permit to operate a source of potential emissions of hazardous air pollutants, volatile organic compounds, and particulate matter. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 129, Chapter 17 | Establishes criteria for obtaining a permit to construct or modify a source of potential emissions of hazardous air pollutants, volatile organic compounds, and particulate matter. | A | 2, 3, 4, 5, 6, 7, 8 |

# TABLE 4-1
# (Continued)
# ARARS

ACTION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Type | Alternatives |
|---|---|---|---|---|
| **Federal** | | | | |
| **Resource Conservation and Recovery Act of 1976 (RCRA), as amended** | 42 U.S.C §§6901-6987 | | | |
| Criteria for Classification of Solid Waste Disposal Facilities and Practices | 40 CFR Part 257 | Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health, and thereby constitute prohibited open dumps | R | 4, 6, 8 |
| Identification and Listing of Hazardous Wastes | 40 CFR Part 261 | Defines those solid wastes which are subject to regulation as hazardous wastes under 40 CFR Parts 263-265 and Parts 124, 270, and 271. | A | 2, 3, 4, 5, 6, 7, 8 |
| Standards Applicable to Generators of Solid Waste | 40 CFR Part 262 | Establishes standards for generators of hazardous wastes. 40 CFR 262.11 requires generators of solid waste to determine if that waste is a hazardous waste. | A | 2, 3, 4, 5, 6, 7, 8 |
| Standards Applicable to Transporters of Hazardous Waste | 40 CFR Part 263 | Applicable to the transportation of spent carbon filters for replacement or disposal. | A | 2, 3, 4, 5, 6, 7, 8 |
| Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities | 40 CFR Part 264 | Establishes minimum national standards which define the acceptable management of hazardous waste for owners and operators of facilities which treat, store, or dispose hazardous waste. | R | 2, 3, 4, 5, 6, 7, 8 |
| | 40 CFR 264, Subpart O - Incinerators | Establishes requirements for incinerator destruction and removal efficiency (DRE) for various organic hazardous constituents and RCRA F-listed wastes | R | 4, 6, 8 |
| | 40 CFR 264, Subpart S | Addresses corrective action at solid waste management units. Establishes requirements for corrective action management units (CAMU's) and temporary units (TUs) for management of remediation wastes during remediation activities. | R | 4, 6, 8 |
| **Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977** | 33 U.S.C. §§1251-1376 | | | |
| Discharge of Stormwater Runoff | 40 CFR 122.2b | Stormwater runoff must be monitored and controlled on construction sites greater than five acres. | A | 2, 3, 4, 5, 6, 7, 8 |

ACTION-SPECIFIC ARARs

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Type | Alternatives |
|---|---|---|---|---|
| **Clean Air Act CAA** | 42 U.S.C. §§7401-7642 | | | |
| Approval and Promulgation of Implementation Plans | 40 CFR Parts 52, Subpart CC (Nebraska) | Establishes air quality control regions and attainment dates for national standards in those regions. | A | 2, 3, 4, 5, 6, 7, 8 |
| State Operating Permit Programs | 40 CFR Part 70 | Establishes requirements for obtaining operating permits and for state issuance of these permits | A | 2, 3, 4, 5, 6, 7, 8 |
| **Hazardous Materials Transportation Act** | Chapter 81 Article 15 | | | |
| Hazardous Materials Program Procedures | 49 CFR 107 | General regulations governing transportation of hazardous materials, e.g., spent carbon filters from groundwater treatment systems. | A | 2, 3, 4, 5, 6, 7, 8 |
| General Information, Regulations, and Definitions | 49 CFR 171 | Contains packaging, marking, and other requirements related to transportation of hazardous materials. | A | 2, 3, 4, 5, 6, 7, 8 |
| Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements | 49 CFR 172 | Provides tables of hazardous materials and associated shipping requirements. | A | 2, 3, 4, 5, 6, 7, 8 |
| **State** | | | | |
| **Nebraska Environmental Protection Act** | Chapter 81 Article 15 | | | |
| National Pollutant Discharge Elimination Systems (NPDES) | Title 119 | Requires permit for discharging pollutants from a point source into the waters of the state. | A | 2, 3, 4, 5, 6, 7, 8 |
| Nebraska General NPDES Rules for New and Existing Sources | Title 121 | Establishes point source effluent standards. | A | 2, 3, 4, 5, 6, 7, 8 |
| Rules and Regulations Governing Hazardous Waste Management in Nebraska | Title 128 | Establishes procedures for notification of hazardous waste activity, identification and listing of hazardous wastes, generators, and operators of treatment, storage, and disposal facilities. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 128, Chapter 21 | Adopts 40 CFR Part 264, Subpart O (referenced above), relating to incinerators. | A | 4, 6, 8 |
| Groundwater Quality Standards and Use Classification | Title 118 | Provides groundwater remedial actions protocol for point source groundwater pollution; defines Remedial Action Classes (RACs) with basic requirements for remedial action. | A | 2, 3, 4, 5, 6, 7, 8 |

## TABLE 4-1
## (Continued)
## ARARS

**ACTION-SPECIFIC ARARs**

| Standard, Requirement, Criterion, or Limitation | Citation | Description | Type | Alternatives |
|---|---|---|---|---|
| Rules and Regulations Pertaining to the Management of Wastes | Title 126 | Requires permits or licenses for various state management activities and establishes policy for releases of oil or hazardous substances. | | 2, 3, 4, 5, 6, 7, 8 |
| Nebraska Air Pollution Control Rules and Regulations | Title 129, Chapter 2 | Defines "major source" of hazardous air pollutants and major stationary sources of other pollutants, including fugitive dust and other particulate emissions. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 129, Chapter 5 | Establishes criteria for obtaining a permit to operate a source of potential emission of hazardous air pollutants, volatile organic compounds, and particulate matter. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 129, Chapter 22 | Establishes emission limits for new incinerators and lists emission report contents. | A | 4, 6, 8 |
| | Title 129, Chapter 16 | Requires good engineering practice in design of the stack height. | A | 4, 6, 8 |
| | Title 129, Chapter 17 | Establishes criteria for obtaining a permit to construct or modify a source of potential emission of hazardous air pollutants, volatile organic compounds, and particulate matter. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 129, Chapter 20 | Prohibits visible dust beyond the limits of the property line where handling, transportation, or construction is taking place. | A | 2, 3, 4, 5, 6, 7, 8 |
| | Title 129, Chapter 39 | Limits visible emissions from diesel-powered construction or transportation equipment. | A | 2, 3, 4, 5, 6, 7, 8 |
| Regulations Governing Licensure of Water Well and Pump Installation Contractors and Certification of Water Well Drilling, and Pump Installation, and Water Well Monitoring Supervisors | Nebraska Administrative Code, Title 178, Nebraska Department of Health, Chapter 10 | Contains rules governing the qualifications of contractors installing water wells | A | 2, 3, 4, 5, 6, 7, 8 |
| Regulations Governing Water Well Construction, Pump Installation, and Water Well Abandonment Standards | Nebraska Administrative Code, Title 178, Nebraska Department of Health, Chapter 12 | Contains rules governing water well construction and abandonment and pump installation. | A | 2, 3, 4, 5, 6, 7, 8 |

**ACTION-SPECIFIC ARARs**

| **Standard, Requirement, Criterion, or Limitation** | **Citation** | **Description** | **Type** | **Alternatives** |
|---|---|---|---|---|
| **State** | | | | |
| Nebraska Air Pollution Control Rules and Regulations | Title 129, Chapter 3 | Establishes air quality control regions. | A | 2, 3, 4, 5, 6, 7, 8 |

Notes. A = Applicable
R = Relevant and Appropriate
TBC = To be considered

TABLE 4-2

SUMMARY COMPARATIVE ANALYSIS OF ALTERNATIVES

| | | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Criterion No.** | **Criteria** | **No Action (1)** | **Hydraulic Containment (2)** | **Focused Extraction (3)** | **Focused Extraction and Soil Excavation (4)** | **Focused Extraction with Air Sparging (5)** | **Focused Extraction with Air Sparging and Soil Excavation (6)** | **Groundwater Extraction (7)** | **Groundwater Extraction and Soil Excavation (8)** |
| **1** | **Overall Protection of Human Health & the Environment** | | | | | | | | |
| * | Groundwater Ingestion For Existing Users | No reduction in human health risk, no protection provided. | Point-of-use systems protect existing users, potential for ingestion of contaminated groundwater minimized. | Point-of-use systems protect existing users, potential for ingestion of contaminated groundwater minimized. | Point-of-use systems protect existing users, potential for ingestion of contaminated groundwater minimized. | Point-of-use systems protect existing users, potential for ingestion of contaminated groundwater minimized. | Point-of-use systems protect existing users, potential for ingestion of contaminated groundwater minimized. | Point-of-use systems protect existing users, potential for ingestion of contaminated groundwater minimized. | Point-of-use systems protect existing users, potential for ingestion of contaminated groundwater minimized. |
| * | Groundwater Ingestion For Potential Future Users | No reduction in human health risk, no protection provided. | Point-of-use systems and containment protect future users. | Point-of-use systems and containment/extraction systems protect future users. | Point-of-use systems and containment/extraction systems protect future users. | Point-of-use systems and containment/extraction systems protect future users. | Point-of-use systems and containment/extraction systems protect future users. | Point-of-use systems and containment/extraction systems protect future users. | Point-of-use systems and containment/extraction systems protect future users. |
| * | Environmental Protection | Migration of contaminated groundwater continues. | Groundwater is contained and off-site migration prevented above the Target Groundwater Cleanup Goal. Groundwater contaminant concentrations are reduced by extraction and treatment. | Groundwater is contained and off-site migration prevented above the Target Groundwater Cleanup Goal. Groundwater is extracted. Groundwater contaminant concentrations are reduced by extraction and treatment. | Groundwater is contained and off-site migration prevented above the Target Groundwater Cleanup Goal. Groundwater is extracted. Groundwater contaminant concentrations are reduced by extraction and treatment. Soil is treated to remove contaminants and minimize the potential for leacheing of contaminants from the soil into the groundwater. | Groundwater is contained and off-site migration prevented above the Target Groundwater Cleanup Goal. Groundwater is extracted. Groundwater contaminant concentrations are reduced by air sparging and groundwater extraction and treatment. | Groundwater is contained and off-site migration prevented above the Target Groundwater Cleanup Goal. Groundwater is extracted. Groundwater contaminant concentrations are reduced by air sparging and groundwater extraction and treatment. Soil is treated to remove contaminants and minimize the potential for leaching of contaminants from the soil into the groundwater. | Groundwater is contained and off-site migration prevented above the Target Groundwater Cleanup Goal. Groundwater is extracted. Groundwater contaminant concentrations are reduced by extraction and treatment. | Groundwater is contained and off-site migration prevented above the Target Groundwater Cleanup Goal. Groundwater is extracted. Groundwater contaminant concentrations are reduced by extraction and treatment. Soil is treated to remove contaminants and minimize the potential for leaching of contaminants from the soil into the groundwater. |
| **2** | **Compliance with ARARs** | | | | | | | | |
| * | Chemical-Specific ARARs | NA (a) | MCLs and health based cleanup goals met at the point-of-use and at the downgradient edge of the plume as soon as system becomes operational. Eventually entire volume of groundwater is remediated. | MCLs and health based cleanup goals met at the point-of-use and at the downgradient edge of the plume as soon as system becomes operational. Eventually entire volume of groundwater is remediated. | MCLs and health based cleanup goals met at the point-of-use and at the downgradient edge of the plume as soon as system becomes operational. Eventually entire volume of groundwater is remediated. | MCLs and health based cleanup goals met at the point-of-use and at the downgradient edge of the plume as soon as system becomes operational. Eventually entire volume of groundwater is remediated. | MCLs and health based cleanup goals met at the point-of-use and at the downgradient edge of the plume as soon as system becomes operational. Eventually entire volume of groundwater is remediated. | MCLs and health based cleanup goals met at the point-of-use and at the downgradient edge of the plume as soon as system becomes operational. Eventually entire volume of groundwater is remediated. | MCLs and health based cleanup goals met at the point-of-use and at the downgradient edge of the plume as soon as system becomes operational. Eventually entire volume of groundwater is remediated. |
| * | Location-Specific ARARs | NA | Can be designed to meet location specific ARARs. | Can be designed to meet location specific ARARs. | Can be designed to meet location specific ARARs. | Can be designed to meet location specific ARARs. | Can be designed to meet location specific ARARs. | Can be designed to meet location specific ARARs. | Can be designed to meet location specific ARARs. |
| * | Action-Specific ARARs | NA | Can be designed to meet action specific ARARs. | Can be designed to meet action specific ARARs. | Can be designed to meet action specific ARARs. | Can be designed to meet action specific ARARs. | Can be designed to meet action specific ARARs. | Can be designed to meet action specific ARARs. | Can be designed to meet action specific ARARs. |
| * | Other Criteria & Guidance | NA | Can be designed to meet other criteria and guidance. | Can be designed to meet other criteria and guidance. | Can be designed to meet other criteria and guidance. | Can be designed to meet other criteria and guidance. | Can be designed to meet other criteria and guidance. | Can be designed to meet other criteria and guidance. | Can be designed to meet other criteria and guidance. |
| **3** | **Long-term Effectiveness & Permanence** | | | | | | | | |
| * | Magnitude of Residual Risk | NA | Residual risk is controlled within the plume by point-of-use treatment and downgradient by containment. | Residual risk is controlled within the plume by point-of-use treatment and extraction and downgradient by containment. | Residual risk is controlled within the plume by point-of-use treatment and extraction, and downgradient by containment. Soils treatment reduces long-term residual risk via leaching. | Residual risk is controlled within the plume by point-of-use treatment, air sparging, and extraction and downgradient by containment. | Residual risk is controlled within the plume by point-of-use treatment, air sparging and extraction, and downgradient by containment. Soils treatment reduces long-term residual risk via leaching. | Residual risk is controlled within the plume by point-of-use treatment and extraction, and downgradient by containment. | Residual risk is controlled within the plume by point-of-use treatment and extraction, and downgradient by containment. Soils treatment reduces long-term residual risk via leaching. |



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TABLE 4-2

SUMMARY COMPARATIVE ANALYSIS OF ALTERNATIVES

| | | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Criterion No.** | **Criteria** | **No Action (1)** | **Hydraulic Containment (2)** | **Focused Extraction (3)** | **Focused Extraction and Soil Excavation (4)** | **Focused Extraction with Air Sparging (5)** | **Focused Extraction with Air Sparging and Soil Excavation (6)** | **Groundwater Extraction (7)** | **Groundwater Extraction and Soil Excavation (8)** |
| * | Adequacy & Reliability of Controls | NA | Point-of use treatment is reliable and adequate. Containment system reliability is high but adequacy must be monitored. | Point-of use treatment is reliable and adequate. Containment and extraction system reliability is high but adequacy must be monitored. | Point-of use treatment is reliable and adequate. Extraction system reliability is high but adequacy must be monitored. Soils treatment removes leaching potential and long-term controls are not required. | Point-of use treatment is reliable and adequate. Containment and extraction system reliability is high but adequacy must be monitored. Air sparging is an emerging technology and reliability and adequacy must be monitored. | Point-of use is reliable and adequate. Extraction system reliability is high but must be monitored. Air sparging is an emerging technology and adequacy must be monitored. Soils treatment removes leaching potential long-term controls not required. | Point-of use treatment is reliable and adequate. Containment and extraction system reliability is high but adequacy must be monitored. | Point-of use treatment is reliable and adequate. Extraction system reliability is high but adequacy must be monitored. Soils treatment removes leaching potential and long-term controls not required. |
| * | Need For 5-Year Review | NA | Review is required to ensure that point-of-use systems and containment system are performing and that contaminant migration has been reduced. | Review is required to ensure that point-of-use systems, extraction system, and containment system are performing and that contaminant migration has been reduced. | Review is required to ensure that point-of-use systems, extraction system, and containment system are performing and that contaminant migration has been reduced. | Review is required to ensure that point-of-use systems, air sparging system, and containment/extraction system are performing and that contaminants are being removed and migration has been reduced. | Review is required to ensure that point-of-use systems, air sparging system, and containment/extraction system are performing and that contaminants are being removed and migration has been reduced. | Review is required to ensure that point-of-use systems, extraction system, and containment system are performing and that contaminant migration has been reduced. | Review is required to ensure that point-of-use systems, extraction system, and containment system are performing and that contaminant migration has been reduced. |
| 4 | **Reduction of Toxicity, Mobility, or Volume Through** | | | | | | | | |
| * | Treatment Process Used | NA | Proven and effective treatment technologies are considered: GAC adsorption, air stripping, advanced oxidation. | Proven and effective treatment technologies are considered: GAC adsorption, air stripping, advanced oxidation. | Proven and effective treatment technologies are considered: GAC adsorption, air stripping, advanced oxidation. Thermal treatment of explosives- contaminated soil is proven and effective. | Proven and effective treatment technologies are considered: GAC adsorption, air stripping, advanced oxidation. Air sparging is an emerging technology. | Proven and effective treatment technologies are considered: GAC adsorption, air stripping, advanced oxidation. Air sparging is an emerging technology. Thermal treatment of explosives-contaminated soil is proven and effective. | Proven and effective treatment technologies are considered: GAC adsorption, air stripping, advanced oxidation. | Proven and effective treatment technologies are considered: GAC adsorption, air stripping, advanced oxidation. Thermal treatment of explosives- contaminated soil is proven and effective. |
| * | Amount Destroyed or Treated | NA | All groundwater contamination above selected target cleanup goals will eventually be destroyed. | All groundwater contamination above selected target cleanup goals will eventually be destroyed. | All groundwater contamination above selected target cleanup goals will eventually be destroyed. 2,600 cy of soil are treated/contaminants destroyed. | All groundwater contamination above selected target cleanup goals will eventually be destroyed. | All groundwater contamination above selected target cleanup goals will eventually be destroyed. 2,600 cy of soil are treated/contaminants destroyed. | All groundwater contamination above selected target cleanup goals will eventually be destroyed. | All groundwater contamination above selected target cleanup goals will eventually be destroyed. 2,600 cy of soil are treated/contaminants destroyed. |
| * | Reduction of Toxicity, Mobility, or Volume | NA | Toxicity and volume are reduced. Mobility (i.e. migration) is managed. | Toxicity and volume are reduced. Contaminants remain mobile but mobility (i.e. migration) is managed. | Toxicity and volume are reduced. Contaminants remain mobile but mobility (i.e. migration) is managed. Thermal treatment of soils reduces toxicity, mobility, and volume and minimizes volume associated with potential leaching. | Toxicity and volume are reduced. Contaminants remain mobile but mobility (i.e. migration) is managed. | Toxicity and volume are reduced. Contaminants remain mobile but mobility (i.e. migration) is managed. Thermal treatment of soils reduces toxicity, mobility, and volume and minimizes volume associated with potential leaching. | Toxicity and volume are reduced. Contaminants remain mobile but mobility (i.e. migration) is managed. | Toxicity and volume are reduced. Contaminants remain mobile but mobility (i.e. migration) is managed. Thermal treatment of soils reduces toxicity, mobility, and volume and minimizes volume associated with potential leaching. |
| * | Irreversible Treatment | NA | Treatment is irreversible. | Treatment is irreversible. | Treatment is irreversible. | Treatment is irreversible. | Treatment is irreversible. | Treatment is irreversible. | Treatment is irreversible. |
| * | Type & Quantity of Residuals Remaining After Treatment | NA | Treatment residuals may include spent carbon from groundwater treatment and off gas treatment. Quantities are manageable and do not pose residual risk when properly managed. | Treatment residuals may include spent carbon from groundwater treatment and off gas treatment. Quantities are manageable and do not pose residual risk when properly managed. | Groundwater treatment residuals include spent carbon from groundwater treatment and off gas treatment. Residuals from thermal treatment may include scrubber water and ash. Quantities are manageable and do not pose residual risk when properly managed. | Treatment residuals may include spent carbon from groundwater treatment and off gas treatment. Quantities are manageable and do not pose residual risk when properly managed. | Groundwater treatment residuals include spent carbon from groundwater treatment and off gas treatment. Residuals from thermal treatment may include scrubber water and ash. Quantities are manageable and do not pose residual risk when properly managed. | Treatment residuals may include spent carbon from groundwater treatment and off gas treatment. Quantities are manageable and do not pose residual risk when properly managed. | Groundwater treatment residuals include spent carbon from groundwater treatment and off gas treatment. Residuals from thermal treatment may include scrubber water and ash. Quantities are manageable and do not pose residual risk when properly managed. |
| * | Statutory Preference For Treatment | NA | Satisfies. | Satisfies. | Satisfies. | Satisfies. | Satisfies. | Satisfies. | Satisfies. |

TABLE 4-2

SUMMARY COMPARATIVE ANALYSIS OF ALTERNATIVES

| Criterion No. | Criteria | Alternative: No Action (1) | Hydraulic Containment (2) | Focused Extraction (3) | Focused Extraction and Soil Excavation (4) | Focused Extraction with Air Sparging (5) | Focused Extraction with Air Sparging and Soil Excavation (6) | Groundwater Extraction (7) | Groundwater Extraction and Soil Excavation (8) |
|---|---|---|---|---|---|---|---|---|---|
| 5 | **Short-term Effectiveness** | | | | | | | | |
| * | Community Protection | NA | Risk to the community is not increased by implementation. | Risk to the community is not increased by implementation. | Risk to the community is not increased by implementation of the groundwater remedy. There is potential for exposure due to airborne emissions during excavation and treatment of contaminated soils. All risks are manageable. | Risk to the community is not increased by implementation. | Risk to the community is not increased by implementation of the groundwater remedy. There is potential for exposure due to airborne emissions during excavation and treatment of contaminated soils. All risks are manageable. | Risk to the community is not increased by implementation. | Risk to the community is not increased by implementation of the groundwater remedy. There is potential for exposure due to airborne emissions during excavation and treatment of contaminated soils. All risks are manageable. |
| * | Site Remediation Worker Protection | NA | Minimal risk to workers outside of general construction safety issues. | Minimal risk to workers outside of general construction safety issues. | Minimal risk to workers outside of general construction safety issues during implementation of the groundwater remedy. Ingestion or inhalation of airborne particulate during excavation of contaminated soil is possible. Exposures can be controlled. | Minimal risk to workers outside of general construction safety issues. | Minimal risk to workers outside of general construction safety issues during implementation of the groundwater remedy. Ingestion or inhalation of airborne particulate during excavation of contaminated soil is possible. Exposures can be controlled. | Minimal risk to workers outside of general construction safety issues. | Minimal risk to workers outside of general construction safety issues during implementation of the groundwater remedy. Ingestion or inhalation of airborne particulate during excavation of contaminated soil is possible. Exposures can be controlled. |
| * | Environmental Impacts | NA | Adverse environmental impacts during implementation are minimal except for potential aquifer drawdown during extraction. | Adverse environmental impacts during implementation are minimal except for potential aquifer drawdown during extraction which is greater than for Alternative 2. | Adverse environmental impacts during implementation minimal except potential aquifer drawdown during extraction greater than Alternative 2. Reduced leaching potential from excavation of contaminated subsurface soil has beneficial environmental impact. | Adverse environmental impacts during implementation are minimal except for potential aquifer drawdown during extraction which is less than for Alternative 3 and 4 but greater than for Alternative 2. | Adverse environmental impacts during implementation minimal except potential aquifer drawdown less than Alt. 3 & 4, greater than Alt. 2. Reduced leaching potential from excavation contaminated subsurface soil beneficial environmental impact. | Adverse environmental impacts during implementation are minimal except for potential aquifer drawdown during extraction which is greater than for Alternatives 2 through 6. | Adverse environmental impacts during implementation minimal except for potential aquifer drawdown greater than Alt. 2 through 6. Reduced leaching potential from excavation contaminated subsurface soil has beneficial environmental impact. |
| * | Target Cleanup Goal I Time Until Action Is Complete | NA | Point of use treatment immediately available. Groundwater containment system operates in perpetuity. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 140 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 140 years. Soil treatment completed within 15 months. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 110 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 110 years. Soil treatment completed within 15 months. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 90 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 90 years. Soil treatment completed within 15 months. |
| * | Target Cleanup Goal II Time Until Action Is Complete | NA | Point of use treatment immediately available. Groundwater containment system operates in perpetuity. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 140 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 140 years. Soil treatment completed within 15 months. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 110 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 110 years. Soil treatment completed within 15 months. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 90 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 90 years. Soil treatment completed within 15 months. |
| * | Target Cleanup Goal III Time Until Action Is Complete | NA | Point of use treatment immediately available. Groundwater containment system operates in perpetuity. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 140 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 140 years. Soil treatment completed within 15 months | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 110 years. | Point of use treatment immediately available. groundwater containment/extraction system operates approximately 110 years. Soil treatment completed within 15 months. | Point of use treatment immediately available. Groundwater containment/extraction system operates greater than 90 years. | Point of use treatment immediately available. Groundwater containment/extraction system operates approximately 90 years. Soil treatment completed within 15 months. |

TABLE 4-2

SUMMARY COMPARATIVE ANALYSIS OF ALTERNATIVES

| Criterion No. | Criteria | Alternative: No Action (1) | Hydraulic Containment (2) | Focused Extraction (3) | Focused Extraction and Soil Excavation (4) | Focused Extraction with Air Sparging (5) | Focused Extraction with Air Sparging and Soil Excavation (6) | Groundwater Extraction (7) | Groundwater Extraction and Soil Excavation (8) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | **Implementability** | | | | | | | | |
| * | Ability to Construct & Operate | NA | Relatively simple to construct and operate. | Relatively simple to construct and operate. | Groundwater treatment system is relatively simple to construct and operate. Thermal treatment of soils involves processes which are commonly used and have demonstrated effectiveness. | Groundwater treatment system is relatively simple to construct/operate. Air sparging requires horizontal drilling which can be complicated. | Groundwater treatment system is simple to construct/operate. Air sparging requires horizontal drilling which can be complicated. Thermal treatment of soils involves processes which are commonly used and have demonstrated effectiveness. | Relatively simple to construct and operate. | Groundwater treatment system is relatively simple to construct and operate. Thermal treatment of soils involves processes which are commonly used and have demonstrated effectiveness. |
| * | Ease of Doing More Action, If Needed | NA | Additional point-of-use systems and containment wells can be added. Treatment system designed to allow varying volumes and concentrations. | Additional point-of-use systems and containment/extraction wells can be added. Treatment system designed to allow varying volumes and concentrations. | Additional point-of-use systems and containment/extraction wells can be added. Treatment system designed to allow varying volumes and concentrations. There is not an anticipated need for the expansion of soil treatment system. | Additional point-of-use systems and containment/extraction wells can be added. Additional air sparging capacity can be added easily. Treatment system designed to allow varying volumes and concentrations. | Additional point-of-use systems, containment/extraction wells, and air sparging capacity added. Treatment system designed to allow varying volumes and concentrations. There is not an anticipated need for the expansion of soil treatment system. | Additional point-of-use systems and containment/extraction wells can be added. Treatment system designed to allow varying volumes and concentrations. | Additional point-of-use systems and containment/extraction wells can be added. Treatment system designed to allow varying volumes and concentrations. There is not an anticipated need for the expansion of soil treatment system. |
| * | Ability to Monitor Effectiveness | NA | No anticipated difficulties for monitoring. Groundwater monitoring will be used to ensure Cleanup Goals met. Groundwater treatment system will require monitoring of system operation and that treated groundwater discharge standards are met. | No anticipated difficulties for monitoring. Groundwater monitoring will be used to ensure Cleanup Goals met. Groundwater treatment system will require monitoring of system operation and that treated groundwater discharge standards are met. | No anticipated difficulties for monitoring. Groundwater monitoring will be used to ensure Cleanup Goals met. Groundwater and soil treatment systems require system monitoring during implementation to ensure effective operation and discharge standards met | No anticipated difficulties for monitoring. Groundwater monitoring will be used to ensure Cleanup Goals met. Groundwater treatment system will require monitoring of system operation and that treated groundwater discharge standards are met. | No anticipated monitoring difficulties. Groundwater monitoring used to ensure Cleanup Goals met. Groundwater and soil treatment systems require system monitoring during implementation to ensure effective operation and discharge standards met. | No anticipated difficulties for monitoring. Groundwater monitoring will be used to ensure Cleanup Goals met. Groundwater treatment system will require monitoring of system operation and that treated groundwater discharge standards are met. | No anticipated monitoring difficulties. Groundwater monitoring used to ensure Cleanup Goals met. Groundwater and soil treatment systems require system monitoring during implementation to ensure effective operation and discharge standards met. |
| * | Ability to Obtain Approvals and Coordinate with Other Agencies | NA | No anticipated difficulties. | No anticipated difficulties. | No anticipated difficulties for groundwater treatment system. Thermal soil treatment will require a trial burn coordinated with the State and EPA. The trial burn will be conducted as part of OU1. | No anticipated difficulties. | No anticipated difficulties for groundwater treatment system. Thermal soil treatment will require a trial burn coordinated with the State and EPA. The trial burn will be conducted as part of OU1. | No anticipated difficulties. | No anticipated difficulties for groundwater treatment system. Thermal soil treatment will require a trial burn coordinated with the State and EPA. The trial burn will be conducted as part of OU1. |
| * | Availability of Services & Capacities | NA | Readily available. | Readily available. | All services for groundwater and soil treatment are readily available. | Readily available. Air sparging is an emerging technology but available. | All services for groundwater and soil treatment are readily available. Air sparging is an emerging technology but available. | Readily available. | All services for groundwater and soil treatment are readily available. |
| * | Availability of Materials, Equipment, & Specialists | NA | Readily available. | Readily available. | All components for groundwater and soil treatment are readily available. | Readily available. Air sparging is an emerging technology but available. | All components for groundwater and soil treatment are readily available. Air sparging is an emerging technology but available. | Readily available. | All components for groundwater and soil treatment are readily available. |
| * | Availability of Technologies | NA | Readily available. | Readily available. | All technologies for groundwater and soil treatment are readily available. | Readily available. Air sparging is an emerging technology but available. | All technologies for groundwater and soil treatment are readily available. Air sparging is an emerging technology but available. | Readily available. | All technologies for groundwater and soil treatment are readily available. |



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TABLE 4-2

SUMMARY COMPARATIVE ANALYSIS OF ALTERNATIVES

| Criterion No. | Criteria | Alternative: No Action (1) | Hydraulic Containment (2) | Focused Extraction (3) | Focused Extraction and Soil Excavation (4) | Focused Extraction with Air Sparging (5) | Focused Extraction with Air Sparging and Soil Excavation (6) | Groundwater Extraction (7) | Groundwater Extraction and Soil Excavation (8) |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Costs | | | | | | | | |
| • | Target Cleanup Goal I Total Capital and Present Worth (6% Discount Rate for 80 years) | $11,100,000 | $29,600,000 | $46,800,000 | $51,100,000 | $67,500,000 | $71,800,000 | $47,100,000 | $51,500,000 |
| • | Target Cleanup Goal II Total Capital and Present Worth (6% Discount Rate for 80 years) | $11,100,000 | $35,300,000 | $57,000,000 | $61,300,000 | $76,300,000 | $80,600,000 | $62,200,000 | $66,500,000 |
| • | Target Cleanup Goal III Total Capital and Present Worth (6% Discount Rate for 80 years) | $11,100,000 | $35,100,000 | $57,100,000 | $61,400,000 | $75,200,000 | $79,500,000 | $66,200,000 | $70,500,000 |

Note: (a) NA = not applicable. Because the "no action" alternative is not protective of human health and the environment, it is not considered further in this analysis as an option at this site.

## TABLE 5-1

## ESTIMATED TOTAL PRESENT WORTH GROUNDWATER REMEDIAL ALTERNATIVE COSTS

| REMEDIAL ALTERNATIVE | REMEDIAL ALTERNATIVE DESCRIPTION | TOTAL PRESENT WORTH COST[a] ($ MILLION) AND APPROXIMATE GROUNDWATER RESTORATION TIME (YEARS) | | |
|---|---|---|---|---|
| | | TARGET GROUNDWATER CLEANUP GOAL[b] | | |
| | | I | II | III |
| 1 | **NO ACTION**<br>• Groundwater Monitoring | $11<br><br>Perpetuity | $11<br><br>Perpetuity | $11<br><br>Perpetuity |
| 2 | **HYDRAULIC CONTAINMENT**<br>• Hydraulic Containment of Groundwater<br>• Potable Water Supply<br>• Groundwater Monitoring | $30<br><br>Perpetuity | $35<br><br>Perpetuity | $35<br><br>Perpetuity |
| 3 | **FOCUSED EXTRACTION**<br>• Focused Extraction of Groundwater<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $47<br><br>Greater than 140 years | $57<br><br>Greater than 140 years | $57<br><br>Greater than 140 years |
| 4 | **FOCUSED EXTRACTION AND SOIL EXCAVATION**<br>• Soil Excavation and Treatment<br>• Focused Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $51<br><br>140 years | $61<br><br>140 years | $61<br><br>140 years |
| 5 | **FOCUSED EXTRACTION WITH AIR SPARGING**<br>• Air Sparging<br>• Focused Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $68<br><br>Greater than 110 years | $76<br><br>Greater than 110 years | $75<br><br>Greater than 110 years |

## TABLE 5-1
## ESTIMATED TOTAL PRESENT WORTH GROUNDWATER REMEDIAL ALTERNATIVE COSTS
## (Continued)

| REMEDIAL ALTERNATIVE | REMEDIAL ALTERNATIVE DESCRIPTION | TOTAL PRESENT WORTH COST[a] ($ MILLION) AND APPROXIMATE GROUNDWATER RESTORATION TIME (YEARS) | | |
|---|---|---|---|---|
| | | TARGET GROUNDWATER CLEANUP GOAL[b] | | |
| | | I | II | III |
| 6 | **FOCUSED EXTRACTION WITH AIR SPARGING AND SOIL EXCAVATION**<br>• Soil Excavation and Treatment<br>• Air Sparging<br>• Focused Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $72<br>110 years | $81<br>110 years | $80<br>110 years |
| 7 | **GROUNDWATER EXTRACTION**<br>• Groundwater Extraction<br>• Hydrau.ic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $47<br>Greater than 90 years | $62<br>Greater than 90 years | $66<br>Greater than 90 years |
| 8 | **GROUNDWATER EXTRACTION AND SOIL EXCAVATION**<br>• Soil Excavation and Treatment<br>• Groundwater Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $51<br>90 years | $66<br>90 years | $71<br>90 years |

Notes: [a]Total present worth cost is sum of capital cost plus sum of present worth of all O&M costs. Presented worth calculated at 6% discount rate for 80 years
[b]Refer to Table 5-2 - Description of Groundwater Target Cleanup Goals

## TABLE 5-2

## DESCRIPTION OF TARGET GROUNDWATER CLEANUP GOALS

| Chemical | Target Groundwater Cleanup Goals (μg/L) | | |
|---|---|---|---|
| | I | II | III |
| Trichloroethene (TCE) | 5[a] | 5[a] | 5[a] |
| RDX | 7.74[c] | 2[e] | 0.774[b] |
| 1,2-Dichloropropane | 5[a] | 5[a] | 5[a] |
| Methylene chloride | 5[a] | 5[a] | 5[a] |
| TNB | 0.778[d] | 0.778[d] | 0.778[d] |
| TNT | 7.78[d] | 2[e] | 2.82[b] |
| 2,4-DNT | 1.24[c] | 1.24[c] | 0.124[b] |

<u>Notes:</u>
[a] Drinking Water MCL
[b] Carcinogenic risk of one in one million ($10^{-6}$)
[c] Carcinogenic risk of one in one hundred thousand ($10^{-5}$)
[d] Non-carcinogenic risk
[e] Health advisory

## TABLE 5-3

## GROUNDWATER EXTRACTION FLOW RATE

| Remedial Alternative | Groundwater Extraction Flow Rate[1] Gallons Per Minute (gpm) — Target Groundwater Cleanup Goal I | II | III |
|---|---|---|---|
| 2 - Hydraulic Containment | 970 | 2,100 | 2,330 |
| 3 - Focused Extraction | 1,980 | 3,300 | 3,530 |
| 4 - Focused Extraction and Soil Excavation | 1,980 | 3,300 | 3,530 |
| 5 - Focused Extraction and Air Sparging | 1,450 | 2,770 | 3,000 |
| 6 - Focused Extraction with Air Sparging and Soil Excavation | 1,450 | 2,770 | 3,000 |
| 7 - Groundwater Extraction | 2,490 | 4,200 | 4,910 |
| 8 - Groundwater Extraction and Soil Excavation | 2,490 | 4,200 | 4,910 |

Note: [1] Flow rates are used for cost estimating purposes. Actual groundwater extraction rates will be developed during design of the selected remedy.

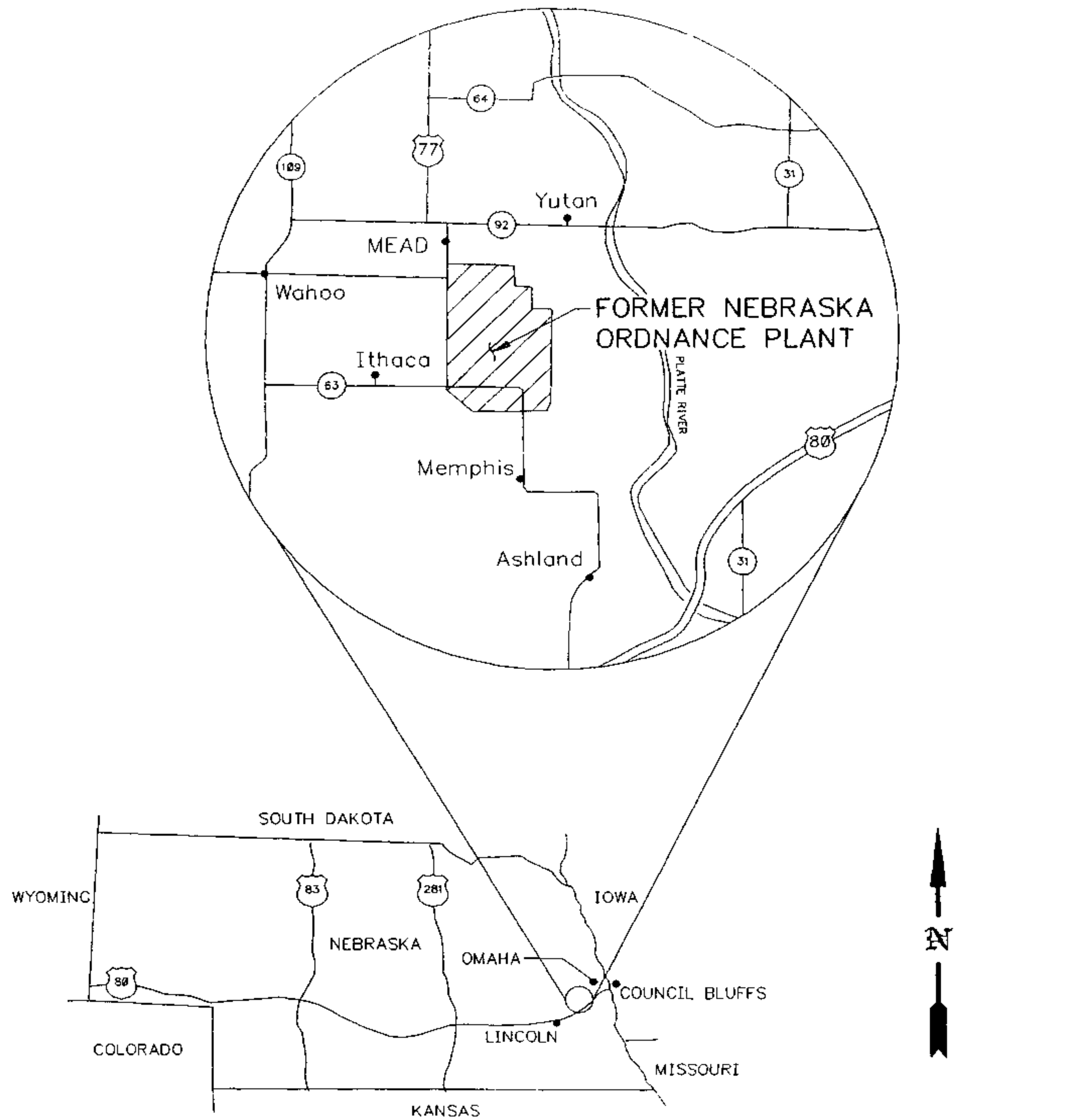
TABLE 5-4

SUMMARY OF ALTERNATIVES COST-EFFECTIVENESS ANALYSIS

| Remedial Alternatives Compared | Evaluation | Approximate Cost Differential ($Million)[1] Target Groundwater Cleanup Goal I | II | III | Additional Benefits | Aquifer Drawdown Disadvantages |
|---|---|---|---|---|---|---|
| Alternative 2 - Hydraulic Containment to Alternative 1 - No Action | Cost increment to contain groundwater contaminant plume. | $19 | $24 | $24 | Potential for exposure to contaminated groundwater at the site reduced. Potential for exposure of downgradient receptors to contaminated groundwater removed. | |
| Alternative 3 - Focused Extraction to Alternative 2 - Hydraulic Containment | Cost increment to extract and treat groundwater within the contaminant plume. | $17 | $22 | $22 | Groundwater within the contaminant plume is extracted and permanently treated. | Potential increased aquifer drawdown. |
| Alternative 4 - Focused Extraction and Soil Excavation to Alternative 3 - Focused Extraction | Cost increment to extract and treat contaminated soil in addition to groundwater. | $ 4 | $ 4 | $ 4 | In addition to groundwater, contaminated soils are removed and permanently treated, thus reducing soil contaminants leaching to groundwater, resulting in reduced estimated restoration time. | |
| Alternative 5 - Focused Extraction with Air Sparging to Alternative 3 - Focused Extraction | Cost increment to treat volatiles-only contaminated groundwater using air sparging. | $21 | $19[2] | $18[2] | Air sparging removes volatiles at locations where only volatiles are present which, in turn, reduces the amount of groundwater that must be extracted and treated. | |
| Alternative 6 - Focused Extraction with Air Sparging and Soil Excavation to Alternative 5 - Focused Extraction with Air Sparging | Cost increment to extract and treat contaminated soil in addition to groundwater. | $ 4 | $ 5[3] | $ 5[3] | Contaminated soils are removed and permanently treated, thus reducing soil contaminants leaching to groundwater, resulting in reduced estimated restoration time. | |
| Alternative 7 - Groundwater Extraction to Alternative 3 - Focused Extraction | Cost increment to increase volume of groundwater extracted and treated. | $ 0 | $ 5 | $ 9 | Groundwater extraction and treatment rates are increased. | Potential increased aquifer drawdown. |
| Alternative 8 - Groundwater Extraction and Soil Excavation to Alternative 4 - Focused Extraction and Soil Excavation | Cost increment to increase volume of groundwater extracted and treated. | $ 0 | $ 5 | $10 | Groundwater extraction and treatment rates are increased. Contaminated soils are removed and permanently treated, thus reducing soil contaminants leaching to groundwater, resulting in reduced estimated restoration times. | Potential increased aquifer drawdown. |

<u>NOTES:</u> [1] Differences of $1 million are not significant due to rounding.
[2] These is no significant differences (refer to Note 1) between $19 and $18 million in comparing Alternatives 5 to 3 for Target Groundwater Cleanup Goals II and II.
[3] These is no significant difference (refer to Note 1) between $4 million for soils excavation and treatment comparing Alternatives 4 to 3 and $5 million for soil excavation and treatment comparing Alternatives 6 to 5.

# DRAWINGS

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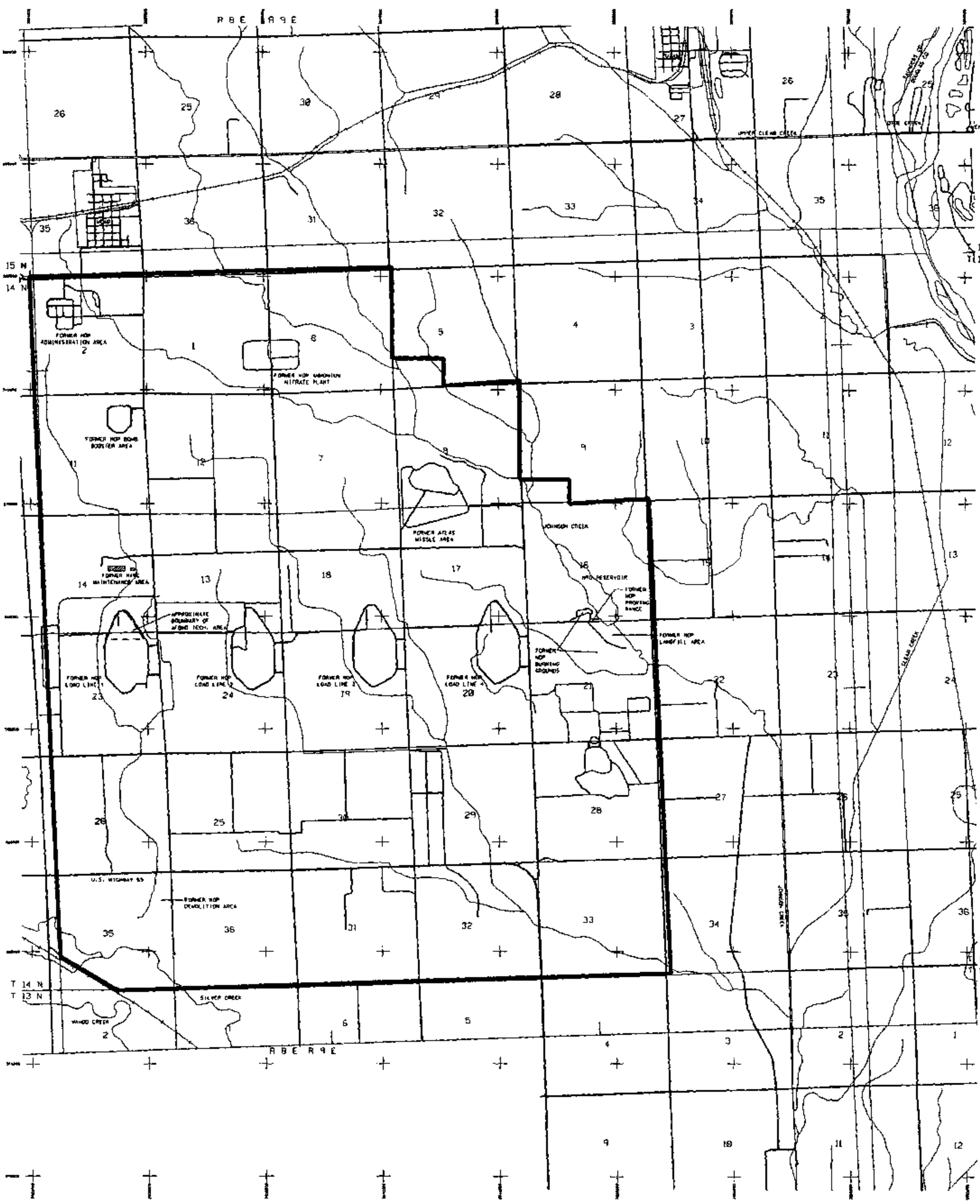
|---|---|
| **Woodward-Clyde Consultants**<br>**Overland Park, Kansas** | **U.S. ARMY ENGINEER DISTRICT**<br>**CORPS OF ENGINEERS**<br>**KANSAS CITY, MISSOURI** |

| | | | |
|---|---|---|---|
| Designed by<br>A.C.E. | U.S. Army Corps of Engineers | FEASIBILITY STUDY<br>FOR OPERABLE UNIT NO. 2 – GROUNDWATER<br>FMR. NEBRASKA ORDNANCE PLANT – MEAD, NE<br>**GENERAL SITE LOCATION MAP** | |
| Drawn by<br>D.R.T. | | | |
| Checked by<br>D.C.C | Scale: AS NOTED | Sheet number<br>**1** | |
| Submitted by: | Date DECEMBER, 1994 | | |
| | Dwg No.: 1–1 | | |

ACAD FILE: 92FS–Y

ACAD 12_c4
11/17/94 11:53:13

D.R.T. SC: 1=1




**LEGEND:**

FORMER NOP SITE BOUNDARY

35 SECTION

T 14 N TOWNSHIP 14 NORTH

R 9 E RANGE 9 EAST

NOTE: NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

N

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'v'd |
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KANSAS CITY, MISSOURI

Designed by: L.A.T.

Drawn by: D.R.T.

Checked by: D.C.C.

Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**SITE MAP**

Scale: AS NOTED

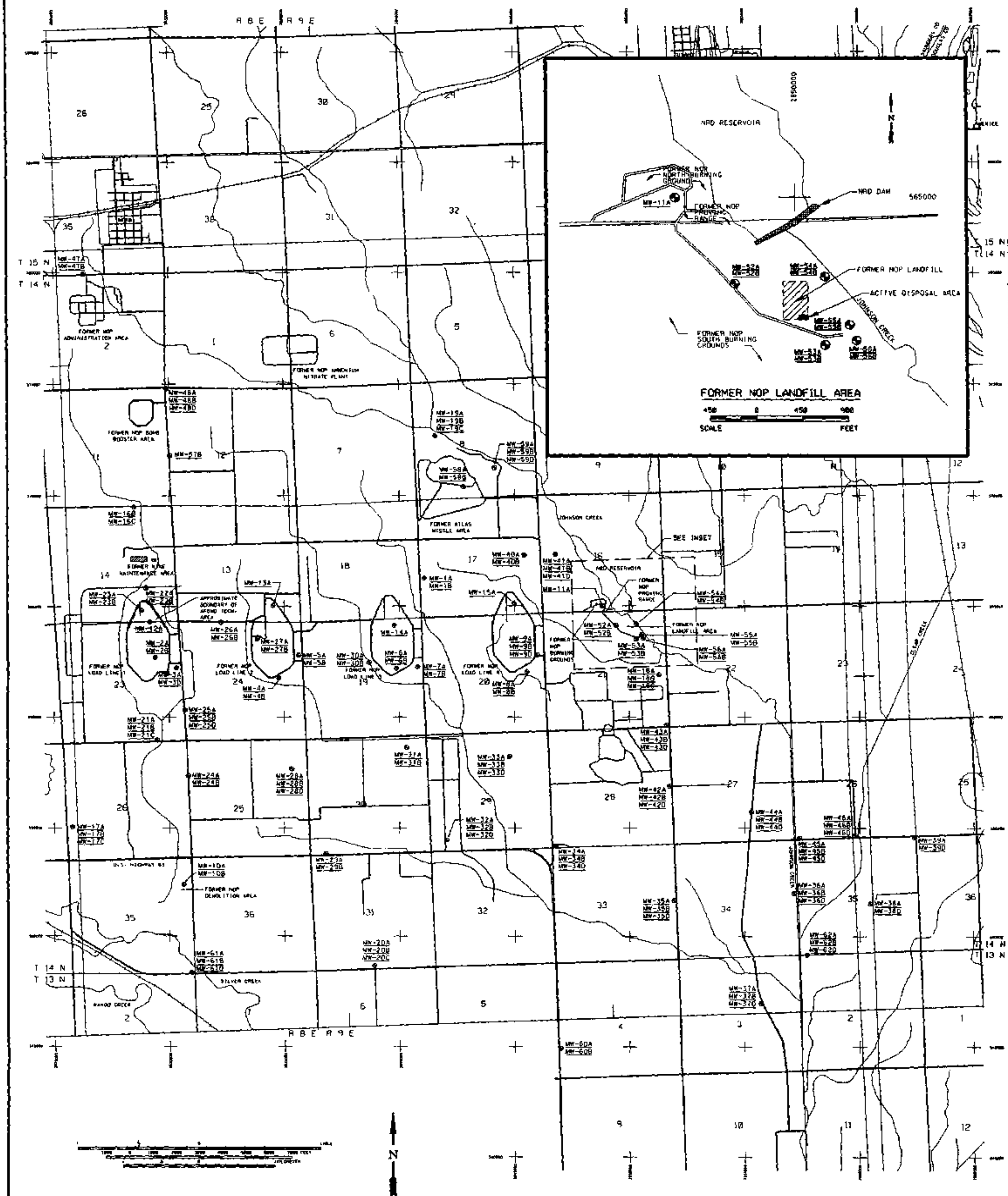
Date: DECEMBER, 1994

Dwg No.: 1-2

Sheet number: 1

WCS FILE 92FS-37

B07NE003702-09103




## LEGEND:

| | |
|---|---|
| MW-10A / MW-10B | GROUNDWATER MONITORING WELL CLUSTER LOCATION (SEE NOTE 1) |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. FOR MONITORING WELL CLUSTER MW-16 THROUGH MW-20 SHALLOW WELLS ARE DESIGNATED BY "C". INTERMEDIATE WELLS BY "B", AND DEEP WELLS BY "A". FOR ALL OTHER MONITORING WELL CLUSTERS (MW-21 THROUGH MW-55), "B" REPRESENTS SHALLOW WELLS, "A" REPRESENTS INTERMEDIATE WELLS, AND "D" REPRESENTS DEEP WELLS. MONITORING WELLS MW-12A THROUGH MW-15A ARE VERY SHALLOW WELLS.
2. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Approved |
| | | | |

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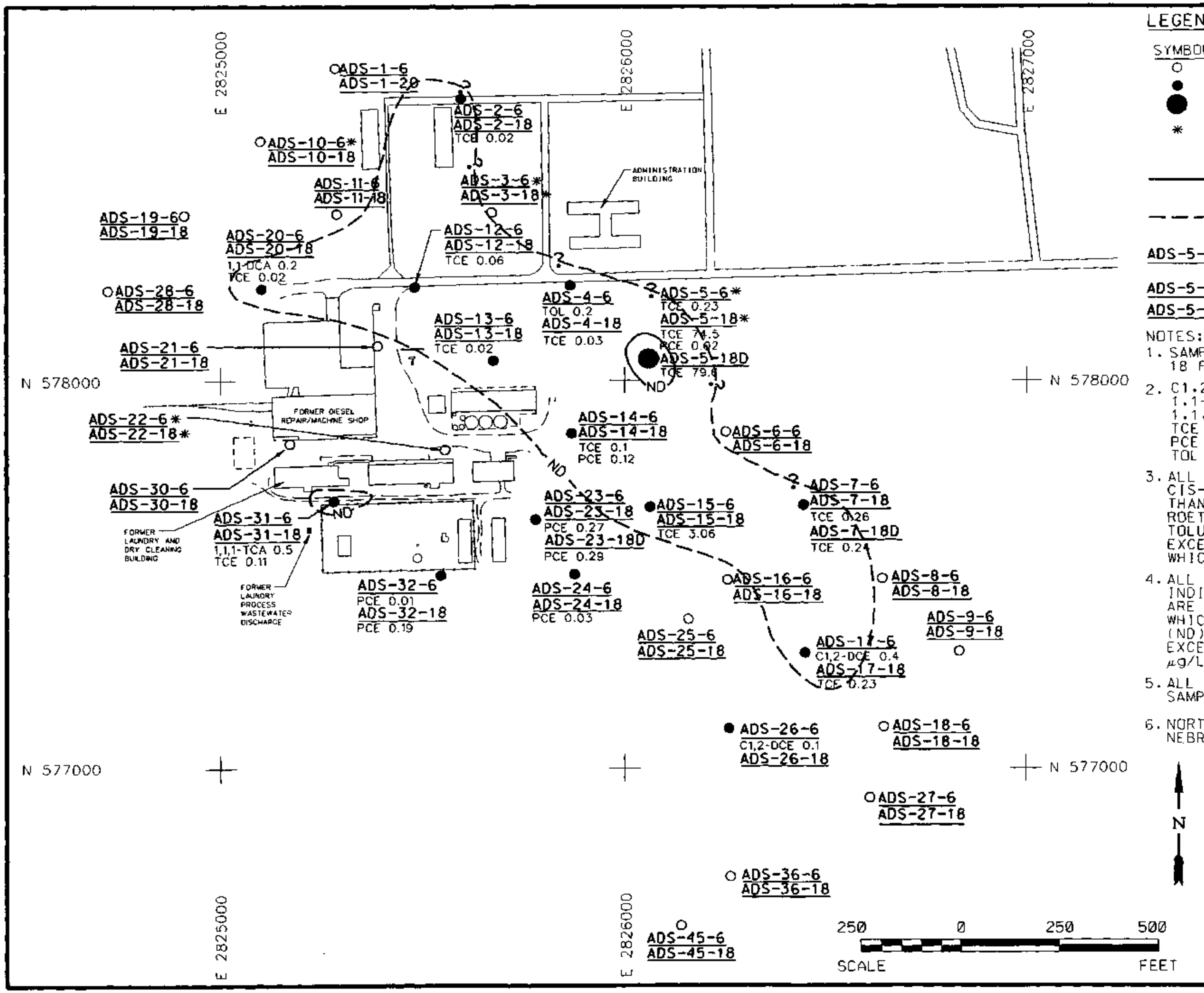
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR NEBRASKA ORDNANCE PLANT - MEAD, NE.

# LOCATIONS OF GROUNDWATER MONITORING WELLS

| | |
|---|---|
| Designed by | L.A.T. |
| Drawn by | D.R.T. |
| Checked by | L.B.V. |
| Submitted by | |
| Scale | AS NOTED |
| Date | DECEMBER, 1994 |
| Dwg. No. | 1-3 |
| Sheet number | 1 |

MICRO FILE: 92F5-50

B07NE003702-09104




**LEGEND:**

| SYMBOL | HIGHEST CONCENTRATION (µg/L) DETECTED AT EACH LOCATION |
|---|---|
| O | NOT DETECTED |
| ● (small) | < 10 |
| ● (large) | 10 - 100 |
| * | UNSATURATED SOIL SAMPLE ALSO COLLECTED AT THIS INTERVAL (SEE NOTE 5 FOR RESULTS) |
| ——— | APPROXIMATE SHALLOW TCE CONCENTRATION CONTOUR IN µg/L |
| — — — | APPROXIMATE DEEP TCE CONCENTRATION CONTOUR IN µg/L |
| ADS-5-6 | SOIL GAS SAMPLE FROM 6 FEET BELOW GROUND SURFACE (BGS) |
| ADS-5-18 | SOIL GAS SAMPLE FROM 18 FEET BGS |
| ADS-5-18D | DUPLICATE SOIL GAS SAMPLE FROM 18 FEET BGS |

NOTES:

1. SAMPLES WERE COLLECTED FROM 6 FEET AND 18 FEET BGS UNLESS OTHERWISE INDICATED.
2. C1,2-DCE = CIS 1,2-DICHLOROETHENE
   1,1-DCA = 1,1-DICHLOROETHANE
   1,1,1-TCA = 1,1,1-TRICHLOROETHANE
   TCE = TRICHLOROETHENE
   PCE = TETRACHLOROETHENE
   TOL = TOLUENE
3. ALL SOIL GAS SAMPLES WERE ANALYZED FOR CIS-1,2-DICHLOROETHANE, 1,1-DICHLOROETHANE, 1,1,1-TRICHLOROETHANE, TRICHLOROETHENE, TETRACHLOROETHENE, BENZENE, TOLUENE, ETHYLBENZENE, AND XYLENE, EXCEPT FOR UNSATURATED SOIL BORINGS WHICH WERE ANALYZED FOR TCL VOCs.
4. ALL ANALYTES ARE NOT DETECTED UNLESS INDICATED, IN WHICH CASE CONCENTRATIONS ARE GIVEN IN µg/L BELOW THE INTERVAL IN WHICH IT WAS OBSERVED. DETECTION LIMITS (ND) FOR ALL ANALYTES ARE 0.1 µg/L, EXCEPT FOR TCE AND PCE, WHICH ARE 0.01 µg/L.
5. ALL ANALYTES FOR UNSATURATED SOIL SAMPLES ARE NON-DETECT.
6. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'd |

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Overland Park, Kansas

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Designed by: A.C.E.
Drawn by: D.R.T.
Checked by: D.C.C.
Submitted by:

U.S. Army Corps of Engineers

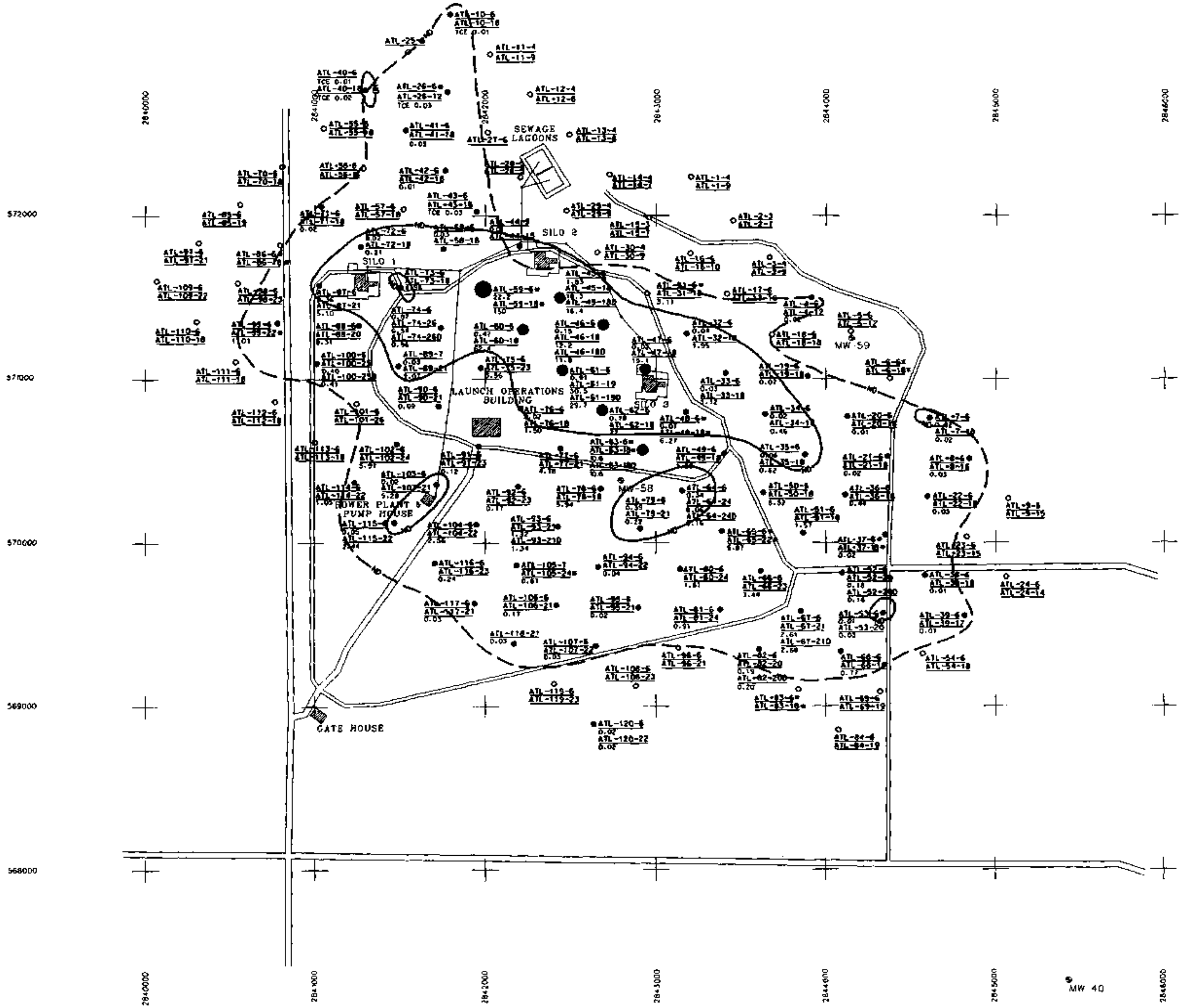
FEASIBILITY STUDY FOR OPERABLE UNIT NO. 2 - GROUNDWATER FMR NEBRASKA ORDNANCE PLANT - MEAD, NE

**APPROXIMATE AREAL EXTENT OF TCE IN SOIL GAS AT THE ADMINISTRATION AREA**

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No: 1-4
Sheet number: 1

WCS FILE: 92FS-39

B07NE003702-09105




**LEGEND:**

| SYMBOL | HIGHEST CONCENTRATION (µg/L) DETECTED AT EACH LOCATION |
|---|---|
| ○ | NOT DETECTED (SEE NOTE 3) |
| • | < 10 |
| ● | 10 - 100 |
| ⬤ | > 100 |
| ——— | APPROXIMATE SHALLOW TCE CONCENTRATION CONTOUR IN µg/L |
| — — | APPROXIMATE DEEP TCE CONCENTRATION CONTOUR IN µg/L |
| ATL-31-6 | SOIL GAS SAMPLE FROM 6 FEET BELOW GROUND SURFACE (BGS) |
| ATL-31-18 | SOIL GAS SAMPLE FROM 18 FEET BGS |
| ATL-31-18D | DUPLICATE SOIL GAS SAMPLE FROM 18 FEET BGS |
| ⊕MW-59 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| * | UNSATURATED SOIL SAMPLE COLLECTED AT THIS INTERVAL (SEE NOTE 6 FOR RESULTS) |
| —+— | SEWER LINES |

NOTES:

1. SAMPLES WERE COLLECTED FROM 6 FEET AND 18 FEET BGS UNLESS OTHERWISE INDICATED.
2. ALL SOIL GAS SAMPLES WERE ANALYZED FOR TRICHLOROETHENE (TCE) ONLY.
3. TCE WAS NOT DETECTED UNLESS INDICATED. IN WHICH CASE CONCENTRATIONS ARE IN µg/L BELOW THE INTERVAL IT WAS OBSERVED. DETECTION LIMIT (ND) FOR TCE IS 0.01 µg/L.
4. NO SOIL GAS SAMPLE WAS COLLECTED AT ATL-25-18 AND ATL-27-18 DUE TO SATURATED SOIL. NO SOIL GAS SAMPLE WAS COLLECTED AT ATL-118-6 DUE TO IMPERMEABILITY.
5. ALL UNSATURATED SOIL SAMPLES WERE ANALYZED FOR TCL VOCs.
6. ALL UNSATURATED SOIL SAMPLE LOCATIONS ARE NON-DETECT WITH THE EXCEPTION OF ATL-59-6 AND ATL-59-18 WHICH EXHIBITED 4 µg/kg OF TCE.
7. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

N

300 0 300 600
SCALE FEET

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| Symbol | Descriptions | Date | Apprv'd |
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Designed by: L.A.T.
Drawn by: D.R.T.
Checked by: D.C.C.
Submitted by:

U.S. Army Corps of Engineers

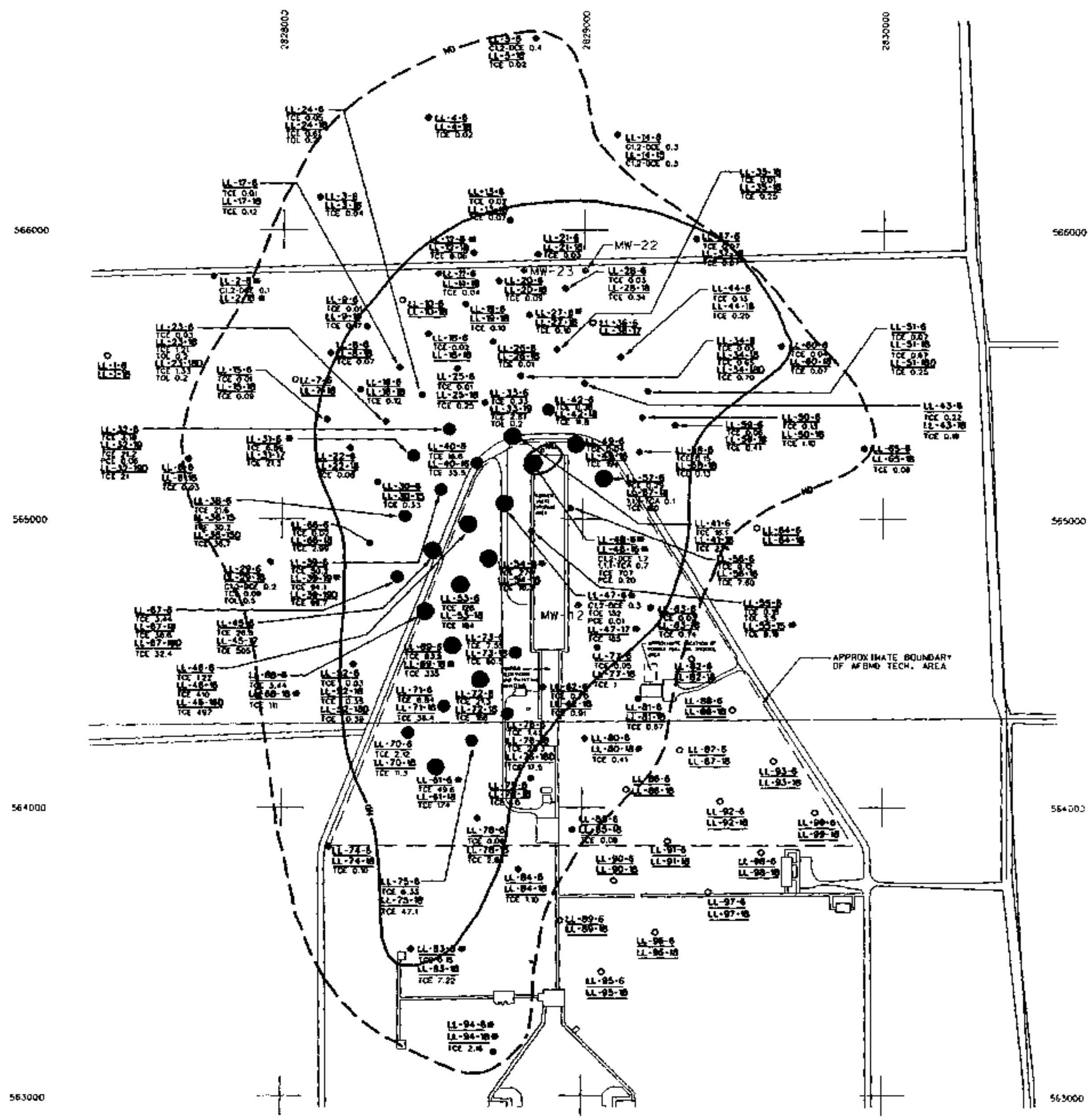
FEASIBILITY STUDY
FOR OPERABLE UNIT NO 2 - GROUNDWATER
FMR NEBRASKA ORDNANCE PLANT - MEAD, NE

**APPROXIMATE AREAL EXTENT OF TCE IN SOIL GAS AT THE ATLAS MISSILE AREA**

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No: 1-5
Sheet number: 1

WCS FILE 92F5-4D

B07NE003702-09106

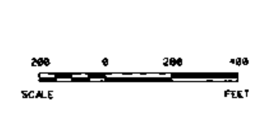



**LEGEND:**

| SYMBOL | HIGHEST CONCENTRATION (µg/L) DETECTED AT EACH LOCATION |
|---|---|
| ○ | NOT DETECTED (SEE NOTE 4) |
| • | < 10 |
| ● | 10 - 100 |
| ⬤ | > 100 |
| ——— | APPROXIMATE SHALLOW TCE CONCENTRATION CONTOUR IN µg/L |
| — — | APPROXIMATE DEEP TCE CONCENTRATION CONTOUR IN µg/L |
| LL-23-6 | SOIL GAS SAMPLE FROM 6 FEET BELOW GROUND SURFACE (BGS) |
| LL-23-18 | SOIL GAS SAMPLE FROM 18 FEET BGS |
| LL-23-18D | DUPLICATE SOIL GAS SAMPLE FROM 18 FEET BGS |
| ⊕ MW-22 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ✱ | UNSATURATED SOIL SAMPLE ALSO COLLECTED AT THIS INTERVAL (SEE NOTE 6 FOR RESULTS) |

NOTES:

1. SAMPLES WERE COLLECTED FROM 6 FEET AND 18 FEET BGS UNLESS OTHERWISE INDICATED.
2. C1,2-DCE = CIS 1,2-DICHLOROETHENE
   1,1,1-TCA = 1,1,1-TRICHLOROETHANE
   TCE = TRICHLOROETHENE
   PCE = TETRACHLOROETHENE
   TOL = TOLUENE
3. ALL SOIL GAS SAMPLES WERE ANALYZED FOR CIS-1,2-DICHLOROETHENE, 1,1-DICHLOROETHANE, 1,1,1-TRICHLOROETHANE, TRICHCHLOROETHENE, TETRACHLOROETHENE, BENZENE, TOLUNE, ETHYLBENZENE, AND XYLENE SAMPLE LOCATIONS LL1-66 THROUGH LL1-99 WERE ANALYZED FOR TCE ONLY.
4. ALL ANALYTES WERE NOT DETECTED UNLESS INDICATED, IN WHICH CASE CONCENTRATIONS ARE IN µg/L BELOW THE INTERVAL IN WHICH IT WAS OBSERVED. DETECTION LIMITS (ND) FOR ALL ANALYTES ARE 0.1 µg/L, EXCEPT FOR TCE AND PCE, WHICH ARE 0.01 µg/L.
5. ALL UNSATURATED SOIL SAMPLES WERE ANALYZED FOR TCL VOCs.
6. ALL UNSATURATED SOIL SAMPLE LOCATIONS ARE NON-DETECT WITH THE EXCEPTION OF LL-54-6 WHICH EXHIBITED 10 µg/kg OF TCE.
7. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

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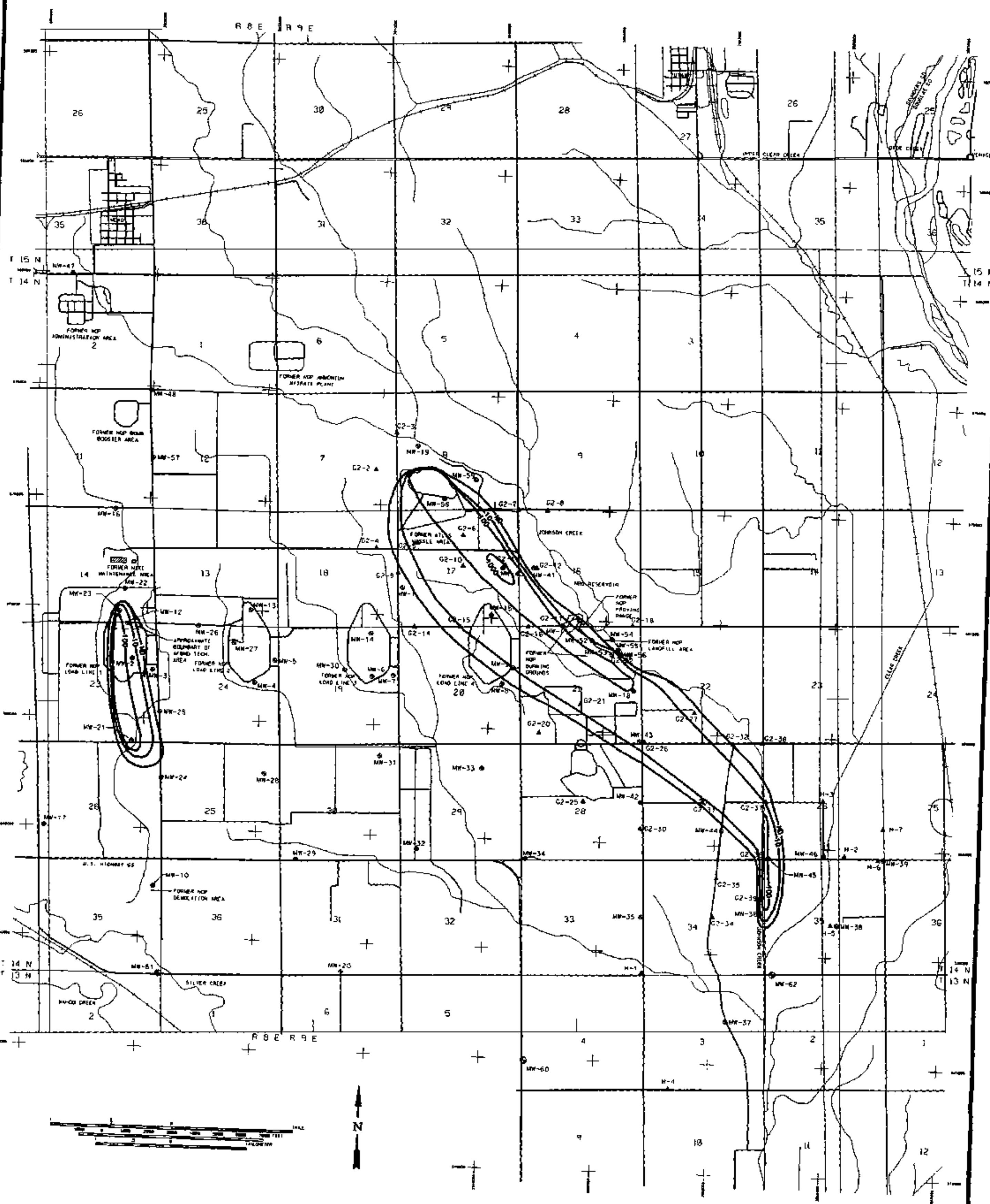
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE

**APPROXIMATE AREAL EXTENT OF TCE IN SOIL GAS AT LOAD LINE 1**

| | |
|---|---|
| Designed by: | L.A.T. |
| Drawn by | D.R.T. |
| Checked by | D.C.C. |
| Submitted by | |
| Scale | AS NOTED |
| Date | DECEMBER, 1994 |
| Dwg No. | 1-6 |
| Sheet number | 1 |

MCS FILE: 92FS-41

B07NE003702-09107




**LEGEND:**

| | |
|---|---|
| ——— | APPROXIMATE TCE CONCENTRATION CONTOUR IN µg/L |
| ⊕ MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992, NOVEMBER 1992, FEBRUARY 1993, MAY 1993, AND JULY 1993 GROUNDWATER SAMPLING DATA.
2. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L.
3. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
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| Symbol | Descriptions | Date | Apprv'd |
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KANSAS CITY, MISSOURI

Designed by: A.C.E.
Drawn by: D.R.T
Checked by: D.C.C
Submitted by:

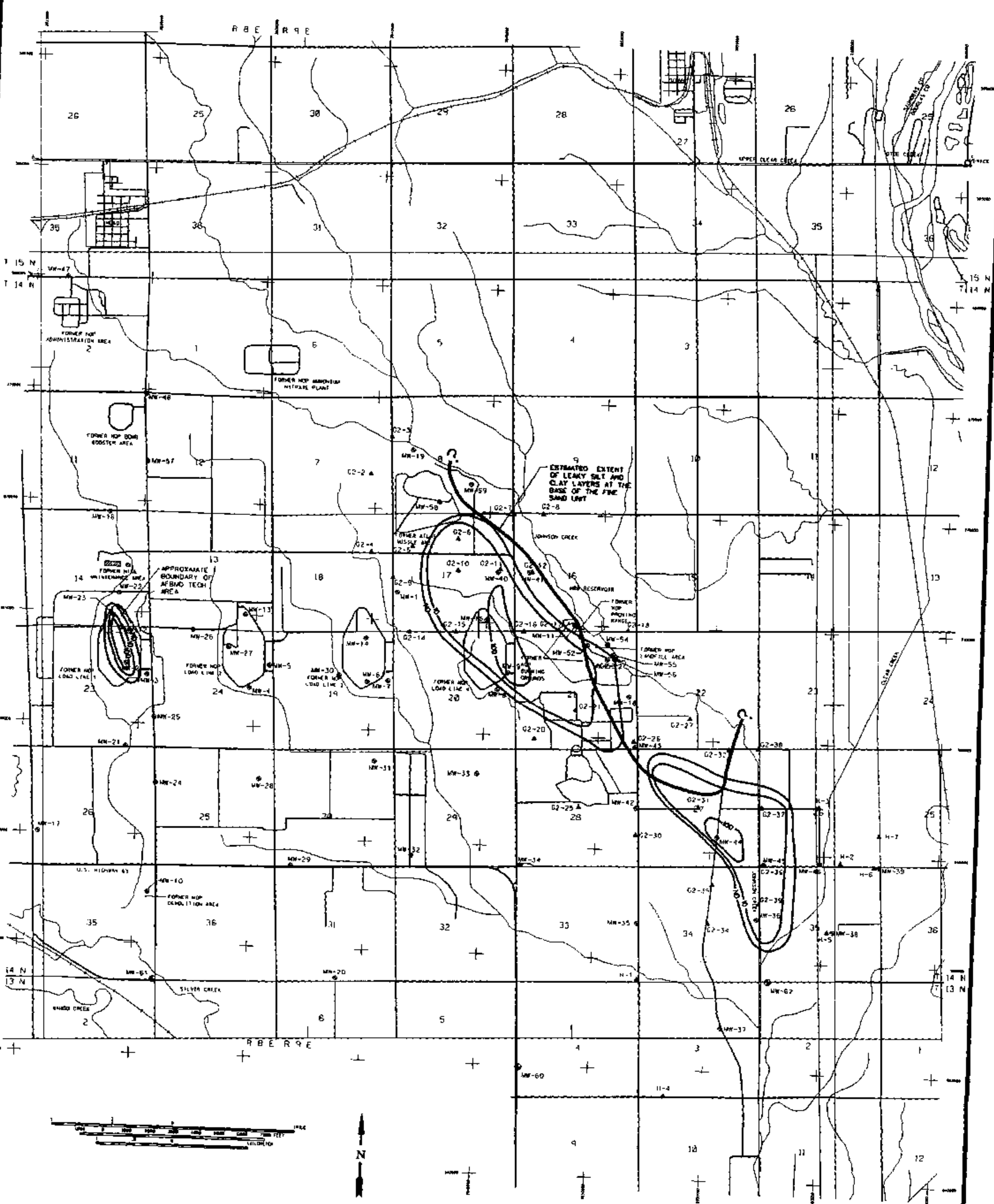
U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT • MEAD, NE.

**APPROXIMATE AREAL EXTENT OF TCE IN SHALLOW GROUNDWATER**

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No.: 1-7
Sheet number: 1

MCS FILE 92FS-31




**LEGEND:**

| | |
|---|---|
| ——— | APPROXIMATE TCE CONCENTRATION CONTOUR IN µg/L |
| ● MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

NOTES:

1. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992, NOVEMBER 1992, FEBRUARY 1993, MAY 1993, AND JULY 1993 GROUNDWATER SAMPLING DATA.
2. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L.
3. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'v'd |
| | | | |

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KANSAS CITY, MISSOURI

Designed by: A.C.E

Drawn by: D.R.T

Checked by: D.C.C

Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**APPROXIMATE AREAL EXTENT OF TCE IN INTERMEDIATE GROUNDWATER**

Scale: AS NOTED

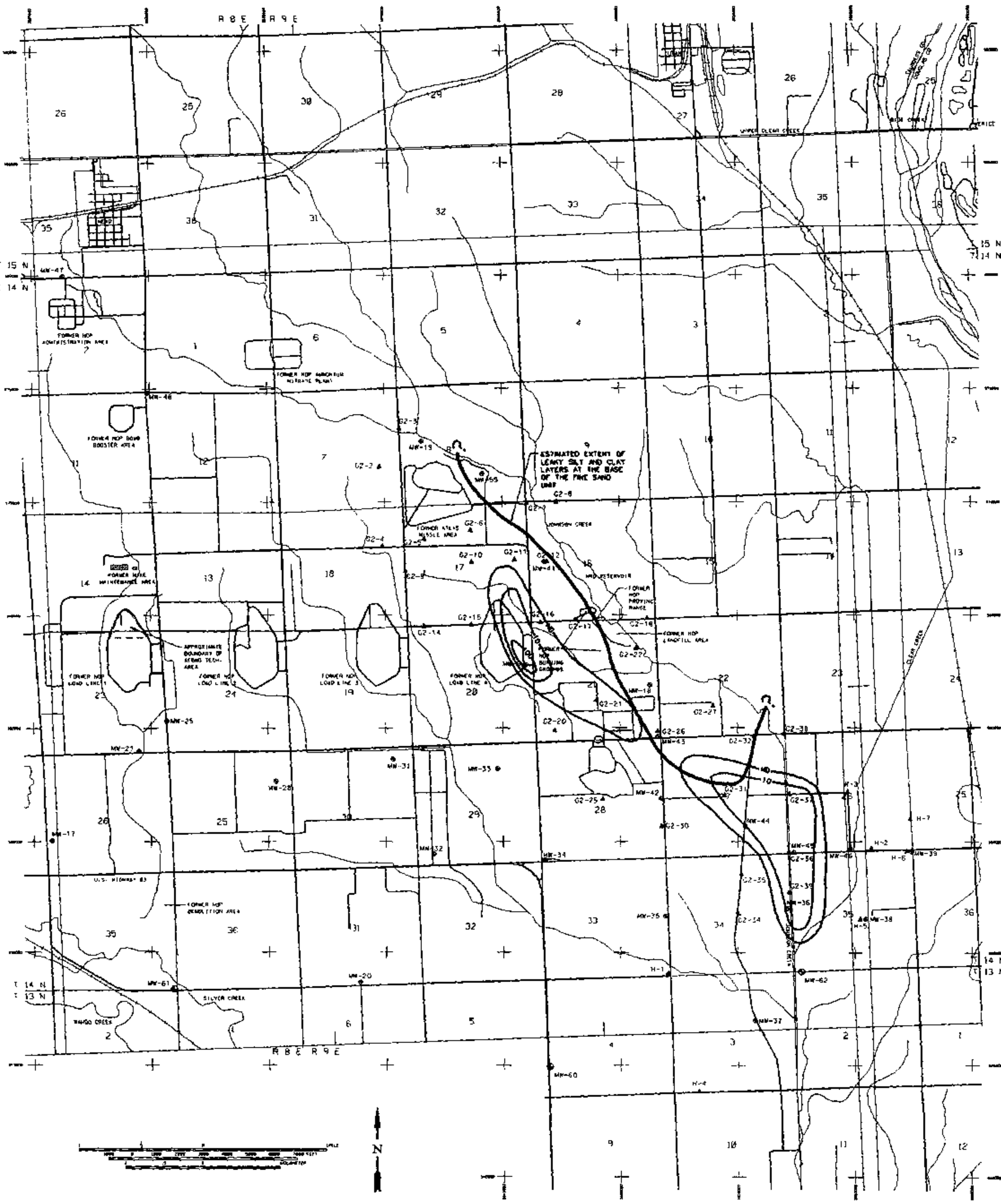
Date: DECEMBER, 1994

Dwg No.: 1-8

Sheet number: 1

MCS (A.E 92)S-32

B07NE003702-09109




**LEGEND:**

- APPROXIMATE TCE CONCENTRATION CONTOUR IN µg/L
- ● MW-10 GROUNDWATER MONITORING WELL CLUSTER LOCATION
- ▲ G2-30 GROUNDWATER HEADSPACE SCREENING LOCATION
- 36 SECTION
- T 14 N TOWNSHIP 14 NORTH
- R 9 E RANGE 9 EAST

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992, NOVEMBER 1992, FEBRUARY 1993, MAY 1993, AND JULY 1993 GROUNDWATER SAMPLING DATA.
2. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L.
3. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'd |
| | | | |

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KANSAS CITY, MISSOURI

Designed by: A.C.E.

Drawn by: D.R.T.

Checked by: D.C.C.

Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR NEBRASKA ORDNANCE PLANT - MEAD, NE.

**APPROXIMATE AREAL EXTENT OF TCE IN DEEP GROUNDWATER**

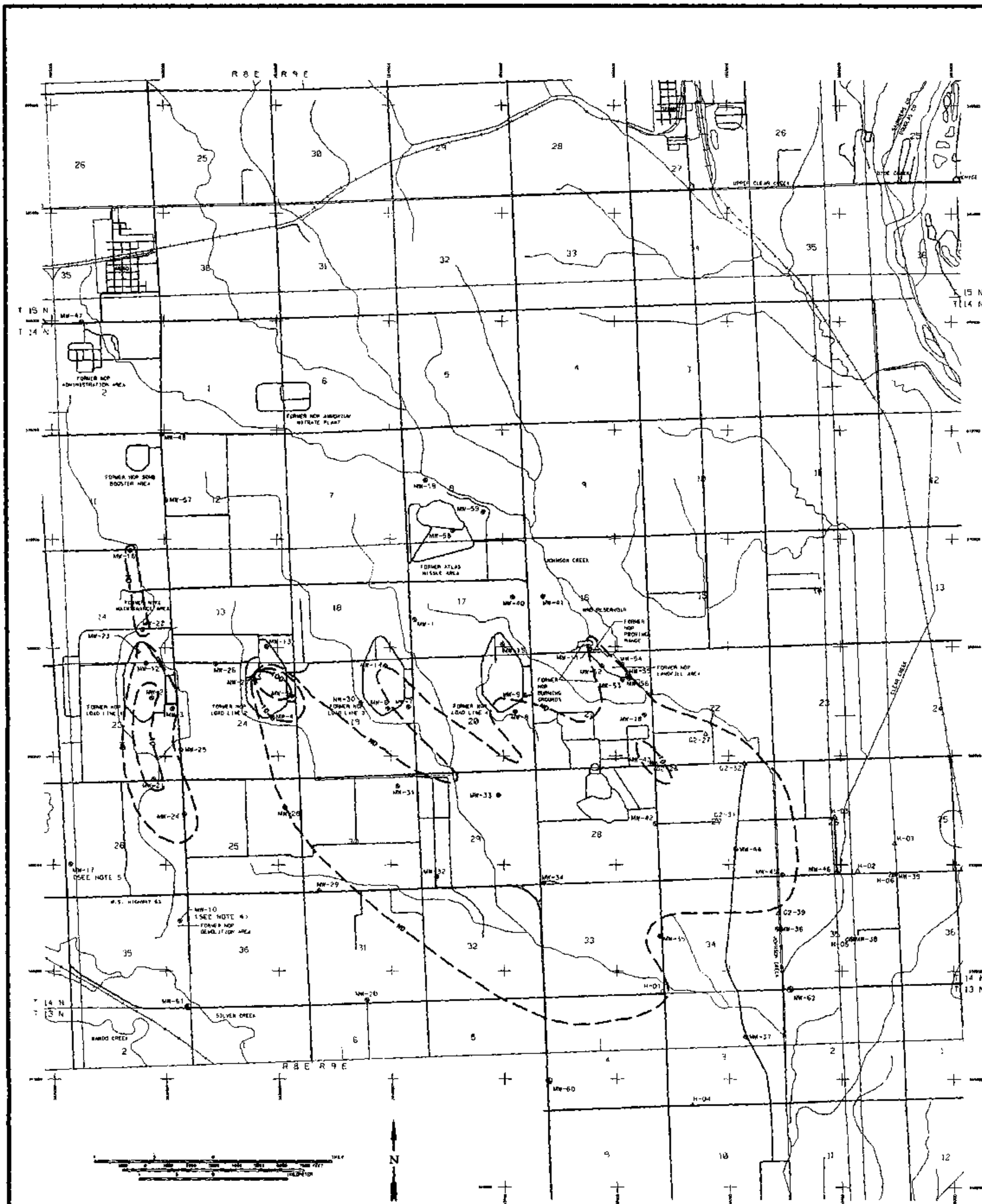
Scale: AS NOTED

Date: DECEMBER, 1994

Dwg. No.: 1-9

Sheet Number: 1

MCS FILE 92FS-33




**LEGEND:**

- APPROXIMATE RDX CONCENTRATION CONTOUR IN µg/L
- MW-10 GROUNDWATER MONITORING WELL CLUSTER LOCATION
- G2-30 GROUNDWATER HEADSPACE SCREENING LOCATION
- H-01 HYDROPUNCH SAMPLING LOCATION
- 36 SECTION
- T 14 N TOWNSHIP 14 NORTH
- R 9 E RANGE 9 EAST

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992, NOVEMBER 1992, FEBRUARY 1993, MAY 1993, AND JULY 1993 GROUNDWATER SAMPLING DATA.
2. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
3. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.
4. RDX WAS DETECTED IN MW-10A DURING THE 2ND AND 4TH QUARTERLY SAMPLING EVENTS AT 0.15 AND 0.19 µg/L, RESPECTIVELY.
5. RDX WAS DETECTED IN MW-17A DURING THE RI AT 0.16 µg/L.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'vd |
| | | | |

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KANSAS CITY MISSOURI

Designed by: A.C.E.
Drawn by: D.R.T.
Checked by: B.C.C.
Submitted by:

U.S. Army Corps of Engineers

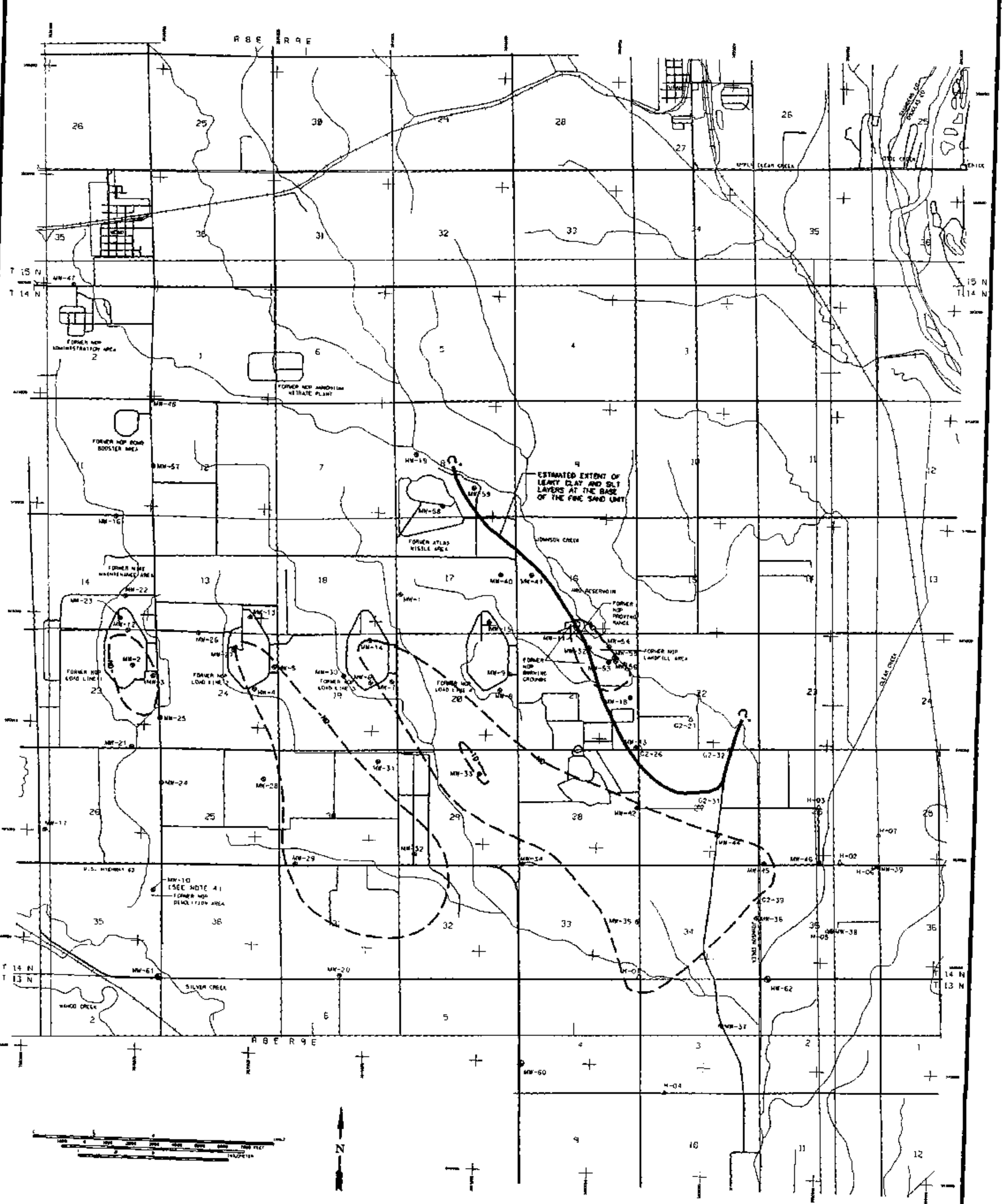
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

# APPROXIMATE AREAL EXTENT OF RDX IN SHALLOW GROUNDWATER

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No.: 1-10
Sheet number: 1

WCS FILE 92F5-34

B07NE003702-09111




**LEGEND:**

| | |
|---|---|
| — — | APPROXIMATE RDX CONCENTRATION CONTOUR IN µg/L |
| ⊕ MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| △ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| △ H-01 | HYDROPUNCH SAMPLING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992, NOVEMBER 1992, FEBRAUARY 1993, MAY 1993, AND JULY 1993 GROUNDWATER SAMPLING DATA.
2. DETECTED LIMIT (MDL) FOR RDX IS 0.08 TO 0.15 µg/L.
3. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.
4. RDX WAS DETECTED IN MW-10B DURING THE 2ND, 3RD AND 4TH QUARTERLY SAMPLING EVENTS AT 0.25, 0.29 AND 0.25 µg/L, RESPECTIVELY.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'd |
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U.S. Army Corps of Engineers

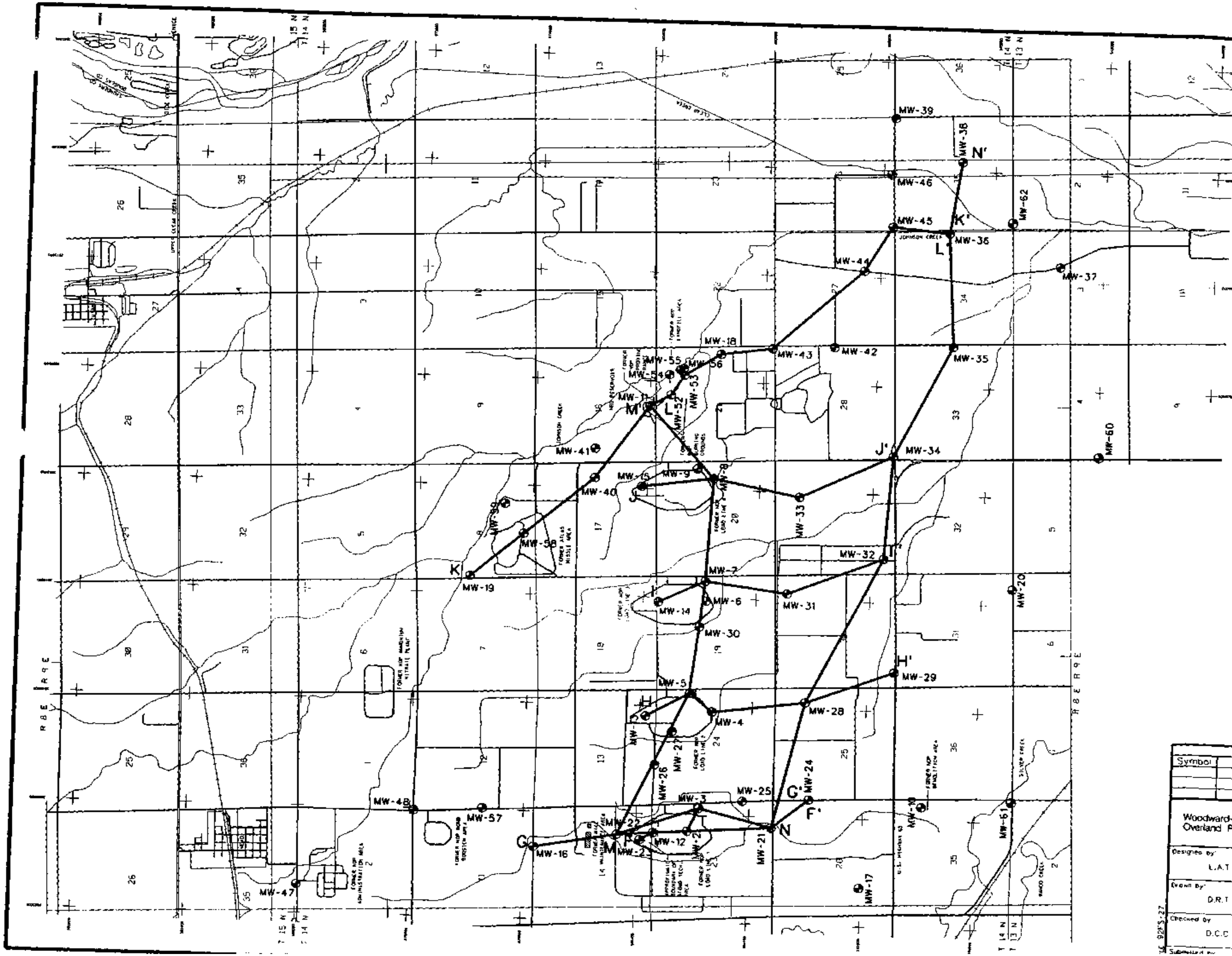
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FOR NEBRASKA ORDNANCE PLANT - MEAD, NE

**APPROXIMATE AREAL EXTENT OF RDX IN INTERMEDIATE GROUNDWATER**

Designed by: A.C.E.
Drawn by: D.R.T.
Checked by: D.C.C.
Submitted by:
Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 1-11
Sheet number: 1

WCC FILE: 92F5-35

B07NE003702-09112




LEGEND:

MW-28 MONITORING WELL LOCATIONS

36 SECTION

T 14 N TOWNSHIP 14 NORTH

R 9 E RANGE 9 EAST

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

| Revisions | | | |
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| Symbol | Descriptions | Date | Apprv'd |
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Designed by: L.A.T

Drawn by: D.R.T

Checked by: D.C.C

Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO 2 - GROUNDWATER
FMR NEBRASKA ORDNANCE PLANT - MEAD, NE.

**LOCATIONS OF RDX AND TCE VERTICAL EXTENT CROSS-SECTIONS**

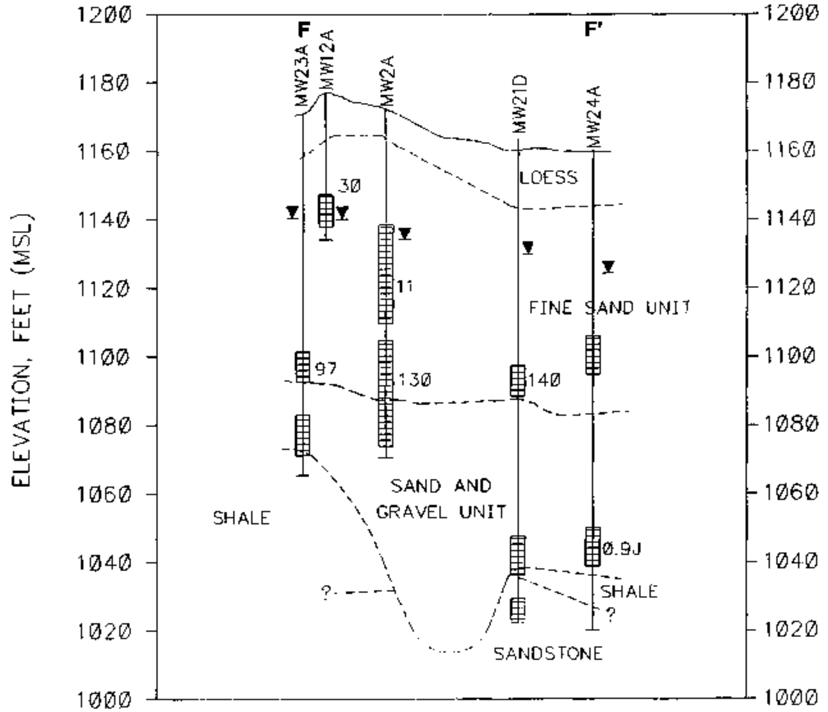
Scale: AS NOTED

Date:

Sheet number:

92FS-27

B07NE003702-09113




LEGEND:

MW23A LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

SCREENED INTERVAL OF EACH WELL IN CLUSTER

GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

Ø.9J TCE CONCENTRATION DETECTED IN GROUNDWATER IN µg/L (LIMIT OF DETECTION 1.Ø µg/L). "J" INDICATES CONCENTRATION BELOW QUANTIFICATION LIMIT.

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 1ØØX.
5. ALL SHALE IN THIS CROSS-SECTION IS PART OF THE OMADI SHALE FACIES.
6. ALL SANDSTONE IN THIS CROSS-SECTION IS PART OF THE OMADI SANDSTONE FACIES.

4ØØØ Ø 4ØØØ 8ØØØ
SCALE FEET

Revisions

| Symbol | Descriptions | Date | Apprv'd |
| --- | --- | --- | --- |
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Designed by: G.P.
Drawn by: C.H.
Checked by: G.W.W.
Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 – GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT – MEAD, NEBRASKA

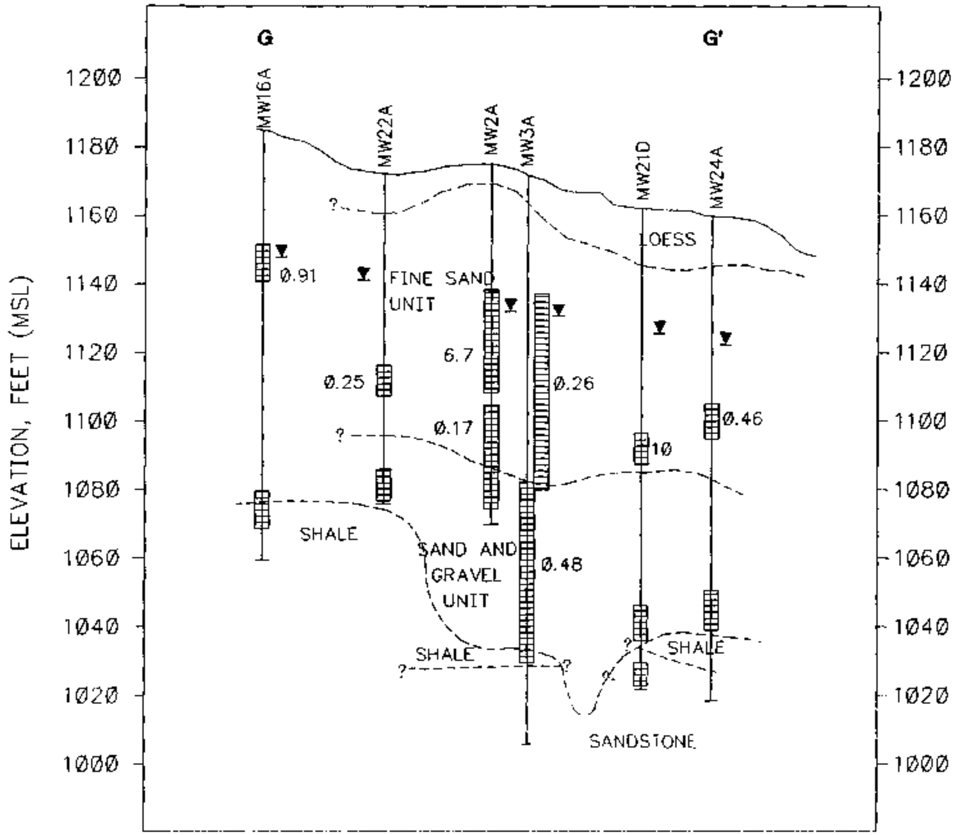
CONCENTRATIONS OF TCE DETECTED IN GROUNDWATER CROSS-SECTION F-F'

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 1-13
Sheet number: 1

ACAD FILE: 92FS-S

ACAD FILE: 92KW030S

B07NE003702-09114




## LEGEND:

MW16A LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

[screened-interval symbol] SCREENED INTERVAL OF EACH WELL IN CLUSTER

[groundwater-level symbol] GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

Ø.25 RDX CONCENTRATION DETECTED IN GROUNDWATER IN µg/l. (LIMIT OF DETECTION Ø.15 µg/l).

NOTES:

1. SEE DRAWING 1–12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 1ØØX.
5. ALL SHALE IN THIS CROSS-SECTION IS PART OF THE OMADI SHALE FACIES.
6. ALL SANDSTONE IN THIS CROSS-SECTION IS PART OF THE OMADI SANDSTONE FACIES.

4ØØØ 0 4ØØØ 8ØØØ

SCALE FEET

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 – GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT – MEAD, NEBRASKA

CONCENTRATIONS OF RDX DETECTED IN GROUNDWATER CROSS-SECTION G-G'

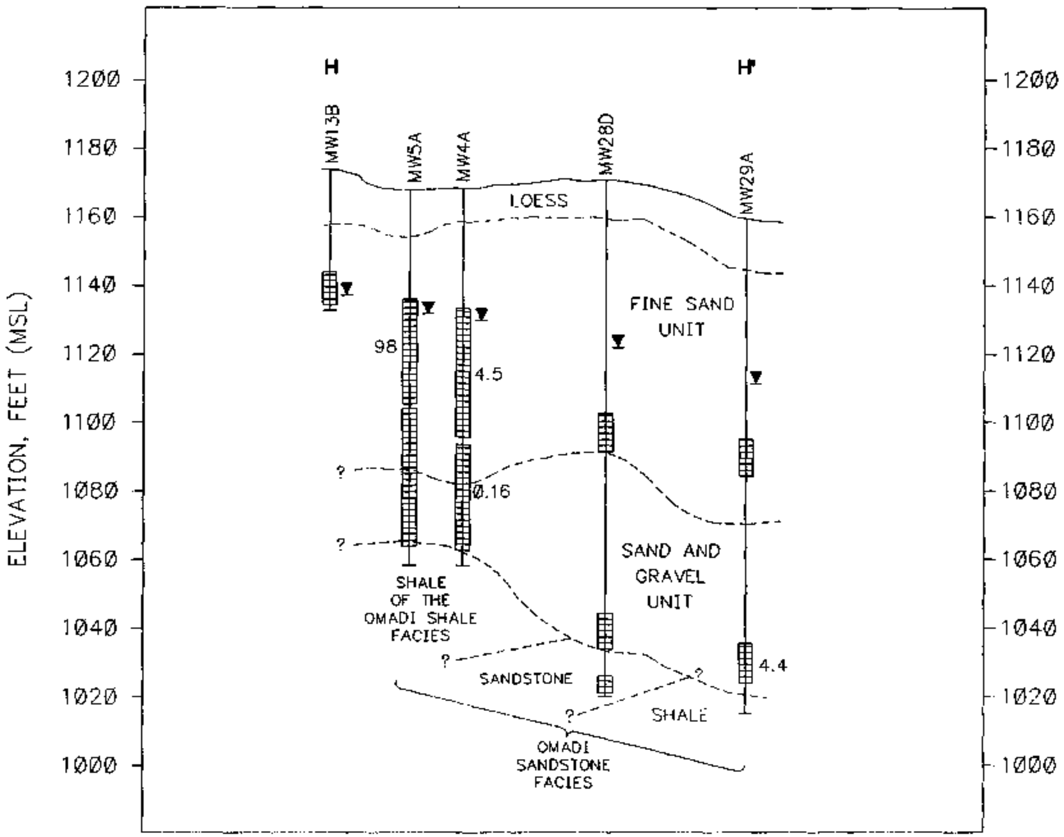
Designed by: G.P.
Drawn by: C.H.
Checked by: G.W.W.
Submitted by: [signature]

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No.: 1-14
Sheet number: 1

ACAD FILE: 92FS-V

ACAD 12_c4 11/17/94 11:15:11
ACAD FILE: 92KW030v

B07NE003702-09115




LEGEND:

MW13B LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

SCREENED INTERVAL OF EACH WELL IN CLUSTER

GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

0.16 RDX CONCENTRATION DETECTED IN GROUNDWATER IN µg/L (LIMIT OF DETECTION 0.15 µg/L).

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 100X.

4000 0 4000 8000

SCALE FEET

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
| | | | |

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KANSAS CITY, MISSOURI

Designed by: G.P.
Drawn by: C.H.
Checked by: G.W.W.
Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 – GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT – MEAD, NEBRASKA

CONCENTRATIONS OF RDX DETECTED IN GROUNDWATER CROSS-SECTION H-H'

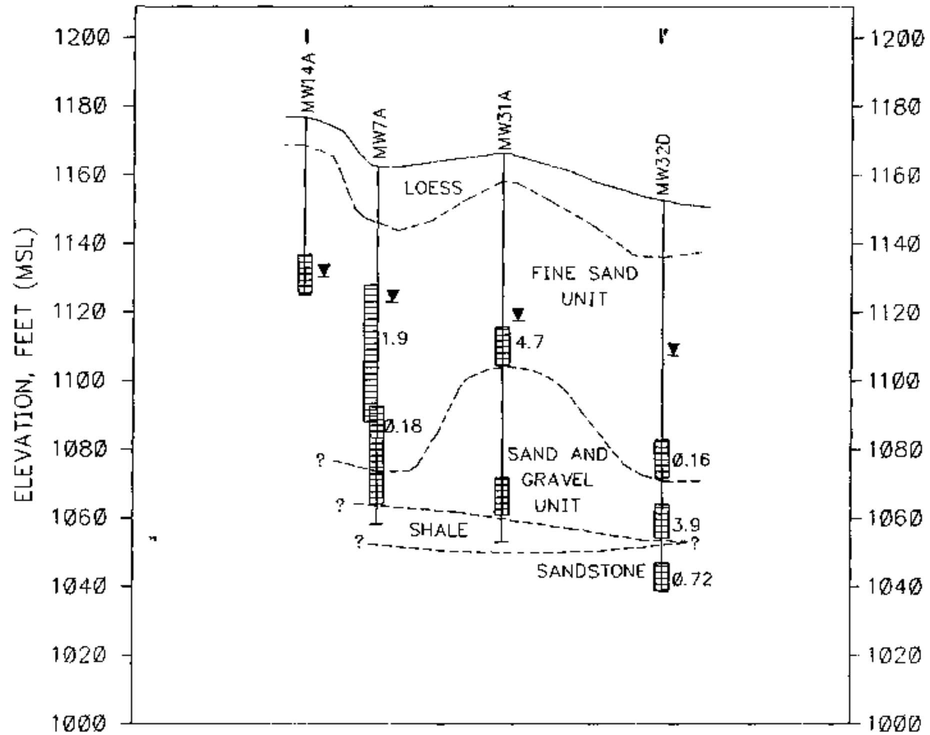
Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 1-15
Sheet number: 1

ACAD FILE: 92FS-U

ACAD 12_c4
11/17/94 11:16:13

ACAD FILE: 92KW830U
D.R.T. SC 1=1

B07NE003702-09116




LEGEND:

| | |
|---|---|
| MW14A | LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER |
| (screen symbol) | SCREENED INTERVAL OF EACH WELL IN CLUSTER |
| ▼ | GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992 |
| Ø.16 | RDX CONCENTRATION DETECTED IN GROUNDWATER IN $\mu$g/L (LIMIT OF DETECTION Ø.15 $\mu$g/L). |

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 1ØØX.
5. ALL SHALE IN THIS CROSS-SECTION IS PART OF THE OMADI SHALE FACIES.
6. ALL SANDSTONE IN THIS CROSS-SECTION IS PART OF THE OMADI SANDSTONE FACIES.

4000 Ø 4000 8000

SCALE FEET

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NEBRASKA

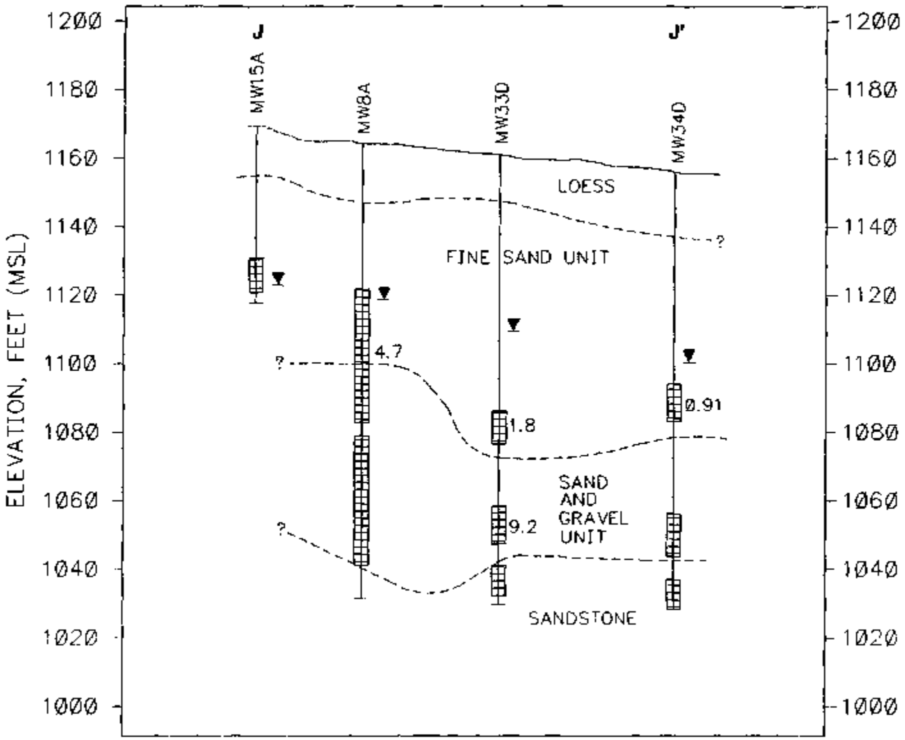
**CONCENTRATIONS OF RDX DETECTED IN GROUNDWATER**
***CROSS-SECTION I-I'***

| | |
|---|---|
| Designed by: | G.P. |
| Drawn by: | C.H. |
| Checked by: | G.W.W. |
| Submitted by: | |
| Scale: | AS NOTED |
| Date: | DECEMBER, 1994 |
| Dwg. No. | 1-16 |
| Sheet number | 1 |

ACAD FILE: 92FS-W

ACAD 12_c4
11/17/94 11:17:29

ACAD FILE: 92KW830W




## LEGEND:

MW15A LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

SCREENED INTERVAL OF EACH WELL IN CLUSTER

GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

0.91 RDX CONCENTRATION DETECTED IN GROUNDWATER IN µg/L (LIMIT OF DETECTION 0.15 µg/L).

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 100X.
5. THE SANDSTONE IN THIS CROSS-SECTION IS PART OF THE OMADI SANDSTONE FACIES.

4000 0 4000 8000

SCALE FEET

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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KANSAS CITY, MISSOURI

Designed by: G.P.
Drawn by: C.H.
Checked by: G.W.W.
Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NEBRASKA

CONCENTRATIONS OF RDX DETECTED IN GROUNDWATER CROSS-SECTION J-J'

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 1-17
Sheet number: 1

ACAD FILE: 92FS-N

ACAD FILE: 92KW810N

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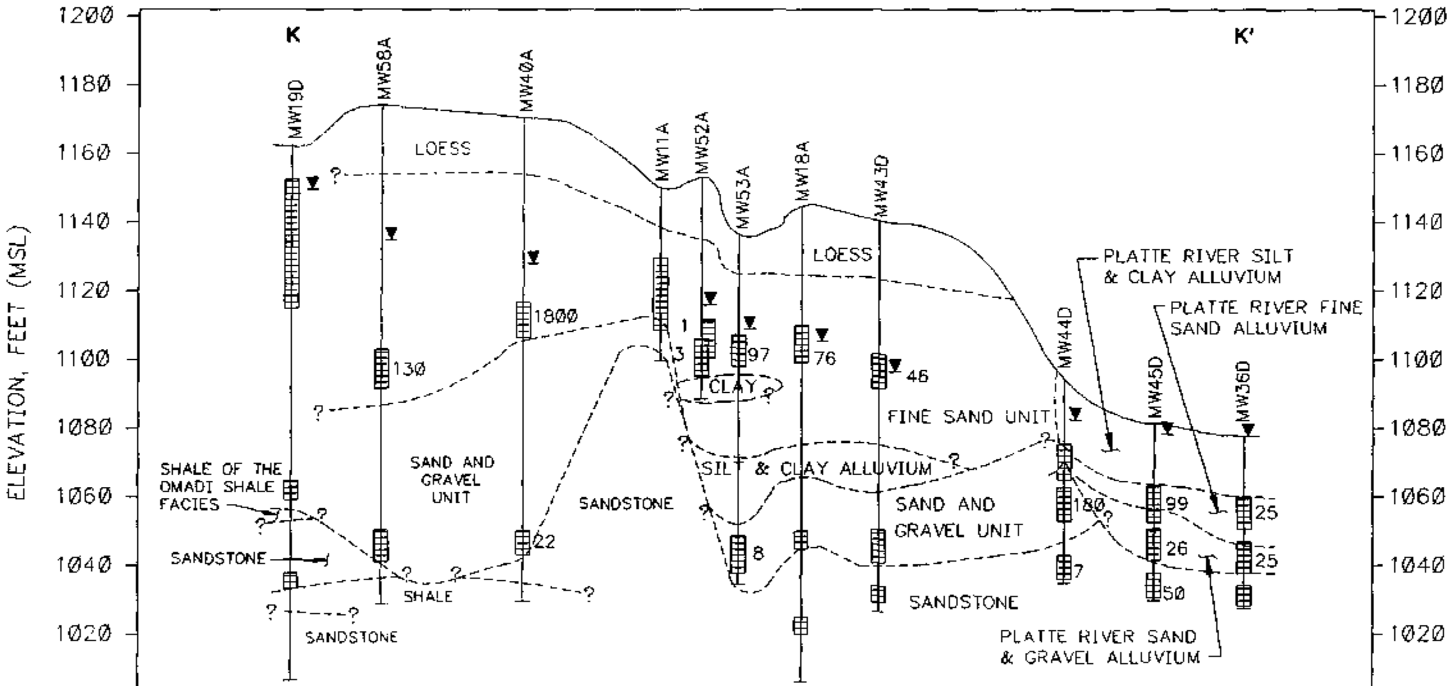


## LEGEND:

MW19D LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

SCREENED INTERVAL OF EACH WELL IN CLUSTER

▼ GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

25 TCE CONCENTRATION DETECTED IN GROUNDWATER IN μg/L (LIMIT OF DETECTION 1.0 μg/L).

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 100X.
5. ALL SANDSTONES AND SHALES IN THIS CROSS-SECTION ARE PART OF THE OMADI SANDSTONE FACIES UNLESS OTHERWISE NOTED.

4000 0 4000 8000

SCALE FEET

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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KANSAS CITY, MISSOURI

Designed by: G.P.
Drawn by: C.H.
Checked by: G.W.W.
Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NEBRASKA

CONCENTRATIONS OF TCE DETECTED IN GROUNDWATER CROSS-SECTION K-K'

Scale: AS NOTED
Date: NOVEMBER, 1994
Dwg No.: 1-18
Sheet number: 1

ACAD FILE: 92FS-P

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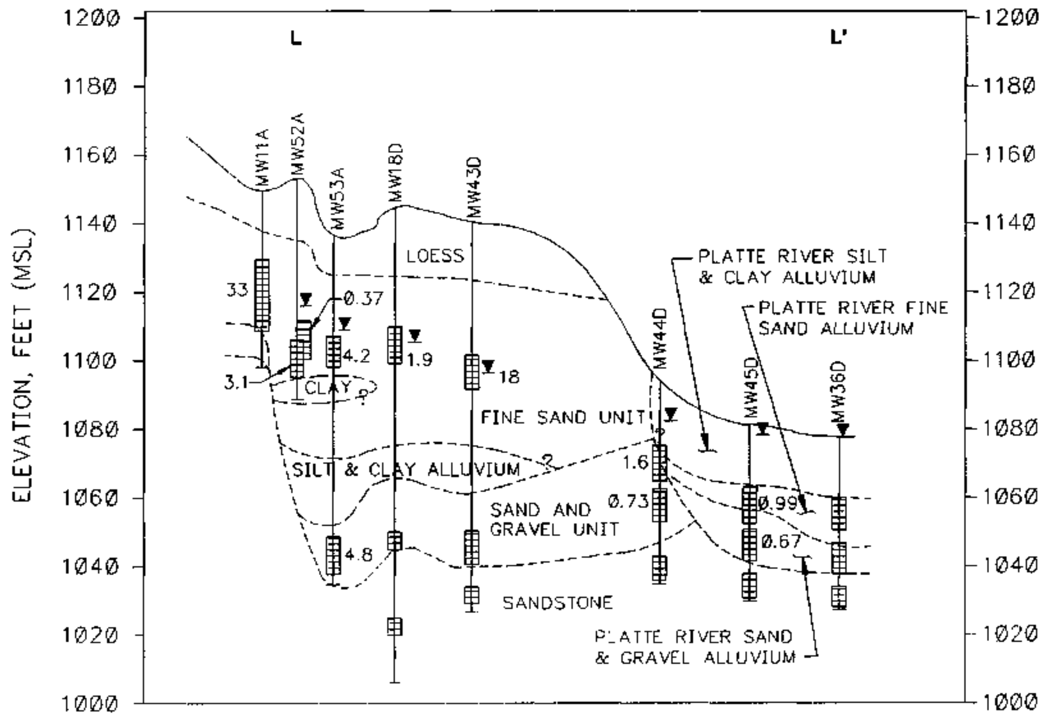
11/17/94 11:19:25
ACAD FILE: 92KW030P
D.R.T. SC: 1=1




LEGEND:

MW52A — LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

[screen symbol] — SCREENED INTERVAL OF EACH WELL IN CLUSTER

▼ — GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

0.37 — RDX CONCENTRATION DETECTED IN GROUNDWATER IN μg/L (LIMIT OF DETECTION 0.15 μg/L).

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 100X.
5. ALL SANDSTONE IN THIS CROSS-SECTION IS PART OF THE OMADI SANDSTONE FACIES.

4000 0 4000 8000
SCALE FEET

| Revisions | | | |
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| Symbol | Descriptions | Date | Apprv'd |
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KANSAS CITY, MISSOURI

Designed by: G.P.
Drawn by: C.H.
Checked by: G.W.W.
Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 – GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT – MEAD, NEBRASKA

CONCENTRATIONS OF RDX DETECTED IN GROUNDWATER CROSS-SECTION L-L'

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 1-19
Sheet number: 1

ACAD FILE: 92FS-X

ACAD 12_c4
11/17/94 11:28:26

ACAD FILE: 92KW030P
D.R.T. SC 1=1

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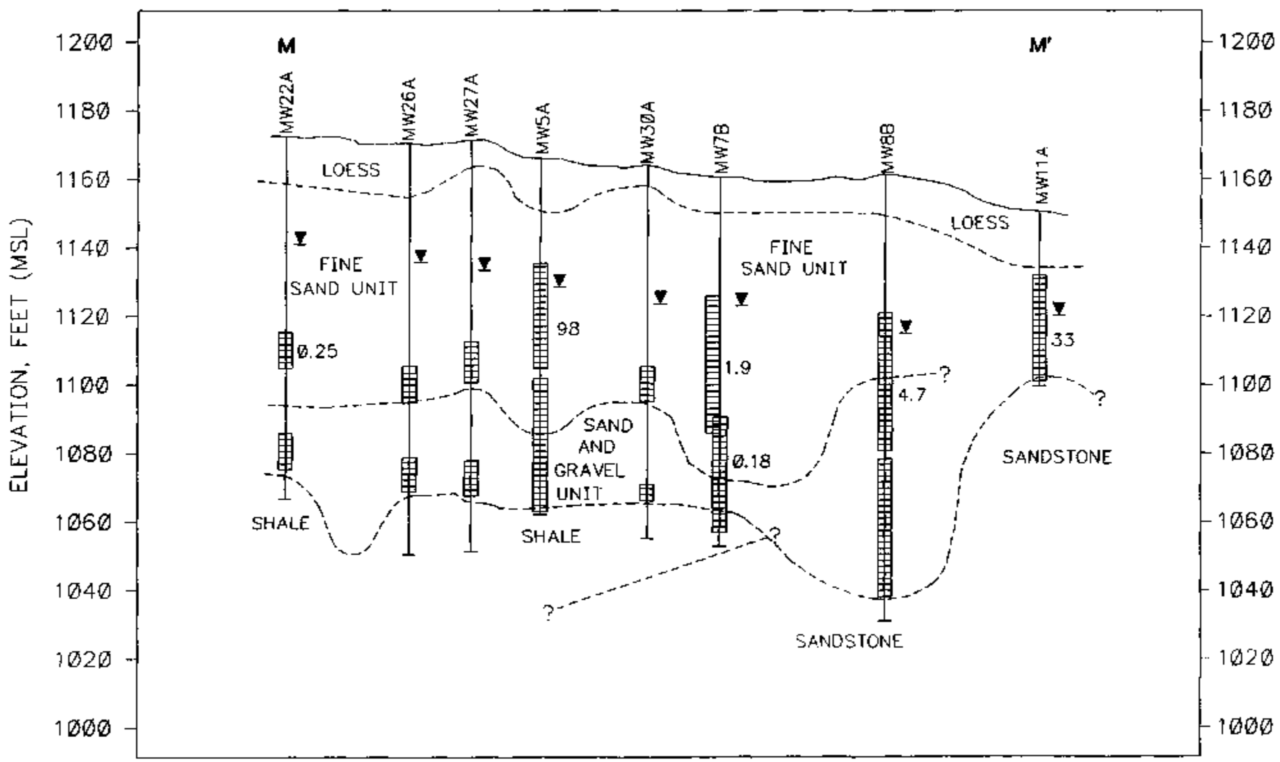


## LEGEND:

MW22A LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

SCREENED INTERVAL OF EACH WELL IN CLUSTER

GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

Ø 25 RDX CONCENTRATION DETECTED IN GROUNDWATER IN μg/L (LIMIT OF DETECTION Ø.15 μg/L).

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 1ØØX.
5. ALL SANDSTONE IN THIS CROSS-SECTION IS PART OF THE OMADI SANDSTONE FACIES.
6. ALL SHALE IN THIS CROSS-SECTION IS PART OF THE OMADI SHALE FACIES.

4ØØØ Ø 4ØØØ 8ØØØ

SCALE FEET

| Revisions | | | |
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| Symbol | Descriptions | Date | Apprv'd |
| | | | |

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KANSAS CITY, MISSOURI

Designed by: G.P.
Drawn by: C.H.
Checked by: G.W.W.
Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NEBRASKA

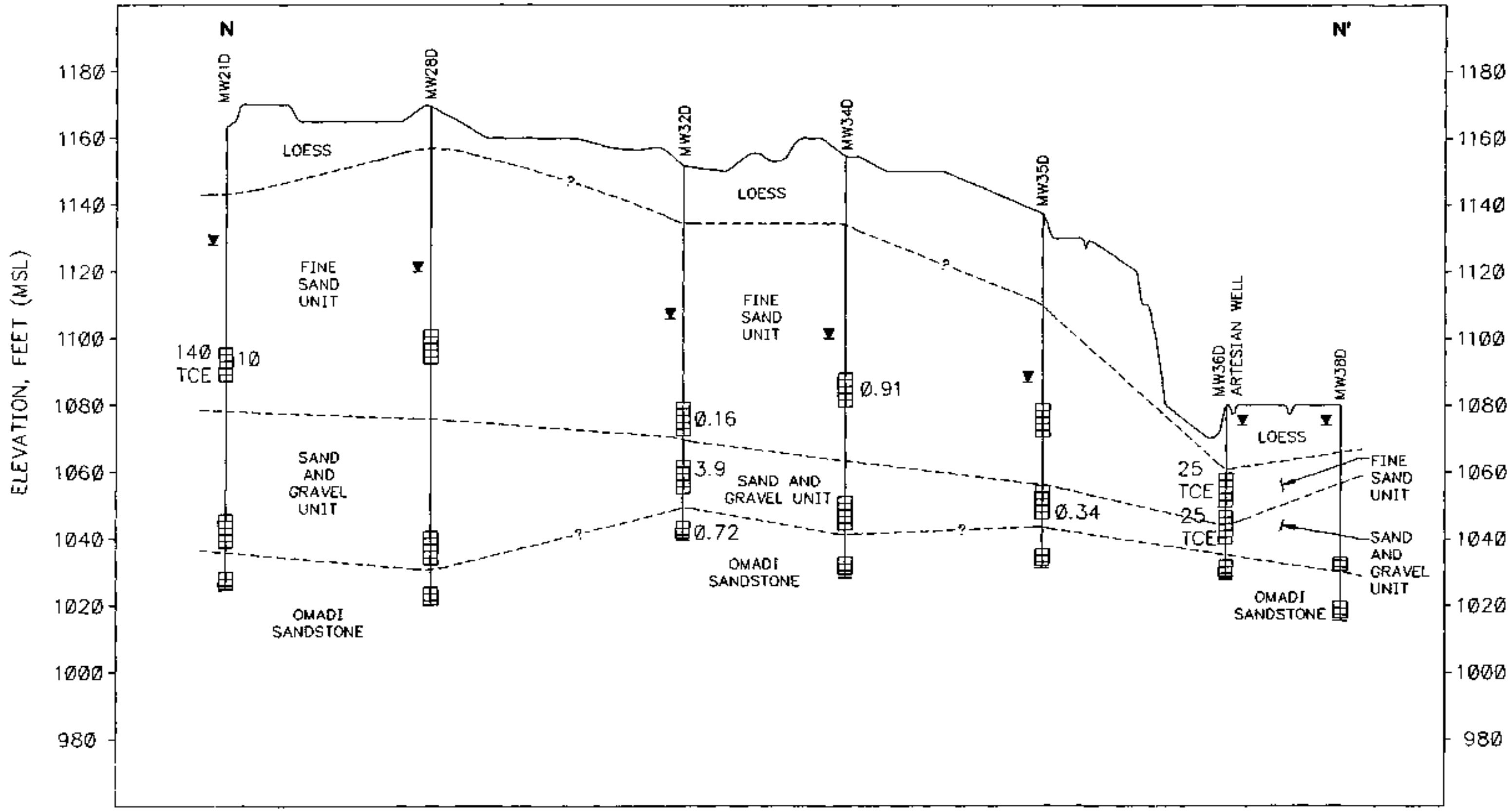
CONCENTRATIONS OF RDX DETECTED IN GROUNDWATER CROSS-SECTION M-M'

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 1-20
Sheet Number: 1

ACAD FILE: 92FS-M

ACAD 12_c4 11/17/94 11:21:37
ACAD FILE: 92KWB30M

B07NE003702-09121




## LEGEND:

MW21D LOCATION OF DEEPEST MONITORING WELL BORING IN EACH CLUSTER

SCREENED INTERVAL OF EACH WELL IN CLUSTER

GROUNDWATER LEVEL FOR DEEPEST WELL IN CLUSTER AS MEASURED ON OCTOBER 14, 1992

10 RDX CONCENTRATION DETECTED IN GROUNDWATER IN µg/L (LIMIT OF DETECTION 0.15 µg/L).

140 TCE — TCE CONCENTRATION DETECTED IN GROUNDWATER IN µg/L (LIMIT OF DETECTION 1.0 µg/L).

NOTES:

1. SEE DRAWING 1-12 FOR VERTICAL EXTENT CROSS-SECTION LOCATIONS.
2. ALL CONCENTRATIONS NOT DETECTED UNLESS INDICATED.
3. SUBSURFACE GEOLOGIC CONDITIONS ARE BASED ON MONITORING WELL BORING LOGS. GEOLOGIC CONDITIONS SHOWN AWAY FROM BORINGS ARE INTERPRETIVE.
4. VERTICAL EXAGGERATION 100X

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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Overland Park, Kansas

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KANSAS CITY, MISSOURI

Designed by: R.G.P.
Drawn by: M.A.L.
Checked by: G.W.W.
Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO.2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NEBRASKA

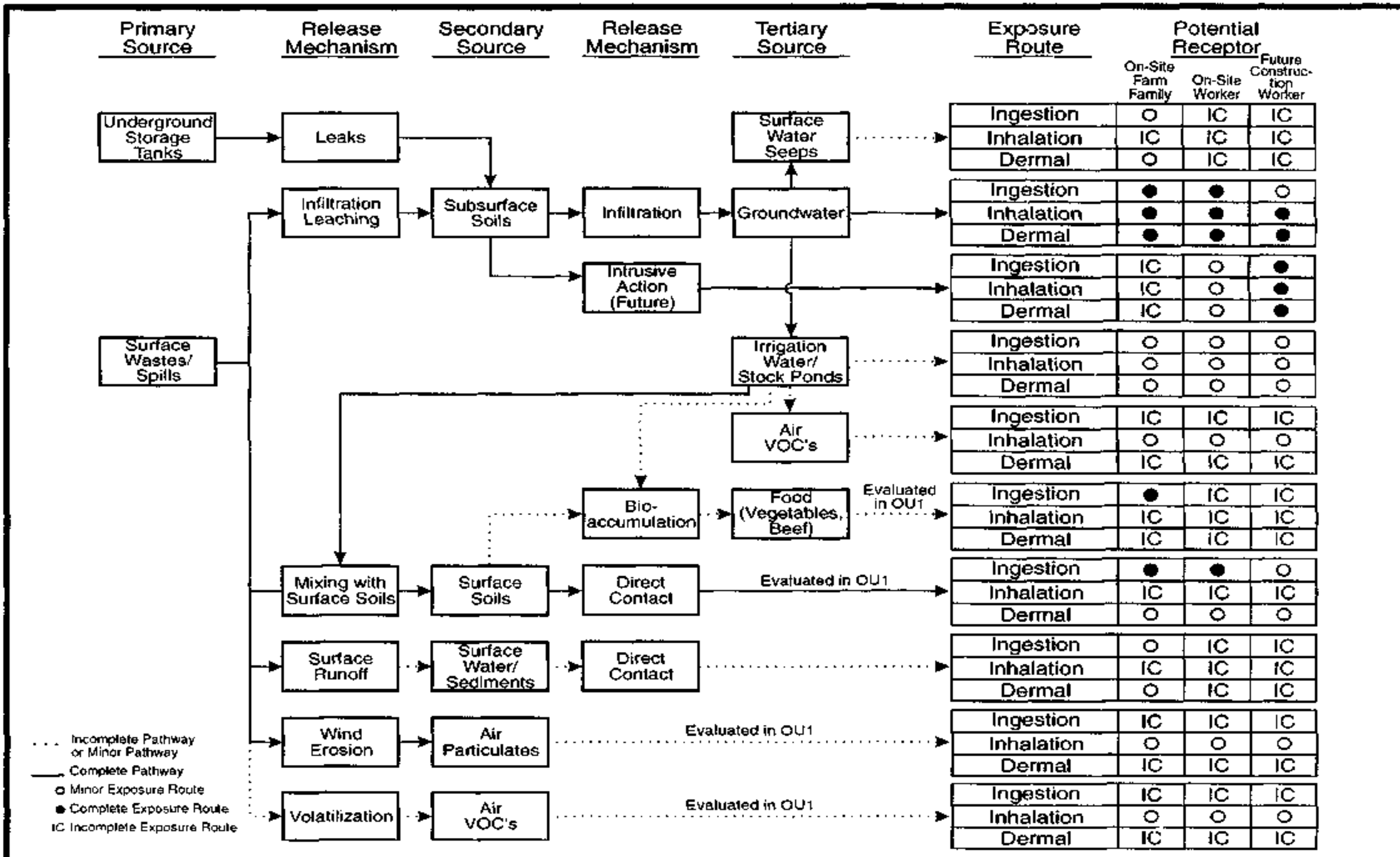
CONCENTRATIONS OF TCE AND RDX DETECTED IN GROUNDWATER CROSS-SECTION N-N'

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 1-21
Sheet number: 1

ACAD FILE: 92FS-G

B07NE003702-09122

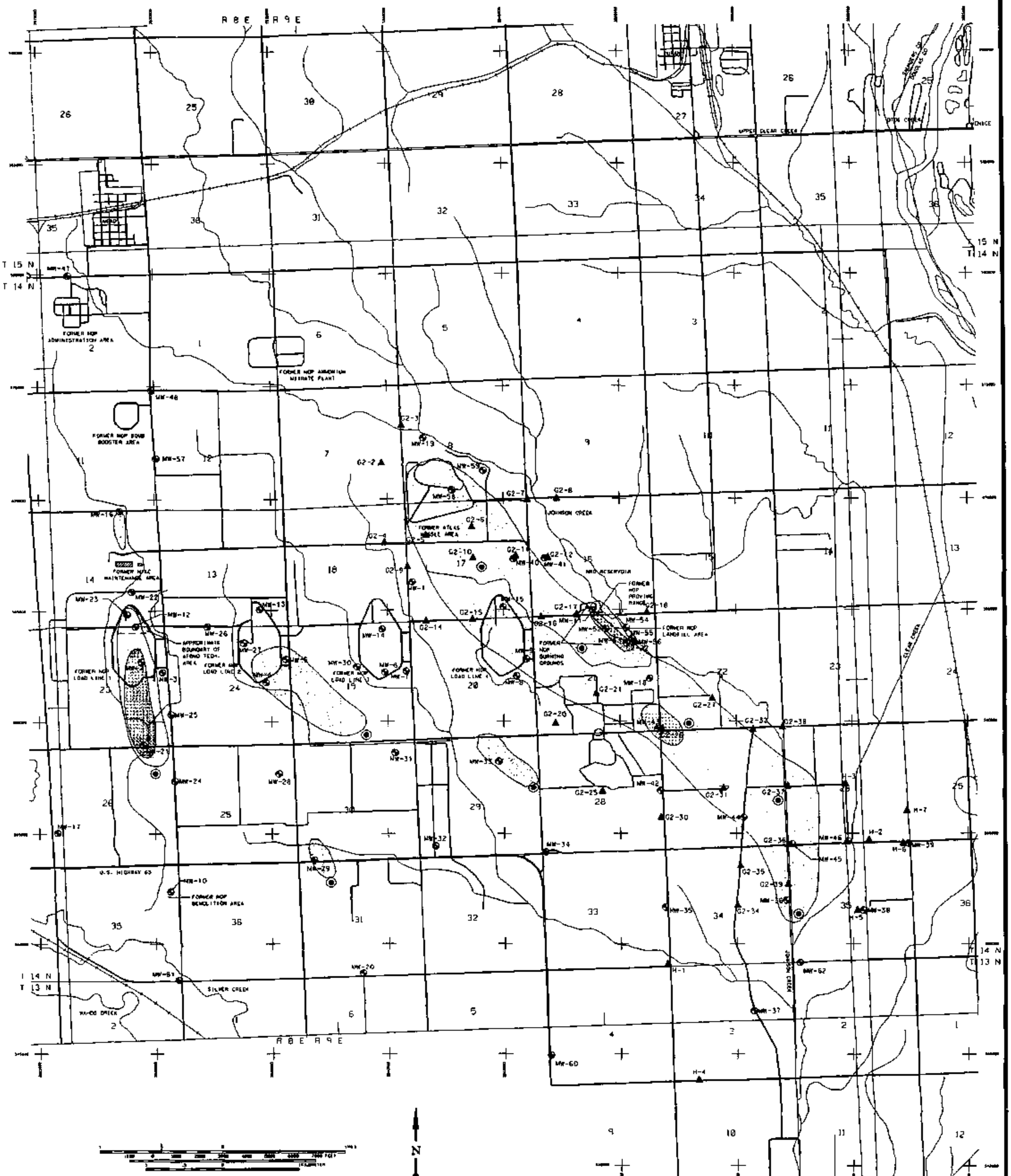
# Drawing 1-22 Site Conceptual Exposure Model Mead OU2 BRA




Graphics\92030\fig1-22 cdr 12/14/94

Woodward-Clyde Consultants

B07NE003702-09123




LEGEND:

APPROXIMATE AREA OF TCE-CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 μg/L)

APPROXIMATE AREA OF EXPLOSIVES-CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > X10-5 CLEANUP GOAL OF 7.74 μg/L

APPROXIMATE AREAS OF COMBINED TCE (CONCENTRATIONS > 5 μg/L) AND EXPLOSIVES (CONCENTRATIONS OF RDX > 7.74 μg/L) CONTAMINATION IN GROUNDWATER

MW-10 GROUNDWATER MONITORING WELL CLUSTER LOCATION

G2-30 GROUNDWATER HEADSPACE SCREENING LOCATION

36 SECTION

T 14 N TOWNSHIP 14 NORTH

R 9 E RANGE 9 EAST

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTE:

1. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
| | | | |

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Overland Park, Kansas

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KANSAS CITY, MISSOURI

Designed by: M.J.F
Drawn by: D R T
Checked by: M.J.F
Submitted by: [signature]

U.S. Army Corps of Engineers

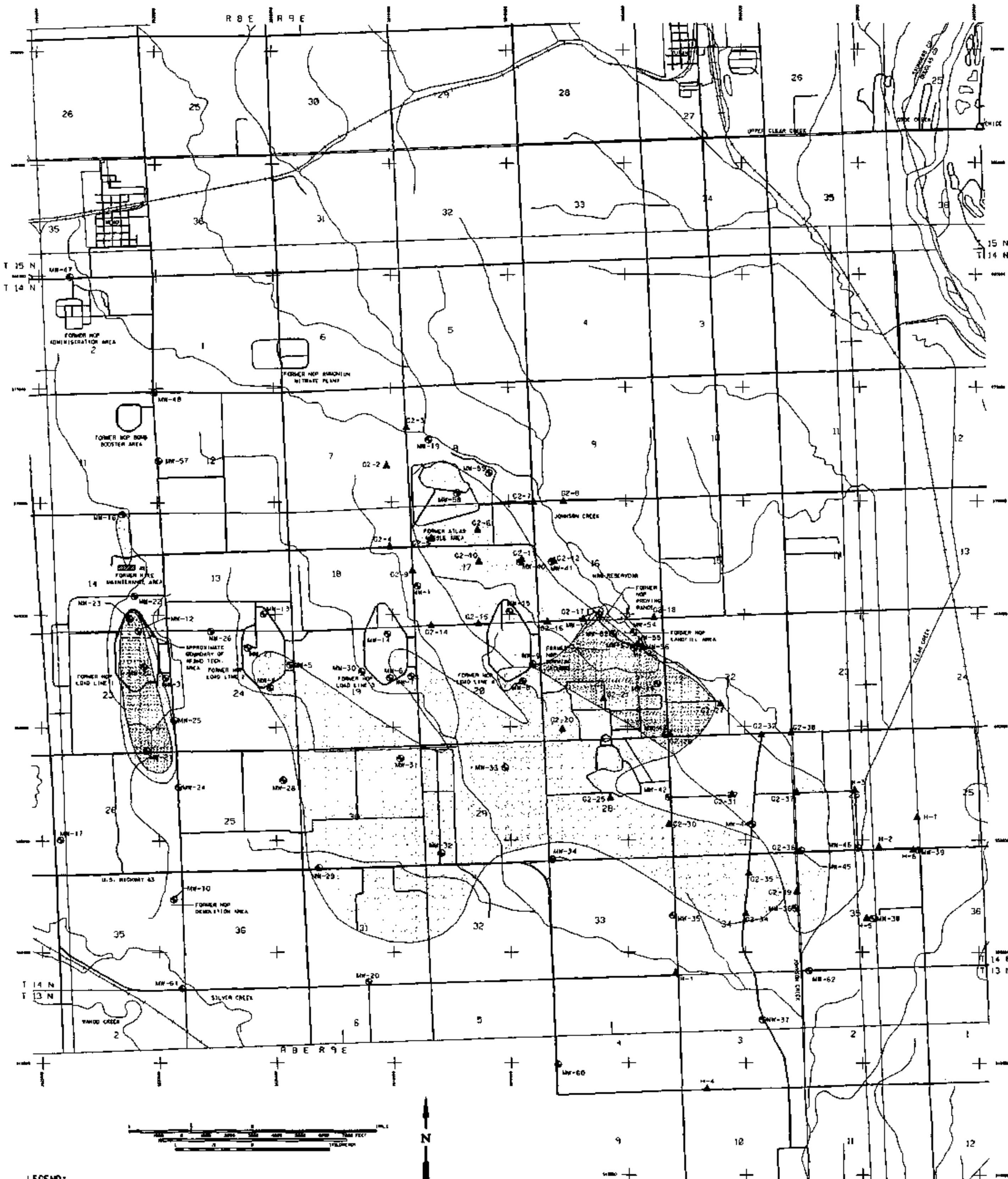
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**CLEANUP GOAL 1**
**AREA OF ATTAINMENT**

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 2-1
Sheet number: 1

WCS FILE: 92F5:43

B07NE003702-09124




**LEGEND:**

APPROXIMATE AREA OF TCE-CONTAMINATED GROUNDWATER (CONCENTRATIONS MCL OF 5 µg/L)

APPROXIMATE AREA OF EXPLOSIVES-CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > HEALTH ADVISORY CLEANUP GOAL OF 2 µg/L)

APPROXIMATE AREAS OF COMBINED TCE (CONCENTRATIONS > 5 µg/L) AND EXPLOSIVES (CONCENTRATIONS OF RDX > 2 µg/L) CONTAMINATION IN GROUNDWATER

MW-10 GROUNDWATER MONITORING WELL CLUSTER LOCATION

G2-30 GROUNDWATER HEADSPACE SCREENING LOCATION

36 SECTION

T 14 N TOWNSHIP 14 NORTH

R 9 E RANGE 9 EAST

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTE:

1. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
| | | | |
| | | | |
| | | | |

Woodward-Clyde Consultants
Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by: M.J.F.

Drawn by: D.R.T.

Checked by: M.J.F.

Submitted by:

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR NEBRASKA ORDNANCE PLANT - MEAD, NE

**CLEANUP GOAL II**
**AREA OF ATTAINMENT**

Scale: AS NOTED

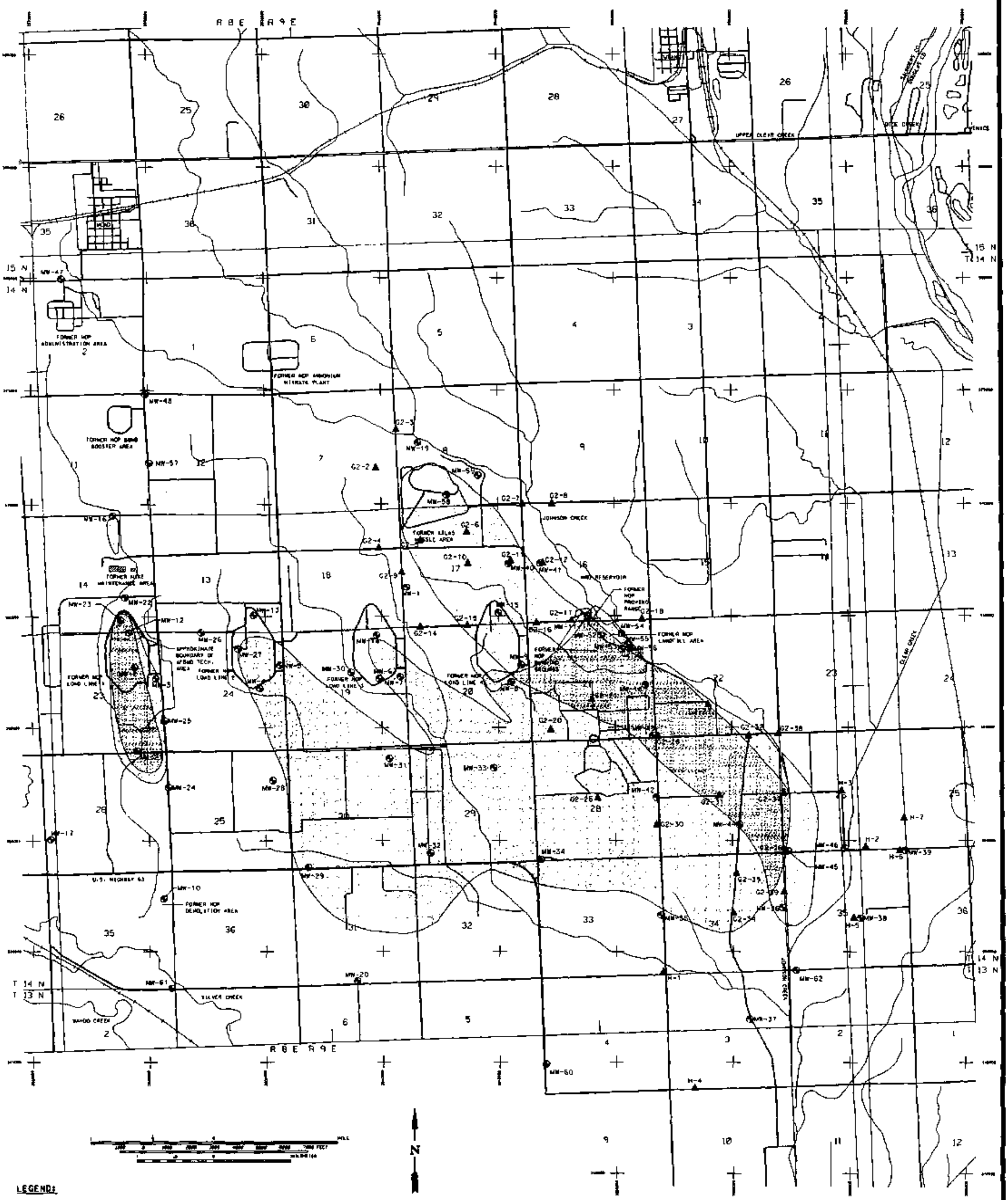
Date: DECEMBER, 1994

Dwg. No.: 2-2

Sheet number: 1

MCS FILE: 92FS-44

B07NE003702-09125




**LEGEND:**

| | |
|---|---|
| (outline symbol) | APPROXIMATE AREA OF TCE-CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline symbol) | APPROXIMATE AREA OF EXPLOSIVES-CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > X10$^{-6}$ CLEANUP GOAL OF 0.774 µg/L |
| (outline symbol) | APPROXIMATE AREAS OF COMBINED TCE (CONCENTRATIONS > 5 µg/L) AND EXPLOSIVES (CONCENTRATIONS > 0.774 µg/L) CONTAMINATION IN GROUNDWATER |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHOO 1927 NAD, 1929 NGVD

NOTE:

1. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'v'd |
| | | | |
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| | | | |

Woodward-Clyde Consultants
Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by: M.J.F.

Drawn by: D.R.J.

Checked by: M.J.F.

Submitted by:

U.S. Army Corps of Engineers

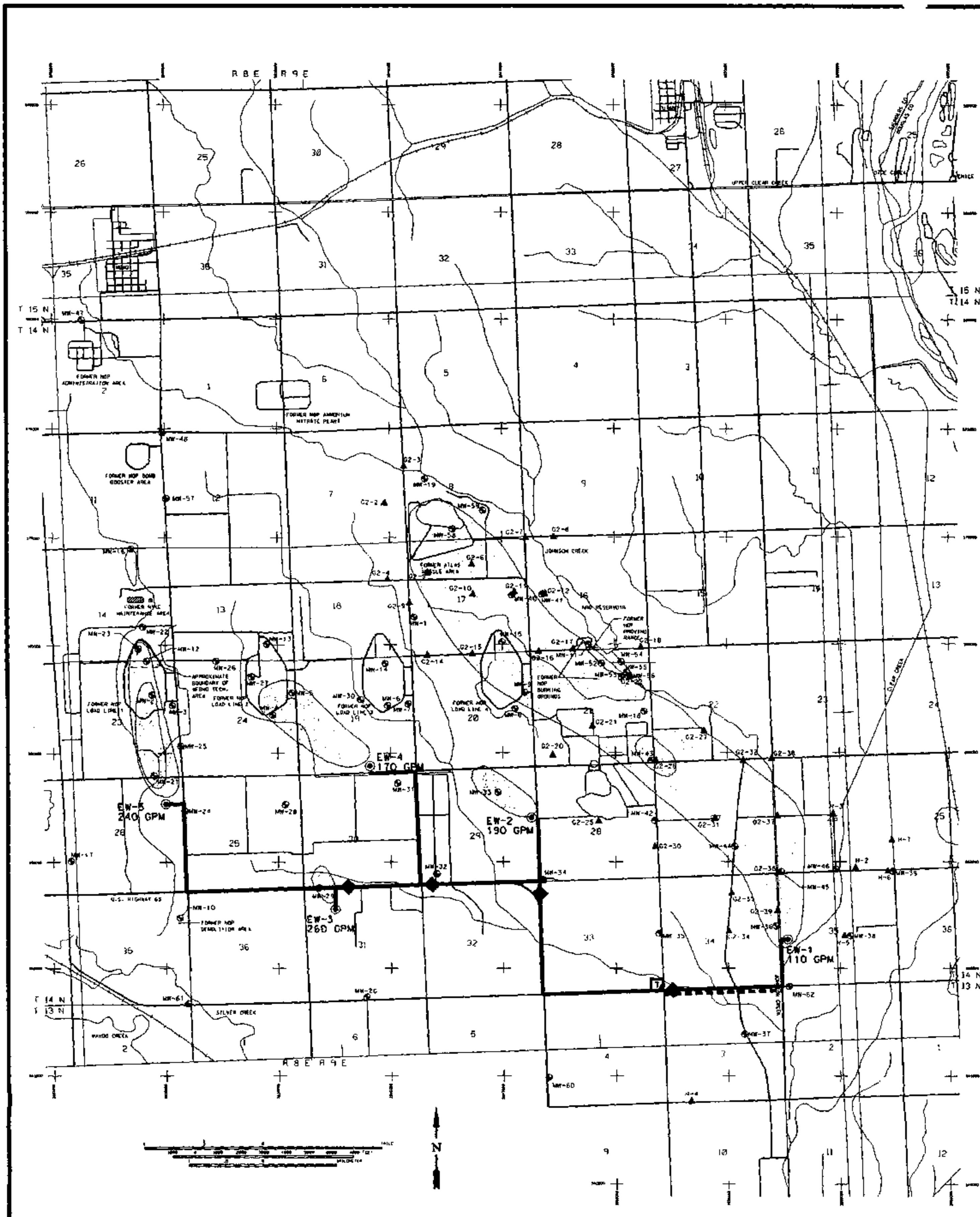
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**CLEANUP GOAL III**
**AREA OF ATTAINMENT**

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No.: 2-3
Sheet number: 1

MCS FILE 9753-45

B07NE003702-09126




**LEGEND:**

| | |
|---|---|
| (heavy solid line) | CONTAINMENT WELL PIPING |
| (heavy dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT WELL LOCATION |
| 260 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF DETECTED EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > $10^{-5}$ CLEANUP GOAL OF 7.14 µg/L) |
| ◉ MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
2. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
4. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'd |
| | | | |
| | | | |
| | | | |

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KANSAS CITY, MISSOURI

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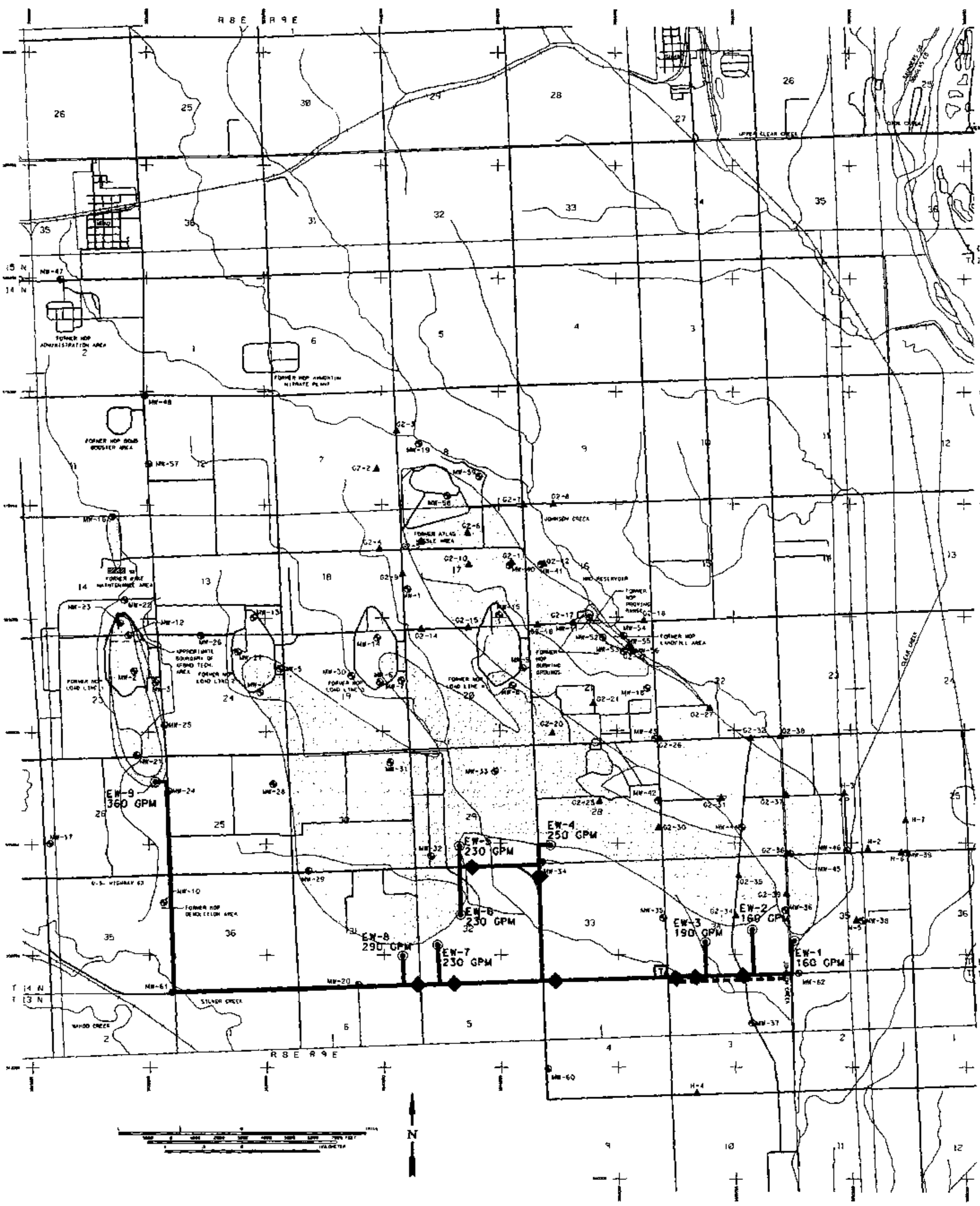
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVE 2 - CONTAINMENT-TARGET CLEANUP GOAL 1**

| | |
|---|---|
| Designed by: | A.C.E. |
| Drawn by: | D.R.T. |
| Checked by: | R.F.S. |
| Submitted by: | DEH |
| Scale: | AS NOTED |
| Date: | DECEMBER, 1994 |
| Dwg No.: | 4-1A |
| Sheet number: | 1 |

MCS FS.E1.OU2-20

B07NE003702-09127




**LEGEND:**

| | |
|---|---|
| (solid heavy line) | CONTAINMENT WELL PIPING |
| (dashed heavy line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT WELL LOCATION |
| 190 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > HEALTH ADVISORY CLEANUP GOAL OF 2 µg/L) |
| ⊕ MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
2. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
4. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
| | | | |

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KANSAS CITY, MISSOURI

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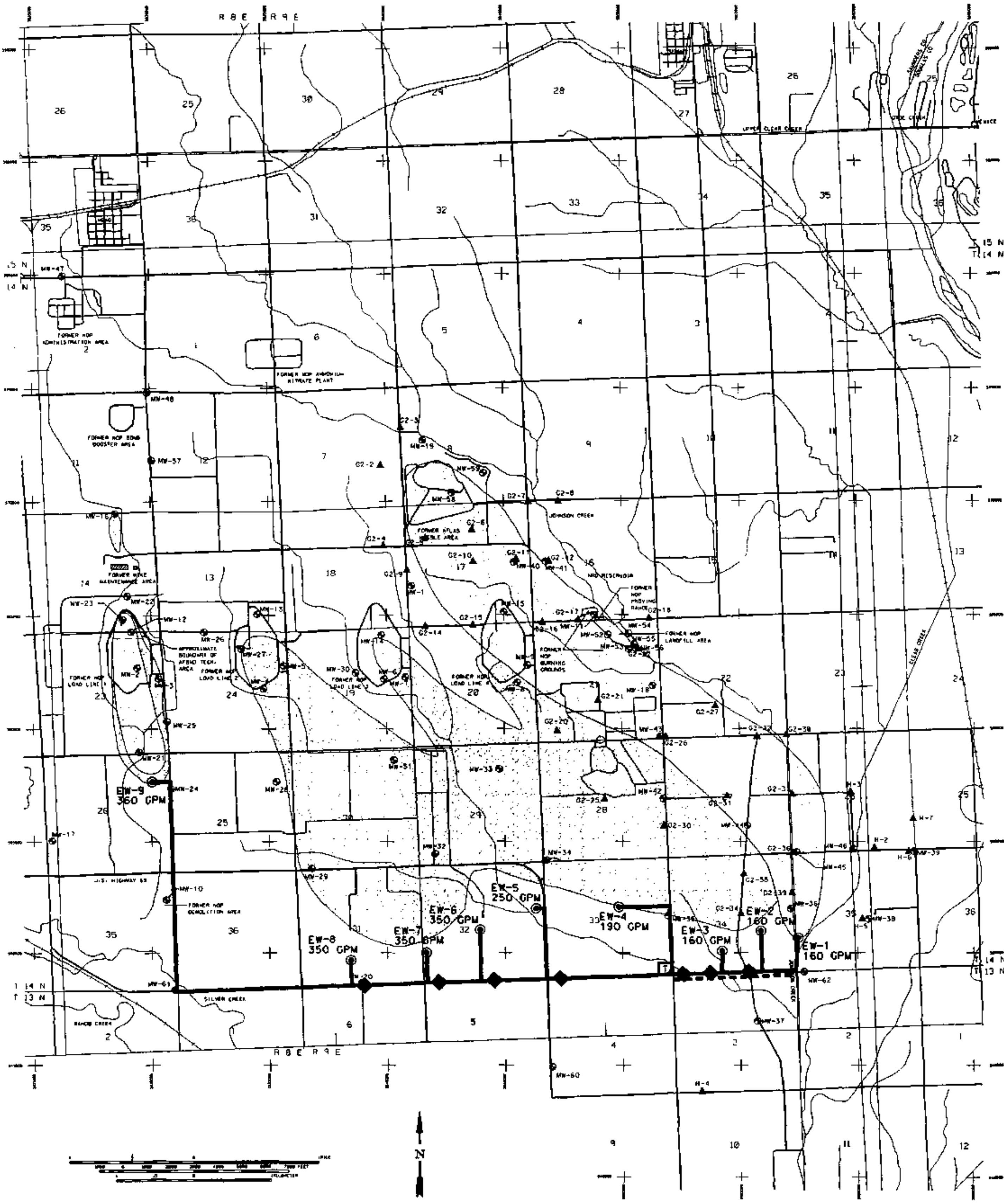
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVE 2 - CONTAINMENT-TARGET CLEANUP GOAL II**

| | |
|---|---|
| Designed by: | A.C.E. |
| Drawn by: | D.R.T. |
| Checked by: | R.F.S. |
| Submitted by: | (signature) |
| Scale: | AS NOTED |
| Date: | DECEMBER, 1994 |
| Dwg. No.: | 4-18 |
| Sheet number: | 1 |

WCS FILE: OU2-24

B07NE003702-09128




LEGEND:

| | |
|---|---|
| (solid line) | CONTAINMENT WELL PIPING |
| (dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT WELL LOCATION |
| 160 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > $10^{-6}$ CLEANUP GOAL OF 0.774 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. TCE AND RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
2. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
3. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'v'd |
| | | | |
| | | | |

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Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by: A.C.E.
Drawn by: D.R.T.
Checked by: R.F.S.
Submitted by: DEH

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVE 2 - CONTAINMENT-TARGET CLEANUP GOAL (1)**

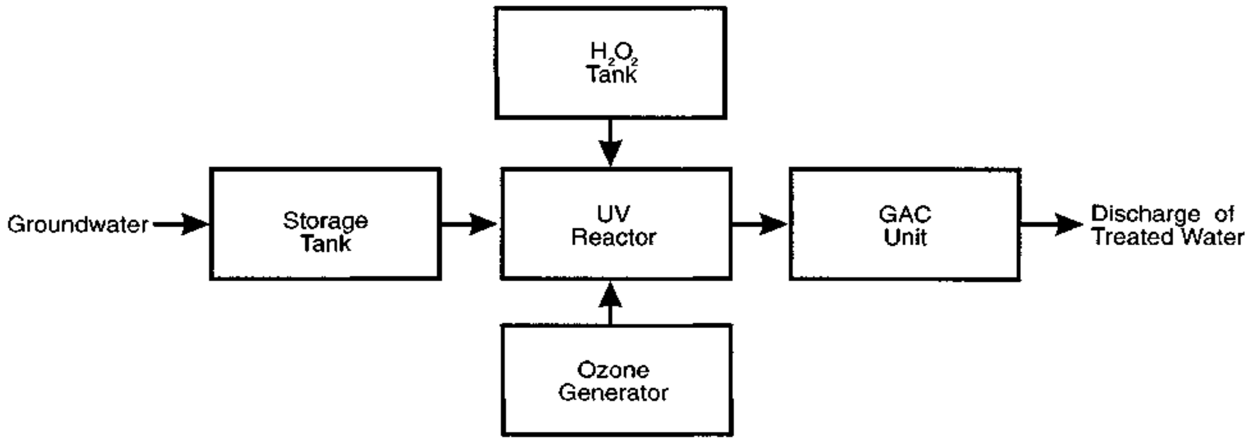
Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No: 4-1C
Sheet number: 1

MK5 FAE: OU2-28

# Drawing 4-2
# GAC System Process Flow Diagram

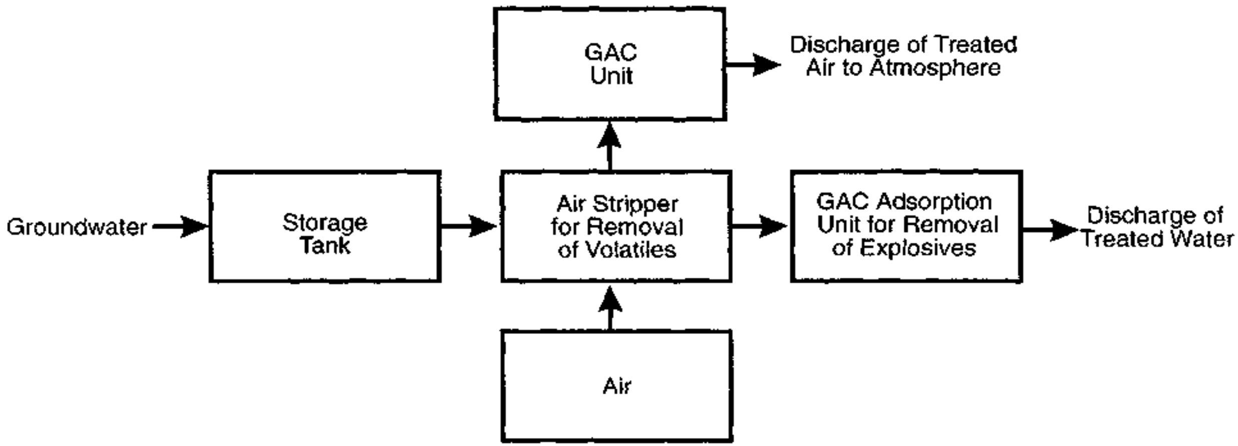

Graphics\92030\gac3.cdr 12/05/94

# Drawing 4-3
# Advanced Oxidation Process Flow Diagram

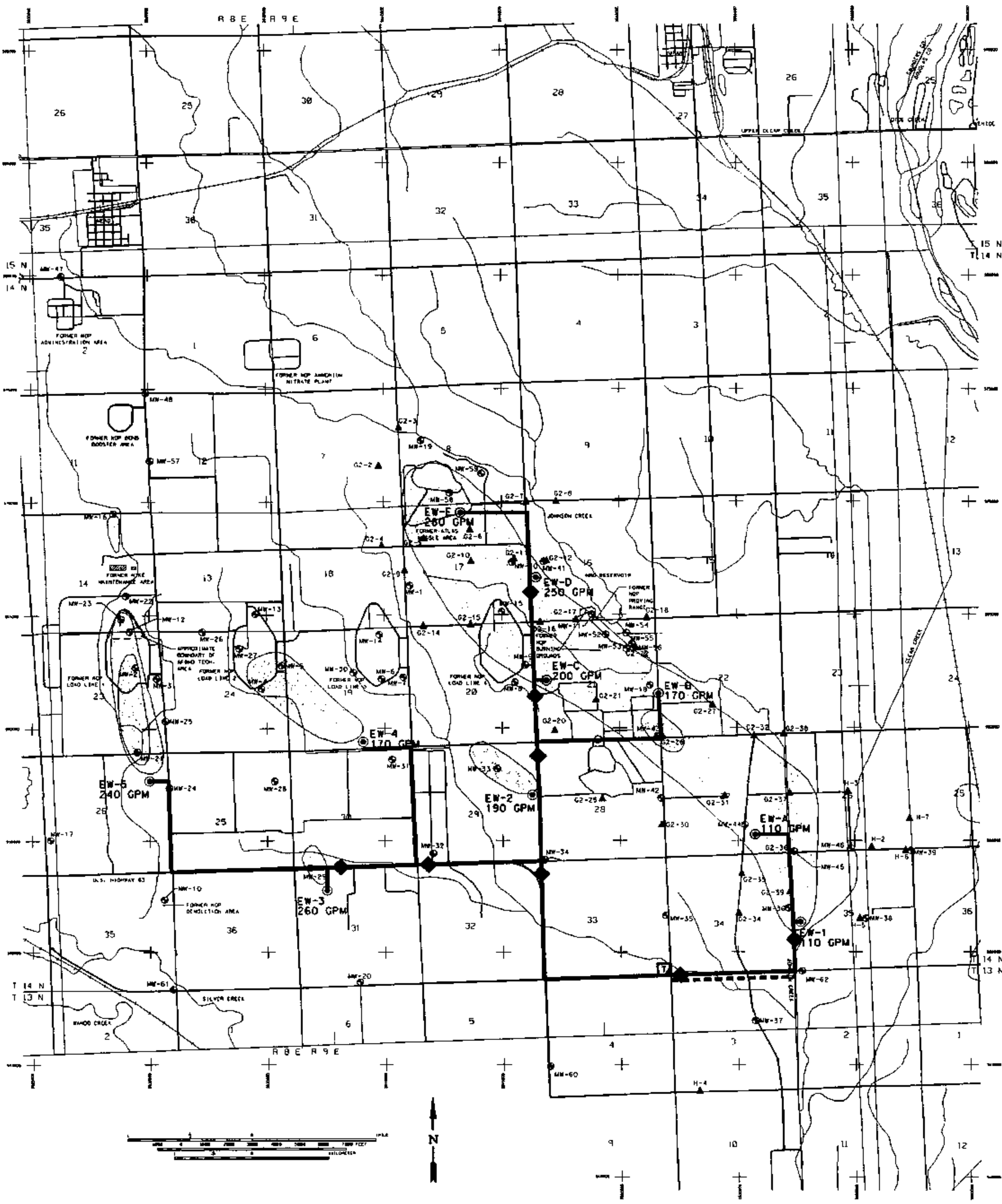



Graphics\92030uv3.cdr 12/05/94

# Drawing 4-4
# Air Stripping Process Flow Diagram




Graphics\92000\air2.cdr 12/05/94




LEGEND:

| | |
|---|---|
| (heavy solid line) | CONTAINMENT WELL PIPING |
| (heavy dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| EW-C | EXTRACTION WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 260 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF DETECTED EXPLOSIVES - CONTAMINATED GROUND-WATER (CONCENTRATIONS OF RDX > $10^{-7}$ CLEANUP GOAL OF 7.74 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 5 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS A THROUGH E ARE PART OF THE FOCUSED EXTRACTION SYSTEM.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
4. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
5. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
| | | | |

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KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

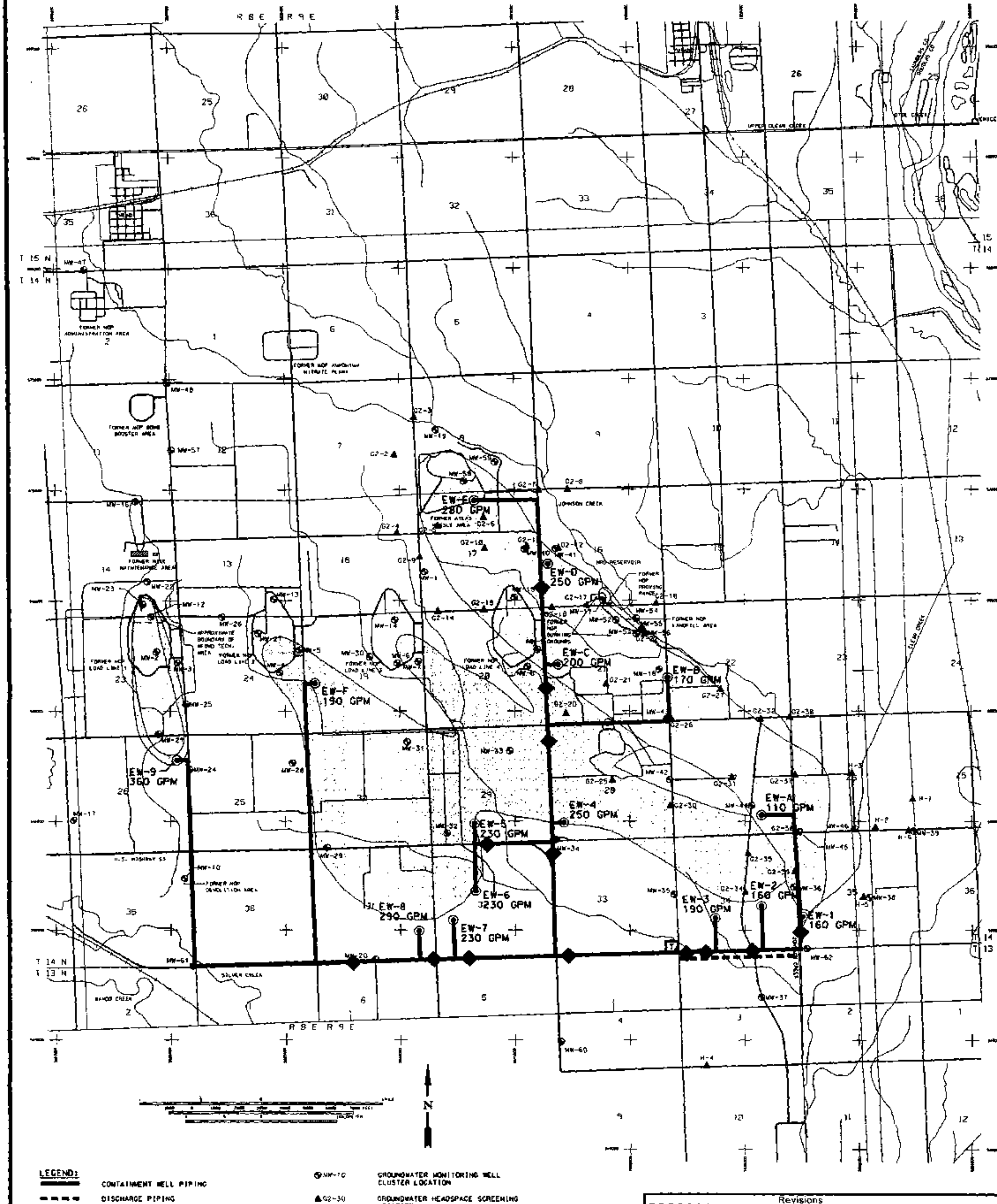
**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 3 AND 4 - CONTAINMENT AND FOCUSED EXTRACTION-TARGET CLEANUP GOAL 1**

Designed by: A.C.E.
Drawn by: O.R.T
Checked by: R.F.S.
Submitted by: [signature]

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg No.: 4-5A
Sheet number: 1

MCS FILE: OU2-21

B07NE003702-09133




LEGEND:

| | |
|---|---|
| (heavy line) | CONTAINMENT WELL PIPING |
| (dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| EW-C | EXTRACTION WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 190 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > HEALTH ADVISORY CLEANUP GOAL OF 2 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 9 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS A THROUGH F ARE PART OF THE FOCUSED EXTRACTION SYSTEM.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
4. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
5. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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Woodward-Clyde Consultants
Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

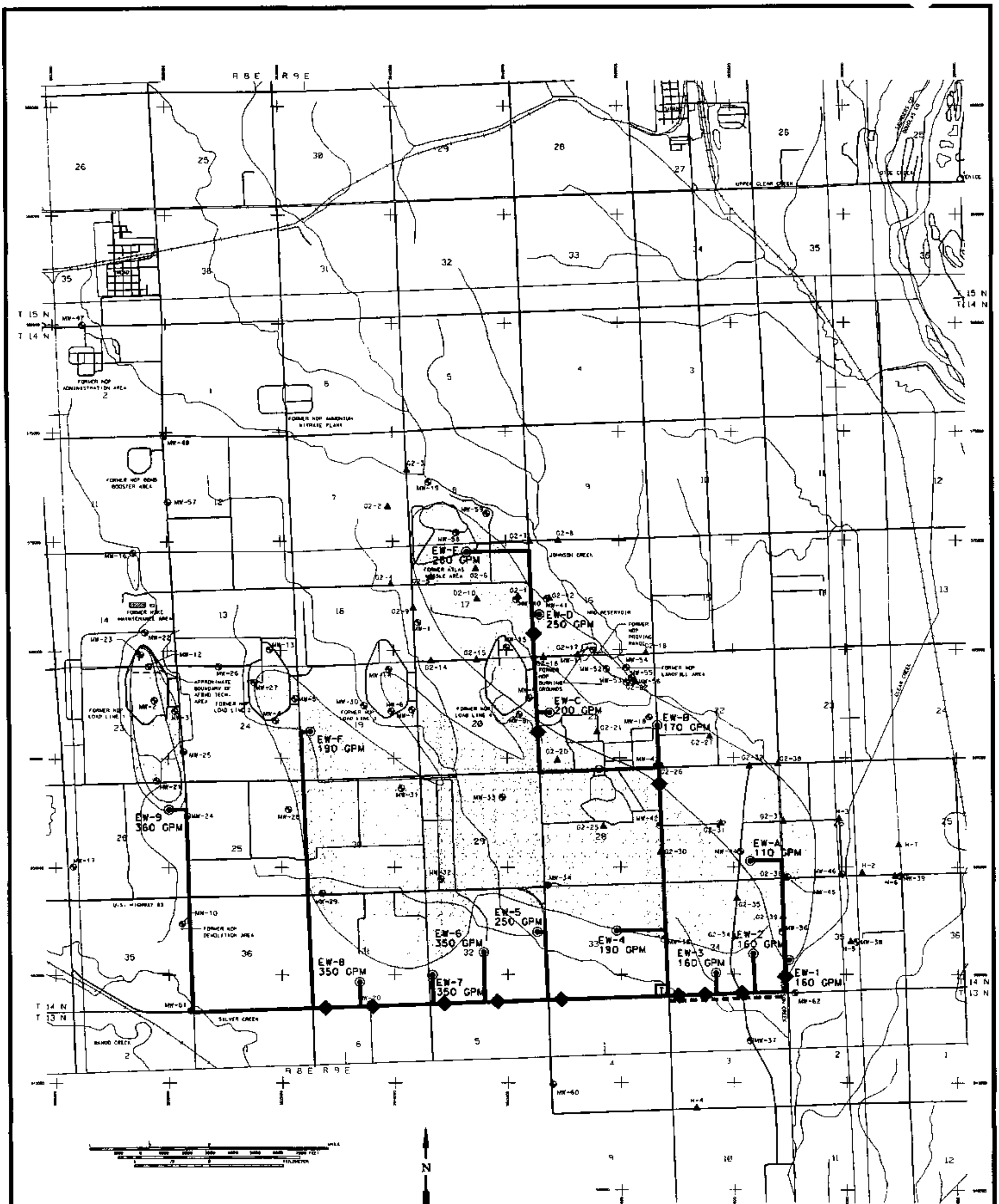
U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 3 AND 4 - CONTAINMENT AND FOCUSED EXTRACTION-TARGET CLEANUP GOAL 1**

| | | | |
|---|---|---|---|
| Designed by: A.C.E. | Scale: AS NOTED | Sheet number: 1 | |
| Drawn by: D.R.T. | Date: DECEMBER, 1994 | | |
| Checked by: R.F.S. | Dwg No: 4-5B | | |
| Submitted by: [signature] | | | |

MCS FILE-OU2-25




**LEGEND:**

| | |
|---|---|
| (solid line) | CONTAINMENT WELL PIPING |
| (dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| EW-C | EXTRACTION WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 160 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > $10^{-6}$ CLEANUP GOAL OF 0.774 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 9 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS A THROUGH F ARE PART OF THE FOCUSED EXTRACTION SYSTEM.
2. TCE AND RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
4. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'v'd |
| | | | |
| | | | |
| | | | |

Woodward-Clyde Consultants
Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

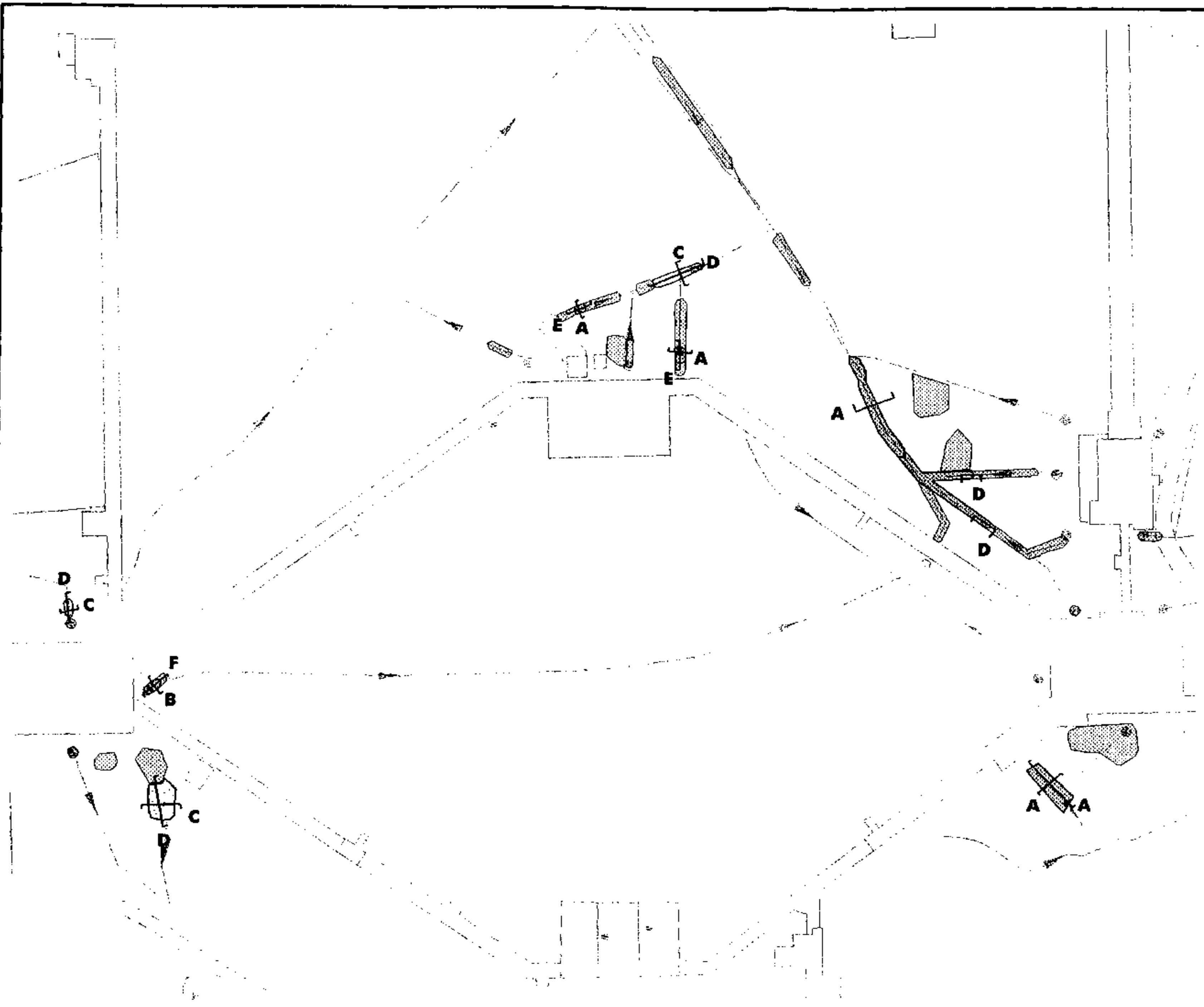
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 3 AND 4- CONTAINMENT FOCUSED EXTRACTION-TARGET CLEANUP GOAL III**

| | |
|---|---|
| Designed by: | A.C.E. |
| Drawn by: | D.R.T. |
| Checked by: | R.F.S. |
| Submitted by: | (signature) |
| Scale: | AS NOTED |
| Date: | DECEMBER, 1994 |
| Dwg No: | 4-5C |
| Sheet number: | 1 |

MCS FILE OU2-28

B07NE003702-09135




## LEGEND

| | |
|---|---|
| (hexagon) | OU2 EXCAVATION AREA |
| (shaded bar) | OU1 EXCAVATION AREA |
| (arrow) | EXISTING DITCH |
| ● | SUMP |

NOTES:

1. OU1 CONTAMINATED SOIL IS THE ESTIMATED VOLUME WHICH EXCEEDS OU1 REMEDIATION GOALS.
2. OU2 CONTAMINATED SOIL IS THE ESTIMATED VOLUME WHICH EXCEEDS OU2 EXCAVATION CRITERIA.
3. OU1 AREAS BASED ON RUST, 1994, DRAFT FINAL FEASIBILITY STUDY, FORMER NOP SITE OU1, 1994.
4. CONTAMINATED SOIL AREAS DO NOT INCLUDE SIDE SLOPES.
5. LETTER LABELS REFER TO TYPICAL SECTONS SHOWN ON DRAWING 4-6D.

SCALE 0' 40' 80'

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd By |
| | | | |
| | | | |
| | | | |

RUST ENVIRONMENT & INFRASTRUCTURE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

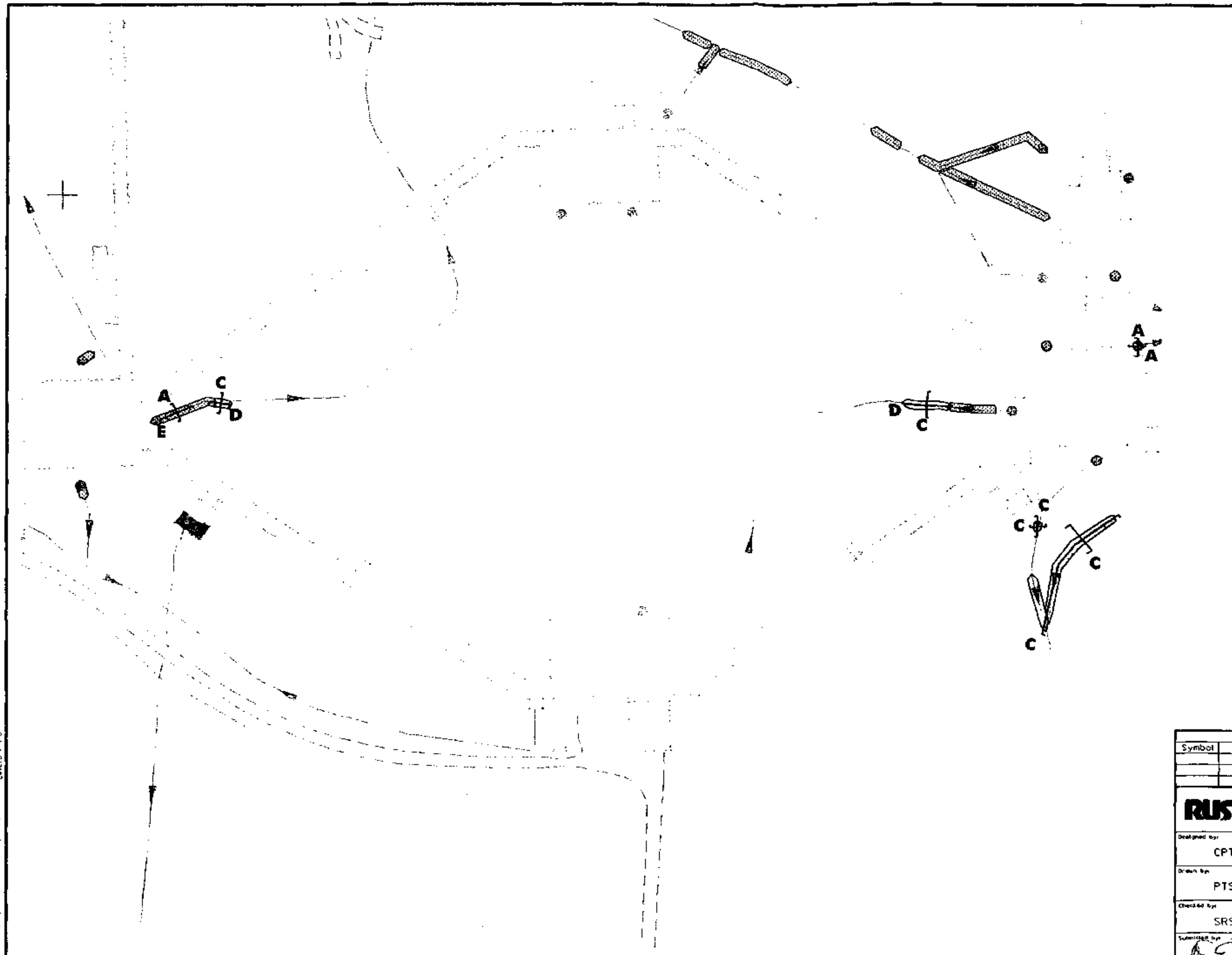
U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD NE.

SOIL EXCAVATION
AREAS-LOAD LINE 1
ALTERNATIVE 4, 6, AND 8

Designed by: CPT
Drawn by: PTS
Checked by: SRS
Submitted by:
Scale: 1 IN = 80 FT
Date: DEC. 1994
Dwg No.: 4-6A

B07NE003702-09136




## LEGEND

- OU2 EXCAVATION AREA
- OUI EXCAVATION AREA
- EXISTING DITCH
- SUMP

NOTES:

1. OUI CONTAMINATED SOIL IS THE ESTIMATED VOLUME WHICH EXCEEDS OUI REMEDIATION GOALS.
2. OU2 CONTAMINATED SOIL IS THE ESTIMATED VOLUME WHICH EXCEEDS OU2 EXCAVATION CRITERIA.
3. OUI AREAS BASED ON RUST, 1994, DRAFT FINAL FEASIBILITY STUDY, FORMER NOP SITE OUI, 1994.
4. CONTAMINATED SOIL AREAS DO NOT INCLUDE SIDE SLOPES.
5. LETTER LABELS REFER TO TYPICAL SECTONS SHOWN ON DRAWING 4-6D.

SCALE 0' 40' 80'

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'v'd By |
| | | | |
| | | | |
| | | | |

RUST ENVIRONMENT & INFRASTRUCTURE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

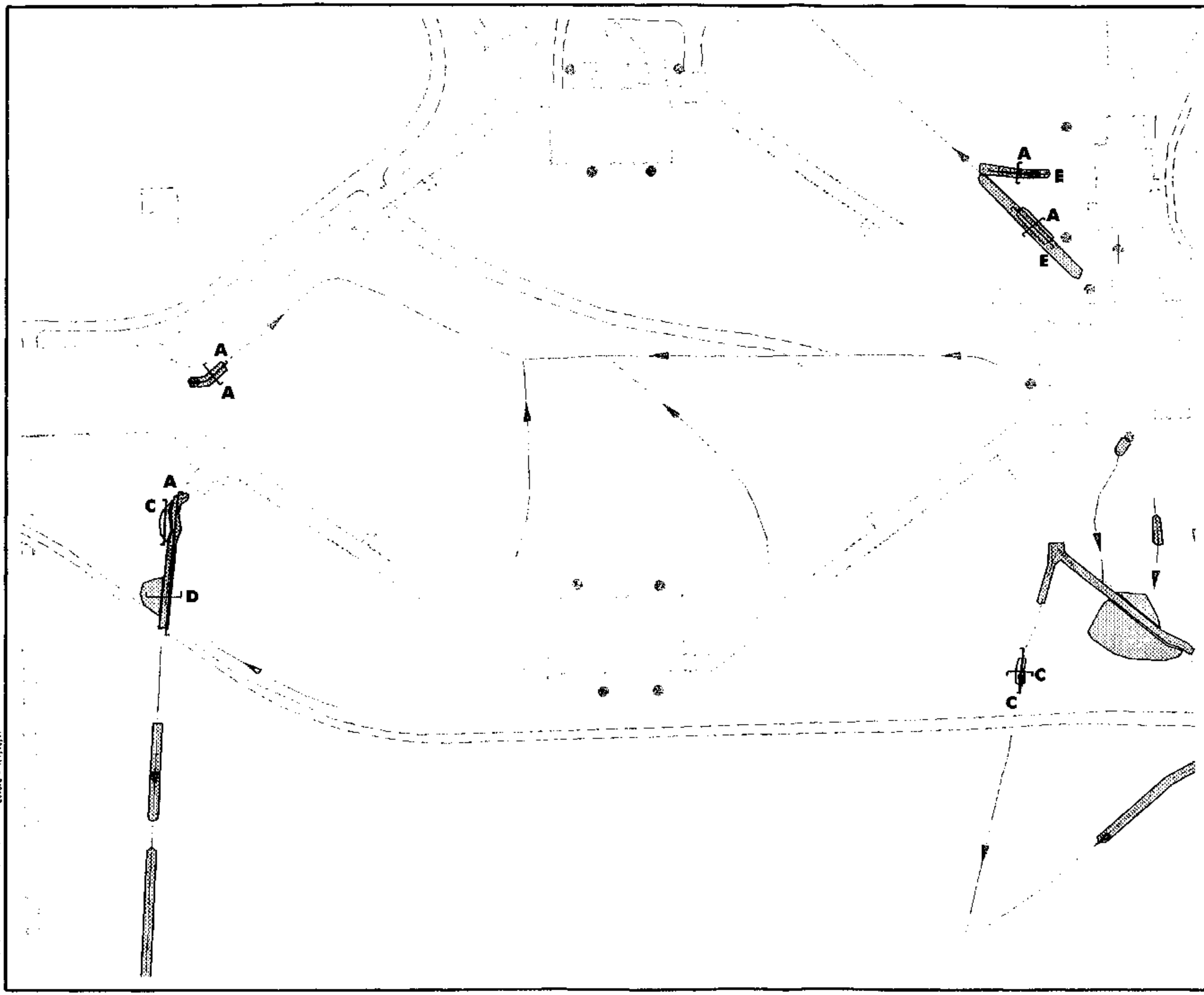
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD NE.

SOIL EXCAVATION
AREAS-LOAD LINE 3
ALTERNATIVE 4, 6, AND 8

Designed by: CPT
Drawn by: PTS
Checked by: SRS
Submitted by: [signature]

Scale: 1 IN = 80 FT
Date: DEC. 1994
Dwg. No.: 4-6C

B07NE003702-09137




## LEGEND

OU2 EXCAVATION AREA

OU1 EXCAVATION AREA

EXISTING DITCH

SUMP

NOTES:

1. OU1 CONTAMINATED SOIL IS THE ESTIMATED VOLUME WHICH EXCEEDS OU1 REMEDIATION GOALS.
2. OU2 CONTAMINATED SOIL IS THE ESTIMATED VOLUME WHICH EXCEEDS OU2 EXCAVATION CRITERIA.
3. OU1 AREAS BASED ON RUST, 1994, DRAFT FINAL FEASIBILITY STUDY, FORMER NOP SITE OU1, 1994.
4. CONTAMINATED SOIL AREAS DO NOT INCLUDE SIDE SLOPES.
5. LETTER LABELS REFER TO TYPICAL SECTONS SHOWN ON DRAWING 4-60.

SCALE 0' 40' 80'

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd By |
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| | | | |
| | | | |

RUST ENVIRONMENT & INFRASTRUCTURE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

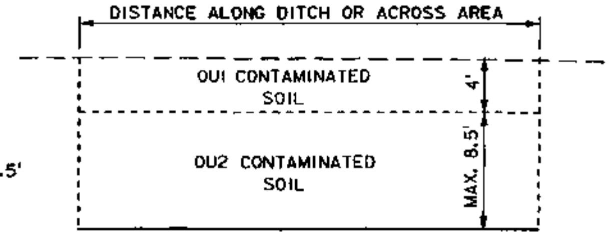
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD NE.

**SOIL EXCAVATION AREAS-LOAD LINE 2 ALTERNATIVE 4, 6, AND 8**

| | |
|---|---|
| Designed by: | CPT |
| Drawn by: | PTS |
| Checked by: | SRS |
| Submitted by: | |
| Scale: | 1 IN = 80 FT |
| Date: | DEC. 1994 |
| Dwg. No.: | 4-68 |

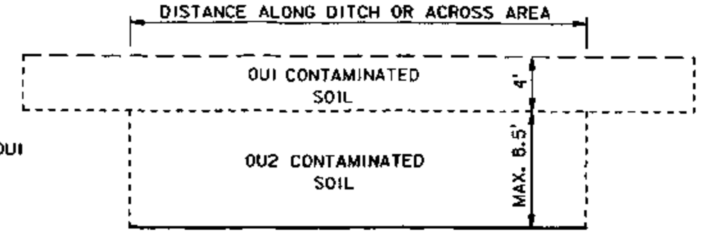
B07NE003702-09138

OU2 CONTAMINATION
DIRECTLY BELOW OUI
CONTAMINATION TO A
MAXIMUM DEPTH OF 12.5'



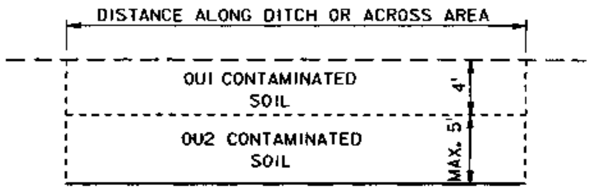

TYPICAL SECTION A

OU2 CONTAMINATION TO A
MAXIMUM DEPTH OF 12.5'
BELOW A PORTION OF AN OUI
CONTAMINATED AREA



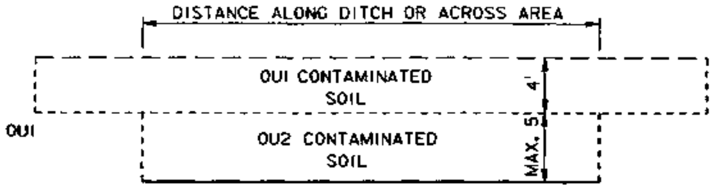

TYPICAL SECTION E

OU2 CONTAMINATION
DIRECTLY BELOW OUI
CONTAMINATION TO A
MAXIMUM DEPTH OF 9'



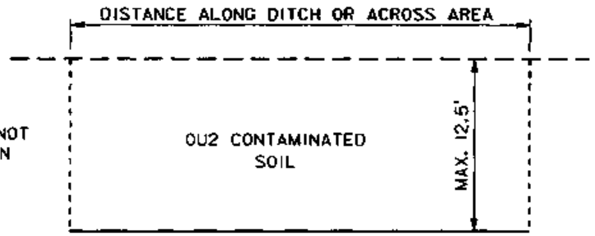

TYPICAL SECTION B

OU2 CONTAMINATION TO A
MAXIMUM DEPTH OF 9'
BELOW A PORTION OF AN OUI
CONTAMINATED AREA



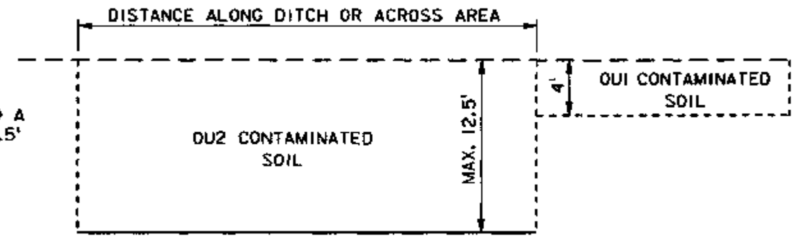

TYPICAL SECTION F

OU2 CONTAMINATION TO A
MAXIMUM DEPTH OF 12.5' NOT
BELOW OR ADJACENT TO AN
OUI CONTAMINATED AREA




TYPICAL SECTION C

OU2 CONTAMINATION TO A
MAXIMUM DEPTH OF 12.5'
ADJACENT TO AN OUI
CONTAMINATED AREA




TYPICAL SECTION D

NOTES:

1. CONTAMINATED SOIL AREAS DO NOT INCLUDE SIDE SLOPES.
2. OUI AREAS BASED ON RUST, 1994 DRAFT FINAL FEASIBILITY STUDY, FORMER NOP SITE OUI.
3. DRAWINGS 4-6A, 4-6B, AND 4-6C INDICATE WHICH SECTION APPLIES TO EACH OU2 AREA.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd By |
| | | | |
| | | | |
| | | | |

RUST ENVIRONMENT & INFRASTRUCTURE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

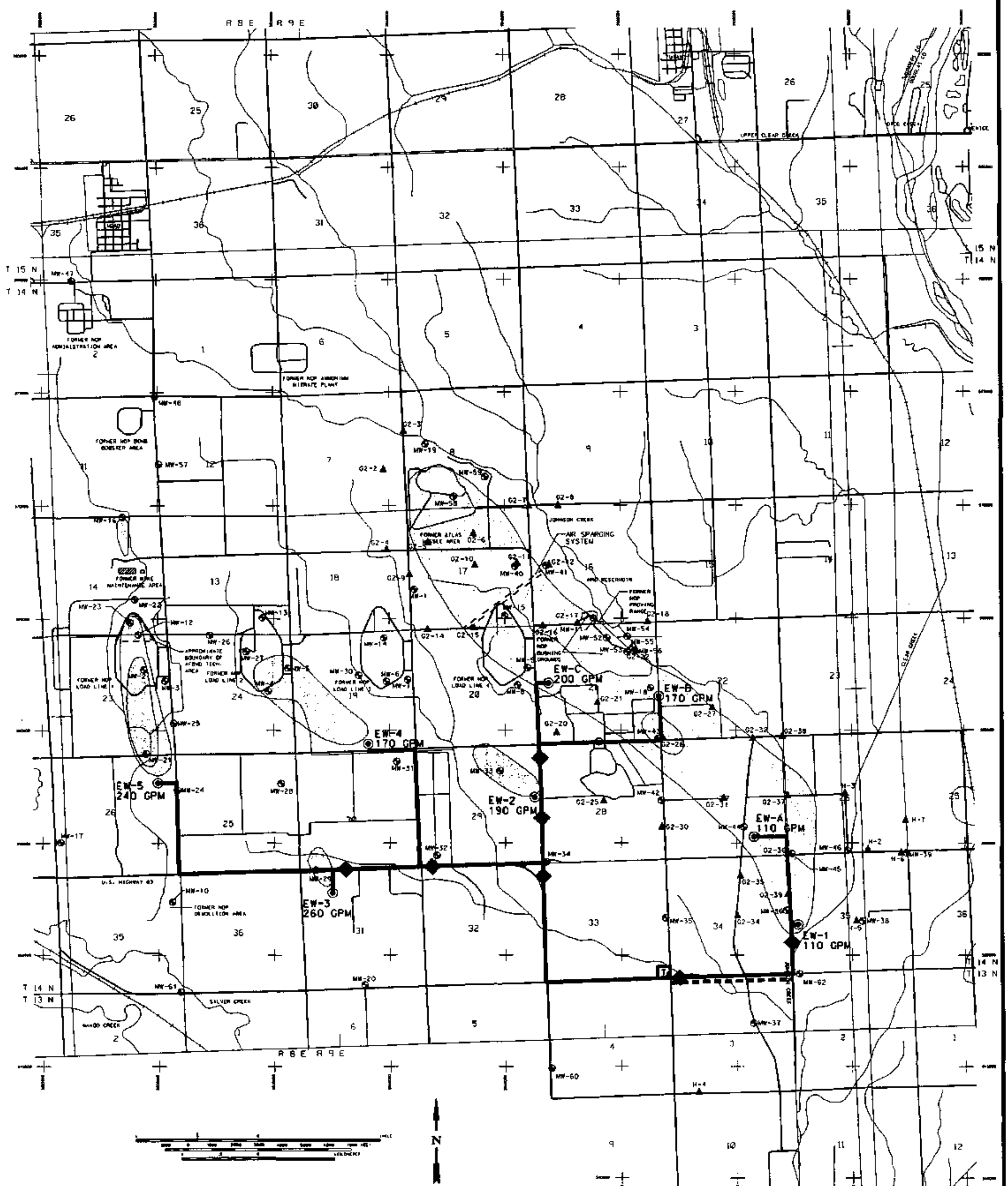
U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD NE.

TYPICAL SOIL
EXCAVATION SECTIONS
ALTERNATIVES 4, 6, AND 8

Designed by: CPT
Drawn by: PTS
Checked by: SRS
Submitted by: [signature]
Scale: NTS
Date: DEC. 1994
Dwg. No.: 4-6D

User is PTS
PEN TABLE: G:\PLOT\TAB  null.tbl
Levels are 1-63
PAF : G:\PLOT\PLOTS\TY
DATE: Thu Dec 22 15:29:56 1994
DGN :e:\project\400198\ou2\typxs.dgn
REFERENCE FILE 01 : fig11x17.bor
Levels = 1-57,61-63




LEGEND:

| | |
|---|---|
| (solid heavy line) | CONTAINMENT WELL PIPING |
| (dashed heavy line) | DISCHARGE PIPING |
| T (boxed) | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| EW-C | EXTRACTION WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 260 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (dash-dot line) | AIR SPARGING SYSTEM |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 μg/L) |
| (outline) | APPROXIMATE BOUNDARY OF DETECTED EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > $10^{-6}$ CLEANUP GOAL OF 7.74 μg/L) |
| ◉ MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 5 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS A THROUGH E ARE PART OF THE FOCUSED EXTRACTION SYSTEM.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
4. DETECTION LIMIT (ND) FOR TCE IS 1.0 μg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 μg/L.
5. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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Woodward-Clyde Consultants
Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

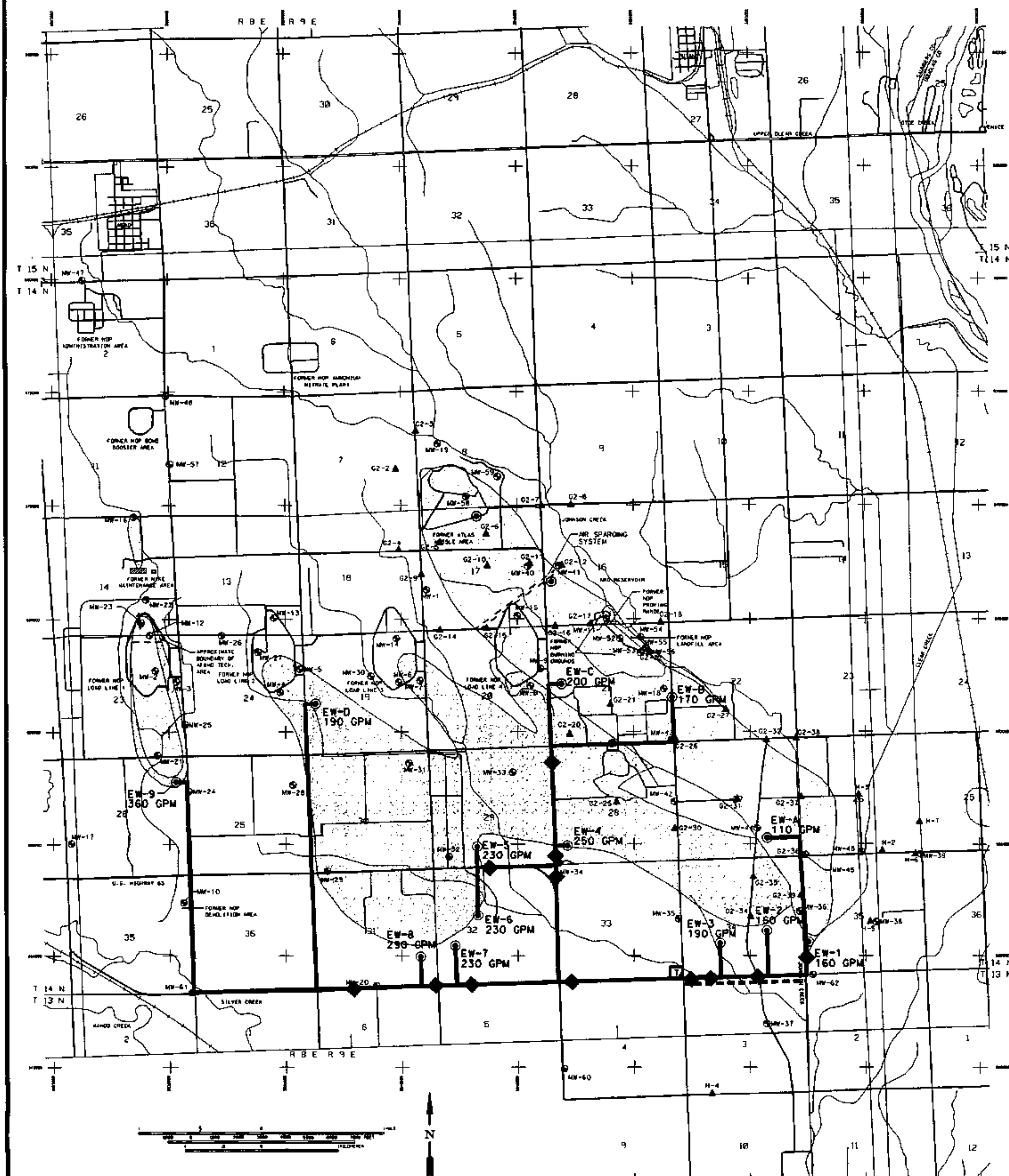
U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 5 AND 6 - CONTAINMENT, FOCUSED EXTRACTION-TARGET CLEANUP GOAL I**

| | |
|---|---|
| Designed by: | A.C.E |
| Drawn by: | D.R.E |
| Checked by: | R.F.S |
| Submitted by: | (signature) |
| Scale: | AS NOTED |
| Date: | DECEMBER, 1994 |
| Dwg. No: | 4-7A |
| Sheet number: | 1 |

WCS FILE: OU2-22




**LEGEND:**

| | |
|---|---|
| (heavy solid line) | CONTAINMENT WELL PIPING |
| (dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| (diamond) | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| EW-C | EXTRACTION WELL NUMBER |
| (circle) | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 190 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (dash-dot line) | AIR SPARGING SYSTEM |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > HEALTH ADVISORY CLEANUP GOAL OF 2 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 9 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS A THROUGH F ARE PART OF THE FOCUSED EXTRACTION SYSTEM.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
4. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.09 TO 0.15 µg/L.
5. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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Woodward-Clyde Consultants
Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

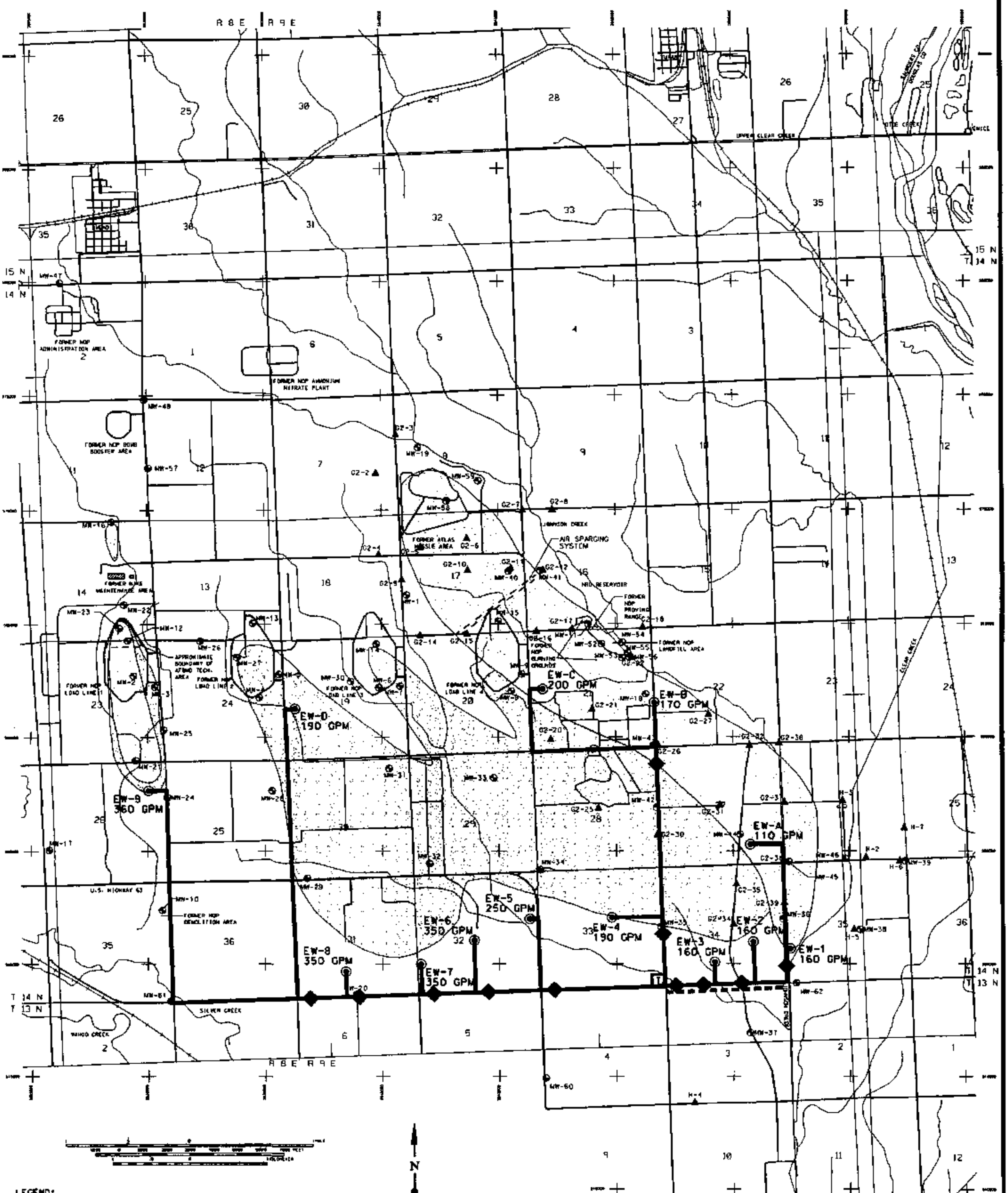
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 5 AND 6 - CONTAINMENT, FOCUSED EXTRACTION AND AIR SPARGING - TARGET CLEANUP GOAL II**

| | |
|---|---|
| Designed by: | A.C.E. |
| Drawn by: | D.R.T. |
| Checked by: | R.F.S. |
| Submitted by: | (signature) |
| Scale: | AS NOTED |
| Date: | DECEMBER, 1994 |
| Dwg. No: | 4-7B |
| Sheet number: | 1 |

MCS FILE: OU2-26

B07NE003702-09141




**LEGEND:**

| | |
|---|---|
| [symbol] | CONTAINMENT WELL PIPING |
| [symbol] | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT WELL NUMBER |
| EW-C | EXTRACTION WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 160 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| [symbol] | AIR SPARGING SYSTEM |
| [symbol] | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 μg/L) |
| [symbol] | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > $10^{-4}$ CLEANUP GOAL OF 0.774 μg/L) |
| ⊕ MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲ G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 9 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS A THROUGH F ARE PART OF THE FOCUSED GROUNDWATER EXTRACTION SYSTEM.
2. TCE AND RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. DETECTION LIMIT (ND) FOR TCE IS 1.0 μg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 μg/L.
4. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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Overland Park, Kansas

U.S ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

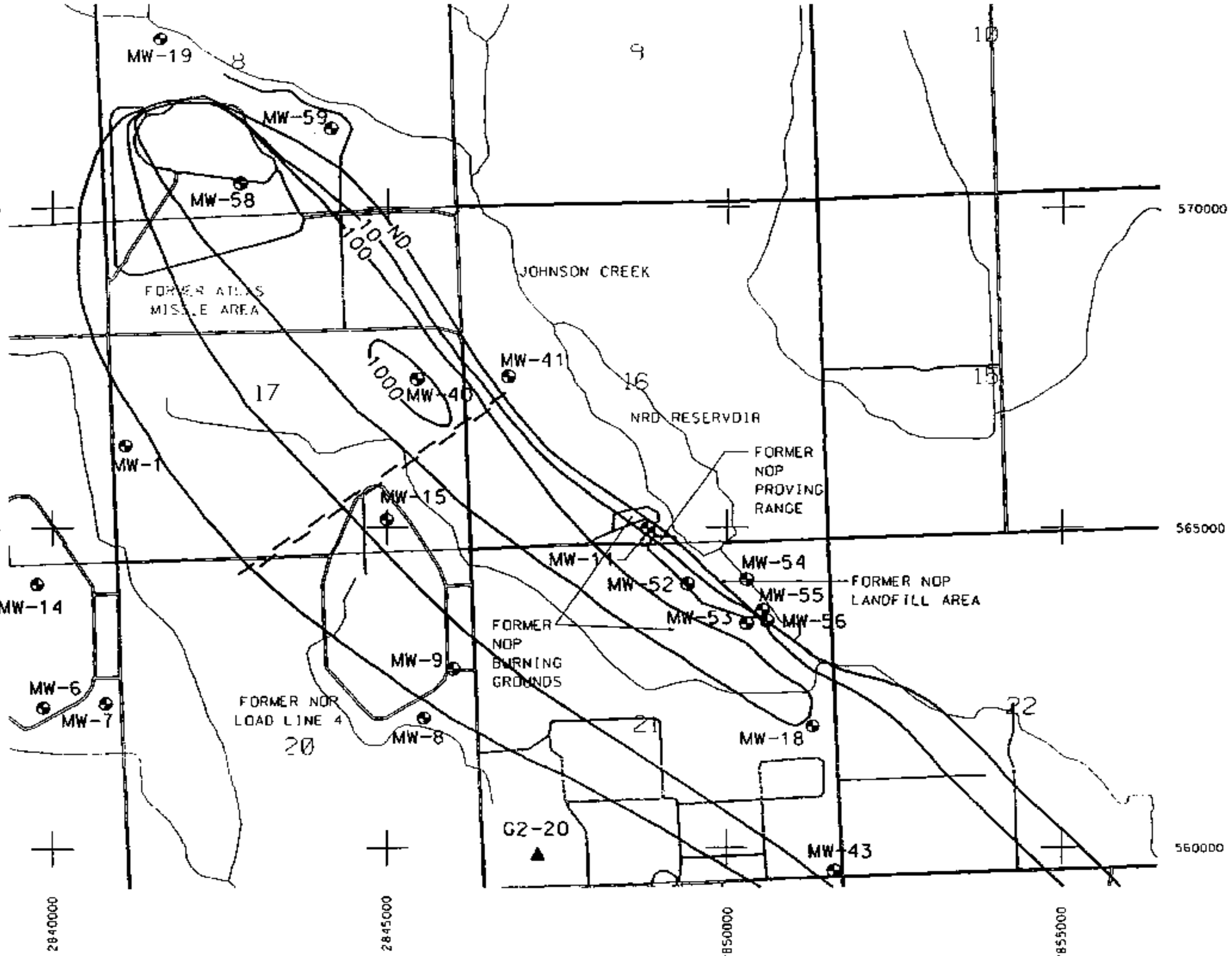
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

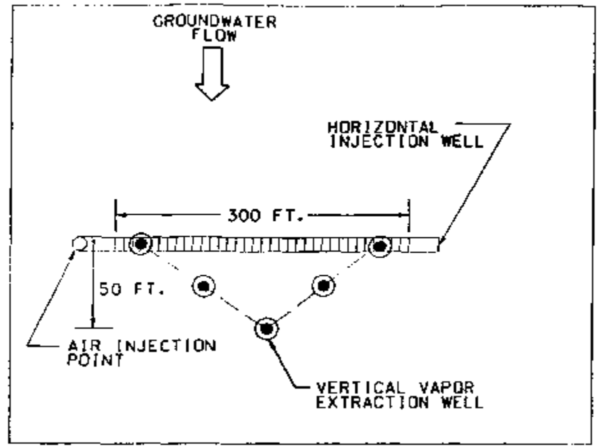
**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 5 AND 6 - CONTAINMENT, FOCUSED EXTRACTION AND AIR SPARGING - TARGET CLEANUP GOAL III**

| | |
|---|---|
| Designed by: | A.C.E |
| Drawn by: | D.R.T. |
| Checked by: | R.F.S |
| Submitted by: | [signature] |
| Scale | AS NOTED |
| Date: | DECEMBER, 1994 |
| Dwg. No. | 4-7C |
| Sheet number | 1 |

MCS FILE: OU2-30

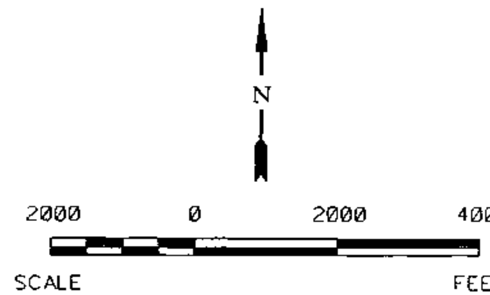
B07NE003702-09142




TYPICAL WELL CONFIGURATION

PLAN VIEW
(NOT TO SCALE)




## LEGEND:

| | |
|---|---|
| ——— | APPROXIMATE TCE CONCENTRATION CONTOUR IN µg/L. INTERMEDIATE PLUME |
| ◉ | VERTICAL WELL |
| — | HORIZONTAL INJECTION WELL |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

NOTES:

1. 15 HORIZONTAL WELLS 300 FEET LONG AND 60 FEET DEEP.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 GROUNDWATER SAMPLING DATA.
3. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L.
4. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'd |
| | | | |

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Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by: M.D.F.
Drawn by: D.R.T.
Checked by: R.F.S.
Submitted by: DEH

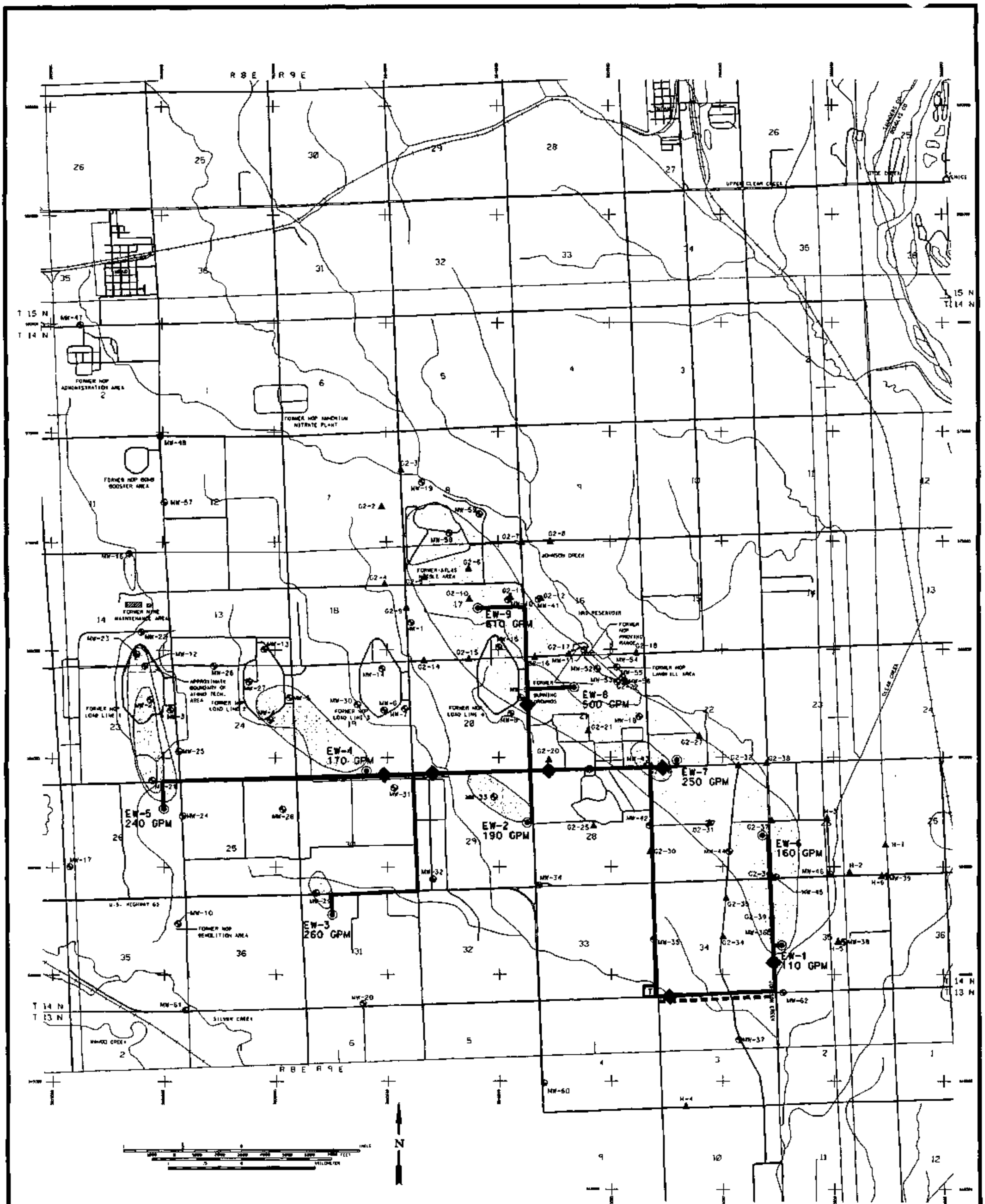
U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR NEBRASKA ORDNANCE PLANT - MEAD NE

**AIR SPARGING SYSTEM
CONCEPTUAL LAYOUT**

Scale: 1 IN = 2000 FT
Date: DECEMBER, 1994
Dwg No.: 4-8
Sheet number: 1

MCS FILE: 92FS-36




**LEGEND:**

| | |
|---|---|
| (heavy line) | CONTAINMENT WELL PIPING |
| (dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT AND EXTRACTION WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 260 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF DETECTED EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > $10^{-6}$ CLEANUP GOAL OF 1.74 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 5 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS 6 THROUGH 9 ARE PART OF THE FULL EXTRACTION SYSTEM.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
4. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
5. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
| | | | |
| | | | |

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Overland Park, Kansas

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CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

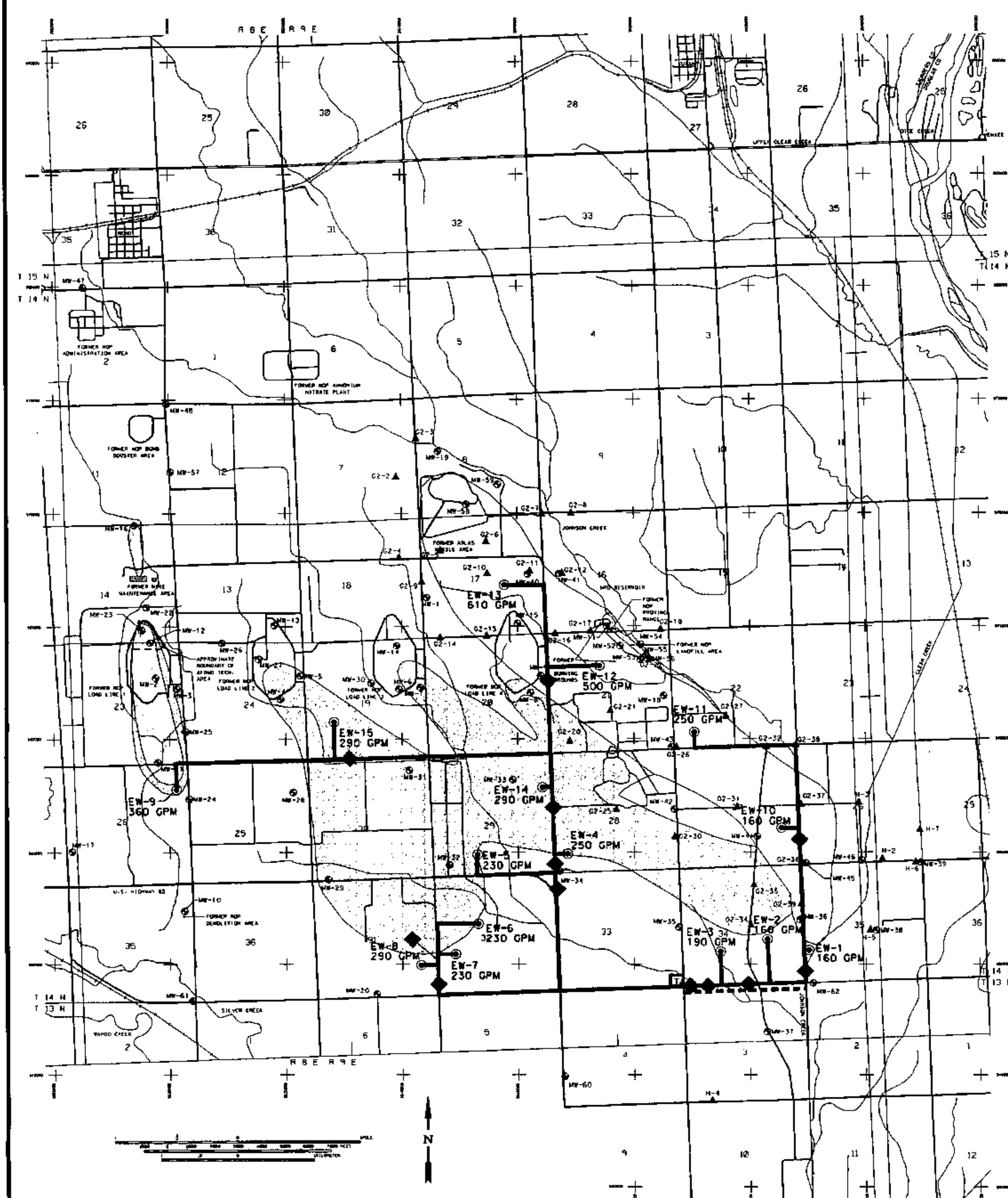
FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 7 AND 8 - CONTAINMENT AND FULL EXTRACTION-TARGET CLEANUP GOAL I**

| | |
|---|---|
| Designed by: | A.C.E |
| Drawn by: | D.R.T. |
| Checked by: | R.F.S |
| Submitted by: | DEH |
| Scale: | AS NOTED |
| Date | DECEMBER, 1994 |
| Dwg. No.: | 4-9A |
| Sheet number: | 1 |

MCS FILE OU2-18

B07NE003702-09144




LEGEND:

| | |
|---|---|
| (solid line) | CONTAINMENT WELL PIPING |
| (dashed line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT AND EXTRACTION WELL NUMBER |
| ◉ | PROPOSED EXTRACTION AND CONTAINMENT WELL LOCATION |
| 190 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (stippled outline) | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > HEALTH ADVISORY CLEANUP GOAL OF 2 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲GZ-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 9 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS 10 THROUGH 15 ARE PART OF THE FULL EXTRACTION SYSTEM.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
4. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
5. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
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| | | | |
| | | | |

Woodward-Clyde Consultants
Overland Park, Kansas

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

Designed by: A.C.E.
Drawn by: D.R.F.
Checked by: R.F.S.
Submitted by: [signature]

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 7 AND 8 - CONTAINMENT AND FULL EXTRACTION-TARGET CLEANUP GOAL II**

Scale: AS NOTED
Date: DECEMBER, 1994
Dwg. No.: 4-9B
Sheet number: 1

MCS FILE: OU2-16

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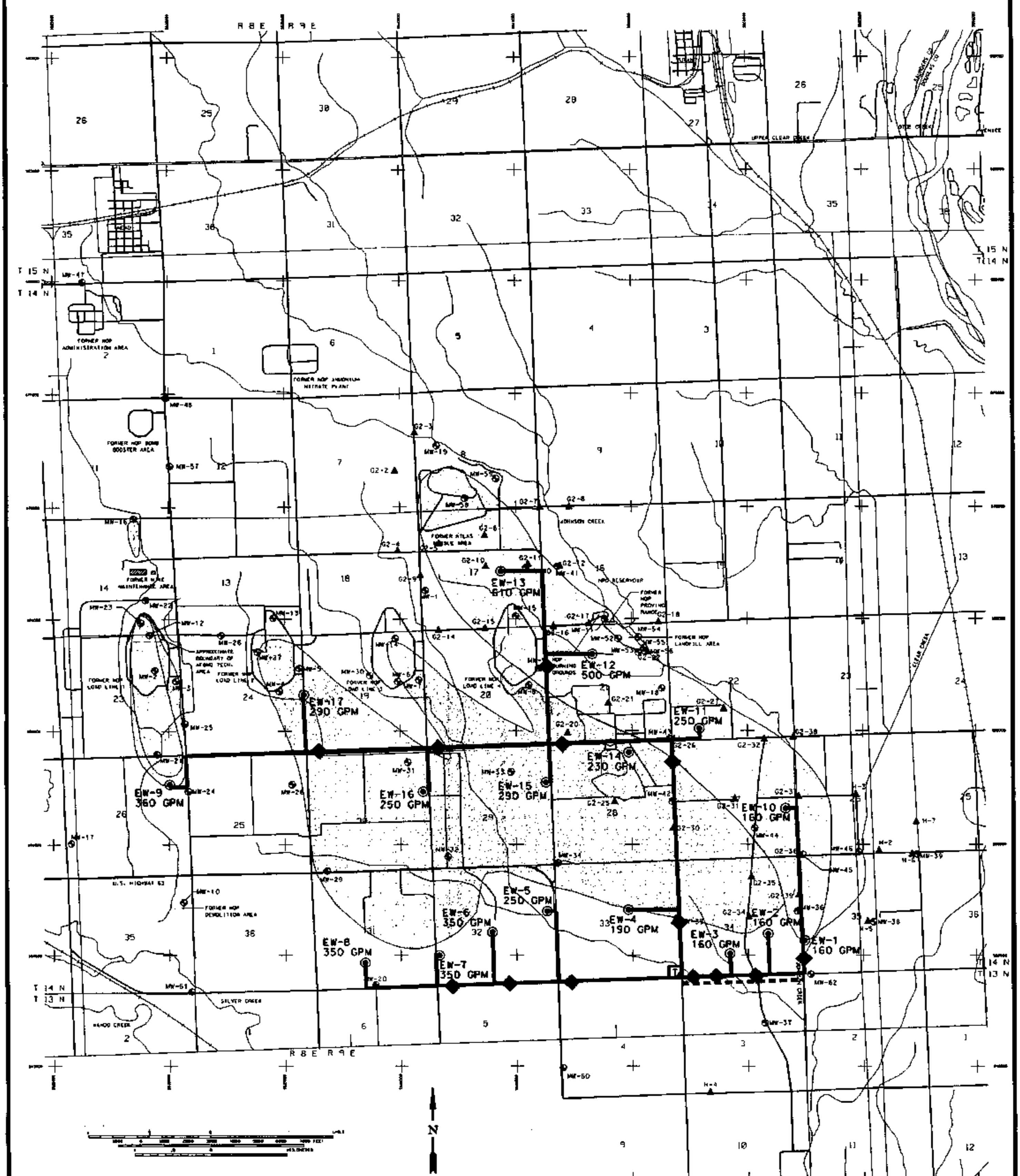


**LEGEND:**

| | |
|---|---|
| (solid heavy line) | CONTAINMENT WELL PIPING |
| (dashed heavy line) | DISCHARGE PIPING |
| T | TREATMENT SYSTEM |
| ◆ | TRANSFER PUMP |
| EW-3 | CONTAINMENT AND EXTRACTION WELL NUMBER |
| ◉ | PROPOSED CONTAINMENT AND EXTRACTION WELL LOCATION |
| 160 GPM | PROPOSED PUMPING RATE, GALLONS PER MINUTE |
| (outline) | APPROXIMATE BOUNDARY OF TCE - CONTAMINATED GROUNDWATER (CONCENTRATIONS > MCL OF 5 µg/L) |
| (outline) | APPROXIMATE BOUNDARY OF EXPLOSIVES - CONTAMINATED GROUNDWATER (CONCENTRATIONS OF RDX > $10^{-6}$ CLEANUP GOAL OF 0.774 µg/L) |
| MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| ▲G2-30 | GROUNDWATER HEADSPACE SCREENING LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WAHN 1927 NAD, 1929 NGVD

NOTES:

1. EXTRACTION WELLS 1 THROUGH 9 ARE PART OF THE HYDRAULIC CONTAINMENT SYSTEM. EXTRACTION WELLS 10 THROUGH 17 ARE PART OF THE FULL EXTRACTION SYSTEM.
2. TCE AND RDX CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 THROUGH JULY 1993 GROUNDWATER SAMPLING DATA.
3. DETECTION LIMIT (ND) FOR TCE IS 1.0 µg/L. DETECTION LIMIT (ND) FOR RDX IS 0.08 TO 0.15 µg/L.
4. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Apprv'd |
| | | | |
| | | | |
| | | | |

Woodward-Clyde Consultants
Overland Park, Kansas

U.S ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

U.S. Army Corps of Engineers

FEASIBILITY STUDY
FOR OPERABLE UNIT NO. 2 - GROUNDWATER
FMR. NEBRASKA ORDNANCE PLANT - MEAD, NE.

**EXTRACTION AND DISCHARGE PIPING SCHEMATIC - ALTERNATIVES 7 AND 8 - CONTAINMENT AND FULL EXTRACTION - TARGET CLEANUP GOAL III**

| | |
|---|---|
| Designed by: | A.C.E. |
| Drawn by: | D.R.T. |
| Checked by: | R.F.S |
| Submitted by: | (signature) |
| Scale: | AS NOTED |
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DRAFT FINAL
VOLUME II OF II
(Revision 2)

# FEASIBILITY STUDY REPORT OPERABLE UNIT NO. 2 (GROUNDWATER) FOR FORMER NEBRASKA ORDNANCE PLANT MEAD, NEBRASKA DACA 41-92-C-0023

Prepared for
Department of the Army
U.S. Army Engineers District
Kansas City District
Corps of Engineers
Kansas City, Missouri
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## VOLUME II

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# APPENDIX A
# PREDICTION OF VOLATILE ORGANIC COMPOUND CONCENTRATIONS IN AIR DURING SHOWERING

# PREDICTION OF VOLATILE ORGANIC COMPOUND CONCENTRATION IN AIR DURING SHOWERING

## GENERAL VOLATILIZATION MODEL:

Calculation based on the Shower Model used in the OU2 Baseline Risk Assessment (WCC, 1994).

**Assumptions:**

Volatile chemical concentration ($C_w$)
Water flow rate ($Q_w$) = 9.5 L/min (approx. 2.5 gal/min)
Volume of shower ($V_d$) = 4.1 $m^3$ (approx. 3 ft x 6 ft x 8 ft)
Fraction volatilized (F) = 100%
Air change rate of room (ach) = 0.03/min (approx. 2 changes per hour)
Mixing factor (K) = 1
Time (t) = one minute time intervals

$$C(i) = C(a) + C(b)$$

$$where\ C(a) = \frac{Q_w \times C_w \times F}{K \times V_d \times ach} (1 - e)^{-(K)\ (ach)\ t}$$

$$C(b) = C(s)e^{-(K)(ach)t}$$

C(i) = Indoor Air Concentration
S = Emission Rate = $Q_w$ x $C_w$ x F
K = Mixing Rate
V = Volume of room
Q = Air flow rate in and out of room
t = Time interval
C(s) = C(i) at time=t-1

For volatile chemical concentration ($C_w$) = 1.0 mg/L

| C(a) ($mg/m^3$) | $Q_w$ (L/min) | F (unitless) | K (unitless) | $V_d$ ($m^3$) | ach ($min^{-1}$) | t (min) |
|---|---|---|---|---|---|---|
| 2.28 | 9.50 | 1.00 | 1.00 | 4.10 | 0.030 | 1.00 |

**APPENDIX A**
**(Continued)**

## PREDICTION OF VOLATILE ORGANIC COMPOUND CONCENTRATION IN AIR DURING SHOWERING

Second part of equation is dependent on C(i) at t-1:

$$C(b) = C(s)e^{-(K)(ach)t}$$

$$where\ C(s) = C(i)\ at\ t-1$$

For volatile chemical concentration ($C_w$) = 1.0 mg/L

| | C(b) (mg/m$^3$) | C(s) (mg/m$^3$) | K (unitless) | ach (min$^{-1}$) | t (min) |
|---|---|---|---|---|---|
| 0-1 min | 0.00 | 0.00 | 1.00 | 0.03 | 1.00 |
| 1-2 min | 2.22 | 2.28 | 1.00 | 0.03 | 1.00 |
| 2-3 min | 4.36 | 4.50 | 1.00 | 0.03 | 1.00 |
| 3-4 min | 6.45 | 6.65 | 1.00 | 0.03 | 1.00 |
| 4-5 min | 8.48 | 8.73 | 1.00 | 0.03 | 1.00 |
| 5-6 min | 10.44 | 10.76 | 1.00 | 0.03 | 1.00 |
| 6-7 min | 12.35 | 12.72 | 1.00 | 0.03 | 1.00 |
| 7-8 min | 14.20 | 14.63 | 1.00 | 0.03 | 1.00 |
| 8-9 min | 15.99 | 16.48 | 1.00 | 0.03 | 1.00 |
| 9-10 min | 17.74 | 18.28 | 1.00 | 0.03 | 1.00 |
| 10-11 min | 19.43 | 20.02 | 1.00 | 0.03 | 1.00 |
| 11-12 min | 21.07 | 21.71 | 1.00 | 0.03 | 1.00 |

## PREDICTION OF VOLATILE ORGANIC COMPOUND CONCENTRATION IN AIR DURING SHOWERING

Third part of equation is dependent on above two:

$$C(i) = C(a) + C(b)$$

For volatile chemical concentration ($C_w$) = 1.0 mg/L

| | C(i) (mg/m$^3$) | C(a) (mg/m$^3$) | C(b) (mg/m$^3$) |
|---|---|---|---|
| 0-1 min | 2.28 | 2.28 | 0.00 |
| 1-2 min | 4.50 | 2.28 | 2.22 |
| 2-3 min | 6.65 | 2.28 | 4.36 |
| 3-4 min | 8.73 | 2.28 | 6.45 |
| 4-5 min | 10.76 | 2.28 | 8.48 |
| 5-6 min | 12.72 | 2.28 | 10.44 |
| 6-7 min | 14.63 | 2.28 | 12.35 |
| 7-8 min | 16.48 | 2.28 | 14.20 |
| 8-9 min | 18.28 | 2.28 | 15.99 |
| 9-10 min | 20.02 | 2.28 | 17.74 |
| 10-11 min | 21.71 | 2.28 | 19.43 |
| 11-12 min | 23.35 | 2.28 | 21.07 |

Average Indoor Air Concentration (C(i)) = 13.34 (mg/m$^3$)

* Based upon assumptions used in the generic equation, 1 mg/L of volatile chemical in groundwater ($C_w$) would generate an average indoor air concentration (C(i)) of 13.34 mg/m$^3$.

## PREDICTION OF VOLATILE ORGANIC COMPOUND CONCENTRATION IN AIR DURING SHOWERING

The generic water to air conversion constant can be calculated as:

$$K_s = \frac{C_a}{C_w} = \frac{13.34}{1} = 13.34$$

where:

$C_a$ = Chemical concentration in the air during showering ($mg/m^3$)
$C_w$ = Chemical concentration in shower water (mg/L)
$K_s$ = Conversion constant ($L/m^3$)
F = Fraction volatilized (for cleanup level calculations, 100% volatilization was assumed for all volatile compounds)

**Site-Specific Application of Generic Model**

Generic Model is modified by chemical concentrations and approximate volatilization rate.

$$C_a = C_w \times F \times K_s$$

where:

$C_a$ = Chemical concentration in the air during showering ($mg/m^3$)
$C_w$ = Chemical concentration in shower water (mg/L)
$K_s$ = Conversion constant ($L/m^3$)
F = Fraction volatilized (for cleanup level calculations, 100% volatilization was assumed for all volatile compounds)

# APPENDIX B
# RESTORATION TIME FRAME ESTIMATES

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ATTACHMENT B2 SECTION 3.0 CALCULATIONS

# 1.0
# INTRODUCTION

## 1.1 PURPOSE

The purposes of the analyses described by this Appendix are:

- Estimate the time frames required to clean up groundwater contamination currently existing at the Site

- Estimate explosives concentrations in soil which may potentially contribute to groundwater contamination after the currently existing groundwater contamination has been cleaned up

The restoration time frame estimates are based on the total extraction well flowrates which were estimated for comparative cost estimates only. The total extraction well flowrate will be estimated during remedial design.

There are explosives-contaminated soils which do not require excavation according to the OU1 excavation preliminary remediation goals (PRGs). Leaching soils are defined as explosives-contaminated soils, exclusive of the OU1 soils, that are estimated to contribute to groundwater contamination for a time period estimated to extend beyond the time required to clean up the currently existing groundwater contamination.

The Feasibility Study (FS) Report evaluates the benefits of remediating leaching soils in the context of the groundwater remediation (i.e., is there a benefit to groundwater remediation in terms of time, cost, or protectiveness if the leaching soils are remediated?).

Alternative 1 is the no action alternative, and as such, it is not included in the evaluations presented in this section.

## 1.2 PREVIOUS WORK

Section 1.2 of **Appendix C**, Unsaturated Zone Modeling Results, summarizes previous work related to the evaluation of leaching soils. **Appendix C** identifies that there is a potential for explosives-contaminated soils to continue to be a source of groundwater contamination even though the soils are no longer a risk with respect to dermal contact or ingestion.

## 1.3 APPENDIX ORGANIZATION

Section 2.0 presents the methodology, application, and results of the estimates of the time required to clean up the currently existing groundwater contamination. Restoration time frame estimates are presented for each combination of remedial alternatives and Target Groundwater Cleanup Goals. Section 3.0 presents a characterization of the time that hypothetical distributions of explosives concentrations in the unsaturated zone soil would contribute to groundwater contamination at the Site. Conclusions drawn from the restoration time frame estimates and the leaching time estimates are presented in Section 4.0, and references cited in the text are presented in Section 5.0. Calculations and printout of computer model output files are contained in various attachments to this Appendix.

**2.0**

# RESTORATION TIME FRAME ESTIMATES FOR EXISTING GROUNDWATER CONTAMINATION

## 2.1 METHODOLOGY

The restoration time frame is the period of time required to achieve the Target Groundwater Cleanup Goals at all locations within the areas of attainment. Guidance on Remedial Actions for Contaminated Groundwater (EPA, 1988) presents the following methodology to estimate restoration time frames:

1) Calculate the estimated number of batch flushes

2) Calculate the estimated volume of groundwater to be extracted by multiplying the number of batch flushes by the estimated volume of contaminated groundwater (as defined by the preliminary Target Groundwater Cleanup Goals)

3) Calculate the estimated restoration time frame by dividing the volume of water calculated in Step 2 by the estimated total extraction flowrate of the particular alternative

A batch flush consists of enough clean water to fill the pore space in a given volume of aquifer. Values of contaminant concentrations for both soil and water following each batch flush are considered. Zheng, et. al. (1991) presents the following equation for calculating the number of batch flushes of pore volumes, $\boldsymbol{PV}$, that are required to lower the maximum initial concentration ($\boldsymbol{C_i}$) of a particular chemical in the aquifer to the Target Groundwater Cleanup Goal ($\boldsymbol{C_S}$):

$$PV = -R \ln\left(\frac{C_S}{C_i}\right) \qquad (1)$$

where $\boldsymbol{R}$ is the retardation factor.

The restoration time frame estimate, ***T***, is calculated using the following equation:

$$T = \frac{PV * VOL}{RATE} \qquad (2)$$

where ***VOL*** is the volume of currently existing contaminated groundwater, and ***RATE*** is the sum of the flowrates for all of the extraction wells located in the contaminated groundwater plumes.

The impact of air sparging was considered when estimating Alternatives 5 and 6 restoration time frames for the Atlas Missile Area groundwater contamination. The Atlas Missile Area plume was divided into two sections whose common boundary coincided with the estimated location of the air sparging system shown on Drawing 4-8 of the FS Report. It was assumed that:

- Water flowing across the air sparging boundary would meet cleanup goals
- The average linear groundwater velocity, ***VEL***, in the air sparging portion of the Site (northwest) section is equal to the estimate of the current average linear velocity for the entire Site

PV was calculated using Equation 1 for both sections of the Atlas Missile Area plume and the volume of currently existing contaminated groundwater, ***VOL***, in the downgradient (southeast) section. The maximum distance from the air sparging boundary to the upgradient edge of the northwest section, ***DIST***, was estimated along a line parallel to the estimated groundwater flow direction. The restoration time frame estimate, $T_{NW}$, was calculated for the air sparging (northwest) section using the following equation:

$$T_{NW} = \frac{PV * DIST}{VEL} \qquad (3)$$

The estimated restoration time frame estimate for the southeast section was calculated using Equation 2. The restoration time frame estimates for the two sections of the Atlas Missile Area plume were compared, and the longer time estimate was selected as the restoration time frame for the entire plume.

## 2.2 APPLICATION AND RESULTS

Alternative 2 includes groundwater extraction solely for hydraulic containment. The objective of hydraulic containment is to prevent the further downgradient migration of contamination, rather than the cleanup of the aquifer. Natural attenuation of the contamination, as well as the passage of uncontaminated groundwater from upgradient of the Site, will eventually remove all of the contamination. However, the restoration time frame is essentially perpetuity and restoration time frame estimates are quantified for Alternative 2 for comparative purposes only.

Retardation coefficients were calculated for TCE and RDX using physical parameters measured at the Site, or literature values when Site-specific values were not available. The assumptions, input values, and calculations associated with all of the analyses in this section are in **Attachment B1**. The assumed retardation factor for TCE in the fine sand unit, $R_{TCE}$, is 1.2, and the corresponding retardation factor for RDX, $R_{RDX}$, is 1.1.

The maximum concentrations of TCE and RDX detected in groundwater monitoring wells are tabulated below according to their respective plumes.

| Plume | Chemical | Concentration ($\mu$g/L) | Monitoring Well | Sampling Event |
|---|---|---|---|---|
| Load Line 1 | TCE | 210 | MW-23B | February 1993 |
| | RDX | 18 | MW-2B<br>MW-21B | February 1993 |
| Load Lines 2 and 3 | TCE | 7 | MW-5A | November 1992 |
| | RDX | 534 | MW-5B | May 1993 |
| Atlas Missile Area | TCE | 4,800 | MW-40B | February 1992 |
| | RDX | 35 | MW-11A | November 1992 |
| Atlas Missile Area - Northwest Section | TCE | 4,800 | MW-40B | February 1993 |
| Atlas Missile Area - Southeast Section | TCE | 300 | MW-9A | August 1992 |

The preliminary Target Groundwater Cleanup Goal concentrations for TCE and RDX are tabulated below.

| Preliminary Target Groundwater Cleanup Goal | TCE Concentration (μg/L) | RDX Concentration (μg/L) |
|---|---|---|
| I | 5 | 7.74 |
| II | 5 | 2 |
| III | 5 | 0.774 |

The following tabulation summarizes the ***PV*** values calculated using Equation 1.

| Plume | Chemical | Preliminary Target Groundwater Cleanup Goal (μg/L) | ***PV*** |
|---|---|---|---|
| Load Line 1 | TCE | 5 | 4.4 ✓ |
| | RDX | 7.74 | 0.97 |
| | | 2 | 2.5 |
| | | 0.774 | 3.6 |
| Load Lines 2 and 3 | TCE | 5 | 0.39 |
| | RDX | 7.74 | 4.9 ✓ |
| | | 2 | 6.4 ✓ |
| | | 0.774 | 7.5 ✓ |
| Atlas Missile Area | TCE | 5 | 8.0 ✓ |
| | RDX | 7.74 | 1.7 |
| | | 2 | 3.3 |
| | | 0.774 | 4.4 |
| Atlas Missile Area - Northwest Section | TCE | 5 | 8.0 ✓ |
| Atlas Missile Area - Southeast Section | TCE | 5 | 4.8 ✓ |

The chemical with the largest ***PV*** value will be used to calculate the restoration time frame estimate for each plume. By using the largest calculated ***PV***, chemical concentrations which resulted in smaller calculated ***PVs*** will also be reduced to the appropriate Target Groundwater Cleanup Goal concentrations. Therefore, the restoration time frame estimates will be based on TCE for the Load Line 1 plume, RDX for the Load Lines 2 and 3 plume, and TCE for the Atlas Missile Area plumes as indicated by the ✓ marks.

The plume volumes, ***VOL***, are summarized from **Appendix D** according to preliminary Target Groundwater Cleanup Goal below:

| Plume | *VOL* (gallons) | | |
|---|---|---|---|
| | Cleanup Goal I | Cleanup Goal II | Cleanup Goal III |
| Load Line 1 | $1.01 \times 10^{9}$ | $1.33 \times 10^{9}$ | $1.37 \times 10^{9}$ |
| Load Lines 2 and 3 | $9.34 \times 10^{8}$ | $1.11 \times 10^{10}$ | $1.53 \times 10^{10}$ |
| Atlas Missile Area | $1.00 \times 10^{10}$ | $1.02 \times 10^{10}$ | $1.03 \times 10^{10}$ |
| Atlas Missile Area - Southeast Section | $7.4 \times 10^{9}$ | $7.5 \times 10^{9}$ | $7.6 \times 10^{9}$ |

The following tabulations summarize the total estimated extraction flowrate, ***RATE***, for each alternative according to preliminary Target Groundwater Cleanup Goals and plume. The total extraction well flowrates were estimated for Alternatives 2 through 8 for comparative estimates only. The total extraction well flowrate will be estimated during remedial design.

| Alternative 2 - Hydraulic Containment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | |
| | Wells | Rate (GPM) | Wells | Rate (GPM) | Wells | Rate (GPM) | Wells | Rate (GPM) |
| I | 1 | 110 | 3 | 620 | 1 | 240 | 5 | 970 |
| II | 1 | 160 | 7 | 1,580 | 1 | 360 | 9 | 2,100 |
| III | 1 | 160 | 7 | 1,810 | 1 | 360 | 9 | 2,330 |

| Alternatives 3 -Focused Extraction & 4 - Focused Extraction and Soil Excavation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | |
| | Wells | Rate (GPM) | Wells | Rate (GPM) | Wells | Rate (GPM) | Wells | Rate (GPM) |
| I | 6 | 1,120 | 3 | 620 | 1 | 240 | 10 | 1,980 |
| II | 6 | 1,170 | 8 | 1,770 | 1 | 360 | 15 | 3,300 |
| III | 6 | 1,170 | 8 | 2,000 | 1 | 360 | 15 | 3,530 |

| Alternatives 5 - Focused Extraction with Air Sparging & 6 - Focused Extraction with Air Sparging and Soil Excavation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cl - Focused Extractio n with eanup Goal | Atlas Missile Area - Northwest Section | | Load Lines 2 & 3 | | Load Line 1 | | Total | |
| | Wells | Rate (GPM) | Wells | Rate (GPM) | Well s | Rate (GPM) | Wells | Rate (GPM) |
| I | 4 | 590 | 3 | 620 | 1 | 240 | 8 | 1,450 |
| II | 4 | 640 | 8 | 1,770 | 1 | 360 | 13 | 2,770 |
| III | 4 | 640 | 8 | 2,000 | 1 | 360 | 13 | 3,000 |

| Alternatives 7 - Groundwater Extraction & 8 - Groundwater Extraction and Soil Excavation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | Total | |
| | Wells | Rate (GPM) | Wells | Rate (GPM) | Wells | Rate (GPM) | Wells | Rate (GPM) |
| I | 5 | 1,630 | 3 | 620 | 1 | 240 | 9 | 2,490 |
| II | 5 | 1,680 | 9 | 2,160 | 1 | 360 | 15 | 4,200 |
| III | 5 | 1,680 | 11 | 2,870 | 1 | 360 | 17 | 4,910 |

Using Equation 2, restoration time frames for currently existing groundwater contamination were estimated for Alternatives 2 through 4, 7, and 8. The impact of air sparging was considered when estimating Alternatives 5 and 6 restoration time frames for currently existing Atlas Missile Area groundwater contamination.

The restoration time frame estimates are calculated for currently existing groundwater contamination only, assuming that there is no continuing contribution to groundwater contamination from leaching. The restoration time frame estimates for alternatives which do not include the elements of leaching soil excavation and treatment are estimated to be larger relative to alternatives that include soil excavation and treatment. Therefore, the restoration time frame estimates for alternatives that do not include leaching soil excavation and treatment are prefaced by a "greater than symbol" (>) to indicate the uncertain contribution to groundwater contamination from the leaching soils. The longest estimated restoration time frame for each preliminary Target Groundwater Cleanup Goal is highlighted in bold font in the tables below. The restoration time frame estimates are based on the total extraction well flowrates which were estimated for comparative cost estimates only. The total extraction well flowrate will be estimated during remedial design.

| ALTERNATIVE 2 RESTORATION TIME FRAME ESTIMATES | | | |
|---|---|---|---|
| Cleanup Goal | Load Line 1 | Load Lines 2 and 3 | Atlas Missile Area |
| I | >35 years | >14 years | >1,400 years |
| II | >31 years | >86 years | >970 years |
| III | >32 years | >120 years | >980 years |

| ALTERNATIVE 3 RESTORATION TIME FRAME ESTIMATES | | | |
|---|---|---|---|
| Cleanup Goal | Load Line 1 | Load Lines 2 and 3 | Atlas Missile Area |
| I | >35 years | >14 years | >140 years |
| II | >31 years | >77 years | >130 years |
| III | >32 years | >110 years | >130 years |

| ALTERNATIVE 4 RESTORATION TIME FRAME ESTIMATES | | | |
|---|---|---|---|
| Cleanup Goal | Load Line 1 | Load Lines 2 and 3 | Atlas Missile Area |
| I | 35 years | 14 years | 140 years |
| II | 31 years | 77 years | 130 years |
| III | 32 years | 110 years | 130 years |

| ALTERNATIVE 5 RESTORATION TIME FRAME ESTIMATES | | | | |
|---|---|---|---|---|
| | | | Atlas Missile Area | |
| Cleanup Goal | Load Line 1 | Load Lines 2 and 3 | Northwest Section | Southeast Section |
| I | >35 years | >14 years | >77 years | >110 years |
| II | >31 years | >77 years | >77 years | >110 years |
| III | >32 years | >110 years | >77 years | >110 years |

| ALTERNATIVE 6 RESTORATION TIME FRAME ESTIMATES | | | | |
|---|---|---|---|---|
| | | | Atlas Missile Area | |
| Cleanup Goal | Load Line 1 | Load Lines 2 and 3 | Northwest Section | Southeast Section |
| I | 35 years | 14 years | 77 years | 110 years |
| II | 31 years | 77 years | 77 years | 110 years |
| III | 32 years | 110 years | 77 years | 110 years |

| ALTERNATIVE 7 RESTORATION TIME FRAME ESTIMATES | | | |
|---|---|---|---|
| Cleanup Goal | Load Line 1 | Load Lines 2 and 3 | Atlas Missile Area |
| I | >35 years | >14 years | >90 years |
| II | >31 years | >63 years | >90 years |
| III | >32 years | >76 years | >90 years |

| ALTERNATIVE 8 RESTORATION TIME FRAME ESTIMATES | | | |
|---|---|---|---|
| Cleanup Goal | Load Line 1 | Load Lines 2 and 3 | Atlas Missile Area |
| I | 35 years | 14 years | 90 years |
| II | 31 years | 63 years | 90 years |
| III | 32 years | 76 years | 90 years |

## 2.3 UNCERTAINTY AND LIMITATIONS

### Batch Flushing Model

The batch flushing model assumes that the aqueous TCE or RDX concentrations reach equilibrium with the aquifer matrix. This is a standard assumption that is used to account for the concept of retardation by the theory of mass transport in a groundwater system. In situations where the chemical reaction is relatively rapid and the volumetric rate of groundwater flow is relatively low, this assumption may be valid. However, at some sites it may be appropriate to use the continuous flushing theory to account for the non-equilibrium adsorption relationship. It is uncertain if the batch flushing model relatively accurately represents the physical process which are taking place at the Site. NRC (1994) states that

> Thus, the two approaches [batch flush and continuous flush] are based on the same physical assumptions. Because both approaches assume instantaneous equilibrium between the sorbed and dissolved phases, if properly formulated they should give the same results except for numerical error. In this sense, the distinction between the 'batch flush' and 'continuous flush' methods described in the EPA's guidance document is misleading. . . .
>
> In general, the batch flush model will underestimate cleanup time because it does not account for ... processes ... (i.e., heterogeneities, NAPLs [nonaqueous phase liquids], and leachate from the original source of contamination). In addition, if the interaction between the dissolved chemical and the chemical attached to the solid media is not represented by linear sorption, as is the case for most inorganic compounds, the batch flush model will tend to underestimate cleanup time. . . .
>
> Detailed, computer-based models that include all the major processes affecting contaminating flow are available for estimating cleanup times (see, for example, Zheng et al., 1992; National Research Council, 1990; EPA, 1985). However, given budget and time constraints typical for hazardous waste investigations, the site-specific data necessary to run such models are rarely collected. Even in research settings, collecting all the necessary data is difficult. As a result, these types of models have been used to estimate cleanup times at only a limited number of sites. In addition, even when these models have been used, they have most often been used only to describe processes represented by the batch flush model and have overlooked the other important influences on cleanup time.

**Volumetric Analysis**

The volumetric analysis that is represented by Equation 2 introduces uncertainty into the restoration time frame estimates because advective and dispersive elements of mass transport are not considered. The magnitude of the potential difference in restoration time frames resulting from this uncertainty is large enough that the actual time frame may not be similar to the estimate, yet the potential difference is not anticipated to be large enough to make the estimate less valid. The restoration time frames may be either over- or under-estimated.

**Plume Analysis**

Uncertainty is introduced in the restoration time frame estimates because the estimation analysis is divided into plumes. The remedial alternatives are generally designed to address the entirety of the groundwater contamination. Assigning the extraction wells to individual contamination plumes, which are actually co-mingled, does not account for the optimization of the extraction system as a whole. It is estimated that the magnitude of the potential difference in restoration time frame estimates is low and the restoration time frames may be either over- or under-estimated.

**Specific Parameters**

There is significant uncertainty associated with the assumed values for three of the parameters used to estimate the restoration time frames:

- Retardation factors
- Maximum RDX and TCE concentrations existing in the aquifer
- Extraction well flowrate

The net effect of the input parameter uncertainty is that the simulated leachate concentration may be over- or under-estimated. Any change in any of the parameter values could potentially change the estimated leachate concentrations.

# 3.0
# TIME ANALYSIS OF POTENTIAL CONTRIBUTION FROM LEACHING SOILS

## 3.1 METHODOLOGY

The explosives concentrations in soils which define leaching soils are estimated using an application of the HYDRUS Model (Kool and van Genuchten, 1991) combined with a modification of the Summers Model (EPA, 1989). Leaching soils are defined as explosives-contaminated soils, exclusive of the OU1 soils, that are estimated to contribute to groundwater contamination for a time period estimated to extend beyond the time required to clean up the currently existing groundwater contamination. The following methodology was used to characterize the explosives concentrations which define leaching soils:

1) Calculate the depth of penetration of the source (mixing zone thickness)

2) Calculate the maximum allowable leachate concentration using the modified Summers Model to account for the mixing zone thickness and the preliminary target groundwater cleanup goals and other Site-specific parameters

3) Simulate mass transport through the unsaturated zone using the HYDRUS Model using a hypothetical unitized concentration profile as initial conditions

4) Evaluate the temporal distribution of the simulated leachate concentration for different initial concentrations with respect to the restoration time periods for the currently existing contaminated groundwater

5) Repeat Steps 3 and 4 for different hypothetical unitized soil concentration profiles

Infiltration of water through a contaminated area above the saturated zone results in the development of a contaminant plume in the groundwater. The thickness of the plume, or mixing zone thickness $\boldsymbol{H}$, can be calculated using the following equation from WCC (1990):

$$H = (2\alpha_v L)^{1/2} + h\left(1 - \exp\left(-\frac{L\,VD_z}{V_s n h}\right)\right) \qquad \textbf{(4)}$$

where $\alpha_v$ is the dimension of the contaminated area parallel to the groundwater flow direction, $h$ is the saturated thickness of the aquifer, $L$ is the distance at which the mixing zone thickness is calculated, $VD_z$ is the infiltration rate at the source area, $V_s$ is the average linear groundwater velocity, and $n$ is the porosity.

The modified Summers Model is used to calculate the maximum allowable leachate concentration in the manner described in **Appendix C** (for an infiltration rate of 2.3 inches/year) with the exception that the current application used $H$ as the height of the mixing zone instead of the arbitrary 5-foot mixing zone height used in **Appendix C**.

The migration of the explosives compounds through the unsaturated zone was simulated using the HYDRUS Model. The methodology is identical to the methodology described in **Appendix C** assuming an infiltration rate of 2.3 inches/year except that the current application used a hypothetical unitized initial concentration profile instead of the representative soil concentration profiles used in **Appendix L**. The hypothetical unitized concentration profile is a step distribution where the initial concentration is zero everywhere except for a 1-foot interval where the initial concentration is unity. The simulated leachate concentrations (leachate is defined for this application as the aqueous concentration immediately above the saturated zone) will always be less than or equal to 1. A step distribution with a specific initial concentration can be evaluated by multiplying the simulated concentrations resulting from an initial unitized profile by the value of the specific initial concentration. The use of a unitized initial concentration profile allows multiple initial concentrations to be evaluated using a single simulation.

The HYDRUS Model leachate output (Step 3) was plotted as percent of initial aqueous concentration, $C_0$, versus time. Parallel to the time axis, a line was plotted for a normalized concentration value (represented by the variable $Z$) calculated using the maximum allowable leachate concentration, $C_p$, and a specific soil concentration, $S$. The intersection of the line and the downward sloping limb of the model output graph represents the time at which the soil contamination is no longer a source of groundwater contamination in excess of the cleanup goal. The intersection of the line and the upward sloping limb of the output graph is the time when the contribution to groundwater contamination from the soil first exceeds the cleanup goal. The relationship between $\boldsymbol{Z}$ and $\boldsymbol{S}$ was derived in the following manner:

The HYDRUS Model leachate concentrations are output in terms of the ratio of the simulated concentration, $\boldsymbol{C}$, to the initial aqueous concentration, $\boldsymbol{C_0}$, expressed as a percent:

$$Z = \left( \frac{C}{C_0} \right) * 100 \text{ percent} \qquad (5)$$

Substituting $\boldsymbol{C_p}$ for $\boldsymbol{C}$ in Equation 5 gives the following equation

$$Z = \left( \frac{C_p}{C_0} \right) * 100 \text{ percent} \qquad (6)$$

The equilibrium relationship between $\boldsymbol{C_0}$ and $\boldsymbol{S}$ is a function of the distribution coefficient, $\boldsymbol{K_d}$.

$$C_0 = \frac{S}{K_d} \qquad (7)$$

$\boldsymbol{Z}$ can be expressed in terms of $\boldsymbol{S}$ by substituting Equation 7 into Equation 6.

$$Z = \left( \frac{K_d * C_p}{S} \right) * 100 \text{ percent} \qquad (8)$$

## 3.2 APPLICATION AND RESULTS

The analysis described in this section is limited to TNB. The results of the unsaturated zone modeling described in **Appendix C** indicated that contribution of explosives-contaminated soil to groundwater contamination was most sensitive to TNB. The sensitivity was due to a combination of factors, primarily the relatively low TNB health-based Target Groundwater Cleanup Goal and the relatively extensive (in terms of vertical and horizontal distribution) occurrence of TNB. Therefore, the leaching soils definition analysis in this section will only explicitly evaluate TNB. The overall assumption is that all leaching soils can be defined by TNB concentrations only.

The mixing zone thickness was calculated using physical parameter values measured at the Site, or literature values when site-specific values were not available. The assumptions, input values, and calculations associated with all of the analyses in this section are in **Attachment B2**.

***H*** was calculated as 53 feet using Equation 4 and the assumed input values tabulated below:

| Parameter | Value | Basis for Value |
|---|---|---|
| $\alpha_v$ | $\alpha_v = \frac{\alpha_L}{160}$ **(9)** | Suggested in Background Document for EPA's Composite Model for Landfills (WCC, 1990) |
| $\alpha_L$ | 40 meters | Estimated from a range of literature values, see discussion in Section 5.3.1.2 of the OU2 RI Report (WCC, 1993) |
| $L$ | 0.25 miles | Estimated minimum distance between potential leaching soils locations and groundwater monitoring points |
| $h$ | 75 feet | Average of values used to estimate volumes of contaminated groundwater (**Appendix D**) |
| $VD_z$ | 2.3 inches/year | Estimated for Site (Piskin, 1971) |
| $V_s$ | $V_s = \frac{K_{fs}\frac{dh}{dl}}{n}$ **(10)** | Derived using the definition of average linear velocity and Darcy's Law |
| $K_{fs}$ | 0.034 feet/minute | Average value of fine sand unit hydraulic conductivity measured at the Site and reported in the OU2 RI Report (WCC, 1993) |
| $dh/dl$ | 12 feet/mile | Calculated using water levels measured at the Site and reported in the OU2 RI Report (WCC, 1993) |
| $n$ | 0.145 | Assumed to be equal to the storativity estimated at the Site (Piskin, 1971) |

The maximum allowable TNB leachate concentration for the infiltration rate of 2.3 inches/year was calculated as described in Section 5.2 of **Appendix C** The arbitrary 5-foot mixing zone value used in **Appendix C** was replaced with the 53-foot mixing zone height described earlier. The maximum allowable TNB leachate concentration was calculated as 110 μg/L.

Initial TNB concentration profiles were developed as input for mass transport simulation using the HYDRUS Model. Each initial concentration profile had a step distribution where the initial aqueous concentration of TNB was zero everywhere except for a one foot interval where the concentration was constant. Six initial concentration profiles were developed for the following depth intervals:

- 4 to 5 feet - interval immediately below the deepest OU1 excavation (4 feet)
- 8 to 9 feet - interval approximately midway between the lower limit of the OU1 excavation and the assumed boundary between the loess and the fine sand
- 11.5 to 12.5 feet - interval immediately above the assumed boundary between the loess and the fine sand
- 12.5 to 13.5 feet - interval immediately below the assumed boundary between the loess and the fine sand
- 24 to 25 feet - intermediate interval within the unsaturated fine sand thickness

A graph of the initial concentration profile corresponding to the first bullet above is included in **Attachment B2**.

With the exception of the distribution of the initial concentration of TNB, the HYDRUS model input files were the same files used for the evaluation of soil cleanup at the load lines described in **Appendix C**. The input values are summarized in the following paragraphs.

The depth intervals of the three hydrostratigraphic units, as well as the soil physical properties used during the modeling are tabulated below.

| Hydrostratigraphic Unit | Depth Below Ground Surface (m) and [ft] | Fraction Organic Carbon (*foc*) | Saturated Hydraulic Conductivity (m/year) | Residual Water Content ($m^3/m^3$) | Saturated Water Content ($m^3/m^3$) | Shape Factor $\alpha$ ($m^{-1}$) | Shape Factor $\beta$ |
|---|---|---|---|---|---|---|---|
| Topsoil | 0 - 0.70 [0 - 2.3] | 0.0149 | 99 | 0.090 | 0.475 | 2.681 | 1.17 |
| Loess | 0.70 - 3.81 [2.3 - 12.5] | 0.017 | 3 | 0.056 | 0.479 | 2.925 | 1.15 |
| Fine Sand | 3.81 - 11.16 [12.5 - 36.6] | 0.000255 | 3,650 | 0.020 | 0.437 | 13.8 | 1.69 |

The lower boundary of the fine sand interval is the estimated depth to the top of the saturated zone which is equivalent to 36.6 feet below the ground surface. The TNB distribution coefficient was estimated as 7.748 mL/g for the topsoil, 8.84 mL/g for the loess, and 0.1326 mL/g for the fine sand. The TNB molecular diffusion coefficient was estimated as 0.0227 $m^2$/year. The dispersivity and bulk density for all three hydrostratigraphic units were estimated as 0.10 m and 1.4 g/$cm^3$, respectively.

**Attachment B2** contains the HYDRUS input and output files for the flow and transport simulation using the 4 to 5-foot initial concentration profile.

Equation 8 was evaluated for various initial soil concentrations for the six initial concentration profiles. The graphs of the simulated leachate concentrations versus time for each initial concentration profile are included in **Attachment B2**. The following tables present the estimated times when the leachate concentrations would no longer exceed the maximum allowable leachate concentrations.

| APPROXIMATE TIME WHEN $C$ BECOMES LESS THAN $C_p$ <br> $S$ IS THE SOIL CONCENTRATION IN THE DEPTH INTERVAL 4 TO 5 FEET | | | |
|---|---|---|---|
| **$S$ (mg/kg)** | | | |
| 5 | 10 | 50 | 100 |
| $C$ is always less than $C_p$ | 610 years | 920 years | > 1,000 years |

| APPROXIMATE TIME WHEN $C$ BECOMES LESS THAN $C_p$ <br> $S$ IS THE SOIL CONCENTRATION IN THE DEPTH INTERVAL 8 TO 9 FEET | | | |
|---|---|---|---|
| **$S$ (mg/kg)** | | | |
| 5 | 10 | 50 | 100 |
| $C$ is always less than $C_p$ | 380 years | 590 years | 660 years |

| APPROXIMATE TIME WHEN *C* BECOMES LESS THAN $C_p$ *S* IS THE SOIL CONCENTRATION IN THE DEPTH INTERVAL 11.5 TO 12.5 FEET | | |
|---|---|---|
| ***S* (mg/kg)** | | |
| 1.25 | 5 | 10 |
| *C* is always less than $C_p$ | 120 years | 160 years |

| APPROXIMATE TIME WHEN *C* BECOMES LESS THAN $C_p$ *S* IS THE SOIL CONCENTRATION IN THE DEPTH INTERVAL 12.5 TO 13.5 FEET | | |
|---|---|---|
| ***S* (mg/kg)** | | |
| 0.1 | 1 | 1.5 |
| 36 years | 49 years | 50 years |

| APPROXIMATE TIME WHEN *C* BECOMES LESS THAN $C_p$ *S* IS THE SOIL CONCENTRATION IN THE DEPTH INTERVAL 24 TO 25 FEET | | | |
|---|---|---|---|
| ***S* (mg/kg)** | | | |
| 0.15 | 0.5 | 1 | 1.5 |
| 19 years | 25 years | 27 years | 28 years |

## 3.3 UNCERTAINTY AND LIMITATIONS

The discussion of the uncertainty of the leachate concentration prediction contained in Section 7.1 of **Appendix C** is valid for the time analysis of potential contribution from leaching soils presented in this appendix. In addition, there is uncertainty introduced into the analysis associated with the reference dose used to calculate the TNB health-based cleanup goal.

## Health-Based Cleanup Goal

The reference dose is the critical toxicity value used to evaluate non-cancer effects. In a personal communication, a representative of the U.S. Army Center for Health Promotion and Preventive Medicine (Provisional) stated that a new reference dose for TNB had been submitted to the U.S. Environmental Protection Agency for consideration. The new reference dose is approximately 100 times higher than the current reference dose which was used to calculate the health-based cleanup goal (Leach, 1994). It is estimated that the magnitude of the potential difference in the time that $C$ exceeds $C_p$ is large, and the time may be over-estimated.

# 4.0
# CONCLUSIONS

## 4.1 RESTORATION TIME FRAME ESTIMATES

The restoration time frame estimates to be used for the comparative cost estimates for Alternatives 2 through 8 are assumed to be the longest of the time frame estimates for the individual plumes. This assumption may potentially result in overestimation of the cost of the alternatives because extraction wells associated with the plumes that require shorter periods of time to clean up will not operate for the time periods tabulated below.

| Alternative | Target Cleanup Goal I | Target Cleanup Goal II | Target Cleanup Goal III |
|---|---|---|---|
| 1 | NA | NA | NA |
| 2 | Perpetuity | Perpetuity | Perpetuity |
| 3 | Greater than 140 years | Greater than 140 years | Greater than 140 years |
| 4 | Approximately 140 years | Approximately 140 years | Approximately 140 years |
| 5 | Greater than 110 years | Greater than 110 years | Greater than 110 years |
| 6 | Approximately 110 years | Approximately 110 years | Approximately 110 years |
| 7 | Greater than 90 years | Greater than 90 years | Greater than 90 years |
| 8 | Approximately 90 years | Approximately 90 years | Approximately 90 years |

The restoration time frame estimates are based on the total extraction well flowrates which were estimated for comparative cost estimates only. The total extraction well flowrate will be estimated during remedial design.

## 4.2 DEFINITION OF LEACHING SOILS

It is estimated that explosives-contaminated soils in the depth interval from the ground surface to 9 feet will not contribute to groundwater contamination in excess of the Target Groundwater Cleanup Goals if the concentration of TNB in the soils is less than or equal to 5 mg/kg. It is estimated that explosives-contaminated soils in the depth interval from 9 to 12.5 feet will not contribute to groundwater contamination in excess of the Target

Groundwater Cleanup Goals for a period of more than 49 years if the concentration of TNB in the soils is less than or equal to 1 mg/kg.

Therefore, the estimated volume of leaching soils is defined by soils satisfying the following criteria:

- TNB soil concentrations greater than or equal to 5 mg/kg in the depth interval from the ground surface to 9 feet
- TNB soil concentrations greater than or equal to 1 mg/kg in the depth interval from 9 feet to 12.5 feet

## 5.0
## REFERENCES

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**ATTACHMENT B1**
**SECTION 2.0 CALCULATIONS**

## RETARDATION FACTOR CALCULATIONS

Calculate the retardation factor for RDX and TCE ($R_{RDX}$ and $R_{TCE}$, respectively). The bulk density, $\rho_b$, for the fine sand hydrostratigraphic unit is given on page 5-5 of Appendix C of the FS Report.

$$\rho_b := 1.4 \cdot \frac{gm}{cm^3}$$

The assumed porosity, n, used to calculate the volume of contaminated groundwater in Appendix D is:

$$n := 0.25 \cdot \frac{cm^3}{cm^3}$$

The fraction of organic carbon in the fine sand and sand and gravel hydrostratigraphic units is given in Attachment 1 to Appendix C of the FS Report and Section 5 of the RI Report as:

$$foc := 0.000255 \cdot \frac{gm}{gm}$$

The RDX distribution coefficient normalized for organic carbon content, $K_{oc}$, is given in Appendix L of the FS Report.

$$K_{oc} := 104.5 \cdot \frac{mL}{gm}$$

$R_{RDX}$ can be calculated using the following equation presented in Zheng et al, 1991, Analysis of Ground-Water Remedial Alternatives at a Superfund Site, Ground Water 29(6) (Zheng, et al, 1991). $R_{RDX}$ is subsequently reported to two significant digits.

$$R := 1 + \frac{K_{oc} \cdot foc \cdot \rho_b}{n} \qquad R_{RDX} := R \qquad R_{RDX} = 1.14923 \qquad R_{RDX} = 1.1$$

The TCE distribution coefficient normalized for organic carbon content is given in the RI Report.

$$K_{oc} := 120 \cdot \frac{mL}{gm}$$

$R_{TCE}$ is calculated using the equation presented above, and reported to two significant digits.

$$R := 1 + \frac{K_{oc} \cdot foc \cdot \rho_b}{n} \qquad R_{TCE} := R \qquad R_{TCE} = 1.17136 \qquad R_{TCE} = 1.2$$

## PORE VOLUME CALCULATIONS

Define micrograms. $ug := \frac{mg}{1000}$

Define the Zheng, et. al. 1991 equation as a function. $PV(R, C_S, C_i) := -R \cdot \ln\left(\frac{C_S}{C_i}\right)$

**Load Line 1 Plume PVs**

TCE (Cleanup Goals I, II, and III) $PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 210 \cdot \frac{ug}{liter}\right) = 4.4$

RDX (Cleanup Goal I) $PV\left(R_{RDX}, 7.74 \cdot \frac{ug}{liter}, 18 \cdot \frac{ug}{liter}\right) = 0.97$

RDX (Cleanup Goal II) $PV\left(R_{RDX}, 2 \cdot \frac{ug}{liter}, 18 \cdot \frac{ug}{liter}\right) = 2.5$

RDX (Cleanup Goal III) $PV\left(R_{RDX}, 0.774 \cdot \frac{ug}{liter}, 18 \cdot \frac{ug}{liter}\right) = 3.6$

**Load Lines 2 and 3 Plume PVs**

TCE (Cleanup Goals I, II, and III) $PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 7 \cdot \frac{ug}{liter}\right) = 0.39$

RDX (Cleanup Goal I) $PV\left(R_{RDX}, 7.74 \cdot \frac{ug}{liter}, 534 \cdot \frac{ug}{liter}\right) = 4.9$

RDX (Cleanup Goal II) $PV\left(R_{RDX}, 2 \cdot \frac{ug}{liter}, 534 \cdot \frac{ug}{liter}\right) = 6.4$

RDX (Cleanup Goal III) $PV\left(R_{RDX}, 0.774 \cdot \frac{ug}{liter}, 534 \cdot \frac{ug}{liter}\right) = 7.5$

**Atlas Missile Area Plume PVs**

TCE (Cleanup Goals I, II, and III) $PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 4800 \cdot \frac{ug}{liter}\right) = 8.0$

RDX (Cleanup Goal I) $PV\left(R_{RDX}, 7.74 \cdot \frac{ug}{liter}, 35 \cdot \frac{ug}{liter}\right) = 1.7$

RDX (Cleanup Goal II) $PV\left(R_{RDX}, 2 \cdot \frac{ug}{liter}, 35 \cdot \frac{ug}{liter}\right) = 3.3$

RDX (Cleanup Goal III) $PV\left(R_{RDX}, 0.774 \cdot \frac{ug}{liter}, 35 \cdot \frac{ug}{liter}\right) = 4.4$

**Atlas Missile Area Plume - Northwest Section PVs**

TCE (Cleanup Goals I, II, and III) $PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right) = 8.0$

**Atlas Missile Area Plume - Southeast Section PVs**

TCE (Cleanup Goals I, II, and III) $PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 300\cdot\frac{ug}{liter}\right) = 4.8$

## VOLUME CALCULATIONS FOR SECTIONS OF ATLAS MISSILE AREA PLUME

The Southeast Section fraction (SEF) of the total Atlas Missile Area Plume area was calculated. The volume of contaminated groundwater in the Southeast Section, SEV, was calculated as the product of SEF and the estimated volume of the entire Atlas Missile Area Plume.

$SEF := 0.7368421$

| | | |
|---|---|---|
| **Cleanup Goal I** | $SEV := SEF\cdot 1\cdot 10^{10}\cdot gal$ | $SEV = 7.4\cdot 10^{9}\ \cdot gal$ |
| **Cleanup Goal II** | $SEV := SEF\cdot 1.02\cdot 10^{10}\cdot gal$ | $SEV = 7.5\cdot 10^{9}\ \cdot gal$ |
| **Cleanup Goal III** | $SEV := SEF\cdot 1.03\cdot 10^{10}\cdot gal$ | $SEV = 7.6\cdot 10^{9}\ \cdot gal$ |

## RESTORATION TIME FRAME ESTIMATES

Define Equation 2 as a function: $T(PV, VOL, RATE) := \frac{PV\cdot VOL}{RATE}$

**Alternative 2**

<u>Cleanup Goal I</u>

Load Line 1

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.01\cdot 10^{9}\cdot gal, 240\cdot\frac{gal}{min}\right) = 35\cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 7.74\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 9.34\cdot 10^{8}\cdot gal, 620\cdot\frac{gal}{min}\right) = 14\cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right), 1.00\cdot 10^{10}\cdot gal, 110\cdot\frac{gal}{min}\right) = 1.4\cdot 10^{3}\ \cdot yr$$

Cleanup Goal II

Load Line 1

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.33\cdot 10^{9}\cdot gal, 360\cdot\frac{gal}{min}\right) = 31\cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 2\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 1.11\cdot 10^{10}\cdot gal, 1580\cdot\frac{gal}{min}\right) = 86\cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right), 1.02\cdot 10^{10}\cdot gal, 160\cdot\frac{gal}{min}\right) = 9.7\cdot 10^{2}\ \cdot yr$$

Cleanup Goal III

Load Line 1

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.37\cdot 10^{9}\cdot gal, 360\cdot\frac{gal}{min}\right) = 32\cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 0.774\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 1.53\cdot 10^{10}\cdot gal, 1810\cdot\frac{gal}{min}\right) = 1.2\cdot 10^{2}\ \cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right), 1.03\cdot 10^{10}\cdot gal, 160\cdot\frac{gal}{min}\right) = 9.8\cdot 10^{2}\ \cdot yr$$

**Alternatives 3 and 4**

Cleanup Goal I

Load Line 1

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.01\cdot 10^{9}\cdot gal, 240\cdot\frac{gal}{min}\right) = 35\cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 7.74\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 9.34\cdot 10^{8}\cdot gal, 620\cdot\frac{gal}{min}\right) = 14\cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right), 1.00\cdot 10^{10}\cdot gal, 1120\cdot\frac{gal}{min}\right) = 1.4\cdot 10^{2}\ \cdot yr$$

Cleanup Goal II

Load Line 1

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.33\cdot 10^{9}\cdot gal, 360\cdot\frac{gal}{min}\right) = 31\cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 2\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 1.11\cdot 10^{10}\cdot gal, 1770\cdot\frac{gal}{min}\right) = 77\cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right), 1.02\cdot 10^{10}\cdot gal, 1170\cdot\frac{gal}{min}\right) = 1.3\cdot 10^{2}\cdot yr$$

Cleanup Goal III

Load Line 1

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.37\cdot 10^{9}\cdot gal, 360\cdot\frac{gal}{min}\right) = 32\cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 0.774\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 1.53\cdot 10^{10}\cdot gal, 2000\cdot\frac{gal}{min}\right) = 1.1\cdot 10^{2}\cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right), 1.03\cdot 10^{10}\cdot gal, 1170\cdot\frac{gal}{min}\right) = 1.3\cdot 10^{2}\cdot yr$$

**Alternatives 5 and 6**

Cleanup Goal I

Load Line 1

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.01\cdot 10^{9}\cdot gal, 240\cdot\frac{gal}{min}\right) = 35\cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 7.74\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 9.34\cdot 10^{8}\cdot gal, 620\cdot\frac{gal}{min}\right) = 14\cdot yr$$

Atlas Missile Area

*Northwest Section*

Define Equation 3 as a function. $T_{NW}(PV, DIST, VEL) := \frac{PV \cdot DIST}{VEL}$

DIST was measured on Drawing 4-8 of the FS Report as 7000 ft.

$DIST := 7000 \cdot ft \qquad VEL := 2 \cdot \frac{ft}{day}$

$$T_{NW}\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 4800 \cdot \frac{ug}{liter}\right), DIST, VEL\right) = 77 \cdot yr$$

*Southeast Section*

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 300 \cdot \frac{ug}{liter}\right), 7.4 \cdot 10^9 \cdot gal, 590 \cdot \frac{gal}{min}\right) = 1.1 \cdot 10^2 \cdot yr$$

<u>Cleanup Goal II</u>

Load Line 1

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 210 \cdot \frac{ug}{liter}\right), 1.33 \cdot 10^9 \cdot gal, 360 \cdot \frac{gal}{min}\right) = 31 \cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 2 \cdot \frac{ug}{liter}, 534 \cdot \frac{ug}{liter}\right), 1.11 \cdot 10^{10} \cdot gal, 1770 \cdot \frac{gal}{min}\right) = 77 \cdot yr$$

Atlas Missile Area

*Northwest Section*

DIST was measured on Drawing 4-8 of the FS Report as 7000 ft.

$DIST := 7000 \cdot ft \qquad VEL := 2 \cdot \frac{ft}{day}$

$$T_{NW}\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 4800 \cdot \frac{ug}{liter}\right), DIST, VEL\right) = 77 \cdot yr$$

*Southeast Section*

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 300 \cdot \frac{ug}{liter}\right), 7.5 \cdot 10^9 \cdot gal, 640 \cdot \frac{gal}{min}\right) = 1.1 \cdot 10^2 \cdot yr$$

<u>Cleanup Goal III</u>

Load Line 1

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 210 \cdot \frac{ug}{liter}\right), 1.37 \cdot 10^9 \cdot gal, 360 \cdot \frac{gal}{min}\right) = 32 \cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 0.774 \cdot \frac{ug}{liter}, 534 \cdot \frac{ug}{liter}\right), 1.53 \cdot 10^{10} \cdot gal, 2000 \cdot \frac{gal}{min}\right) = 1.1 \cdot 10^2 \cdot yr$$

Atlas Missile Area

**DIST was measured on Drawing 4-8 of the FS Report as 7000 ft.**

$DIST := 7000 \cdot ft \qquad VEL := 2 \cdot \frac{ft}{day}$

$$T_{NW}\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 4800 \cdot \frac{ug}{liter}\right), DIST, VEL\right) = 77 \cdot yr$$

*Southeast Section*

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 300 \cdot \frac{ug}{liter}\right), 7.6 \cdot 10^{9} \cdot gal, 640 \cdot \frac{gal}{min}\right) = 1.1 \cdot 10^{2} \cdot yr$$

**Alternatives 7 and 8**

<u>Cleanup Goal I</u>

Load Line 1

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 210 \cdot \frac{ug}{liter}\right), 1.01 \cdot 10^{9} \cdot gal, 240 \cdot \frac{gal}{min}\right) = 35 \cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 7.74 \cdot \frac{ug}{liter}, 534 \cdot \frac{ug}{liter}\right), 9.34 \cdot 10^{8} \cdot gal, 620 \cdot \frac{gal}{min}\right) = 14 \cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 4800 \cdot \frac{ug}{liter}\right), 1.00 \cdot 10^{10} \cdot gal, 1630 \cdot \frac{gal}{min}\right) = 94 \cdot yr$$

<u>Cleanup Goal II</u>

Load Line 1

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 210 \cdot \frac{ug}{liter}\right), 1.33 \cdot 10^{9} \cdot gal, 360 \cdot \frac{gal}{min}\right) = 31 \cdot yr$$

Load Lines 2 and 3

$$T\left(PV\left(R_{RDX}, 2 \cdot \frac{ug}{liter}, 534 \cdot \frac{ug}{liter}\right), 1.11 \cdot 10^{10} \cdot gal, 2160 \cdot \frac{gal}{min}\right) = 63 \cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5 \cdot \frac{ug}{liter}, 4800 \cdot \frac{ug}{liter}\right), 1.02 \cdot 10^{10} \cdot gal, 1680 \cdot \frac{gal}{min}\right) = 93 \cdot yr$$

__Cleanup Goal III__

**Load Line 1**

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 210\cdot\frac{ug}{liter}\right), 1.37\cdot 10^{9}\cdot gal, 360\cdot\frac{gal}{min}\right) = 32\cdot yr$$

**Load Lines 2 and 3**

$$T\left(PV\left(R_{RDX}, 0.774\cdot\frac{ug}{liter}, 534\cdot\frac{ug}{liter}\right), 1.53\cdot 10^{10}\cdot gal, 2870\cdot\frac{gal}{min}\right) = 76\cdot yr$$

Atlas Missile Area

$$T\left(PV\left(R_{TCE}, 5\cdot\frac{ug}{liter}, 4800\cdot\frac{ug}{liter}\right), 1.03\cdot 10^{10}\cdot gal, 1680\cdot\frac{gal}{min}\right) = 94\cdot yr$$

## ATTACHMENT B2
## SECTION 3.0 CALCULATIONS

## MIXING ZONE THICKNESS CALCULATIONS

Calculate $\alpha_V$

$\alpha_L := 40 \cdot m \qquad \alpha_V := \frac{\alpha_L}{160} \qquad \alpha_V = 0.8 \cdot ft$

Table C-2 of Appendix C gives estimated saturated thicknesses for the fine sand and sand and gravel hydrostratigraphic units which were used to calculate volumes of contaminated groundwater. The average thickness for Load Line 1 and and Load Lines 2 and 3 will be used to calculate h.

$h := \frac{(44 \cdot ft + 38 \cdot ft) + (38 \cdot ft + 30 \cdot ft)}{2} \qquad h = 75 \cdot ft$

Calculate the average linear velocity $V_s$ in the fine sand unit. Substitue the symbol i for dh/dl.

$K_{fs} := 0.034 \cdot \frac{ft}{min} \qquad i := 12 \cdot \frac{ft}{mi} \qquad n := 0.145$

$V_s := \frac{K_{fs} \cdot i}{n} \qquad V_s = 0.767 \cdot \frac{ft}{day}$

The remainder of the input values are defined below, and Equation 4 is used to calculate H.

$L := 0.25 \cdot mi \qquad VD_z := 2.3 \cdot \frac{in}{yr}$

$H := \left(2 \cdot \alpha_V \cdot L\right)^{\frac{1}{2}} + h \cdot \left(1 - \exp\left(\frac{-L \cdot VD_z}{V_s \cdot n \cdot h}\right)\right) \qquad H = 53 \cdot ft$

## MAXIMUM ALLOWABLE LEACHATE CONCENTRATION CALCULATIONS

Define the units of microgram. $\quad ug := \frac{mg}{1000}$

Define the TNB concentration in groundwater, $C_{gw}$, as the cleanup goal for TNB presented in Section 2.2.1.4 of the FS Report (the concentation is the same for Cleanup Goals I, II, and III).

$C_{gw} := 0.000778 \cdot \frac{mg}{liter}$

The area of contamination, $A_p$, is assumed to be circular with a 100-ft of diameter, w.

$w := 100 \cdot ft \qquad A_p := \frac{\pi}{4} \cdot w^2 \qquad A_p = 7.9 \cdot 10^3 \cdot ft^2$

The groundwater concentration prior to the introduction of the leachate, $C_A$, is assumed to be zero.

$C_A := 0 \cdot \frac{mg}{liter}$

The infiltration rate, VDz, is assumed to be 2.3 inches/year, and $V_D$ is the Darcy Velocity in the fine sand unit.

$VD_z := 2.3 \cdot \frac{in}{yr} \qquad V_D := K_{fs} \cdot i \qquad V_D = 0.111 \cdot \frac{ft}{day}$

$Q_A$ and $Q_p$ are defined for the Summers Model in the following manner.

$Q_A := V_D \cdot H \cdot w$ $\qquad Q_p := VD_z \cdot A_p$

The following analysis solves the Summers Model for the leachate concentration, $C_p$.

$C_{gw} = \dfrac{Q_p \cdot C_p + Q_A \cdot C_A}{Q_p + Q_A}$ Solve for $C_p$. $\quad C_p := \left[C_{gw} - \dfrac{1}{(Q_p + Q_A)} \cdot Q_A \cdot C_A\right] \cdot \dfrac{(Q_p + Q_A)}{Q_p}$

$C_p = 0.111 \cdot \dfrac{mg}{liter}$ $\qquad C_p = 1.1 \cdot 10^2 \cdot \dfrac{ug}{liter}$

## NORMALIZED CONCENTRATION CALCULATIONS

Define Equation 8 as a function. $\quad Z(K_d, C_p, S) := \left(\dfrac{K_d \cdot C_p}{S}\right) \cdot 100$

**Loess**

$K_d := 8.84 \cdot \dfrac{mL}{gm}$

**4 to 5 feet and 8 to 9 feet** The following TNB soil concentrations (S) will be evaluated: 5 mg/kg, 10 mg/kg, 50 mg/kg, 100 mg/kg.

$Z\left(K_d, C_p, 5 \cdot \dfrac{mg}{kg}\right) = 20$ $\quad Z\left(K_d, C_p, 10 \cdot \dfrac{mg}{kg}\right) = 10$ $\quad Z\left(K_d, C_p, 50 \cdot \dfrac{mg}{kg}\right) = 2.0$ $\quad Z\left(K_d, C_p, 100 \cdot \dfrac{mg}{kg}\right) = 1.0$

11.5 to 12.5 feet The following TNB soil concentrations (S) will be evaluated: 1.25 mg/kg, 5 mg/kg, 10mg/kg.

$Z\left(K_d, C_p, 1.25 \cdot \dfrac{mg}{kg}\right) = 79$ $\quad Z\left(K_d, C_p, 5 \cdot \dfrac{mg}{kg}\right) = 20$ $\quad Z\left(K_d, C_p, 10 \cdot \dfrac{mg}{kg}\right) = 9.8$

**Fine Sand**

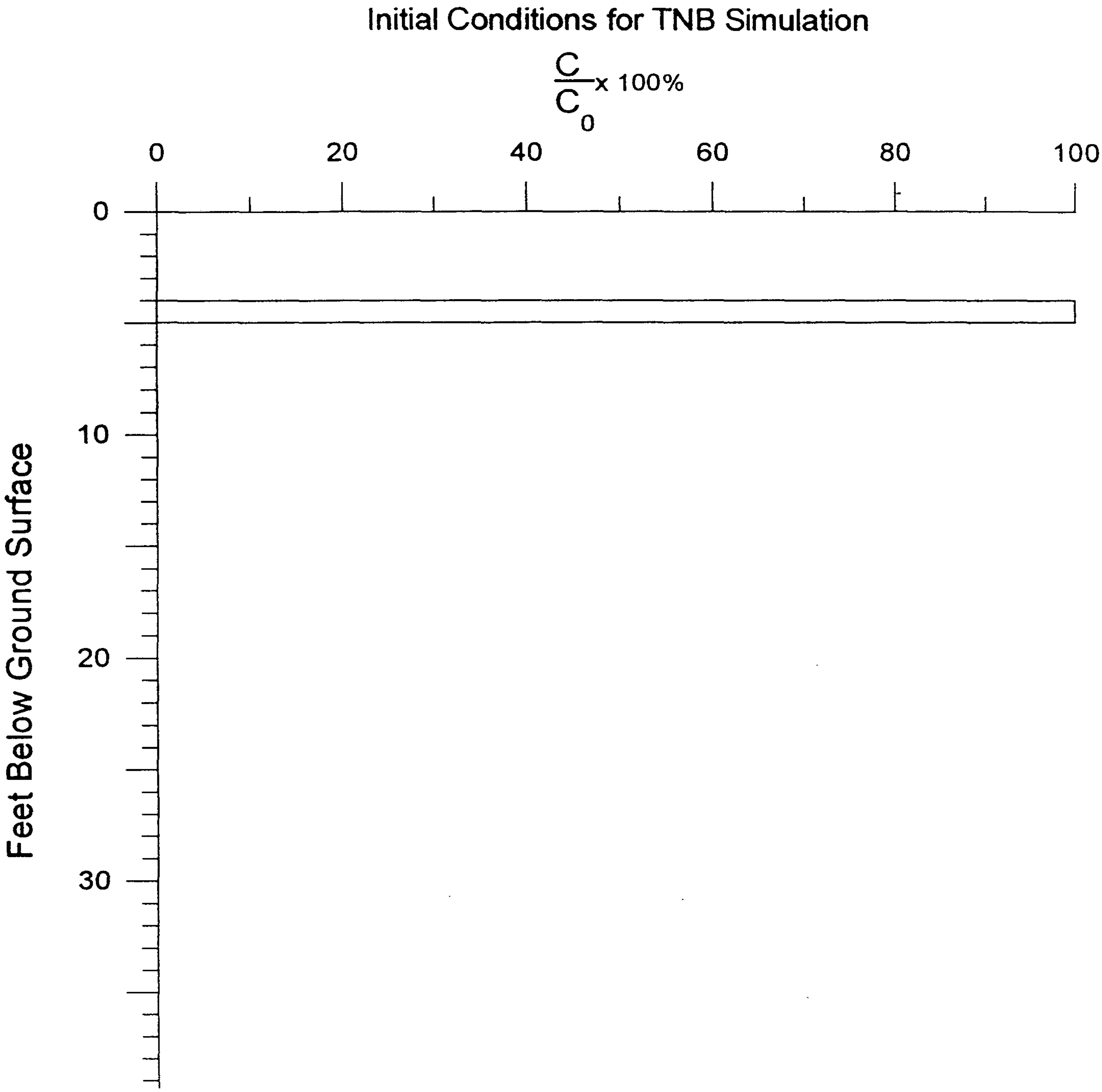
$K_d := 0.1326 \cdot \dfrac{mL}{gm}$

12.5 to 13.5 feet The following TNB soil concentrations (S) will be evaluated: 0.1 mg/kg, 1 mg/kg, 1.5 mg/kg.

$Z\left(K_d, C_p, 0.1 \cdot \dfrac{mg}{kg}\right) = 15$ $\quad Z\left(K_d, C_p, 1 \cdot \dfrac{mg}{kg}\right) = 1.5$ $\quad Z\left(K_d, C_p, 1.5 \cdot \dfrac{mg}{kg}\right) = 1.0$

24 to 25 feet The following TNB soil concentrations (S) will be evaluated: 0.15 mg/kg, 0.5 mg/kg, 1 mg/kg, 1.5 mg/kg.

$Z\left(K_d, C_p, 0.15 \cdot \dfrac{mg}{kg}\right) = 10$ $\quad Z\left(K_d, C_p, 0.5 \cdot \dfrac{mg}{kg}\right) = 2.9$ $\quad Z\left(K_d, C_p, 1 \cdot \dfrac{mg}{kg}\right) = 1.5$ $\quad Z\left(K_d, C_p, 1.5 \cdot \dfrac{mg}{kg}\right) = 1.0$




B07NE003702-09193

```
*****************************************************************
*                                                               *
*        ONE-DIMENSIONAL FLOW AND TRANSPORT MODEL               *
*                HYDRUS v. 3.4                                  *
*                                                               *
*   DATA INPUT FILE: 162.dat                                    *
*                                                               *
*  hypothetical, time units = years, infiltration = 2.3 in/yr   *
*  TNB, C tnb = 100 from 4 to 5, 162.dat                        *
*                                                               *
*****************************************************************
```

PROBLEM CONTROL PARAMETERS

SIMULATION CONTROL CODE .............(ITKOD) = 1
HYSTERESIS MODELING CODE .............(IHKOD) = 0
TRANSPORT BOUNDARY COND. CODE ........(ICOKOD) = 0
ROOT WATER UPTAKE CODE ...............(IRUKOD) = 0
CONDUCTIVITY UPSTREAM WEIGHTING ......(IUPKOD) = 0
FLOW MASS MATRIX OPTION ..............(ILKOD) = 1
FLOW INITIAL CONDITION CODE ..........(ICKOD) = 1
BOUNDARY CONDITION CODE ..............(IBCKOD) = 0
PLOT OUTPUT CODE .......................(IOKOD) = 0
RESTART OUTPUT CODE ..................(IRSKOD) = 2

TIME STEPPING PARAMETERS

INITIAL TIMESTEP .......................(DELIN) = 0.100E-02
MINIMUM TIMESTEP ......................(DELMIN) = 0.100E-04
MAXIMUM TIMESTEP ......................(DELMAX) = 100.
TOTAL SIMULATION TIME .................(TMAX) = 0.100E+04
REL. PR. HEAD CONVERGENCE TOLERANCE ....(TOL1) = 0.100E-01
ABS. " " " ....(TOL2) = 0.100E-01
NUMBER OF NONLINEAR ITERATIONS ......(NITMAX) = 9900

PROBLEM SPECIFICATION PARAMETERS

MAXIMUM NUMBER OF TIMESTEPS ..........(NSTEPS) = 7500
NUMBER OF SOIL MATERIALS ..............(NMAT) = 3
NUMBER OF SOIL LAYERS .................(NLAYR) = 3
NUMBER OF BOUNDARY COND. TIME VALUES ....(NBC) = 1
NUMBER OF OUTPUT TIME VALUES .........(NPRINT) = 7
NUMBER OF OBSERVATION POINTS ..........(NOBS) = 1
SOIL DEPTH ..........................(TDEPTH) = 11.2
GROUNDWATER SOLUTE CONCENTRATION ........(CNN) = 0.000

PROBLEM GEOMETRY

LAYER NUMBER ........ 1
MATERIAL INDEX ........................(MATL) = 1
LAYER THICKNESS ......................(THICK) = 0.700
BEGINNING DEPTH .......................(TOPL) = 0.000
ENDING DEPTH ..........................(BOTL) = 0.700
NODAL SPACING .........................(DELZ) = 0.233

LAYER NUMBER ........ 2
MATERIAL INDEX ........................(MATL) = 2
LAYER THICKNESS ......................(THICK) = 3.11
BEGINNING DEPTH .......................(TOPL) = 0.700
ENDING DEPTH ..........................(BOTL) = 3.81
NODAL SPACING .........................(DELZ) = 0.239

LAYER NUMBER ........ 3
MATERIAL INDEX ........................(MATL) = 3
LAYER THICKNESS ......................(THICK) = 7.35
BEGINNING DEPTH .......................(TOPL) = 3.81
ENDING DEPTH ..........................(BOTL) = 11.2
NODAL SPACING .........................(DELZ) = 0.245

## SOIL HYDRAULIC AND TRANSPORT PROPERTIES

HYDRAULIC PROPERTIES FOR MATERIAL: 1

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.6810 | 1.1700 | 0.4750 | 0.0900 | 9.855E+01 |

HYDRAULIC PROPERTIES FOR MATERIAL: 2

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.9250 | 1.1500 | 0.4790 | 0.0560 | 3.285E+00 |

HYDRAULIC PROPERTIES FOR MATERIAL: 3

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 13.8000 | 1.6900 | 0.4370 | 0.0200 | 3.650E+03 |

TRANSPORT PROPERTIES FOR MATERIAL: 1

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 7.748 |

TRANSPORT PROPERTIES FOR MATERIAL: 2

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 8.840 |

TRANSPORT PROPERTIES FOR MATERIAL: 3

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 0.133 |

MAXIMUM VALUE OF GRID PECLET NUMBER IS 2.450 FOR LAYER NO. 3

## BOUNDARY CONDITION DATA

| TIME | IRTYP | IDRTYP | BCN1 | BCNN | CN1 | POTET |
|---|---|---|---|---|---|---|
| 0.000 | 1 | 0 | 0.058 | 0.000 | 0.000 | 0.000 |

## OUTPUT TIME VALUES

0.300E+03 0.400E+03 0.500E+03 0.600E+03 0.700E+03 0.800E+03 0.900E+03

## OBSERVATION POINT COORDINATES

11.159

## INITIAL CONDITIONS

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.482E-01 | 0.4050 | 0.000E+00 | 0.23 | -7.879E-01 | 0.4123 | 0.000E+00 |
| 0.47 | -5.997E-01 | 0.4225 | 0.000E+00 | 0.70 | -3.897E-01 | 0.4368 | 0.000E+00 |
| 0.94 | -1.835E-01 | 0.4576 | 0.000E+00 | 1.18 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.42 | -1.835E-01 | 0.4576 | 1.000E+02 | 1.66 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.90 | -1.835E-01 | 0.4576 | 0.000E+00 | 2.14 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 2.37 | -1.835E-01 | 0.4576 | 0.000E+00 | 2.61 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 2.85 | -1.844E-01 | 0.4575 | 0.000E+00 | 3.09 | -1.920E-01 | 0.4567 | 0.000E+00 |
| 3.33 | -2.611E-01 | 0.4497 | 0.000E+00 | 3.57 | -6.737E-01 | 0.4197 | 0.000E+00 |
| 3.81 | -8.631E-01 | 0.0950 | 0.000E+00 | 4.06 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 4.30 | -8.631E-01 | 0.0950 | 0.000E+00 | 4.55 | -8.631E-01 | 0.0950 | 0.000E+00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4.79 | -8.631E-01 | 0.0950 | 0.000E+00 | 5.04 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 5.28 | -8.631E-01 | 0.0950 | 0.000E+00 | 5.53 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 5.77 | -8.631E-01 | 0.0950 | 0.000E+00 | 6.02 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 6.26 | -8.631E-01 | 0.0950 | 0.000E+00 | 6.51 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 6.75 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.00 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 7.24 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.49 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 7.73 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.98 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 8.22 | -8.631E-01 | 0.0950 | 0.000E+00 | 8.47 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 8.71 | -8.631E-01 | 0.0950 | 0.000E+00 | 8.96 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 9.20 | -8.614E-01 | 0.0951 | 0.000E+00 | 9.44 | -8.597E-01 | 0.0952 | 0.000E+00 |
| 9.69 | -8.564E-01 | 0.0954 | 0.000E+00 | 9.93 | -8.399E-01 | 0.0964 | 0.000E+00 |
| 10.18 | -7.965E-01 | 0.0992 | 0.000E+00 | 10.42 | -6.788E-01 | 0.1083 | 0.000E+00 |
| 10.67 | -4.852E-01 | 0.1305 | 0.000E+00 | 10.91 | -2.339E-01 | 0.1962 | 0.000E+00 |
| 11.16 | -8.691E-10 | 0.4370 | 0.000E+00 | | | | |

INITIAL MOISTURE IN PROFILE : 2.44
INITIAL SALT IN PROFILE : 307.

STEADY STATE FLOW SOLUTION PERFORMED IN 1 ITERATIONS

****************************** TIME = 3.000E+02 ******************************

ISTEP = 286 RAIN = 5.844E-02 TRAIN = 1.758E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 1.758E+01 SLTIN =-1.093E-20
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.394E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 2.931E+02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.0075 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.614E-05 | 0.23 | -7.796E-01 | 0.4127 | 3.255E-04 |
| 0.47 | -5.923E-01 | 0.4229 | 3.096E-03 | 0.70 | -3.823E-01 | 0.4374 | 2.161E-02 |
| 0.94 | -1.756E-01 | 0.4585 | 1.164E-01 | 1.18 | -1.753E-01 | 0.4585 | 4.447E-01 |
| 1.42 | -1.750E-01 | 0.4585 | 1.348E+00 | 1.66 | -1.747E-01 | 0.4586 | 3.241E+00 |
| 1.90 | -1.744E-01 | 0.4586 | 6.247E+00 | 2.14 | -1.741E-01 | 0.4586 | 9.847E+00 |
| 2.37 | -1.739E-01 | 0.4586 | 1.298E+01 | 2.61 | -1.736E-01 | 0.4587 | 1.459E+01 |
| 2.85 | -1.741E-01 | 0.4586 | 1.424E+01 | 3.09 | -1.818E-01 | 0.4578 | 1.228E+01 |
| 3.33 | -2.505E-01 | 0.4507 | 9.504E+00 | 3.57 | -6.657E-01 | 0.4202 | 6.729E+00 |
| 3.81 | -8.544E-01 | 0.0955 | 6.666E+00 | 4.06 | -8.550E-01 | 0.0955 | 6.597E+00 |
| 4.30 | -8.555E-01 | 0.0955 | 6.527E+00 | 4.55 | -8.560E-01 | 0.0954 | 6.457E+00 |
| 4.79 | -8.566E-01 | 0.0954 | 6.387E+00 | 5.04 | -8.571E-01 | 0.0954 | 6.317E+00 |
| 5.28 | -8.576E-01 | 0.0953 | 6.247E+00 | 5.53 | -8.582E-01 | 0.0953 | 6.177E+00 |
| 5.77 | -8.587E-01 | 0.0953 | 6.107E+00 | 6.02 | -8.592E-01 | 0.0952 | 6.037E+00 |
| 6.26 | -8.598E-01 | 0.0952 | 5.967E+00 | 6.51 | -8.603E-01 | 0.0952 | 5.897E+00 |
| 6.75 | -8.609E-01 | 0.0951 | 5.828E+00 | 7.00 | -8.614E-01 | 0.0951 | 5.758E+00 |
| 7.24 | -8.619E-01 | 0.0951 | 5.688E+00 | 7.49 | -8.625E-01 | 0.0950 | 5.618E+00 |
| 7.73 | -8.630E-01 | 0.0950 | 5.548E+00 | 7.98 | -8.635E-01 | 0.0950 | 5.479E+00 |
| 8.22 | -8.641E-01 | 0.0949 | 5.409E+00 | 8.47 | -8.646E-01 | 0.0949 | 5.340E+00 |
| 8.71 | -8.651E-01 | 0.0949 | 5.271E+00 | 8.96 | -8.657E-01 | 0.0948 | 5.202E+00 |
| 9.20 | -8.653E-01 | 0.0949 | 5.133E+00 | 9.44 | -8.632E-01 | 0.0950 | 5.064E+00 |
| 9.69 | -8.585E-01 | 0.0953 | 4.995E+00 | 9.93 | -8.435E-01 | 0.0962 | 4.926E+00 |
| 10.18 | -7.990E-01 | 0.0990 | 4.857E+00 | 10.42 | -6.846E-01 | 0.1077 | 4.786E+00 |
| 10.67 | -4.858E-01 | 0.1304 | 4.712E+00 | 10.91 | -2.450E-01 | 0.1913 | 4.612E+00 |
| 11.16 | 0.000E+00 | 0.4370 | 4.612E+00 | | | | |

****************************** TIME = 4.000E+02 ******************************

ISTEP = 372 RAIN = 5.844E-02 TRAIN = 2.343E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 2.343E+01 SLTIN =-2.135E-20
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 5.753E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 2.495E+02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.0088 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.647E-05 | 0.23 | -7.796E-01 | 0.4127 | 1.897E-04 |
| 0.47 | -5.923E-01 | 0.4229 | 1.540E-03 | 0.70 | -3.823E-01 | 0.4374 | 9.405E-03 |
| 0.94 | -1.756E-01 | 0.4585 | 4.582E-02 | 1.18 | -1.753E-01 | 0.4585 | 1.631E-01 |
| 1.42 | -1.750E-01 | 0.4585 | 4.820E-01 | 1.66 | -1.747E-01 | 0.4586 | 1.199E+00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1.90 | -1.744E-01 | 0.4586 | 2.528E+00 | 2.14 | -1.741E-01 | 0.4586 | 4.560E+00 |
| 2.37 | -1.739E-01 | 0.4586 | 7.116E+00 | 2.61 | -1.736E-01 | 0.4587 | 9.715E+00 |
| 2.85 | -1.741E-01 | 0.4586 | 1.173E+01 | 3.09 | -1.818E-01 | 0.4578 | 1.268E+01 |
| 3.33 | -2.505E-01 | 0.4507 | 1.244E+01 | 3.57 | -6.657E-01 | 0.4202 | 1.126E+01 |
| 3.81 | -8.544E-01 | 0.0955 | 1.123E+01 | 4.06 | -8.550E-01 | 0.0955 | 1.120E+01 |
| 4.30 | -8.555E-01 | 0.0955 | 1.117E+01 | 4.55 | -8.560E-01 | 0.0954 | 1.113E+01 |
| 4.79 | -8.566E-01 | 0.0954 | 1.110E+01 | 5.04 | -8.571E-01 | 0.0954 | 1.107E+01 |
| 5.28 | -8.576E-01 | 0.0953 | 1.103E+01 | 5.53 | -8.582E-01 | 0.0953 | 1.100E+01 |
| 5.77 | -8.587E-01 | 0.0953 | 1.096E+01 | 6.02 | -8.592E-01 | 0.0952 | 1.093E+01 |
| 6.26 | -8.598E-01 | 0.0952 | 1.089E+01 | 6.51 | -8.603E-01 | 0.0952 | 1.085E+01 |
| 6.75 | -8.609E-01 | 0.0951 | 1.082E+01 | 7.00 | -8.614E-01 | 0.0951 | 1.078E+01 |
| 7.24 | -8.619E-01 | 0.0951 | 1.074E+01 | 7.49 | -8.625E-01 | 0.0950 | 1.070E+01 |
| 7.73 | -8.630E-01 | 0.0950 | 1.066E+01 | 7.98 | -8.635E-01 | 0.0950 | 1.062E+01 |
| 8.22 | -8.641E-01 | 0.0949 | 1.058E+01 | 8.47 | -8.646E-01 | 0.0949 | 1.053E+01 |
| 8.71 | -8.651E-01 | 0.0949 | 1.049E+01 | 8.96 | -8.657E-01 | 0.0948 | 1.045E+01 |
| 9.20 | -8.653E-01 | 0.0949 | 1.040E+01 | 9.44 | -8.632E-01 | 0.0950 | 1.036E+01 |
| 9.69 | -8.585E-01 | 0.0953 | 1.031E+01 | 9.93 | -8.435E-01 | 0.0962 | 1.027E+01 |
| 10.18 | -7.990E-01 | 0.0990 | 1.022E+01 | 10.42 | -6.846E-01 | 0.1077 | 1.017E+01 |
| 10.67 | -4.858E-01 | 0.1304 | 1.012E+01 | 10.91 | -2.450E-01 | 0.1913 | 1.005E+01 |
| 11.16 | 0.000E+00 | 0.4370 | 1.005E+01 | | | | |

****************************** TIME = 5.000E+02 ******************************

```
ISTEP =     458  RAIN  = 5.844E-02  TRAIN  = 2.928E+01  CIN   = 0.000E+00
DELT  = 1.164E+00  DRAIN = 5.844E-02  TDRAIN = 2.928E+01  SLTIN =-1.907E-20
NIT   =       1  PET   = 0.000E+00  TRUPTK = 0.000E+00  SLTOUT= 1.240E+02
RELAXF=   1.000  ACTET = 0.000E+00  STORW  = 0.000E+00  STORS = 1.831E+02
                                    QDECAY= 0.000E+00
```

MASS BALANCE ERROR WATER :   0.0000 %
 ..   .. SOLUTE:  -0.0120 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 8.169E-06 | 0.23 | -7.796E-01 | 0.4127 | 9.047E-05 |
| 0.47 | -5.923E-01 | 0.4229 | 6.728E-04 | 0.70 | -3.823E-01 | 0.4374 | 3.817E-03 |
| 0.94 | -1.756E-01 | 0.4585 | 1.765E-02 | 1.18 | -1.753E-01 | 0.4585 | 6.078E-02 |
| 1.42 | -1.750E-01 | 0.4585 | 1.780E-01 | 1.66 | -1.747E-01 | 0.4586 | 4.524E-01 |
| 1.90 | -1.744E-01 | 0.4586 | 1.007E+00 | 2.14 | -1.741E-01 | 0.4586 | 1.973E+00 |
| 2.37 | -1.739E-01 | 0.4586 | 3.427E+00 | 2.61 | -1.736E-01 | 0.4587 | 5.316E+00 |
| 2.85 | -1.741E-01 | 0.4586 | 7.411E+00 | 3.09 | -1.818E-01 | 0.4578 | 9.357E+00 |
| 3.33 | -2.505E-01 | 0.4507 | 1.080E+01 | 3.57 | -6.657E-01 | 0.4202 | 1.156E+01 |
| 3.81 | -8.544E-01 | 0.0955 | 1.157E+01 | 4.06 | -8.550E-01 | 0.0955 | 1.159E+01 |
| 4.30 | -8.555E-01 | 0.0955 | 1.161E+01 | 4.55 | -8.560E-01 | 0.0954 | 1.163E+01 |
| 4.79 | -8.566E-01 | 0.0954 | 1.164E+01 | 5.04 | -8.571E-01 | 0.0954 | 1.166E+01 |
| 5.28 | -8.576E-01 | 0.0953 | 1.167E+01 | 5.53 | -8.582E-01 | 0.0953 | 1.169E+01 |
| 5.77 | -8.587E-01 | 0.0953 | 1.171E+01 | 6.02 | -8.592E-01 | 0.0952 | 1.172E+01 |
| 6.26 | -8.598E-01 | 0.0952 | 1.173E+01 | 6.51 | -8.603E-01 | 0.0952 | 1.175E+01 |
| 6.75 | -8.609E-01 | 0.0951 | 1.176E+01 | 7.00 | -8.614E-01 | 0.0951 | 1.177E+01 |
| 7.24 | -8.619E-01 | 0.0951 | 1.179E+01 | 7.49 | -8.625E-01 | 0.0950 | 1.180E+01 |
| 7.73 | -8.630E-01 | 0.0950 | 1.181E+01 | 7.98 | -8.635E-01 | 0.0950 | 1.182E+01 |
| 8.22 | -8.641E-01 | 0.0949 | 1.183E+01 | 8.47 | -8.646E-01 | 0.0949 | 1.184E+01 |
| 8.71 | -8.651E-01 | 0.0949 | 1.185E+01 | 8.96 | -8.657E-01 | 0.0948 | 1.186E+01 |
| 9.20 | -8.653E-01 | 0.0949 | 1.187E+01 | 9.44 | -8.632E-01 | 0.0950 | 1.187E+01 |
| 9.69 | -8.585E-01 | 0.0953 | 1.188E+01 | 9.93 | -8.435E-01 | 0.0962 | 1.189E+01 |
| 10.18 | -7.990E-01 | 0.0990 | 1.189E+01 | 10.42 | -6.846E-01 | 0.1077 | 1.190E+01 |
| 10.67 | -4.858E-01 | 0.1304 | 1.190E+01 | 10.91 | -2.450E-01 | 0.1913 | 1.191E+01 |
| 11.16 | 0.000E+00 | 0.4370 | 1.191E+01 | | | | |

****************************** TIME = 6.000E+02 ******************************

```
ISTEP =     543  RAIN  = 5.844E-02  TRAIN  = 3.507E+01  CIN   = 0.000E+00
DELT  = 1.164E+00  DRAIN = 5.844E-02  TDRAIN = 3.507E+01  SLTIN =-2.098E-20
NIT   =       1  PET   = 0.000E+00  TRUPTK = 0.000E+00  SLTOUT= 1.888E+02
RELAXF=   1.000  ACTET = 0.000E+00  STORW  = 0.000E+00  STORS = 1.182E+02
                                    QDECAY= 0.000E+00
```

MASS BALANCE ERROR WATER :   0.0000 %
 ..   .. SOLUTE:  -0.0186 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 3.595E-06 | 0.23 | -7.796E-01 | 0.4127 | 3.897E-05 |
| 0.47 | -5.923E-01 | 0.4229 | 2.759E-04 | 0.70 | -3.823E-01 | 0.4374 | 1.502E-03 |
| 0.94 | -1.756E-01 | 0.4585 | 6.756E-03 | 1.18 | -1.753E-01 | 0.4585 | 2.289E-02 |
| 1.42 | -1.750E-01 | 0.4585 | 6.694E-02 | 1.66 | -1.747E-01 | 0.4586 | 1.730E-01 |
| 1.90 | -1.744E-01 | 0.4586 | 3.993E-01 | 2.14 | -1.741E-01 | 0.4586 | 8.277E-01 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2.37 | -1.739E-01 | 0.4586 | 1.548E+00 | 2.61 | -1.736E-01 | 0.4587 | 2.625E+00 |
| 2.85 | -1.741E-01 | 0.4586 | 4.052E+00 | 3.09 | -1.818E-01 | 0.4578 | 5.720E+00 |
| 3.33 | -2.505E-01 | 0.4507 | 7.422E+00 | 3.57 | -6.657E-01 | 0.4202 | 8.934E+00 |
| 3.81 | -8.544E-01 | 0.0955 | 8.968E+00 | 4.06 | -8.550E-01 | 0.0955 | 9.005E+00 |
| 4.30 | -8.555E-01 | 0.0955 | 9.043E+00 | 4.55 | -8.560E-01 | 0.0954 | 9.081E+00 |
| 4.79 | -8.566E-01 | 0.0954 | 9.118E+00 | 5.04 | -8.571E-01 | 0.0954 | 9.156E+00 |
| 5.28 | -8.576E-01 | 0.0953 | 9.193E+00 | 5.53 | -8.582E-01 | 0.0953 | 9.230E+00 |
| 5.77 | -8.587E-01 | 0.0953 | 9.267E+00 | 6.02 | -8.592E-01 | 0.0952 | 9.304E+00 |
| 6.26 | -8.598E-01 | 0.0952 | 9.341E+00 | 6.51 | -8.603E-01 | 0.0952 | 9.378E+00 |
| 6.75 | -8.609E-01 | 0.0951 | 9.415E+00 | 7.00 | -8.614E-01 | 0.0951 | 9.452E+00 |
| 7.24 | -8.619E-01 | 0.0951 | 9.488E+00 | 7.49 | -8.625E-01 | 0.0950 | 9.525E+00 |
| 7.73 | -8.630E-01 | 0.0950 | 9.561E+00 | 7.98 | -8.635E-01 | 0.0950 | 9.597E+00 |
| 8.22 | -8.641E-01 | 0.0949 | 9.633E+00 | 8.47 | -8.646E-01 | 0.0949 | 9.669E+00 |
| 8.71 | -8.651E-01 | 0.0949 | 9.705E+00 | 8.96 | -8.657E-01 | 0.0948 | 9.741E+00 |
| 9.20 | -8.653E-01 | 0.0949 | 9.776E+00 | 9.44 | -8.632E-01 | 0.0950 | 9.812E+00 |
| 9.69 | -8.585E-01 | 0.0953 | 9.847E+00 | 9.93 | -8.435E-01 | 0.0962 | 9.882E+00 |
| 10.18 | -7.990E-01 | 0.0990 | 9.918E+00 | 10.42 | -6.846E-01 | 0.1077 | 9.954E+00 |
| 10.67 | -4.858E-01 | 0.1304 | 9.992E+00 | 10.91 | -2.450E-01 | 0.1913 | 1.004E+01 |
| 11.16 | 0.000E+00 | 0.4370 | 1.004E+01 | | | | |

**************************** TIME = 7.000E+02 ****************************

ISTEP = 629 RAIN = 5.844E-02 TRAIN = 4.092E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 4.092E+01 SLTIN =-2.244E-20
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 2.386E+02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 6.845E+01
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.0321 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.485E-06 | 0.23 | -7.796E-01 | 0.4127 | 1.591E-05 |
| 0.47 | -5.923E-01 | 0.4229 | 1.095E-04 | 0.70 | -3.823E-01 | 0.4374 | 5.827E-04 |
| 0.94 | -1.756E-01 | 0.4585 | 2.582E-03 | 1.18 | -1.753E-01 | 0.4585 | 8.689E-03 |
| 1.42 | -1.750E-01 | 0.4585 | 2.547E-02 | 1.66 | -1.747E-01 | 0.4586 | 6.677E-02 |
| 1.90 | -1.744E-01 | 0.4586 | 1.584E-01 | 2.14 | -1.741E-01 | 0.4586 | 3.419E-01 |
| 2.37 | -1.739E-01 | 0.4586 | 6.748E-01 | 2.61 | -1.736E-01 | 0.4587 | 1.222E+00 |
| 2.85 | -1.741E-01 | 0.4586 | 2.034E+00 | 3.09 | -1.818E-01 | 0.4578 | 3.118E+00 |
| 3.33 | -2.505E-01 | 0.4507 | 4.410E+00 | 3.57 | -6.657E-01 | 0.4202 | 5.778E+00 |
| 3.81 | -8.544E-01 | 0.0955 | 5.808E+00 | 4.06 | -8.550E-01 | 0.0955 | 5.843E+00 |
| 4.30 | -8.555E-01 | 0.0955 | 5.877E+00 | 4.55 | -8.560E-01 | 0.0954 | 5.912E+00 |
| 4.79 | -8.566E-01 | 0.0954 | 5.947E+00 | 5.04 | -8.571E-01 | 0.0954 | 5.981E+00 |
| 5.28 | -8.576E-01 | 0.0953 | 6.016E+00 | 5.53 | -8.582E-01 | 0.0953 | 6.051E+00 |
| 5.77 | -8.587E-01 | 0.0953 | 6.087E+00 | 6.02 | -8.592E-01 | 0.0952 | 6.122E+00 |
| 6.26 | -8.598E-01 | 0.0952 | 6.157E+00 | 6.51 | -8.603E-01 | 0.0952 | 6.192E+00 |
| 6.75 | -8.609E-01 | 0.0951 | 6.228E+00 | 7.00 | -8.614E-01 | 0.0951 | 6.264E+00 |
| 7.24 | -8.619E-01 | 0.0951 | 6.299E+00 | 7.49 | -8.625E-01 | 0.0950 | 6.335E+00 |
| 7.73 | -8.630E-01 | 0.0950 | 6.371E+00 | 7.98 | -8.635E-01 | 0.0950 | 6.407E+00 |
| 8.22 | -8.641E-01 | 0.0949 | 6.443E+00 | 8.47 | -8.646E-01 | 0.0949 | 6.479E+00 |
| 8.71 | -8.651E-01 | 0.0949 | 6.515E+00 | 8.96 | -8.657E-01 | 0.0948 | 6.551E+00 |
| 9.20 | -8.653E-01 | 0.0949 | 6.588E+00 | 9.44 | -8.632E-01 | 0.0950 | 6.624E+00 |
| 9.69 | -8.585E-01 | 0.0953 | 6.661E+00 | 9.93 | -8.435E-01 | 0.0962 | 6.697E+00 |
| 10.18 | -7.990E-01 | 0.0990 | 6.735E+00 | 10.42 | -6.846E-01 | 0.1077 | 6.773E+00 |
| 10.67 | -4.858E-01 | 0.1304 | 6.813E+00 | 10.91 | -2.450E-01 | 0.1913 | 6.868E+00 |
| 11.16 | 0.000E+00 | 0.4370 | 6.868E+00 | | | | |

**************************** TIME = 8.000E+02 ****************************

ISTEP = 715 RAIN = 5.844E-02 TRAIN = 4.677E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 4.677E+01 SLTIN =-2.188E-20
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 2.704E+02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 3.660E+01
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.0601 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 5.921E-07 | 0.23 | -7.796E-01 | 0.4127 | 6.303E-06 |
| 0.47 | -5.923E-01 | 0.4229 | 4.273E-05 | 0.70 | -3.823E-01 | 0.4374 | 2.245E-04 |
| 0.94 | -1.756E-01 | 0.4585 | 9.877E-04 | 1.18 | -1.753E-01 | 0.4585 | 3.317E-03 |
| 1.42 | -1.750E-01 | 0.4585 | 9.766E-03 | 1.66 | -1.747E-01 | 0.4586 | 2.593E-02 |
| 1.90 | -1.744E-01 | 0.4586 | 6.285E-02 | 2.14 | -1.741E-01 | 0.4586 | 1.400E-01 |
| 2.37 | -1.739E-01 | 0.4586 | 2.880E-01 | 2.61 | -1.736E-01 | 0.4587 | 5.480E-01 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2.85 | -1.741E-01 | 0.4586 | 9.665E-01 | 3.09 | -1.818E-01 | 0.4578 | 1.578E+00 |
| 3.33 | -2.505E-01 | 0.4507 | 2.380E+00 | 3.57 | -6.657E-01 | 0.4202 | 3.318E+00 |
| 3.81 | -8.544E-01 | 0.0955 | 3.339E+00 | 4.06 | -8.550E-01 | 0.0955 | 3.363E+00 |
| 4.30 | -8.555E-01 | 0.0955 | 3.387E+00 | 4.55 | -8.560E-01 | 0.0954 | 3.411E+00 |
| 4.79 | -8.566E-01 | 0.0954 | 3.435E+00 | 5.04 | -8.571E-01 | 0.0954 | 3.459E+00 |
| 5.28 | -8.576E-01 | 0.0953 | 3.484E+00 | 5.53 | -8.582E-01 | 0.0953 | 3.508E+00 |
| 5.77 | -8.587E-01 | 0.0953 | 3.533E+00 | 6.02 | -8.592E-01 | 0.0952 | 3.557E+00 |
| 6.26 | -8.598E-01 | 0.0952 | 3.582E+00 | 6.51 | -8.603E-01 | 0.0952 | 3.607E+00 |
| 6.75 | -8.609E-01 | 0.0951 | 3.632E+00 | 7.00 | -8.614E-01 | 0.0951 | 3.658E+00 |
| 7.24 | -8.619E-01 | 0.0951 | 3.683E+00 | 7.49 | -8.625E-01 | 0.0950 | 3.708E+00 |
| 7.73 | -8.630E-01 | 0.0950 | 3.734E+00 | 7.98 | -8.635E-01 | 0.0950 | 3.760E+00 |
| 8.22 | -8.641E-01 | 0.0949 | 3.786E+00 | 8.47 | -8.646E-01 | 0.0949 | 3.812E+00 |
| 8.71 | -8.651E-01 | 0.0949 | 3.838E+00 | 8.96 | -8.657E-01 | 0.0948 | 3.864E+00 |
| 9.20 | -8.653E-01 | 0.0949 | 3.891E+00 | 9.44 | -8.632E-01 | 0.0950 | 3.917E+00 |
| 9.69 | -8.585E-01 | 0.0953 | 3.944E+00 | 9.93 | -8.435E-01 | 0.0962 | 3.971E+00 |
| 10.18 | -7.990E-01 | 0.0990 | 3.998E+00 | 10.42 | -6.846E-01 | 0.1077 | 4.026E+00 |
| 10.67 | -4.858E-01 | 0.1304 | 4.056E+00 | 10.91 | -2.450E-01 | 0.1913 | 4.096E+00 |
| 11.16 | 0.000E+00 | 0.4370 | 4.096E+00 | | | | |

****************************** TIME = 9.000E+02 ******************************

```
ISTEP =     801  RAIN  = 5.844E-02  TRAIN  = 5.262E+01  CIN   = 0.000E+00
DELT  = 1.164E+00  DRAIN = 5.844E-02  TDRAIN = 5.262E+01  SLTIN =-2.216E-20
NIT   =       1  PET   = 0.000E+00  TRUPTK = 0.000E+00  SLTOUT= 2.886E+02
RELAXF=    1.000  ACTET = 0.000E+00  STORW  = 0.000E+00  STORS = 1.844E+01
                                                          QDECAY= 0.000E+00
```

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.1193 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.318E-07 | 0.23 | -7.796E-01 | 0.4127 | 2.459E-06 |
| 0.47 | -5.923E-01 | 0.4229 | 1.653E-05 | 0.70 | -3.823E-01 | 0.4374 | 8.633E-05 |
| 0.94 | -1.756E-01 | 0.4585 | 3.786E-04 | 1.18 | -1.753E-01 | 0.4585 | 1.273E-03 |
| 1.42 | -1.750E-01 | 0.4585 | 3.767E-03 | 1.66 | -1.747E-01 | 0.4586 | 1.011E-02 |
| 1.90 | -1.744E-01 | 0.4586 | 2.497E-02 | 2.14 | -1.741E-01 | 0.4586 | 5.705E-02 |
| 2.37 | -1.739E-01 | 0.4586 | 1.212E-01 | 2.61 | -1.736E-01 | 0.4587 | 2.399E-01 |
| 2.85 | -1.741E-01 | 0.4586 | 4.426E-01 | 3.09 | -1.818E-01 | 0.4578 | 7.588E-01 |
| 3.33 | -2.505E-01 | 0.4507 | 1.202E+00 | 3.57 | -6.657E-01 | 0.4202 | 1.756E+00 |
| 3.81 | -8.544E-01 | 0.0955 | 1.768E+00 | 4.06 | -8.550E-01 | 0.0955 | 1.782E+00 |
| 4.30 | -8.555E-01 | 0.0955 | 1.796E+00 | 4.55 | -8.560E-01 | 0.0954 | 1.810E+00 |
| 4.79 | -8.566E-01 | 0.0954 | 1.825E+00 | 5.04 | -8.571E-01 | 0.0954 | 1.839E+00 |
| 5.28 | -8.576E-01 | 0.0953 | 1.854E+00 | 5.53 | -8.582E-01 | 0.0953 | 1.868E+00 |
| 5.77 | -8.587E-01 | 0.0953 | 1.883E+00 | 6.02 | -8.592E-01 | 0.0952 | 1.898E+00 |
| 6.26 | -8.598E-01 | 0.0952 | 1.913E+00 | 6.51 | -8.603E-01 | 0.0952 | 1.928E+00 |
| 6.75 | -8.609E-01 | 0.0951 | 1.943E+00 | 7.00 | -8.614E-01 | 0.0951 | 1.958E+00 |
| 7.24 | -8.619E-01 | 0.0951 | 1.973E+00 | 7.49 | -8.625E-01 | 0.0950 | 1.988E+00 |
| 7.73 | -8.630E-01 | 0.0950 | 2.004E+00 | 7.98 | -8.635E-01 | 0.0950 | 2.020E+00 |
| 8.22 | -8.641E-01 | 0.0949 | 2.035E+00 | 8.47 | -8.646E-01 | 0.0949 | 2.051E+00 |
| 8.71 | -8.651E-01 | 0.0949 | 2.067E+00 | 8.96 | -8.657E-01 | 0.0948 | 2.083E+00 |
| 9.20 | -8.653E-01 | 0.0949 | 2.099E+00 | 9.44 | -8.632E-01 | 0.0950 | 2.115E+00 |
| 9.69 | -8.585E-01 | 0.0953 | 2.132E+00 | 9.93 | -8.435E-01 | 0.0962 | 2.148E+00 |
| 10.18 | -7.990E-01 | 0.0990 | 2.165E+00 | 10.42 | -6.846E-01 | 0.1077 | 2.182E+00 |
| 10.67 | -4.858E-01 | 0.1304 | 2.200E+00 | 10.91 | -2.450E-01 | 0.1913 | 2.225E+00 |
| 11.16 | 0.000E+00 | 0.4370 | 2.225E+00 | | | | |

****************************** TIME = 1.000E+03 ******************************

```
ISTEP =     887  RAIN  = 5.844E-02  TRAIN  = 5.848E+01  CIN   = 0.000E+00
DELT  = 1.164E+00  DRAIN = 5.844E-02  TDRAIN = 5.848E+01  SLTIN =-2.210E-20
NIT   =       1  PET   = 0.000E+00  TRUPTK = 0.000E+00  SLTOUT= 2.982E+02
RELAXF=    1.000  ACTET = 0.000E+00  STORW  = 0.000E+00  STORS = 8.886E+00
                                                          QDECAY= 0.000E+00
```

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.2478 %

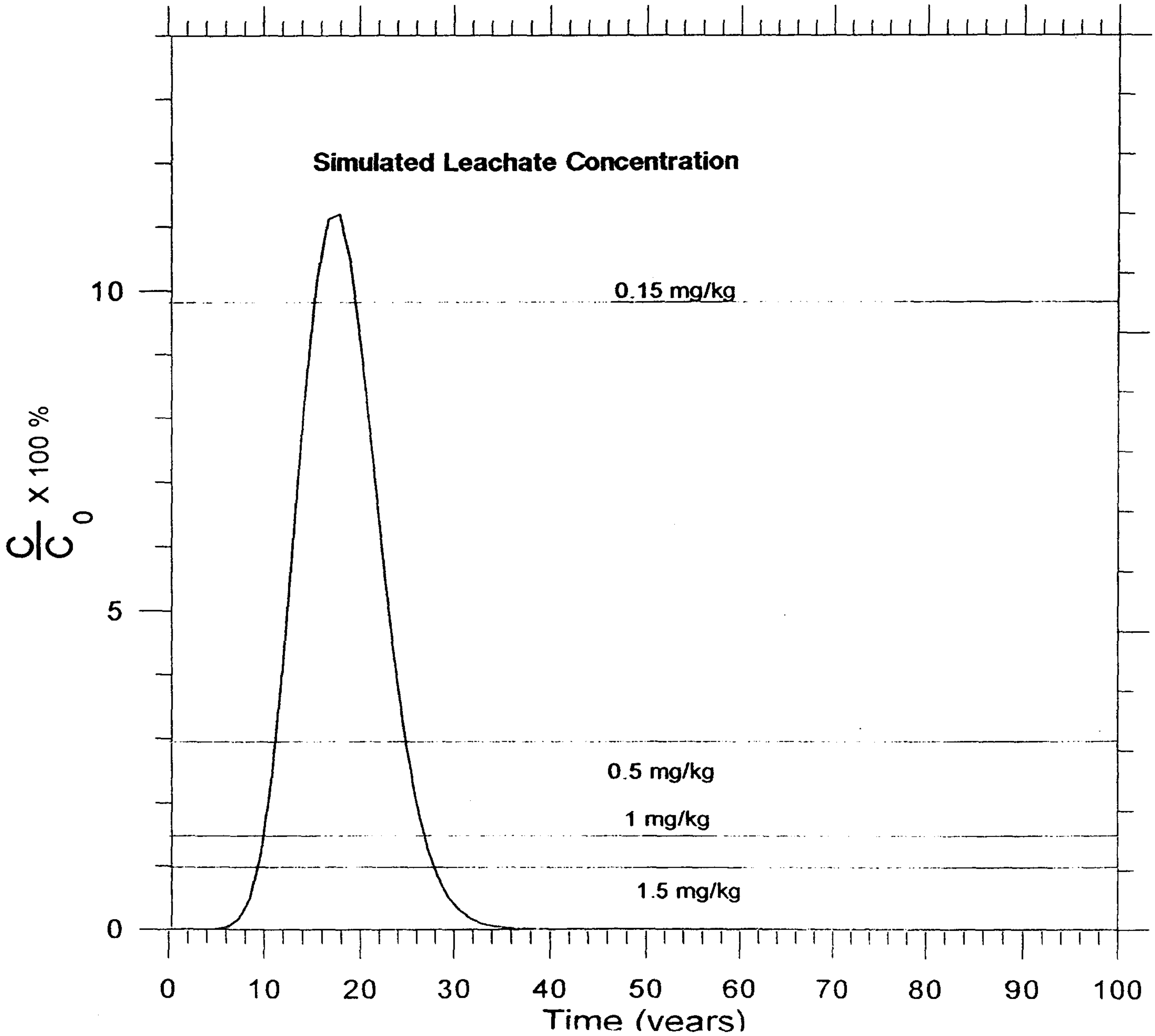
| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 8.985E-08 | 0.23 | -7.796E-01 | 0.4127 | 9.514E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 6.372E-06 | 0.70 | -3.823E-01 | 0.4374 | 3.319E-05 |
| 0.94 | -1.756E-01 | 0.4585 | 1.455E-04 | 1.18 | -1.753E-01 | 0.4585 | 4.902E-04 |
| 1.42 | -1.750E-01 | 0.4585 | 1.460E-03 | 1.66 | -1.747E-01 | 0.4586 | 3.960E-03 |
| 1.90 | -1.744E-01 | 0.4586 | 9.927E-03 | 2.14 | -1.741E-01 | 0.4586 | 2.317E-02 |
| 2.37 | -1.739E-01 | 0.4586 | 5.054E-02 | 2.61 | -1.736E-01 | 0.4587 | 1.033E-01 |
| 2.85 | -1.741E-01 | 0.4586 | 1.975E-01 | 3.09 | -1.818E-01 | 0.4578 | 3.519E-01 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3.33 | -2.505E-01 | 0.4507 | 5.792E-01 | 3.57 | -6.657E-01 | 0.4202 | 8.757E-01 |
| 3.81 | -8.544E-01 | 0.0955 | 8.824E-01 | 4.06 | -8.550E-01 | 0.0955 | 8.900E-01 |
| 4.30 | -8.555E-01 | 0.0955 | 8.976E-01 | 4.55 | -8.560E-01 | 0.0954 | 9.052E-01 |
| 4.79 | -8.566E-01 | 0.0954 | 9.129E-01 | 5.04 | -8.571E-01 | 0.0954 | 9.207E-01 |
| 5.28 | -8.576E-01 | 0.0953 | 9.285E-01 | 5.53 | -8.582E-01 | 0.0953 | 9.364E-01 |
| 5.77 | -8.587E-01 | 0.0953 | 9.443E-01 | 6.02 | -8.592E-01 | 0.0952 | 9.523E-01 |
| 6.26 | -8.598E-01 | 0.0952 | 9.604E-01 | 6.51 | -8.603E-01 | 0.0952 | 9.685E-01 |
| 6.75 | -8.609E-01 | 0.0951 | 9.767E-01 | 7.00 | -8.614E-01 | 0.0951 | 9.849E-01 |
| 7.24 | -8.619E-01 | 0.0951 | 9.932E-01 | 7.49 | -8.625E-01 | 0.0950 | 1.002E+00 |
| 7.73 | -8.630E-01 | 0.0950 | 1.010E+00 | 7.98 | -8.635E-01 | 0.0950 | 1.019E+00 |
| 8.22 | -8.641E-01 | 0.0949 | 1.027E+00 | 8.47 | -8.646E-01 | 0.0949 | 1.036E+00 |
| 8.71 | -8.651E-01 | 0.0949 | 1.044E+00 | 8.96 | -8.657E-01 | 0.0948 | 1.053E+00 |
| 9.20 | -8.653E-01 | 0.0949 | 1.062E+00 | 9.44 | -8.632E-01 | 0.0950 | 1.071E+00 |
| 9.69 | -8.585E-01 | 0.0953 | 1.080E+00 | 9.93 | -8.435E-01 | 0.0962 | 1.089E+00 |
| 10.18 | -7.990E-01 | 0.0990 | 1.098E+00 | 10.42 | -6.846E-01 | 0.1077 | 1.108E+00 |
| 10.67 | -4.858E-01 | 0.1304 | 1.118E+00 | 10.91 | -2.450E-01 | 0.1913 | 1.132E+00 |
| 11.16 | 0.000E+00 | 0.4370 | 1.132E+00 | | | | |

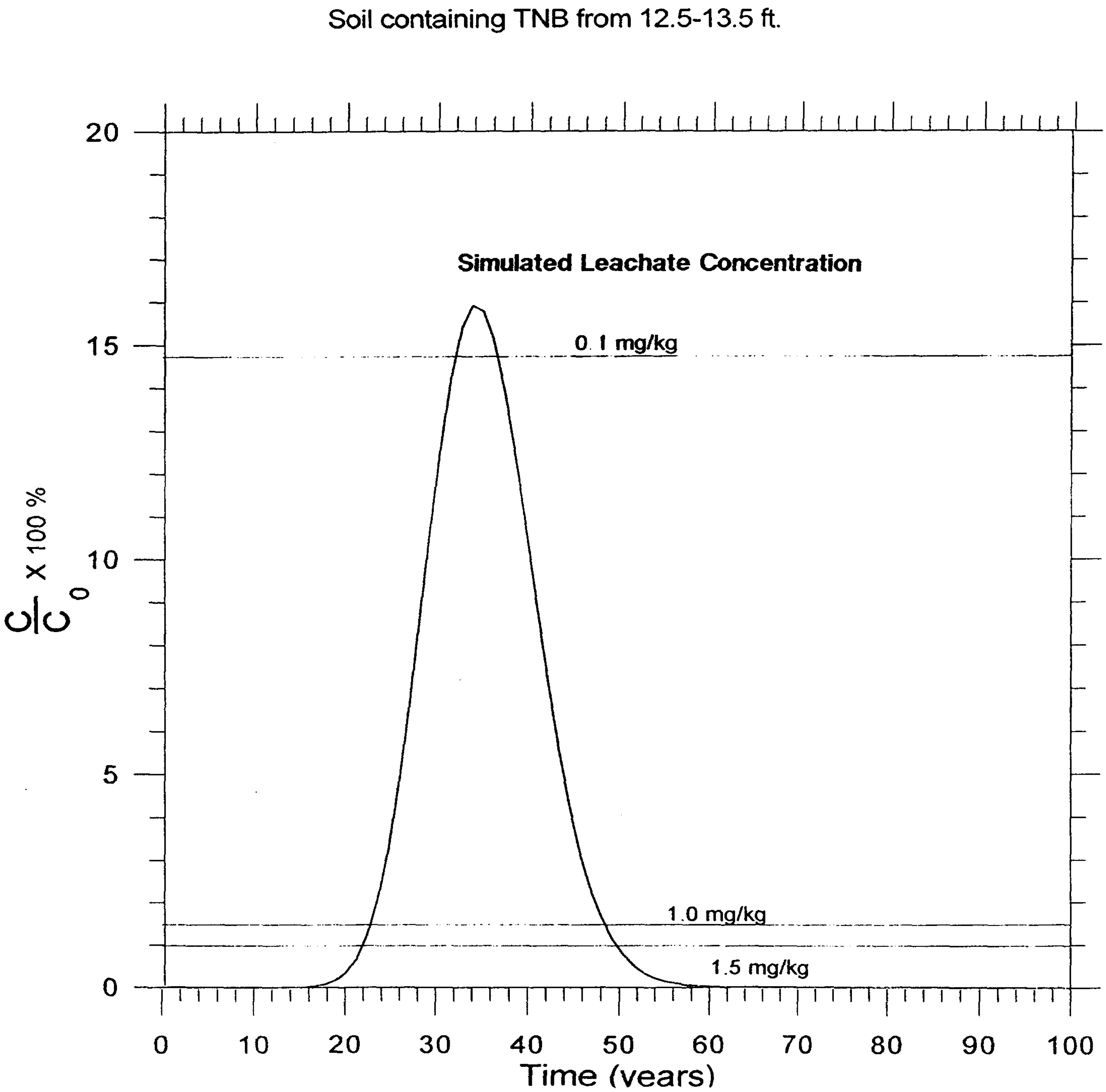
***** NORMAL TERMINATION TIME = 1000.6279 AND STEP NUMBER = 887

```
hypothetical, time units = years, infiltration = 2.3 in/yr
TNB, C tnb = 100 from 4 to 5, 162.dat
  1   0   0   0   0   1   1   0   0   2
 7500   3   3   1   7   1        0.0
    .001   .00001    100.0    1000.     .010      .01 9900
    1   1      0.0      0.7     0.25
    2   2      0.7     3.81     0.25
    3   3     3.81    11.16     0.25
    2.681     1.17    0.475    0.090    98.55
    2.925     1.15    0.479    0.056    3.285
     13.8     1.69    0.437    0.020    3650.
   2.27e-2    0.10      1.4      0.0      0.0    7.748      1.0
   2.27e-2    0.10      1.4      0.0      0.0     8.84      1.0
   2.27e-2    0.10      1.4      0.0      0.0   0.1326      1.0
0.000E+00 -9.476E-01  0.4050  0.000E+00
2.333E-01 -7.876E-01  0.4123  0.000E+00
4.667E-01 -6.004E-01  0.4225  0.000E+00
7.000E-01 -3.903E-01  0.4368  0.000E+00
9.392E-01 -1.838E-01  0.4576  0.000E+00
1.220E+00 0.0         0.4576  0.000E+00
1.22      0.0         0.4576  100.
1.52      0.0         0.4576  100.
1.52      0.0         0.4576  0.
1.657E+00 -1.838E-01  0.4576  0.
1.83      0.0         0.4576  0.
1.896E+00 -1.838E-01  0.4576  0.
2.135E+00 -1.838E-01  0.4576  0.
2.375E+00 -1.838E-01  0.4576  0.
2.614E+00 -1.838E-01  0.4576  0.
2.74      0.0         0.4576  0.
2.853E+00 -1.845E-01  0.4575  0.
3.092E+00 -1.922E-01  0.4567  0.
3.332E+00 -2.607E-01  0.4497  0.
3.571E+00 -6.748E-01  0.4197  0.
3.810E+00 -8.628E-01  0.0950  0.
4.12      0.0         0.0950  0.
5.770E+00 -8.628E-01  0.0950  0.
6.015E+00 -8.628E-01  0.0950  0.
6.1       0.0         0.0950  0.
6.260E+00 -8.628E-01  0.0950  0.
6.505E+00 -8.628E-01  0.0950  0.
6.750E+00 -8.628E-01  0.0950  0.
6.995E+00 -8.628E-01  0.0950  0.
7.240E+00 -8.628E-01  0.0950  0.
7.485     0.0         0.0950  0.0
7.485E+00 -8.628E-01  0.0950  0.0
7.62      0.0         0.0950  0.0
7.730E+00 -8.628E-01  0.0950  0.0
7.975E+00 -8.628E-01  0.0950  0.0
8.220E+00 -8.628E-01  0.0950  0.0
8.465E+00 -8.628E-01  0.0950  0.0
8.955E+00 -8.625E-01  0.0950  0.0
9.200E+00 -8.621E-01  0.0951  0.0
9.445E+00 -8.605E-01  0.0952  0.0
9.690E+00 -8.557E-01  0.0954  0.0
9.935E+00 -8.407E-01  0.0964  0.0
1.018E+01 -7.961E-01  0.0992  0.0
1.042E+01 -6.837E-01  0.1078  0.0
1.067E+01 -4.851E-01  0.1305  0.0
1.091E+01 -2.450E-01  0.1913  0.0
1.116E+01  0.000E+00  0.4370  0.0
      0.0    1    0    .05844      0.0
    300.0    400.0    500.0    600.0    700.0    800.0    900.0
   11.159
```

Soil containing TNB from 24-25 ft.

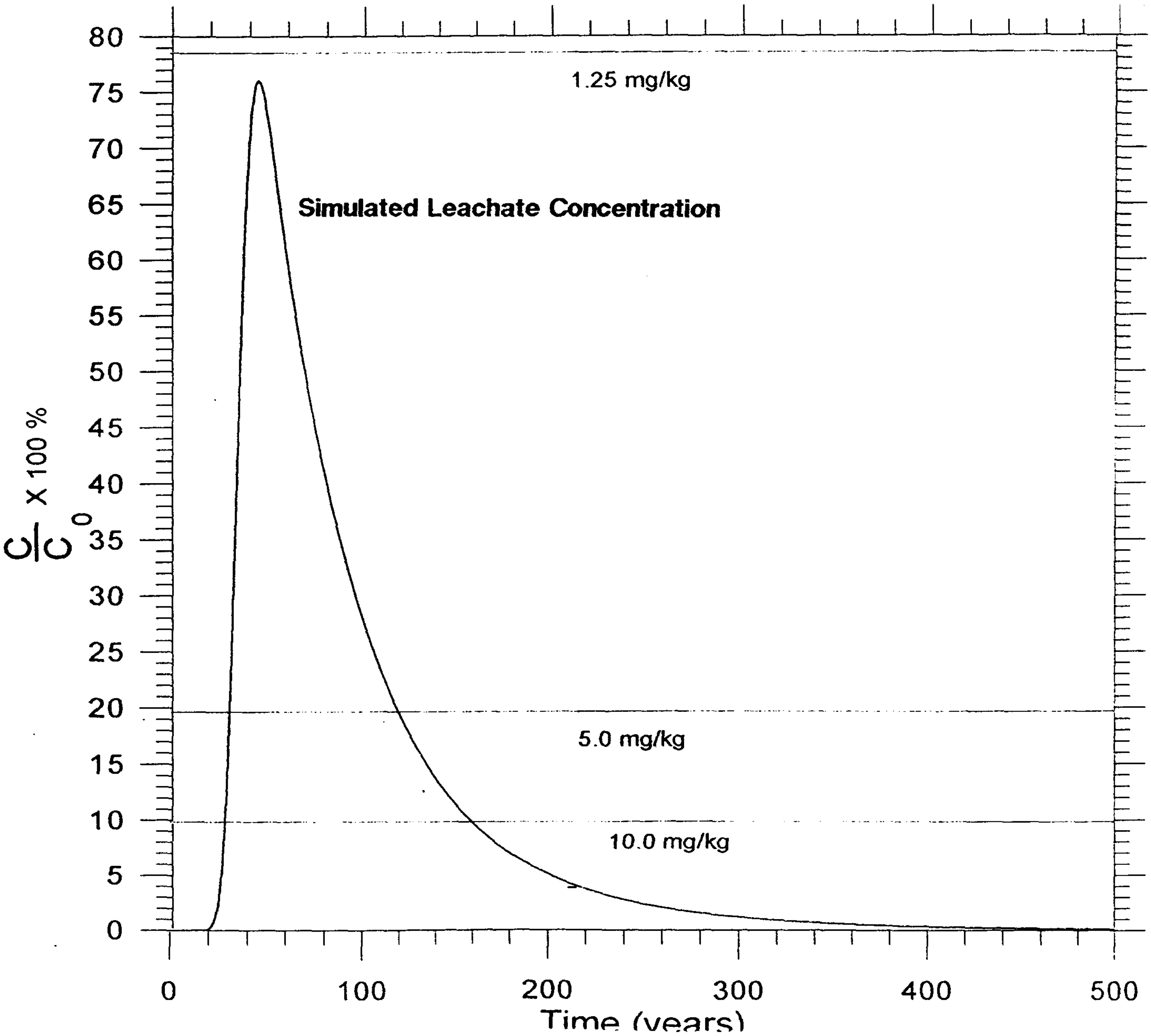



B07NE003702-09202

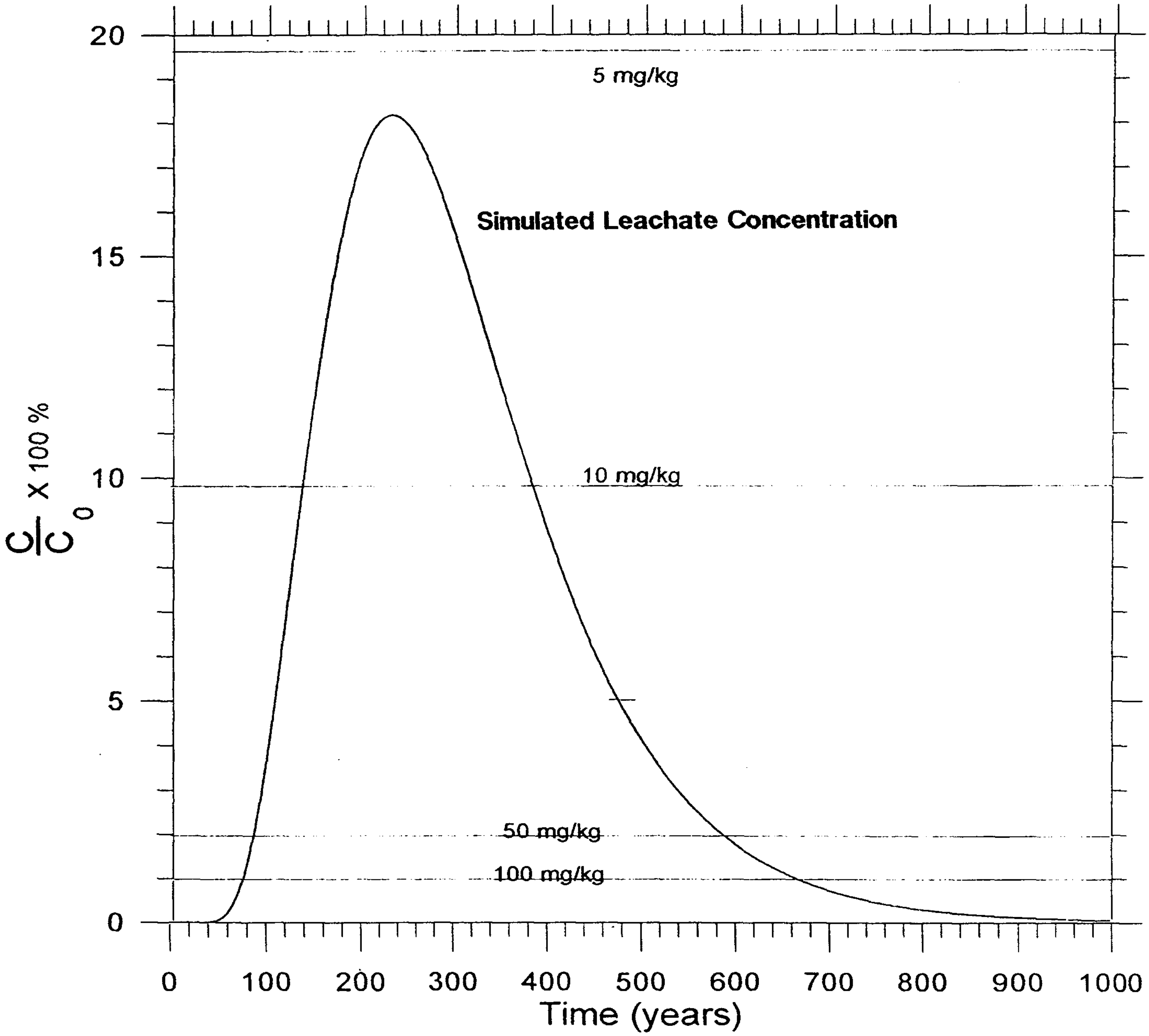



B07NE003702-09203

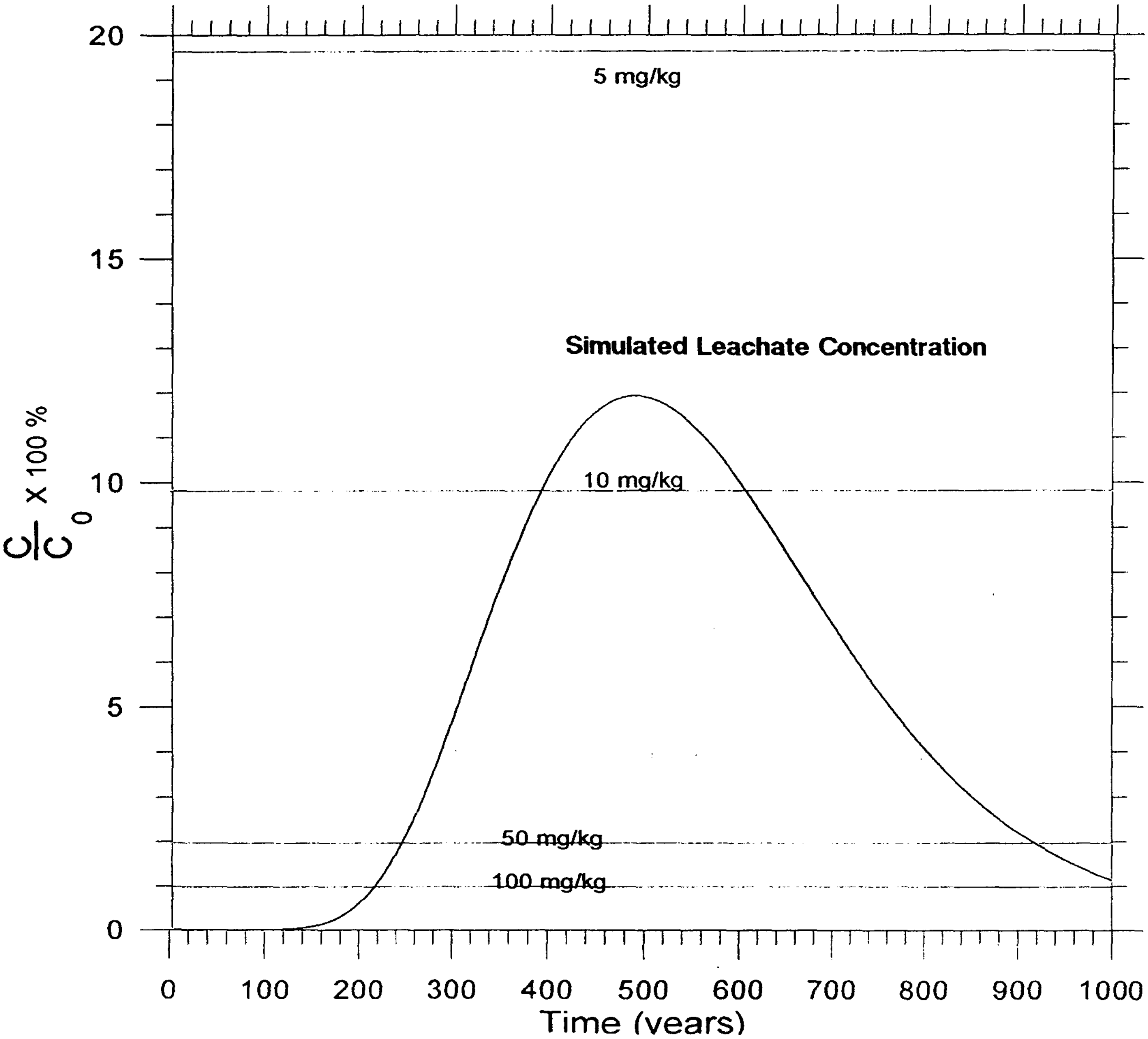
Soil containing TNB from 11.5-12.5 ft.



Soil containing TNB from 8-9 ft.



Soil containing TNB from 4-5 ft.




B07NE003702-09206

# APPENDIX C
# UNSATURATED ZONE MODELING RESULTS

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# 1.0 INTRODUCTION

## 1.1 PURPOSE

The purpose of the unsaturated zone modeling is the evaluation of two soil remediation alternative actions, soil cleanup and infiltration control, whose common purpose is to protect groundwater from exceeding specific concentrations of explosives contamination.

## 1.2 PREVIOUS WORK

The Operable Unit No. 1 (OU1) Supplemental Remedial Investigation (RI) Report (Donohue, 1992) used the Summers Model (EPA, 1989) to estimate concentrations of explosives in soil which would result in sufficient groundwater protection for each chemical of interest (TNT, 2,4-DNT, 2,6-DNT, and RDX), using risk-based groundwater preliminary remediation goals (PRGs).

The Unsaturated Zone Model Selection and Document Schedule Technical Memorandum (WCC, 1993a) discussed the modification of OU2 to include soils contaminated by explosives which may contribute to groundwater contamination through leaching processes. The purpose of the technical memorandum was to present an unsaturated zone contaminant transport model that had been selected to estimate explosives concentrations in soil that may be indicative of leaching processes, and the methodology for estimating model input parameter values.

A teleconference was held between U.S. Army Corps of Engineers (USACE), Nebraska Department of Environmental Quality (NDEQ), and the U.S. Environmental Protection Agency (EPA) on August 20, 1993. The purpose of the teleconference was to review the model selection technical memorandum. As a result of the teleconference, a consensus was reached regarding the application of four approaches for estimating explosives concentrations in leaching soils. All four of the estimating approaches were different from the single estimating approach presented in the model selection technical memorandum.

The Unsaturated Zone Modeling Technical Memorandum (WCC, 1994a) documented the application of the four estimating approaches. Soil concentration limits were recommended based on the results of Approach 4, HYDRUS Model (Kool and van Genuchten, 1991) applied in conjunction with the Summers Model modified to include a 5-ft saturated zone.

The responses to Agency comments on the Unsaturated Zone Technical Memorandum (WCC, 1994b) presented a new program for the application of the HYDRUS Model combined with the modified Summers Model. The new program was developed to evaluate two soil remediation alternative actions: soil cleanup and infiltration control. The new program was intended to account for certain limitations of the four estimating approaches, primarily the assumption of an infinite source of explosives in the soil. The new program also accounted for capping or other infiltration control which had not been considered during previous work. The infinite source limitation was not necessary for the new program because the cleanup of near surface soil contamination (which may include solid phase explosives particles) during OU1 is considered.

During the meeting to discuss the responses to comments, a number of suggestions were adopted as documented in the minutes of the meeting (WCC, 1994c). Some of the adopted suggestions included: the inclusion of an uncertainty discussion and HYDRUS Model input and output files in the modeling effort documentation, and the use of a mass balance analysis to account for the contaminant mass during the HYDRUS simulations.

A briefing for EPA and NDEQ was held on May 19, 1994 to present the preliminary results of the current unsaturated zone modeling.

## 1.3 SCOPE OF THE MODELING EFFORT

The modeling effort was limited to two general soil remediation alternative actions: soil cleanup and infiltration control. The OU2 Feasibility Study (FS) Report develops, screens, and evaluates the specific potential remedial actions. The scope of the soil cleanup evaluation is defined by the assumptions listed in Section 5.1, and the scope of the infiltration control evaluation is defined by the assumptions listed in Section 6.1.

In response to NDEQ questions asked during the May 19, 1994 briefing, an evaluation of equilibrium concentrations using soil-water partition coefficients, and an application of the Summers Model modified to include a 5-ft saturated zone have been included in **Attachment 1**. These are two of the four approaches presented in the Unsaturated Zone Modeling Technical Memorandum (WCC, 1994a). As discussed in Section 1.2, these approaches are limited by the assumption that an infinite source of explosives is available in the soil.

### 1.4 APPENDIX ORGANIZATION

Sections 2.0, 3.0, and 4.0 present the maximum acceptable groundwater concentrations, the representative soil concentration profiles, and the representative soil columns, respectively. Those parameters are common to both the simulation of soil cleanup and infiltration control. Section 5.0 documents both the methodology and the results of the soil cleanup simulation, while Section 6.0 describes the infiltration control analysis. The uncertainties and limitations of simulations are discussed qualitatively in Section 7.0. The conclusions of the unsaturated zone modeling are summarized in Section 8.0, and Section 9.0 is the list of references. **Attachments 1** and **2** include backup information/calculations, and HYDRUS input files and output files in both tabular and graphical presentations, respectively.

# 2.0
# MAXIMUM ACCEPTABLE GROUNDWATER CONCENTRATIONS

Six explosives compounds were selected for analysis in the Unsaturated Zone Technical Memorandum (WCC, 1994a). The maximum acceptable groundwater concentrations are assumed to be equal to the Proposed PRGs presented by USACE (1994), and are tabulated below:

| Chemical | Proposed Groundwater PRG (mg/L) |
|---|---|
| Trinitrobenzene (TNB) | 0.001 |
| Trinitrotoluene (TNT) | 0.0282 |
| Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) | 0.00774 |
| Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) | 0.782 |
| 2,4-Dinitrotoluene (2,4-DNT) | 0.00124 |

USACE (1994) did not propose a groundwater PRG for tetryl because tetryl was not detected in groundwater samples collected during the OU2 Remedial Investigation. However, tetryl was detected during OU1 soil investigations, and there may be a potential for migration of tetryl through the unsaturated zone. Therefore, the tap water PRG, 0.370 mg/L, listed in EPA (1993) is presented. The same value was used in the analyses presented in the Unsaturated Zone Technical Memorandum (WCC, 1994a).

It should be noted that groundwater concentrations are frequently given in units of µg/L as well as mg/L. The conversion between units is: ***1,000 µg/L = 1 mg/L.***

# 3.0
# REPRESENTATIVE SOIL CONCENTRATION PROFILES

Twenty-six locations for representative soil concentrations were selected in cooperation with OU1 project team members.

The basis for the selection of the 26 areas is as follows:

- A 50-ft radius circle is centered on the head (beginning) of selected ditches or on selected sumps in Load Line 1 and Load Line 2
- If two sumps of interest are adjacent to each other, the center of the circle is an arbitrary point between the sumps
- In ditches where an area of relatively large sample density extends more than 50 feet from the head of the ditch, the 50-ft diameter circles are located tangentially to cover the area
- Two 50-ft radius circles are located at the Bomb Booster Area

The basis for the calculation of average concentrations within each area is as follows:

- Calculations are generally done for the following depth intervals (in feet below ground surface)
  - 0 - 1
  - 1 - 2
  - 2 - 4
  - 4 - 8
  - 8 - 10
  - 10 - 15
  - 15 - 25
  - 25 - Bottom of the boring
- The bottom depth of the sample is used to define the depth of the sample interval (therefore, the 2 - 4 foot interval was defined by those samples with bottom depth greater than 2 feet and less than or equal to 4 feet)
- Results reported as not detected above the method detection limit are assumed to be zero

- Field screen results were not used to calculate the average concentrations

The soil concentration profiles are primarily located at Load Lines 1 and 2 because those load lines have more extensive soil contamination relative to the other areas at the Site. Two locations at the Bomb Booster area were selected based on high concentrations of tetryl detected in the soil there (relative to other areas at the Site). It is estimated that the extrapolation of results generated from these areas to Load Lines 3 and 4 and other Site areas, would be a conservative assumption.

The average explosives concentration calculated for the depth intervals were used instead of using either the maximum or minimum concentrations detected for the intervals. It is estimated that use of the average concentrations would be a realistic assumption.

**Table 3-1** presents the average concentrations and the State Planar Coordinates of the center of the 26 circles. The designations listed in the table indicate the area and sump where the circle was centered. For example, LL1[H] designates a circle centered on Sump H of Load Line 1.

## 4.0 REPRESENTATIVE SOIL COLUMNS

### 4.1 LOAD LINES

The development of a representative soil column for the load line areas is discussed in the Unsaturated Zone Technical Memorandum (WCC, 1994a). The depth intervals of the three hydrostratigraphic soil units, as well as the soil physical properties used during the modeling are tabulated below.

| Hydrostratigraphic Unit | Depth Below Ground Surface (m) and [ft] | Fraction Organic Carbon ($f_{oc}$) | Saturated Hydraulic Conductivity (m/year) | Residual Water Content ($m^3/m^3$) | Saturated Water Content ($m^3/m^3$) | Shape Factor $\alpha$ ($m^{-1}$)) | Shape Factor $\beta$ |
|---|---|---|---|---|---|---|---|
| Topsoil | 0 - 0.70 [0 - 2.3] | 0.0149 | 99 | 0.090 | 0.475 | 2.681 | 1.17 |
| Loess | 0.70 - 3.81 [2.3 - 12.5] | 0.017 | 3 | 0.056 | 0.479 | 2.925 | 1.15 |
| Fine Sand | 3.81 - 11.16 [12.5 - 36.6] | 0.000255 | 3,650 | 0.020 | 0.437 | 13.8 | 1.69 |

The following items should be noted with regard to the tabulation above:

- The tabulated values are identical to the values presented in the Unsaturated Zone Technical Memorandum (WCC, 1994a) with the exception of unit conversions

- The lower bound of the fine sand interval is the estimated depth to the top of the saturated zone (equivalent to 36.6 feet below the ground surface)

### 4.2 BOMB BOOSTER AREA

A separate representative soil column was developed for the Bomb Booster Area because the load lines and the Bomb Booster Area are separate geographic areas with different hydrostratigraphic unit thicknesses. The depth intervals of the hydrostratigraphic units were estimated from boring logs contained in USACE (1989) and Donohue (1992). The depth intervals are tabulated below, and the physical parameters are identical to the tabulation in Section 4.1.

| Hydrostratigraphic Unit | Depth Below Ground Surface (m) and [ft] |
|---|---|
| Topsoil | 0 - 1.07<br>[0 - 3.5] |
| Loess | 1.07 - 5.79<br>[3.5 - 19.0] |
| Fine Sand | 5.79 - 12.58<br>[19.0 - 41.25] |

The lower bound of the fine sand interval is the estimated depth to the top of the saturated zone (equivalent to 41.25 feet below the ground surface).

## 5.0
## SOIL CLEANUP SIMULATION

### 5.1 ASSUMPTIONS

The following assumptions were used to simulate soil cleanup:

- The infiltration rate is constant with a value of 2.3 inches/year
- The average soil concentrations presented in Section 3.0 are the concentrations at the depths equal to the center of the interval over which the samples were collected
- The soil concentration from the ground surface to the depth of the shallowest soil sample is equal to the concentration measured in the shallowest sample
- The soil concentrations vary linearly between sample depths
- The soil concentration is zero at depths where the sample concentration is reported as not detected
- The soil concentration from the depth of the deepest soil sample to the estimated top of the saturated zone is equal to the concentration assigned to the deepest sample depth
- The "cleaned-up" soil has hydraulic properties and hydrostratigraphic unit thicknesses equivalent to the conditions prior to cleanup, and the chemical concentrations are zero
- The adsorbed and solution explosives concentrations are always in local equilibrium

The infiltration value listed in the first assumption above is the value presented in the Unsaturated Zone Technical Memorandum (WCC, 1994a). The last assumption listed above is a typical assumption used in groundwater models, including the HYDRUS Model.

Furthermore, it was assumed that, at an individual soil concentration location, all explosives will be cleaned-up to a depth of 4-ft if any of the average explosives concentrations at depths less than 4-ft exceed the OU1 excavation PRGs tabulated below:

| Chemical | Soil Excavation PRGs (mg/kg) |
|---|---|
| TNB | 1.7 |
| TNT | 17.2 |
| RDX | 5.8 |
| HMX | 1715.2 |
| 2,4-DNT | 0.9 |
| Tetryl | 343 |

The source of the excavation PRGs listed above is the OU1 FS Report (RUST, 1994).

## 5.2 APPLICATION OF THE SUMMERS MODEL TO CALCULATE MAXIMUM ALLOWABLE LEACHATE CONCENTRATIONS

For the purposes of this analysis, leachate was defined as the soil moisture immediately above the saturated zone. The graphs of simulated leachate concentration contained in **Attachment 2** are the soil moisture concentrations simulated 0.001 cm above the top of the saturated zone (11.159 m below the ground surface for load lines representative soil column. It was assumed that the relationship between the explosives concentrations in the leachate and the explosives concentration in the groundwater comprising the top 5 feet of the saturated zone could be calculated using the modified Summers Model. The maximum allowable leachate concentration was calculated for each of the six explosives compounds using the following assumptions:

- The area of contamination is circular with a 50-ft radius, which corresponds to the areas used to calculate the average concentrations for the representative soil concentration profile
- The height of the mixing zone is 5-ft

- The horizontal Darcy velocity of the water in the saturated zone was calculated using the hydraulic conductivity, 0.034 feet/minute, and gradient, 12 feet/mile, estimated in the OU2 Remedial Investigation (RI) Report (WCC, 1993b)

- The vertical infiltration rate is 2.3 inches/year which was the value used in the Unsaturated Zone Technical Memorandum (WCC, 1994a)

The same assumptions were used to calculate maximum allowable leachate concentrations during the infiltration control evaluation, with the exception of the vertical infiltration rate, which is fully discussed in Section 6.2.

The maximum allowable leachate concentration calculations are presented in **Attachment 1**, and are tabulated below as calculated using the modified Summers Model and an infiltration rate of 2.3 inches/year.

| Chemical | Proposed Groundwater PRG (mg/L) | Maximum Allowable Leachate Concentration for Infiltration = 2.3 inches/year (mg/L) |
|---|---|---|
| TNB | 0.001 | 0.0145 |
| TNT | 0.0282 | 0.408 |
| RDX | 0.00774 | 0.112 |
| HMX | 0.782 | 11.3 |
| 2,4-DNT | 0.00124 | 0.018 |
| Tetryl | 0.370 | 5.4 |

## 5.3 METHODOLOGY

The following steps were used to evaluate soil cleanup:

1) The initial soil moisture concentration (in the unsaturated zone), $C_i$, was calculated using the soil concentrations, $S$, tabulated in **Table 3-1** and the distribution coefficients, $K_d$ (tabulated below), according to the equation below:

$$C_i = S / K_d \qquad 5.1$$

2) The HYDRUS Model was used to simulate both flow and transport using the flow parameters presented in Section 4.1 and Section 4.2 and the transport parameters tabulated below

3) The leachate concentration was plotted as a function of time, and compared to the maximum allowable leachate concentration

4) The mass of contaminant remaining in the unsaturated zone was plotted as a function of time

For the simulation of soil cleanup, it was planned that the steps above would be repeated with different distributions of $C_i$ representing various stages of soil cleanup.

For the simulation of infiltration control, it was planned that the distribution of $C_i$ represent the cleanup of soil to a depth of 4 feet, and the steps above be repeated with different values of infiltration rate.

The distribution coefficient was calculated for each soil type and each explosive compound using the equation:

$$K_d = K_{oc} \times foc \quad 5.2$$

where $K_{oc}$ is the distribution coefficient normalized with respect to fraction organic carbon (*foc*).

The following tabulations list the $K_{oc}$ and $K_d$ values used for both the soil cleanup and infiltration control simulations.

| Chemical | $K_{oc}$ (mL/g) | $K_d$ (mL/g) | | |
|---|---|---|---|---|
| | | Topsoil | Loess | Fine Sand |
| TNB | 520 | 7.748 | 8.84 | 0.1326 |
| TNT | 780 | 12 | 13 | 0.2 |
| RDX | 104.5 | 1.6 | 1.8 | 0.027 |
| HMX | 3.47 | 0.052 | 0.059 | 0.00088 |
| 2,4-DNT | 251 | 3.7 | 4.3 | 0.064 |
| Tetryl | 44.7 | 0.67 | 0.76 | 0.011 |

The $K_{oc}$ and $K_d$ values tabulated above are the same as the values presented in the Unsaturated Zone Technical Memorandum (WCC, 1994a) with the exception of TNB. The TNB $K_{oc}$ presented in the Unsaturated Zone Technical Memorandum (WCC, 1994a) was 20 mL/g, and the $K_d$ values were calculated using that value. The TNB $K_{oc}$ was re-evaluated based on the following information:

- Burrows et. al. (undated) estimated that $log\ K_{oc}$ was 1.3 (which is equivalent to $K_{oc}$ = 20 mL/g)
- Spanggord, et. al. (1980) estimated that $K_{oc}$ was 520 mL/g
- IRIS (1992) listed estimated $K_{oc}$ values of 104 mL/g and 178 mL/g using different methodologies

A qualitative review of the extent of TNB detected in groundwater monitoring wells at former Nebraska Ordnance Plant (NOP) near Mead, Nebraska (Site) showed a similarity between the spatial distribution of TNT and TNB. The similar distributions indicate that the two explosives have relatively similar mobilities in groundwater, if it is assumed that both chemicals were introduced to the saturated zone at approximately the same time. Mobility is related to the distribution coefficient. The $K_{oc}$ value for TNT is 780 mL/g and the TNB $K_{oc}$ value (520 mL/g) closest to the TNT value was selected.

The dispersivity and bulk density for all three hydrostratigraphic units were estimated as 0.10 m and 1.4 g/cm$^3$, respectively. The molecular diffusion coefficient values were estimated as:

| Chemical | Molecular Diffusion Coeff. ($m^2$/year) |
|---|---|
| TNB | 0.0227 |
| TNT | 0.0212 |
| RDX | 0.0226 |
| HMX | 0.0190 |
| 2,4-DNT | 0.0231 |
| Tetryl | 0.0189 |

The dispersivity, bulk density, and molecular diffusion coefficient values were identical to the values presented in the Unsaturated Zone Technical Memorandum (WCC, 1994a) with the exception of unit conversions.

## 5.4 RESULTS

### 5.4.1 Evaluation of TNB Soil Contamination

Soil cleanup simulation began with TNB contamination for location LL1[D(1)]. The backup calculations of the initial soil moisture concentrations, $C_i$, are contained in **Attachment 1**. The HYDRUS input and output files, as well as graphs of $C_i$, the leachate concentration, and the contaminant mass are included in **Attachment 2A**. All HYDRUS output files included in **Attachment 2A** contain outputs at various time intervals to evaluate the temporal movement of the contaminant mass through the soil column.

Inspection of the **Attachment 2A** graphs show that the simulated leachate concentration simulated for LL1[D(1)] greatly exceeds the maximum allowable leachate concentration.

TNB transport was modeled at other arbitrarily selected representative areas and, in all cases, complete cleanup of the soil was required before the simulated leachate concentration was below the maximum allowable leachate concentration. Therefore, a hypothetical evaluation of TNB transport was performed using the following assumptions:

- The top 1-ft of the fine sand unit was assumed to be initially contaminated with TNB at 0.0121 mg/kg
- The remainder of the soil column is free from contamination
- The infiltration rate is equal to 2.3 inches/year

The HYDRUS input and output files, and associated graphs are included in **Attachment 2B**.

The assumed TNB soil concentration (0.0121 mg/kg) was determined iteratively so that the simulated leachate concentration did not exceed the maximum allowable leachate concentration.

The **Attachment 2B** graphs show that the simulated leachate concentration does not exceed the maximum allowable leachate concentration. Because the leachate concentration will increase for a given initial concentration as the depth of the initial concentration approaches the top of the saturated zone (because there is a shorter distance for transport processes to act), the TNB concentrations in the fine sand cannot be greater than 0.0121 mg/kg without exceeding the maximum acceptable groundwater concentration.

Therefore, TNB soil concentrations at the following 17 representative soil concentration profile locations (out of the total 26 locations) exceed the maximum allowable TNB groundwater concentration:

| | | | | | | |
|---|---|---|---|---|---|---|
| LL1[A(1)] | LL1[A(2)] | LL1[B(1)] | LL1[B(3)] | LL1[B(4)] | LL1[C(1)] | LL1[C(2)] |
| LL1[D(1)] | LL1[D(2)] | LL1[G] | LL1[H] | LL2[B(1)] | LL2[B(2)] | LL2[C(2)] |
| LL2[C(5)] | LL2[G(S)] | LL2[H] | | | | |

In addition, the simulation of TNB transport at locations LL1[I] and LL1[J] with soil cleanup equal to 4 feet also exceeded the maximum allowable leachate concentration, although the fine sand concentrations were assumed to be less than 0.0121 mg/kg.

A second hypothetical evaluation of TNB transport was performed using the following assumptions:

- The loess interval from 4 to 5 feet was assumed to be initially contaminated with TNB at an initial concentration equivalent to a low TNB concentration at detection limit, 0.107 mg/kg, listed in Table D-1 in Donohue (1992)
- The remainder of the soil column is free of contamination
- The infiltration rate is equal to 2.3 inches/year

The results of the second hypothetical evaluation showed that the simulated leachate concentration did not exceed the maximum allowable leachate concentration.

### 5.4.2 Evaluation of TNT Soil Contamination

TNT transport was simulated for soil cleanup to 4 feet at LL1[B(2)] and LL2[C(1)], and the simulated leachate concentrations exceeded the maximum allowable leachate concentration. At both locations, TNT was detected in soil at the last interval sampled and therefore, the soil contamination was assumed to be constant from that interval to the top of the saturated zone (using the sixth assumption listed in Section 5.1).

The HYDRUS input and output files and associated graphs are included in **Attachment 2C**.

### 5.4.3 Evaluation of RDX Soil Contamination

RDX transport was simulated for soil cleanup to 4 feet at LL2[C(3)] and LL2[C(4)], and the simulated leachate concentrations exceeded the maximum allowable leachate concentration. Further evaluation at those locations showed that complete cleanup of the soil was required before the simulated leachate concentration was below the maximum allowable leachate concentration. Therefore, a hypothetical evaluation of RDX transport was performed using the following assumptions:

- The top 1-ft of the fine sand unit was assumed to be initially contaminated with RDX at 0.0195 mg/kg
- The remainder of the soil column is free from contamination
- The infiltration rate is equal to 2.3 inches/year

The HYDRUS input and output files, and associated graphs are included in **Attachment 2D**.

The assumed RDX soil concentration (0.0195 mg/kg) was determined iteratively so that the simulated leachate concentration did not exceed the maximum allowable leachate concentration.

The **Attachment 2D** graphs show that the simulated leachate concentration does not exceed the maximum allowable leachate concentration. Because the leachate concentration will increase for a given initial concentration as depth the of the initial concentration approaches the top of the saturated zone (because there is a shorter distance for transport processes to act), the TNB concentrations in the fine sand cannot be greater than 0.0195 mg/kg without exceeding the maximum acceptable groundwater concentration.

Two additional hypothetical simulations were evaluated. In the first additional evaluation, the initial concentration of RDX was assumed to be 1.7 mg/kg from 4 - 5 feet, and the second additional evaluation assumed that the initial concentration of RDX was 0.32 mg/kg from 11.5 - 12.5 feet. The last two assumptions listed for the first hypothetical evaluation in this section were also assumed for the additional hypothetical evaluations. The simulated leachate concentration did not exceed the maximum allowable leachate concentration for both of the additional hypothetical simulations.

### 5.4.4 Evaluation of Tetryl Soil Contamination

The average tetryl concentration (3300 mg/kg) in soil for the depth interval of 0 - 1 feet exceeds the excavation PRG, and thus soil will be cleaned up to 4 feet. Tetryl transport was simulated for soil cleanup to 4 feet at BBA[2], and the simulated leachate concentrations did not exceed the maximum allowable leachate concentration.

### 5.4.5 Evaluation of Other Soil Contamination

Soil contamination was not detected in samples collected from borings located within the 50-ft diameter circles at BBA[1] and LL2[G(N)]. Therefore, soil cleanup was not simulated at those locations.

After applying the soil cleanup evaluations of TNB, TNT, RDX, and tetryl to the representative soil concentration profiles, it was not necessary to evaluate transport of 2,4-DNT and HMX.

## 6.1 ASSUMPTIONS

All of the assumptions listed in Section 5.1 were also used to simulate infiltration control with the following exceptions:

- The infiltration rate is constant at the value discussed in the next section
- The soil concentration profiles are cleaned-up to a depth of 4 feet below ground surface as was required according to the OU1 excavation PRGs tabulated in Section 5.1

## 6.2 ESTIMATED INFILTRATION RATES

For the purposes of the infiltration control analysis, the estimated infiltration rate used during the simulations is important, while the mechanism by which the reduction is realized is of no consequence. However, it was assumed that infiltration control would involve some type of compacted soil or flexible membrane liner. Therefore, it was possible to estimate infiltration rates by assuming that the infiltration rate was equal to the minimum detectable leakage of the cap. The following data are provided in EPA (1987):

| | | Minimum Detectable Leakage Rate | |
|---|---|---|---|
| **Liner Material** | **Hydraulic Conductivity (m/s)** | **L/1000m²/d** | **m/year** |
| Compacted Soil | $10^{-8}$ | 860 | 0.31 |
| Compacted Soil | $10^{-9}$ | 86 | 0.031 |
| Flexible Membrane Liner | $10^{-13}$ | 0.01 | $3.7 \times 10^{-6}$ |
| Flexible Membrane Liner | $10^{-14}$ | 0.001 | $3.7 \times 10^{-7}$ |

The calculations for converting leakage units from L/1000 $m^2$/d to m/year is included in **Attachment 1.**

According to EPA (1987), the minimum top liner leakage rate that can be detected must be greater than the rate at which liquid will flow, due to gravity, into the bottom liner of a double-lined landfill, with the hydraulic head just equal to zero. The actual minimum detectable leakage rate is site-specific and will depend on many factors (e.g., type of leak, location of leak, effective hydraulic conductivity, and the cap design). The minimum detectable leakage rate is calculated using the assumption that the hydraulic head is constant and equal to the top of the cap (the hydraulic gradient is one). Therefore, the minimum detectable leakage of the cap is potentially larger than the actual infiltration of water for the cap. Comparison of the minimum detectable leakage rates shows that the average infiltration rate used during the soil cleanup simulations, 2.3 inches/year (0.058 m/year), is approximately one-fifth of the leakage for the $10^{-8}$ m/s compacted soil cap, and is approximately twice as large as the leakage for the $10^{-9}$ m/s compacted soil cap. Clearly, it is unreasonable to assume that the infiltration would be five times greater through a compacted soil cap relative to uncapped conditions. Therefore, the use of the value of the minimum detectable leakage rate of a flexible membrane liner as the infiltration control evaluation infiltration rate does not require that the cap be constructed using a flexible membrane liner.

Based on the results of the soil cleanup evaluation, it was estimated that the impact of reducing the natural (2.3 inches/year) infiltration rate by 50 percent would not result in estimated groundwater concentrations less than the maximum allowable groundwater concentrations. Therefore, infiltration control simulations were performed using an infiltration rate equal to the $10^{-13}$ m/s flexible membrane liner cap leakage rate.

## 6.3 APPLICATION OF THE SUMMERS MODEL TO CALCULATE MAXIMUM ALLOWABLE LEACHATE CONCENTRATIONS

The maximum allowable leachate concentration for infiltration control was calculated for each of the six explosives compounds in a manner identical to that described in Section 5.2 with the substitution of $3.7 \times 10^{-6}$ m/year for 2.3 inches/year (0.0584 m/year) as the infiltration rate.

The maximum allowable leachate concentration calculations are presented in **Attachment 1**, and are tabulated below as calculated using the modified Summers model and an infiltration rate of 3.7 x $10^{-6}$ m/year.

| **Chemical** | **Proposed Groundwater PRG (mg/L)** | **Maximum Allowable Leachate Concentration for Infiltration = 3.7 x $10^{-6}$ m/year (mg/L)** |
|---|---|---|
| TNB | 0.001 | 700 |
| TNT | 0.0282 | 19,700 |
| RDX | 0.00774 | 5,410 |
| HMX | 0.782 | 546,000 |
| 2,4-DNT | 0.00124 | 866 |
| Tetryl | 0.370 | 260,000 |

## 6.4 RESULTS

The first step of the infiltration control evaluation (where the infiltration rate was equal to 3.7 x $10^{-6}$ m/year) was the calculation of equilibrium soil concentrations from the maximum allowable leachate concentrations using the distribution coefficients. The calculations are in **Attachment 1**, and the results are tabulated below.

| **Hydrostratigraphic Unit** | **Soil Concentration (mg/kg)** | | | | | |
|---|---|---|---|---|---|---|
| | **TNB** | **TNT** | **RDX** | **HMX** | **2,4-DNT** | **Tetryl** |
| **Topsoil** | 5,000 | 240,000 | 8,700 | 28,000 | 3,200 | 170,000 |
| **Loess** | 6,000 | 260,000 | 9,700 | 32,000 | 3,700 | 200,000 |
| **Fine Sand** | 90 | 3,900 | 150 | 480 | 55 | 2,900 |

Under equilibrium conditions, soils with concentrations less than those tabulated above will not partition to the aqueous phase at concentrations above the maximum allowable leachate concentrations, and transport modeling using the HYDRUS Model is not required. However, if soil concentrations are greater than those tabulated above, modeling is required for comparison of simulated leachate concentrations to the maximum allowable leachate concentrations. All of the soil concentrations below 4 feet presented in **Table 3-1** are below the equilibrium concentrations listed above. Therefore, at the 26 representative areas, controlling the infiltration rate to be no greater than 3.7 x $10^{-6}$ m/year will prevent the migration of the six explosives compounds to the saturated zone in concentrations greater than the maximum allowable groundwater concentrations.

## 7.0
## UNCERTAINTY AND LIMITATIONS

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### 7.1 UNCERTAINTY OF LEACHATE CONCENTRATION PREDICTION

Accepted methodology has been used to evaluate two soil remediation alternative actions whose common purpose is to protect groundwater. The methodology involved using a numerical model to simulate one-dimensional variably saturated water flow and solute transport and a mass balance model to estimate dilution in a small portion of the saturated zone.

There are different sources of uncertainty encountered during the simulation of groundwater flow. Yeh (1988) stated that the uncertainty associated with the natural heterogeneous state of the flow and transport domain is much greater than:

- The uncertainties associated with the mathematical conceptualization of the physical processes
- The evaluation of the mathematical equations representing the physical processes

Smith and Schwartz (1981) cite specific sources of uncertainty as the heterogeneous nature of aquifers; limited field data; uncertain boundary conditions; the inability to predict future changes in the hydraulic and chemical natures of the simulation domain; and the uncertainty concerning the location, strength, and release function of the contaminant mass source.

Limited field data collected at the Site contribute a relatively large uncertainty for the simulations described in this appendix. The following parameters were estimated from data collected at the Site:

- Hydrostratigraphic unit depth intervals including the depth to the saturated zone
- Fraction organic carbon (for the topsoil and fine sand)

- Explosives concentrations in soil
- The horizontal Darcy velocity of the water in the top 5 feet of the saturated zone

The 2.3 inches/year infiltration rate was also estimated by a site-specific analysis. The remainder of the flow and transport parameters used during the simulations were estimated from literature values. The net effect of the input parameter uncertainty is that the simulated leachate concentration may be over- or under-estimated. Any change in any of the parameters could potentially change the estimated leachate concentrations.

Typically, the processes of calibration and verification are used to estimate model input parameters prior to using the model for prediction. Wang and Anderson (1982) defines calibration as the process by which, given a certain combination of parameters and boundary conditions, a model will produce field measured values of specific parameters at given locations. The combination of input parameters and boundary conditions is found using an iterative process, and the combination may not be unique. According to Wang and Anderson (1982), verification is the adjustment of the calibrated combination of input parameters and boundary conditions so that the model is capable of simulating some historical event for which field data are available. A sufficient historical record of field data was not available to allow the calibration and verification process to be performed for unsaturated zone flow and contaminant transport simulations. Simulating flow and transport without calibration and verification has a high estimated magnitude of effect on predicting leachate concentrations.

There is inherent uncertainty associated with estimating the performance of any spatially heterogenous porous media using homogenous parameter values. Therefore, it will always be necessary to monitor water levels and contaminant concentrations during the life of the soil remediation alternative action to continually evaluate the effectiveness of the system. The monitoring data can also provide the basis for any necessary corrective actions.

## 7.2 UNCERTAINTY OF MAXIMUM ALLOWABLE LEACHATE CONCENTRATION ESTIMATE

The discussion regarding the uncertainty associated with the prediction of the leachate concentration also applies when evaluating the uncertainty associated with the estimate of the maximum allowable leachate concentration.

The maximum allowable leachate concentration tabulated below was calculated by using the assumptions listed in Section 5.2 with the substitution a 30-ft mixing zone for the 5-ft mixing zone assumed in Section 5.2.

| Chemical | Proposed Groundwater PRG (mg/L) | Maximum Allowable Leachate Concentration for Infiltration = 2.3 inches/year and 30-ft mixing zone (mg/L) |
|---|---|---|
| TNB | 0.001 | 0.08 |
| TNT | 0.0282 | 2.31 |
| RDX | 0.00774 | 0.633 |
| HMX | 0.782 | 64.0 |
| 2,4-DNT | 0.00124 | 0.102 |
| Tetryl | 0.370 | 30 |

The calculations for the tabulation above are in **Attachment 1**.

The concentrations above are about 5.66 times larger than the concentrations presented in Section 5.2 while the assumed mixing zone is exactly 6.0 times greater.

The maximum allowable leachate concentrations would vary linearly with the maximum allowable groundwater concentration if all other variables were held constant.

Based on the limited sensitivity analysis presented above, it is estimated that the arbitrary assumption of a 5-ft saturated thickness used as input to the modified Summers Model has a moderate to high estimated magnitude of effect on the maximum allowable leachate concentration estimate. The impact of underestimating the maximum allowable leachate concentration is that the guidelines for development of the soil remediation alternative actions may be more protective than estimated.

## 8.0 CONCLUSIONS

Conclusions of the soil cleanup simulation are as follows:

- Soil cleanup depths and volumes calculated using the following criteria will be protective of groundwater with regard to explosives leaching:
  - Remove all fine sand with TNB concentrations exceeding 0.0121 mg/kg
  - Remove all fine sand with RDX concentrations exceeding 0.0195 mg/kg
  - Remove all loess with RDX concentrations equal to or exceeding 0.32 mg/kg occurring between the bottom of the OU1 excavation interval (4 feet) and the top of the fine sand
  - No soil removal beyond the excavation required according to the OU1 PRGs is necessary for tetryl-contaminated soils at the Bomb Booster Area

The following concepts should be considered when evaluating the soil cleanup conclusions:

- A cleanup criterion for TNT was not provided because TNT soil contamination is generally co-located with TNB, and it is estimated that the TNB criterion will govern cleanup decisions
- A cleanup criterion for TNB at intervals above the fine sand was not included because TNB contamination is commonly present in the fine sand at locations when the topsoil or loess intervals are also contaminated
- The cleanup criteria for TNB and RDX are less than the detection limits listed for those chemicals in soil in Donohue (1992), and therefore, detection limits should be used when calculating cleanup volumes or field verifying cleanup depths.

Conclusions of the infiltration control analysis are as follows:

- An infiltration control resulting in an infiltration of 3.7 x $10^{-6}$ m/year will protective of groundwater in conjunction with the cleanup of the top 4 feet of soil

The following concept should be considered when evaluating the infiltration control conclusions:

- The assumed infiltration rate, 3.7 x $10^{-6}$ m/year, is not the optimum rate, and a higher rate can be established during a subsequent analysis (such as a Pre-Design Analysis)

## 9.0
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# TABLE 3-1
# REPRESENTATIVE SOIL CONCENTRATION PROFILE

| BBA-1 | State Planar Coordinates of Center (Feet) (2,828,848.8 , 574,027.52) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 - 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 - 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 - 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

| BBA-2 | State Planar Coordinates of Center (Feet) (2,828,761.83 , 573,884.8) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0.266 | 0.454 | 0 | 0 | 0 | 3299.788 |
| 1 - 2 | 0 | 0 | 0 | 0 | 0 | 18.406 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0.428 |
| 4 - 8 | 0 | 0 | 0 | 0 | 0 | 7.37 |
| 8 - 10 | 0 | 0 | 0 | 0 | 0 | 0.22 |
| 10 - 15 | 0 | 0 | 0 | 0 | 0 | 2.266 |
| 15 - 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

| LL1 [A(1)] | State Planar Coordinates of Center (Feet) (2,828,847.382 , 563,363.789) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 1.935 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0.155 | 135 | 0 | 0 | 0.484 | 0 |
| 4 - 8 | 0 | 17.625 | 0 | 0 | 0 | 0 |
| 8 - 10 | 0.123 | 0 | 0 | 0 | 1.16 | 0 |
| 10 - 15 | 0 | 1.54 | 0 | 0 | 0 | 0 |
| > 25 | 0.047 | 0.77 | 0 | 0 | 0 | 0 |

| LL1 [A(2)] | State Planar Coordinates of Center (Feet) (2,828,723.398 , 563,365.368) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 0.663 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 - 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 15 | 0.336 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 3-1
# REPRESENTATIVE SOIL CONCENTRATION PROFILE

| LL1 [B(1)] | State Planar Coordinates of Center (Feet) (2,828,844.097 , 563,295.382) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 13.064 | 2617.702 | 3.67 | 0 | 2.528 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0.043 | 4.467 | 0 | 0 | 0 | 0 |
| 8 - 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 - 15 | 0.635 | 0.338 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0.182 | 0 | 0 | 0 | 0 |

| LL1 [B(2)] | State Planar Coordinates of Center (Feet) (2,828742.321 , 563,284.796) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 2.573 | 1218.616 | 1.05 | 0 | 0.862 | 0 |
| 4 - 8 | 0 | 0.328 | 0 | 0 | 0.108 | 0 |

| LL1 [B(3)] | State Planar Coordinates of Center (Feet) (2,828797.534 , 563,188.046) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 57.943 | 5265.421 | 0 | 0 | 2.374 | 0 |
| 1 - 2 | 22.195 | 16.46 | 0 | 0 | 0.15 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 - 10 | 5.623 | 0 | 0 | 0 | 0.22 | 0 |
| 10 - 15 | 12.257 | 0 | 0 | 0 | 0.96 | 0 |
| 15 - 25 | 1.615 | 52.7 | 0 | 0 | 0 | 0 |
| > 25 | 0.988 | 1.06 | 0 | 0 | 0 | 0 |

| LL1 [B(4)] | State Planar Coordinates of Center (Feet) (2,828,692.389 , 563,188.046) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 127.721 | 7951.731 | 3.006 | 0 | 4.383 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 18.523 | 1.841 | 0.201 | 0 | 0.271 | 0 |
| 8 - 10 | 19.2 | 0.55 | 0 | 0 | 0.286 | 0 |
| 10 - 15 | 14.917 | 0.087 | 0 | 0 | 0.422 | 0 |
| 15 - 25 | 2.29 | 0.4 | 0 | 0 | 0 | 0 |
| > 25 | 1.152 | 0.123 | 0 | 0 | 0 | 0 |

## TABLE 3-1
## REPRESENTATIVE SOIL CONCENTRATION PROFILE

| LL1 [C(1)] | State Planar Coordinates of Center (Feet) (2,829,003.249 , 563,315.026) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0.194 | 23.514 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0 | 0.155 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0 | 0.8 | 0 | 0 | 0 | 0 |
| 8 - 10 | 1.006 | 0.126 | 0 | 0 | 0 | 0 |
| 10 - 15 | 15.925 | 0.097 | 0 | 0 | 0 | 0 |
| > 25 | 2.882 | 0.428 | 0 | 0 | 0 | 0 |

| LL1 [C(2)] | State Planar Coordinates of Center (Feet) (2,829,001.697 , 563,404.666) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 4.2 | 42.5 | 0 | 0 | 1.58 | 0 |
| 2 - 4 | 4.85 | 76.53 | 0 | 0 | 2.359 | 0 |
| 4 - 8 | 0.212 | 11.457 | 0 | 0 | 0 | 0 |
| 8 - 10 | 0.189 | 5.928 | 0 | 0 | 0.099 | 0 |
| 10 - 15 | 0.19 | 1.124 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0.132 | 0 | 0 | 0 | 0 |

| LL1 [D(1)] | State Planar Coordinates of Center (Feet) (2,828,649.327 , 562,970.153) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 2.435 | 5885.63 | 1.877 | 0 | 1.065 | 0 |
| 1 - 2 | 3.35 | 4960 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0.616 | 968.57 | 0.143 | 0 | 0 | 0 |
| 4 - 8 | 0.229 | 244.379 | 0 | 0 | 0 | 0 |
| 8 - 10 | 6.116 | 80.758 | 0 | 0 | 0.104 | 0 |
| 10 - 15 | 0.325 | 7.958 | 0 | 0 | 0 | 0 |
| 15 - 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0.611 | 1.352 | 0 | 0 | 0 | 0 |

| LL1 [D(2)] | State Planar Coordinates of Center (Feet) (2,828,649.481 , 562,876.274) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 1.009 | 633.092 | 0 | 0 | 0.313 | 0 |
| 1 - 2 | 1.01 | 388.625 | 0 | 0 | 0.165 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0.832 | 29.241 | 0.5 | 0 | 0 | 0 |
| 8 - 10 | 2.33 | 0.32 | 0 | 0 | 0 | 0 |

# TABLE 3-1
# REPRESENTATIVE SOIL CONCENTRATION PROFILE

| LL1 [G] | State Planar Coordinates of Center (Feet) (2,828,931.884 , 562,604.487) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 1.388 | 3426.362 | 0 | 0 | 1.678 | 0 |
| 1 - 2 | 2.18 | 1180 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0.095 | 0.045 | 0 | 0 | 0 | 0 |
| 4 - 8 | 1.546 | 0.049 | 0 | 0 | 0 | 0 |
| 8 - 10 | 8.396 | 0 | 0 | 0 | 0 | 0 |
| 10 - 15 | 0.22 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0.493 | 0 | 0 | 0 | 0 |

| LL1 [H] | State Planar Coordinates of Center (Feet) (2,829,047.536 , 562,588.769) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0.272 | 11.15 | 0 | 0 | 0 | 0 |
| 2 - 4 | 1.36 | 0.818 | 0 | 0 | 0 | 0 |
| 4 - 8 | 2.59 | 0.389 | 0 | 0 | 0 | 0 |
| 8 - 10 | 1.62 | 0 | 0 | 0 | 0 | 0 |
| 10 - 15 | 1.59 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 3.03 | 0 | 0 | 0 | 0 | 0 |

| LL1 [I] | State Planar Coordinates of Center (Feet) (2,828,997.557 , 562,512.526) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0.22 | 276.496 | 0 | 0 | 0 | 0 |
| 1 - 2 | 0.899 | 1030 | 0 | 0 | 0.494 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 - 10 | 0.283 | 0 | 0 | 0 | 0 | 0 |
| 10 - 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

| LL1 [J] | State Planar Coordinates of Center (Feet) (2,828,881.347 , 562,510.03) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0.545 | 9.4 | 0 | 0 | 0 | 0 |
| 1 - 2 | 0.326 | 134 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0 | 0.233 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 - 10 | 4.46 | 0 | 0 | 0 | 0 | 0 |
| 10 - 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 3-1
# REPRESENTATIVE SOIL CONCENTRATION PROFILE

| LL2 [B(1)] | State Planar Coordinates of Center (Feet) (2,834,250.211 , 563,443.357) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0.451 | 120.876 | 2120 | 505.124 | 0.121 | 0 |
| 1 - 2 | 0.235 | 1.11 | 803.295 | 120.73 | 0 | 0 |
| 2 - 4 | 0 | 0 | 25.864 | 5.738 | 0 | 0 |
| 4 - 8 | 0 | 0.107 | 10.76 | 12.45 | 0 | 0 |
| 8 - 10 | 0 | 0 | 14.3 | 0 | 0 | 0 |
| 10 - 15 | 1.012 | 0.095 | 14.884 | 1.611 | 0.074 | 0 |
| 15 - 25 | 0.18 | 0.309 | 12.98 | 1.008 | 0 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

| LL2 [B(2)] | State Planar Coordinates of Center (Feet) (2,834,156.276 , 563,409.336) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 7.289 | 10610.904 | 264.298 | 86.631 | 7.09 | 0 |
| 1 - 2 | 13.893 | 29.31 | 7.407 | 13.703 | 0.077 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 3.658 | 318.382 | 1.367 | 1.661 | 0.041 | 0.545 |
| 8 - 10 | 20.072 | 0.922 | 8.712 | 1.801 | 0.927 | 0 |
| 10 - 15 | 26.887 | 0.689 | 9.935 | 1.49 | 1.461 | 0 |
| 15 - 25 | 2.739 | 0.044 | 0.432 | 0 | 0.08 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

| LL2 [C(1)] | State Planar Coordinates of Center (Feet) (2,834,417.192 , 563,482.657) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 0.797 | 58.11 | 32.573 | 0 | 0 |
| 1 - 2 | 0 | 3.75 | 1.35 | 1.03 | 0 | 0 |
| 4 - 8 | 0 | 0.28 | 0 | 0 | 0 | 0 |

| LL2 [C(2)] | State Planar Coordinates of Center (Feet) (2,834,493.511 , 563,437.87) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 57.262 | 1942.328 | 2134.058 | 261.79 | 1.046 | 0 |
| 2 - 4 | 0.316 | 0.35 | 6.056 | 2.298 | 0 | 0 |
| 4 - 8 | 0.108 | 0.753 | 7.62 | 2.324 | 0 | 0 |
| 8 - 10 | 0.067 | 0 | 0.409 | 0.144 | 0 | 0 |
| 10 - 15 | 0 | 0 | 0.36 | 0 | 0 | 0 |
| 15 - 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0.102 | 0 | 0 | 0 | 0 | 0 |

# TABLE 3-1
# REPRESENTATIVE SOIL CONCENTRATION PROFILE

| LL2 [C(3)] | State Planar Coordinates of Center (Feet) (2,834,543.098 , 563,520.203) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 60.337 | 934.331 | 565.24 | 87.21 | 1.749 | 0 |
| 1 - 2 | 75.64 | 74.48 | 176.12 | 36.92 | 1.32 | 0 |
| 2 - 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 - 8 | 0 | 77.924 | 15.031 | 3.266 | 0 | 0 |
| 8 - 10 | 0 | 0 | 2.318 | 0 | 0 | 0 |
| 10 - 15 | 0 | 0 | 2.08 | 0 | 0 | 0 |
| 15 - 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 25 | 0 | 0 | 0 | 0 | 0 | 0 |

| LL2 [C(4)] | State Planar Coordinates of Center (Feet) (2,834,628.119 , 563,570.859) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 0.639 | 71.95 | 48.108 | 0 | 0 |
| 2 - 4 | 0 | 0 | 4.98 | 0.532 | 0 | 0 |
| 4 - 8 | 0 | 0 | 1.33 | 0 | 0 | 0 |
| 8 - 10 | 0 | 0 | 2.74 | 0.221 | 0 | 0 |
| > 25 | 0 | 0 | 1.795 | 0 | 0 | 0 |

| LL2 [C(5)] | State Planar Coordinates of Center (Feet) (2,834,577.942 , 563,389.738) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 2.037 | 0 | 0 | 0 | 0 |
| 2 - 4 | 0 | 0 | 0.601 | 0.715 | 0 | 0 |
| 4 - 8 | 0 | 0.66 | 0.437 | 1.285 | 0 | 0 |
| 8 - 10 | 1.817 | 0 | 1.064 | 0.569 | 0 | 0 |
| 10 - 15 | 0.295 | 0 | 0.655 | 0.234 | 0 | 0 |
| > 25 | 0.243 | 0.162 | 0 | 0 | 0 | 0 |

| LL2 [G(N)] | State Planar Coordinates of Center (Feet) (2,834,325.833 , 563,390.467) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 0 | 0 | 0 | 0 | 0 |

# TABLE 3-1
# REPRESENTATIVE SOIL CONCENTRATION PROFILE

| LL2 [G(S)] | State Planar Coordinates of Center (Feet) (2,834,327.858 , 562,739.264) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 0 | 0.253 | 112.12 | 40.73 | 0 | 0 |
| 2 - 4 | 0 | 8.849 | 67.756 | 7.778 | 0.357 | 0.824 |
| 4 - 8 | 0 | 0.607 | 12.101 | 3.658 | 0.33 | 0.805 |
| 8 - 10 | 2.269 | 11.023 | 58.963 | 5.452 | 0.305 | 0.84 |
| 10 - 15 | 6.504 | 0.949 | 6.223 | 0 | 0.151 | 0 |
| > 25 | 0.257 | 0.151 | 0.626 | 0 | 0 | 0.669 |

| LL2 [H] | State Planar Coordinates of Center (Feet) (2,834,469.942 , 562,706.118) | | | | | |
|---|---|---|---|---|---|---|
| Depth Below Ground Surface (Feet) | Average Soil Concentration (mg/kg) | | | | | |
| | TNB | TNT | RDX | HMX | 2,4-DNT | TETRYL |
| <= 1 | 9.775 | 81.057 | 535.565 | 72.112 | 0 | 0 |
| 1 - 2 | 93.69 | 12.8 | 60.51 | 11.86 | 0 | 0 |
| 2 - 4 | 17.269 | 6.148 | 13.779 | 3.733 | 0 | 0 |
| 4 - 8 | 21.744 | 103.09 | 357.081 | 34.512 | 0.088 | 0.385 |
| 8 - 10 | 21.244 | 21.164 | 236.035 | 27.554 | 1.647 | 0 |
| 10 - 15 | 6.474 | 0.136 | 2.532 | 0.131 | 0.391 | 0 |
| 15 - 25 | 2.73 | 0 | 0.741 | 0 | 0.033 | 0 |
| > 25 | 1.654 | 0 | 1.091 | 0 | 0.081 | 0 |

## ATTACHMENT 1
## BACKUP CALCULATIONS/INFORMATION

# Equilibrium Soil Concentrations Evaluated Using Soil-Water Partition Coefficients

| Hydrostratigraphic Unit | Fraction Organic Carbon (foc) | Explosive Compound | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | TNT | | | RDX | | | HMX | | |
| | | Koc (mL/g) | Kd (mL/g) | Estimated Equilibrium Soil Concentration (mg/kg) | Koc (mL/g) | Kd (mL/g) | Estimated Equilibrium Soil Concentration (mg/kg) | Koc (mL/g) | Kd (mL/g) | Estimated Equilibrium Soil Concentration (mg/kg) |
| Top soil | 0.0149 | | 1.2E+01 | 3.E-01 | | 1.6E+00 | 1.E-02 | | 5.2E-02 | 4.0E-02 |
| Loess | 0.017 | 780 | 1.3E+01 | 4.E-01 | 104.5 | 1.8E+00 | 1.E-02 | 3.47 | 5.9E-02 | 4.6E-02 |
| Fine Sand | 0.000255 | | 2.0E-01 | 6.E-03 | | 2.7E-02 | 2.E-04 | | 8.8E-04 | 6.9E-04 |

| Hydrostratigraphic Unit | Fraction Organic Carbon (foc) | Explosive Compound | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2,4 DNT | | | Tetryl | | | TNB | | |
| | | Koc (mL/g) | Kd (mL/g) | Estimated Equilibrium Soil Concentration (mg/kg) | Koc (mL/g) | Kd (mL/g) | Estimated Equilibrium Soil Concentration (mg/kg) | Koc (mL/g) | Kd (mL/g) | Estimated Equilibrium Soil Concentration (mg/kg) |
| Top soil | 0.0149 | | 3.7E+00 | 5.E-03 | | 6.7E-01 | 2.E-01 | | 7.7E+00 | 8.E-03 |
| Loess | 0.017 | 251 | 4.3E+00 | 5.E-03 | 44.7 | 7.6E-01 | 3.E-01 | 520.0 | 8.8E+00 | 9.E-03 |
| Fine Sand | 0.000255 | | 6.4E-02 | 8.E-05 | | 1.1E-02 | 4.E-03 | | 1.3E-01 | 1.E-04 |

Notes:

1. Kd = (Koc)(foc) = (mass of solute on the solid phase per unit mass of solid phase)/(concentration of solute in solution), therefore, assuming that the target groundwater clean-up goals are equilibrium concentration of solutes in solution: Estimated equilibrium soil concentration = (Koc)(foc)(target clean-up goal concentration)

**Soil Concentrations Estimated Using an Application of Summers Model to Include a 5-ft Saturated Zone**

| Hydrostratigraphic Unit | Explosive Compound | | | | | |
|---|---|---|---|---|---|---|
| | TNT | | RDX | | HMX | |
| | Kd (mL/g) | Estimated Soil Concentration (mg/kg) | Kd (mL/g) | Estimated Soil Concentration (mg/kg) | Kd (mL/g) | Estimated Soil Concentration (mg/kg) |
| Top soil | 1.2E+01 | 2.E+01 | 1.6E+00 | 7.E-01 | 5.2E-02 | 2.E+00 |
| Loess | 1.3E+01 | 2.E+01 | 1.8E+00 | 7.E-01 | 5.9E-02 | 2.E+00 |
| Fine Sand | 2.0E-01 | 3.E-01 | 2.7E-02 | 1.E-02 | 8.8E-04 | 4.E-02 |

| Hydrostratigraphic Unit | Explosive Compound | | | | | |
|---|---|---|---|---|---|---|
| | 2,4 DNT | | Tetryl | | TNB | |
| | Kd (mL/g) | Estimated Soil Concentration (mg/kg) | Kd (mL/g) | Estimated Soil Concentration (mg/kg) | Kd (mL/g) | Estimated Soil Concentration (mg/kg) |
| Top soil | 3.7E+00 | 3.E-01 | 6.7E-01 | 1.E+01 | 7.7E+00 | 4.E-01 |
| Loess | 4.3E+00 | 3.E-01 | 7.6E-01 | 2.E+01 | 8.8E+00 | 5.E-01 |
| Fine Sand | 6.4E-02 | 4.E-03 | 1.1E-02 | 2.E-01 | 1.3E-01 | 7.E-03 |

Notes:
1. Soil Concentration = 54(Cgw)(Kd).
2. For the calculations on this page, the area of contamination is assumed to be a circle with 25-ft diameter. The current effort assumes a 100-ft
3. See WCC (1994b) for supporting calculations.

**Woodward-Clyde**

Sheet No. 1 of 2

FOR: U/S Zone Modeling

Project No: 92KW030M.0002
Made by: ACE Date: 5/2/94
Checked by: RGP Date: 6/8/94

Summers Model:

$$C_{gw} = \frac{Q_P C_P + Q_A C_A}{Q_P + Q_A} \checkmark$$

assume $C_A = 0$

$$C_{gw} = \frac{Q_P C_P}{Q_P + Q_A} \checkmark$$

$$C_{gw} Q_P + C_{gw} Q_A = Q_P C_P$$

$$C_P = \frac{C_{gw}(Q_P + Q_A)}{Q_P} \checkmark$$

$$Q_A = V_D\, h w, \quad Q_P = VD_Z A_P$$

$$C_P = C_{gw} \frac{(VD_Z A_P + V_D h w)}{VD_Z A_P}$$

assume circular area of contamination with diameter $w = 100\ ft \Rightarrow A_P = \frac{\pi}{4}(100 ft)^2 = 7{,}854\ ft^2 \checkmark$

$V_D$ = Darcy velocity in fine sand

$$V_D = \left(\frac{12 ft}{mile}\right)\left(\frac{mile}{5280 ft}\right)\left(0.034 \frac{ft}{min}\right)\left(60 \frac{min}{hr}\right)\left(24 \frac{hr}{d}\right)\left(365 \frac{d}{yr}\right)$$

$$= 40.6\ ft/yr \checkmark$$

h = the height of the mixing zone which has been arbitrarily selected as 5 ft.

$$C_P = C_{gw} \frac{VD_Z(7854 ft^2) + (40.6 ft/yr)(5 ft)(100 ft)}{VD_Z(7854 ft^2)}$$

$$= C_{gw} \frac{7854 VD_Z + 20{,}300}{7854 VD_Z} \checkmark$$

where $VD_Z$ is the infiltration rate in ft/yr, $C_P$ is the soil moisture concentration at the bottom of the unsaturated zone, and $C_{gw}$ is the concentration in the top 5 ft of the saturated zone ($C_{gw}$ and $C_P$ have the same units).

**Woodward-Clyde**



Project No: 92KW030M
Made by: ACE Date: 5/12/94
Checked by: RGP Date: 06/08/94

FOR: U/S Zone Modeling

$V_{Dz}$ = 2.3 in/yr [illegible] = 0.917 ~~in~~ ft/yr,

[illegible] = 0.917([illegible]754 − 20,300) $C_{gw}$ / ([illegible] 7754)

= [illegible] $C_{gw}$ ✓

Calculate the maximum $C_p$ (also referred to as the leachate concentration) by assuming that $C_{gw}$ = target groundwater clean-up goal (currently the proposed PRG).

| Chemical | Proposed PRG (mg/L) | Maximum Leachate Conc (mg/L) |
|---|---|---|
| TNB | 0.001 ✓ | 0.0145 ✓ |
| TNT | 0.0282 | 0.408 ✓ |
| RDX | 0.00774 | 0.112 ✓ |
| HMX | 0.782 | 11.3 ✓ |
| TETRYL* | 0.37 | 5.4 ✓ |
| 2,4-DNT | 0.00124 | 0.018 ✓ |

* Tap water PRG presented in EPA (1993).

**Woodward-Clyde**

Sheet No. 1 of 1

FOR: U/S Zone Modeling

Project No: 92KW030M
Made by: ACE Date: 5/12/94
Checked by: RGR Date: 06/08/94

Soil profile : LL1 D1 – TN3

| Depth (feet) | Depth (meters) | Soil Concentration (mg/kg) | Kd (mL/g) | Soil-Water Concentration (mg/L) |
|---|---|---|---|---|
| 3 .5 1.5 4 | 1.22 | 0* | 8.84 | 0 ✓ |
| 4 | 1.22 | 0.4870* ✓ | 8.84 | 0.05509 ✓ |
| 6 | 1.83 | 0.2290 ✓ | 8.84 | 0.0259 ✓ |
| 9 | 2.74 | 6.1160 ✓ | 8.84 | 0.6919 ✓ |
| 12.5 | 3.81 | 0.3250 ✓ | 8.84 | 0.0368 ✓ |
| 12.5 | 3.81 | 0.3250 ✓ | 0.1326 | 2.451 ✓ |
| 20 | 6.10 | 0.0 ✓ | 0.1326 | 0 ✓ |
| 25 | 7.62 | 0.6110 ✓ | 0.1326 | 4.608 ✓ |

Clean-up to 4 ft

B07NE003702-09252

**Woodward-Clyde**

Sheet No. 1 of 1

FOR: U/S Zone Modeling

Project No: 92KW1030 M
Made by: ACE Date: 5/16/94
Checked by: KGR Date: 06/08/94

Assume that the minimum detectable leakage rates are equal to the infiltration.

| K of the cap (m/s) | Compacted Soil Leakage Rate (L/1000 m²/d) |
|---|---|
| $10^{-8}$ | 860 |
| $10^{-9}$ | 86 |

$$860 \frac{L}{(1000m^2)(d)}\left(\frac{365d}{yr}\right)\left(\frac{10^{-3}m^3}{L}\right) = 3.1 \times 10^{-1} \frac{m}{yr} \checkmark$$

$$86 \frac{L}{(1000m^2)(d)}\left(\frac{365d}{yr}\right)\left(\frac{10^{-3}m^3}{L}\right) = 3.1 \times 10^{-2} \frac{m}{yr} \checkmark$$

Geomembrane

| K of the cap (m/s) | Geomembrane Leakage Rate (L/1000m²/d) |
|---|---|
| $10^{-13}$ | 0.01 ✓ |
| $10^{-14}$ | 0.001 ✓ |

$$0.01 \frac{L}{(1000m^2)(d)}\left(\frac{365d}{yr}\right)\left(\frac{10^{-3}m^3}{L}\right) = 3.7 \times 10^{-6} \frac{m}{yr} \checkmark$$

$$0.001 \frac{L}{(1000m^2)(d)}\left(\frac{365d}{yr}\right)\left(\frac{10^{-3}m^3}{L}\right) = 3.7 \times 10^{-7} \frac{m}{yr} \checkmark$$

Compare to current estimated infiltration rate:

$$(2.3\ in/yr)\left(\frac{ft}{12in}\right)\left(\frac{m}{3.28ft}\right) = 5.844 \times 10^{-2}\ m/yr \checkmark$$

$$\frac{3.1\times10^{-1}\ m/yr}{5.844\times10^{-2}\ m/yr}(100\%) = 530.46\% \qquad \frac{3.1\times10^{-2}\ m/yr}{5.844\times10^{-2}\ m/yr} = 53.05\% \checkmark$$

$$\frac{3.7\times10^{-6}\ m/yr}{5.844\times10^{-2}\ m/yr}(100\%) = 6.33\times10^{-3}\% \qquad \frac{3.7\times10^{-7}\ m/yr}{5.844\times10^{-2}\ m/yr}(100\%) = 6.33\times10^{-4}\% \checkmark$$

**Woodward-Clyde**

Sheet No. 1 of 1

Project No: 92KW030M
Made by: ACE Date: 5/17/94
Checked by: KGP Date: 06/08/94

FOR: U/S Zone Modeling

Using the previous assumption a circular area of contamination with diameter, 2r = 100 ft

$$C_p = C_{gw}\left[\frac{VD_z(7854\ ft^2) + 20{,}300}{7854\ VD_z}\right]$$

$VD_z$ (m/yr)

| Chemical | Proposed GW RG (mg/L) | | $3.1 \times 10^{-2}$ Cp (mg/L) | $3.7 \times 10^{-6}$ Cp (mg/L) |
|---|---|---|---|---|
| TNB | 0.001 | | 0.08 ✓ | 700 ✓ |
| TNT | 0.0282 | | 2.38 ✓ | 19,700 ✓ |
| RDX | 0.00774 | | 0.653 ✓ | 5,410 ✓ |
| HMX | 0.782 | | 66.0 ✓ | 546,000 ✓ |
| TETRYL | 0.37 | | 31 ✓ | 260,000 ✓ |
| 4-DNT | 0.00124 | | 0.105 ✓ | 866 ✓ |

B07NE003702-09254

**Woodward-Clyde**

Sheet No. 1 of 1

Project No: 92KW030M
Made by: ACE Date: 5/17/94
Checked by: RGP Date: 06/09/94

FOR: U/S Zone Modeling

infiltration rate = $3.7 \times 10^{-6}$ m/yr

$S = K_d C$

| | Cp (mg/L) | Kd (mL/g) | S (mg/kg) |
|---|---|---|---|
| TNB | | | |
| topsoil | 700 | 7.748 ✓ | 5,000 ✓ |
| loess | | 8.84 ✓ | 6,000 ✓ |
| fine sand | | 0.1326 ✓ | 90 ✓ |
| TNT | 19,700 | | |
| topsoil | | 12 ✓ | 240,000 ✓ |
| loess | | 13 ✓ | 260,000 ✓ |
| fine sand | | 0.20 ✓ | 3,900 ✓ |
| RDX | 5,410 | | |
| topsoil | | 1.6 ✓ | 8,700 ✓ |
| loess | | 1.8 ✓ | 9,700 ✓ |
| fine sand | | 0.027 ✓ | 150 ✓ |
| HMX | 546,000 | | |
| topsoil | | 0.052 ✓ | 28,000 ✓ |
| loess | | 0.059 ✓ | 32,000 ✓ |
| fine sand | | 0.00088 ✓ | 480 ✓ |
| TETRYL | 260,000 | | |
| topsoil | | 0.67 ✓ | 170,000 ✓ |
| loess | | 0.76 ✓ | 200,000 ✓ |
| fine sand | | 0.011 ✓ | 2,900 ✓ |
| 2,4-DNT | 866 | | |
| topsoil | | 3.7 ✓ | 3,200 ✓ |
| loess | | 4.3 ✓ | 3,700 ✓ |
| fine sand | | 0.064 ✓ | 55 ✓ |

BY ACE DATE 6/7/94 PROJECT NAME Mead PROJECT NUMBER 92KK1030M

CHKD. BY RGP DATE 06/9/94 SUBJECT U/S Zone Modeling SHEET NO. 1 OF 1

$$C_p = C_{gw} \frac{VDz\,(7854\,ft^2) + (40.6\,ft/yr)(30\,ft)(100\,ft)}{VDz\,(7854\,ft^2)}$$

$$= C_{gw} \frac{7854\,VDz + 121{,}800}{7854\,VDz} \checkmark$$ (for 30-ft mixing zone)

for $VDz = 2.3$ in/yr (0.1917 ft/yr)

$C_p = 81.9\,C_{gw}$ ✓

| Chemical | $C_{gw}$ Proposed PRG (mg/L) | $C_p$ max. Allow. Leach (mg/L) |
|---|---|---|
| TNB | 0.001 | 0.08 ✓ |
| TNT | 0.0282 | 2.31 ✓ |
| RDX | 0.00774 | 0.633 ✓ |
| HMX | 0.782 | 64.0 ✓ |
| TETRYL | 0.37 | 30 ✓ |
| 2,4-DNT | 0.00124 | 0.102 ✓ |

# ATTACHMENT 2A
# HYDRUS MODEL INPUT FILES, OUTPUT FILES AND ASSOCIATED GRAPHS FOR LL1[D(1)]

```
LL1D1, time units = years, infiltration = 2.3 in/yr
TNB, clean up to 4 ft, 1.dat
  1   0   0   0   0   1   1   0   0   2
 7500   3   3   1   7   1      0.0
    .001   .00001    100.0    1000.     .010      .01 9900
   1   1      0.0      0.7     0.25
   2   2      0.7     3.81     0.25
   3   3     3.81    11.16     0.25
   2.681     1.17    0.475    0.090    98.55
   2.925     1.15    0.479    0.056    3.285
    13.8     1.69    0.437    0.020    3650.
  2.27e-2    0.10      1.4      0.0      0.0    7.748     1.0
  2.27e-2    0.10      1.4      0.0      0.0     8.84     1.0
  2.27e-2    0.10      1.4      0.0      0.0   0.1326     1.0
0.000E+00 -9.476E-01  0.4050  0.000E+00
2.333E-01 -7.876E-01  0.4123  0.000E+00
4.667E-01 -6.004E-01  0.4225  0.000E+00
7.000E-01 -3.903E-01  0.4368  0.000E+00
9.392E-01 -1.838E-01  0.4576  0.000E+00
1.220E+00 0.0         0.4576  0.000E+00
1.22      0.0         0.4576  0.05509
1.657E+00 -1.838E-01  0.4576  0.03418
1.83      0.0         0.4576  0.02590
1.896E+00 -1.838E-01  0.4576  0.0742
2.135E+00 -1.838E-01  0.4576  0.24912
2.375E+00 -1.838E-01  0.4576  0.42477
2.614E+00 -1.838E-01  0.4576  0.59968
2.74      0.0         0.4576  0.6919
2.853E+00 -1.845E-01  0.4575  0.62271
3.092E+00 -1.922E-01  0.4567  0.47638
3.332E+00 -2.607E-01  0.4497  0.32943
3.571E+00 -6.748E-01  0.4197  0.18310
3.810E+00 -8.628E-01  0.0950  0.03676
3.81      0.0         0.0950  2.451
4.055E+00 -8.628E-01  0.0950  2.18878
4.545E+00 -8.628E-01  0.0950  1.66433
5.280E+00 -8.628E-01  0.0950  0.87765
5.770E+00 -8.628E-01  0.0950  0.35320
6.015E+00 -8.628E-01  0.0950  0.09098
6.1       0.0         0.0950  0.0
6.260E+00 -8.628E-01  0.0950  0.48505
6.505E+00 -8.628E-01  0.0950  1.22779
6.750E+00 -8.628E-01  0.0950  1.97053
6.995E+00 -8.628E-01  0.0950  2.71326
7.240E+00 -8.628E-01  0.0950  3.456
7.485E+00 -8.628E-01  0.0950  4.19874
7.62      0.0         0.0950  4.608
7.730E+00 -8.628E-01  0.0950  4.608
7.975E+00 -8.628E-01  0.0950  4.608
8.220E+00 -8.628E-01  0.0950  4.608
8.465E+00 -8.628E-01  0.0950  4.608
8.955E+00 -8.625E-01  0.0950  4.608
9.200E+00 -8.621E-01  0.0951  4.608
9.445E+00 -8.605E-01  0.0952  4.608
9.690E+00 -8.557E-01  0.0954  4.608
9.935E+00 -8.407E-01  0.0964  4.608
1.018E+01 -7.961E-01  0.0992  4.608
1.042E+01 -6.837E-01  0.1078  4.608
1.067E+01 -4.851E-01  0.1305  4.608
1.091E+01 -2.450E-01  0.1913  4.608
1.116E+01  0.000E+00  0.4370  4.608
     0.0   1   0   .05844     0.0
   300.0    400.0    500.0    600.0    700.0    800.0    900.0
  11.159
```

```
*******************************************************************
*                                                    *
*         ONE-DIMENSIONAL FLOW AND TRANSPORT MODEL                   *
*                  HYDRUS  v. 3.4                          *
*                                                    *
*    DATA INPUT FILE: 1.dat                                  *
*                                                    *
*   LL1D1, time units = years, infiltration = 2.3 in/yr            *
*   TNB, clean up to 4 ft, 1.dat                           *
*                                                    *
*******************************************************************
```

PROBLEM CONTROL PARAMETERS
======================

SIMULATION CONTROL CODE ...............(ITKOD) = 1
HYSTERESIS MODELING CODE ..............(IHKOD) = 0
TRANSPORT BOUNDARY COND. CODE ........(ICOKOD) = 0
ROOT WATER UPTAKE CODE ...............(IRUKOD) = 0
CONDUCTIVITY UPSTREAM WEIGHTING ......(IUPKOD) = 0
FLOW MASS MATRIX OPTION ...............(ILKOD) = 1
FLOW INITIAL CONDITION CODE ...........(ICKOD) = 1
BOUNDARY CONDITION CODE ..............(IBCKOD) = 0
PLOT OUTPUT CODE .......................(IOKOD) = 0
RESTART OUTPUT CODE ..................(IRSKOD) = 2

TIME STEPPING PARAMETERS
=====================

INITIAL TIMESTEP ......................(DELIN) = 0.100E-02
MINIMUM TIMESTEP .....................(DELMIN) = 0.100E-04
MAXIMUM TIMESTEP .....................(DELMAX) = 100.
TOTAL SIMULATION TIME ..................(TMAX) = 0.100E+04
REL. PR. HEAD CONVERGENCE TOLERANCE ....(TOL1) = 0.100E-01
ABS. " " " ....(TOL2) = 0.100E-01
NUMBER OF NONLINEAR ITERATIONS .......(NITMAX) = 9900

PROBLEM SPECIFICATION PARAMETERS
============================

MAXIMUM NUMBER OF TIMESTEPS ..........(NSTEPS) = 7500
NUMBER OF SOIL MATERIALS ...............(NMAT) = 3
NUMBER OF SOIL LAYERS .................(NLAYR) = 3
NUMBER OF BOUNDARY COND. TIME VALUES ....(NBC) = 1
NUMBER OF OUTPUT TIME VALUES .........(NPRINT) = 7
NUMBER OF OBSERVATION POINTS ...........(NOBS) = 1
SOIL DEPTH ...........................(TDEPTH) = 11.2
GROUNDWATER SOLUTE CONCENTRATION ........(CNN) = 0.000

PROBLEM GEOMETRY
===============

LAYER NUMBER ......... 1
MATERIAL INDEX .........................(MATL) = 1
LAYER THICKNESS .......................(THICK) = 0.700
BEGINNING DEPTH ........................(TOPL) = 0.000
ENDING DEPTH ...........................(BOTL) = 0.700
NODAL SPACING ..........................(DELZ) = 0.233

LAYER NUMBER ......... 2
MATERIAL INDEX .........................(MATL) = 2
LAYER THICKNESS .......................(THICK) = 3.11
BEGINNING DEPTH ........................(TOPL) = 0.700
ENDING DEPTH ...........................(BOTL) = 3.81
NODAL SPACING ..........................(DELZ) = 0.239

LAYER NUMBER ......... 3
MATERIAL INDEX ..........................(MATL) = 3
LAYER THICKNESS ........................(THICK) = 7.35
BEGINNING DEPTH ........................(TOPL) = 3.81
ENDING DEPTH ............................(BOTL) = 11.2
NODAL SPACING ...........................(DELZ) = 0.245

SOIL HYDRAULIC AND TRANSPORT PROPERTIES

HYDRAULIC PROPERTIES FOR MATERIAL: 1

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.6810 | 1.1700 | 0.4750 | 0.0900 | 9.855E+01 |

HYDRAULIC PROPERTIES FOR MATERIAL: 2

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.9250 | 1.1500 | 0.4790 | 0.0560 | 3.285E+00 |

HYDRAULIC PROPERTIES FOR MATERIAL: 3

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 13.8000 | 1.6900 | 0.4370 | 0.0200 | 3.650E+03 |

TRANSPORT PROPERTIES FOR MATERIAL: 1

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 7.748 |

TRANSPORT PROPERTIES FOR MATERIAL: 2

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 8.840 |

TRANSPORT PROPERTIES FOR MATERIAL: 3

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 0.133 |

MAXIMUM VALUE OF GRID PECLET NUMBER IS 2.450 FOR LAYER NO. 3

BOUNDARY CONDITION DATA

| TIME | IRTYP | IDRTYP | BCN1 | BCNN | CN1 | POTET |
|---|---|---|---|---|---|---|
| 0.000 | 1 | 0 | 0.058 | 0.000 | 0.000 | 0.000 |

OUTPUT TIME VALUES

0.300E+03 0.400E+03 0.500E+03 0.600E+03 0.700E+03 0.800E+03 0.900E+03

OBSERVATION POINT COORDINATES

11.159

INITIAL CONDITIONS
================

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.482E-01 | 0.4050 | 0.000E+00 | 0.23 | -7.879E-01 | 0.4123 | 0.000E+00 |
| 0.47 | -5.997E-01 | 0.4225 | 0.000E+00 | 0.70 | -3.897E-01 | 0.4368 | 0.000E+00 |
| 0.94 | -1.835E-01 | 0.4576 | 0.000E+00 | 1.18 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.42 | -1.835E-01 | 0.4576 | 4.563E-02 | 1.66 | -1.835E-01 | 0.4576 | 3.418E-02 |
| 1.90 | -1.835E-01 | 0.4576 | 7.431E-02 | 2.14 | -1.835E-01 | 0.4576 | 2.494E-01 |
| 2.37 | -1.835E-01 | 0.4576 | 4.245E-01 | 2.61 | -1.835E-01 | 0.4576 | 5.996E-01 |
| 2.85 | -1.844E-01 | 0.4575 | 6.227E-01 | 3.09 | -1.920E-01 | 0.4567 | 4.762E-01 |
| 3.33 | -2.611E-01 | 0.4497 | 3.297E-01 | 3.57 | -6.737E-01 | 0.4197 | 1.832E-01 |
| 3.81 | -8.631E-01 | 0.0950 | 2.451E+00 | 4.06 | -8.631E-01 | 0.0950 | 2.189E+00 |
| 4.30 | -8.631E-01 | 0.0950 | 1.927E+00 | 4.55 | -8.631E-01 | 0.0950 | 1.664E+00 |
| 4.79 | -8.631E-01 | 0.0950 | 1.402E+00 | 5.04 | -8.631E-01 | 0.0950 | 1.140E+00 |
| 5.28 | -8.631E-01 | 0.0950 | 8.776E-01 | 5.53 | -8.631E-01 | 0.0950 | 6.154E-01 |
| 5.77 | -8.631E-01 | 0.0950 | 3.532E-01 | 6.02 | -8.631E-01 | 0.0950 | 9.098E-02 |
| 6.26 | -8.631E-01 | 0.0950 | 4.851E-01 | 6.51 | -8.631E-01 | 0.0950 | 1.228E+00 |
| 6.75 | -8.631E-01 | 0.0950 | 1.971E+00 | 7.00 | -8.631E-01 | 0.0950 | 2.713E+00 |
| 7.24 | -8.631E-01 | 0.0950 | 3.456E+00 | 7.49 | -8.631E-01 | 0.0950 | 4.199E+00 |
| 7.73 | -8.631E-01 | 0.0950 | 4.608E+00 | 7.98 | -8.631E-01 | 0.0950 | 4.608E+00 |
| 8.22 | -8.631E-01 | 0.0950 | 4.608E+00 | 8.47 | -8.631E-01 | 0.0950 | 4.608E+00 |
| 8.71 | -8.631E-01 | 0.0950 | 4.608E+00 | 8.96 | -8.631E-01 | 0.0950 | 4.608E+00 |
| 9.20 | -8.614E-01 | 0.0951 | 4.608E+00 | 9.44 | -8.597E-01 | 0.0952 | 4.608E+00 |
| 9.69 | -8.564E-01 | 0.0954 | 4.608E+00 | 9.93 | -8.399E-01 | 0.0964 | 4.608E+00 |
| 10.18 | -7.965E-01 | 0.0992 | 4.608E+00 | 10.42 | -6.788E-01 | 0.1083 | 4.608E+00 |
| 10.67 | -4.852E-01 | 0.1305 | 4.608E+00 | 10.91 | -2.339E-01 | 0.1962 | 4.608E+00 |
| 11.16 | -8.691E-10 | 0.4370 | 4.608E+00 | | | | |

INITIAL MOISTURE IN PROFILE : 2.44
INITIAL SALT IN PROFILE : 16.1

STEADY STATE FLOW SOLUTION PERFORMED IN 1 ITERATIONS

****************************** TIME = 3.000E+02 ******************************

ISTEP = 286 RAIN = 5.844E-02 TRAIN = 1.758E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 1.758E+01 SLTIN =-1.074E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.268E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 3.441E+00
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.1562 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.353E-08 | 0.23 | -7.796E-01 | 0.4127 | 1.703E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 1.661E-06 | 0.70 | -3.823E-01 | 0.4374 | 1.199E-05 |
| 0.94 | -1.756E-01 | 0.4585 | 6.754E-05 | 1.18 | -1.753E-01 | 0.4585 | 2.775E-04 |
| 1.42 | -1.750E-01 | 0.4585 | 9.434E-04 | 1.66 | -1.747E-01 | 0.4586 | 2.706E-03 |
| 1.90 | -1.744E-01 | 0.4586 | 6.758E-03 | 2.14 | -1.741E-01 | 0.4586 | 1.518E-02 |
| 2.37 | -1.739E-01 | 0.4586 | 3.128E-02 | 2.61 | -1.736E-01 | 0.4587 | 5.925E-02 |
| 2.85 | -1.741E-01 | 0.4586 | 1.025E-01 | 3.09 | -1.818E-01 | 0.4578 | 1.606E-01 |
| 3.33 | -2.505E-01 | 0.4507 | 2.275E-01 | 3.57 | -6.657E-01 | 0.4202 | 2.933E-01 |
| 3.81 | -8.544E-01 | 0.0955 | 2.947E-01 | 4.06 | -8.550E-01 | 0.0955 | 2.964E-01 |
| 4.30 | -8.555E-01 | 0.0955 | 2.980E-01 | 4.55 | -8.560E-01 | 0.0954 | 2.997E-01 |
| 4.79 | -8.566E-01 | 0.0954 | 3.013E-01 | 5.04 | -8.571E-01 | 0.0954 | 3.030E-01 |
| 5.28 | -8.576E-01 | 0.0953 | 3.046E-01 | 5.53 | -8.582E-01 | 0.0953 | 3.063E-01 |
| 5.77 | -8.587E-01 | 0.0953 | 3.080E-01 | 6.02 | -8.592E-01 | 0.0952 | 3.096E-01 |
| 6.26 | -8.598E-01 | 0.0952 | 3.113E-01 | 6.51 | -8.603E-01 | 0.0952 | 3.129E-01 |
| 6.75 | -8.609E-01 | 0.0951 | 3.146E-01 | 7.00 | -8.614E-01 | 0.0951 | 3.163E-01 |
| 7.24 | -8.619E-01 | 0.0951 | 3.179E-01 | 7.49 | -8.625E-01 | 0.0950 | 3.196E-01 |
| 7.73 | -8.630E-01 | 0.0950 | 3.212E-01 | 7.98 | -8.635E-01 | 0.0950 | 3.229E-01 |
| 8.22 | -8.641E-01 | 0.0949 | 3.245E-01 | 8.47 | -8.646E-01 | 0.0949 | 3.262E-01 |
| 8.71 | -8.651E-01 | 0.0949 | 3.279E-01 | 8.96 | -8.657E-01 | 0.0948 | 3.295E-01 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9.20 | -8.653E-01 | 0.0949 | 3.312E-01 | 9.44 | -8.632E-01 | 0.0950 | 3.328E-01 |
| 9.69 | -8.585E-01 | 0.0953 | 3.345E-01 | 9.93 | -8.435E-01 | 0.0962 | 3.361E-01 |
| 10.18 | -7.990E-01 | 0.0990 | 3.378E-01 | 10.42 | -6.846E-01 | 0.1077 | 3.395E-01 |
| 10.67 | -4.858E-01 | 0.1304 | 3.413E-01 | 10.91 | -2.450E-01 | 0.1913 | 3.437E-01 |
| 11.16 | 0.000E+00 | 0.4370 | 3.437E-01 | | | | |

****************************** TIME = 4.000E+02 ******************************

ISTEP = 372 RAIN = 5.844E-02 TRAIN = 2.343E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 2.343E+01 SLTIN =-1.314E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.430E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.830E+00
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.2934 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 8.956E-09 | 0.23 | -7.796E-01 | 0.4127 | 1.045E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 8.740E-07 | 0.70 | -3.823E-01 | 0.4374 | 5.545E-06 |
| 0.94 | -1.756E-01 | 0.4585 | 2.835E-05 | 1.18 | -1.753E-01 | 0.4585 | 1.084E-04 |
| 1.42 | -1.750E-01 | 0.4585 | 3.555E-04 | 1.66 | -1.747E-01 | 0.4586 | 1.023E-03 |
| 1.90 | -1.744E-01 | 0.4586 | 2.626E-03 | 2.14 | -1.741E-01 | 0.4586 | 6.117E-03 |
| 2.37 | -1.739E-01 | 0.4586 | 1.308E-02 | 2.61 | -1.736E-01 | 0.4587 | 2.584E-02 |
| 2.85 | -1.741E-01 | 0.4586 | 4.711E-02 | 3.09 | -1.818E-01 | 0.4578 | 7.892E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 1.209E-01 | 3.57 | -6.657E-01 | 0.4202 | 1.694E-01 |
| 3.81 | -8.544E-01 | 0.0955 | 1.705E-01 | 4.06 | -8.550E-01 | 0.0955 | 1.718E-01 |
| 4.30 | -8.555E-01 | 0.0955 | 1.730E-01 | 4.55 | -8.560E-01 | 0.0954 | 1.742E-01 |
| 4.79 | -8.566E-01 | 0.0954 | 1.755E-01 | 5.04 | -8.571E-01 | 0.0954 | 1.767E-01 |
| 5.28 | -8.576E-01 | 0.0953 | 1.780E-01 | 5.53 | -8.582E-01 | 0.0953 | 1.793E-01 |
| 5.77 | -8.587E-01 | 0.0953 | 1.805E-01 | 6.02 | -8.592E-01 | 0.0952 | 1.818E-01 |
| 6.26 | -8.598E-01 | 0.0952 | 1.831E-01 | 6.51 | -8.603E-01 | 0.0952 | 1.844E-01 |
| 6.75 | -8.609E-01 | 0.0951 | 1.857E-01 | 7.00 | -8.614E-01 | 0.0951 | 1.870E-01 |
| 7.24 | -8.619E-01 | 0.0951 | 1.883E-01 | 7.49 | -8.625E-01 | 0.0950 | 1.896E-01 |
| 7.73 | -8.630E-01 | 0.0950 | 1.909E-01 | 7.98 | -8.635E-01 | 0.0950 | 1.922E-01 |
| 8.22 | -8.641E-01 | 0.0949 | 1.936E-01 | 8.47 | -8.646E-01 | 0.0949 | 1.949E-01 |
| 8.71 | -8.651E-01 | 0.0949 | 1.963E-01 | 8.96 | -8.657E-01 | 0.0948 | 1.976E-01 |
| 9.20 | -8.653E-01 | 0.0949 | 1.990E-01 | 9.44 | -8.632E-01 | 0.0950 | 2.003E-01 |
| 9.69 | -8.585E-01 | 0.0953 | 2.017E-01 | 9.93 | -8.435E-01 | 0.0962 | 2.031E-01 |
| 10.18 | -7.990E-01 | 0.0990 | 2.045E-01 | 10.42 | -6.846E-01 | 0.1077 | 2.059E-01 |
| 10.67 | -4.858E-01 | 0.1304 | 2.074E-01 | 10.91 | -2.450E-01 | 0.1913 | 2.095E-01 |
| 11.16 | 0.000E+00 | 0.4370 | 2.095E-01 | | | | |

****************************** TIME = 5.000E+02 ******************************

ISTEP = 458 RAIN = 5.844E-02 TRAIN = 2.928E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 2.928E+01 SLTIN =-1.475E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.522E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 9.074E-01
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.5900 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 4.673E-09 | 0.23 | -7.796E-01 | 0.4127 | 5.240E-08 |
| 0.47 | -5.923E-01 | 0.4229 | 4.025E-07 | 0.70 | -3.823E-01 | 0.4374 | 2.377E-06 |
| 0.94 | -1.756E-01 | 0.4585 | 1.153E-05 | 1.18 | -1.753E-01 | 0.4585 | 4.246E-05 |
| 1.42 | -1.750E-01 | 0.4585 | 1.365E-04 | 1.66 | -1.747E-01 | 0.4586 | 3.926E-04 |
| 1.90 | -1.744E-01 | 0.4586 | 1.024E-03 | 2.14 | -1.741E-01 | 0.4586 | 2.448E-03 |
| 2.37 | -1.739E-01 | 0.4586 | 5.403E-03 | 2.61 | -1.736E-01 | 0.4587 | 1.107E-02 |
| 2.85 | -1.741E-01 | 0.4586 | 2.104E-02 | 3.09 | -1.818E-01 | 0.4578 | 3.700E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 5.975E-02 | 3.57 | -6.657E-01 | 0.4202 | 8.836E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 8.901E-02 | 4.06 | -8.550E-01 | 0.0955 | 8.973E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 9.046E-02 | 4.55 | -8.560E-01 | 0.0954 | 9.120E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 9.194E-02 | 5.04 | -8.571E-01 | 0.0954 | 9.268E-02 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5.28 | -8.576E-01 | 0.0953 | 9.343E-02 | 5.53 | -8.582E-01 | 0.0953 | 9.419E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 9.495E-02 | 6.02 | -8.592E-01 | 0.0952 | 9.572E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 9.649E-02 | 6.51 | -8.603E-01 | 0.0952 | 9.726E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 9.804E-02 | 7.00 | -8.614E-01 | 0.0951 | 9.883E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 9.962E-02 | 7.49 | -8.625E-01 | 0.0950 | 1.004E-01 |
| 7.73 | -8.630E-01 | 0.0950 | 1.012E-01 | 7.98 | -8.635E-01 | 0.0950 | 1.020E-01 |
| 8.22 | -8.641E-01 | 0.0949 | 1.028E-01 | 8.47 | -8.646E-01 | 0.0949 | 1.037E-01 |
| 8.71 | -8.651E-01 | 0.0949 | 1.045E-01 | 8.96 | -8.657E-01 | 0.0948 | 1.053E-01 |
| 9.20 | -8.653E-01 | 0.0949 | 1.062E-01 | 9.44 | -8.632E-01 | 0.0950 | 1.070E-01 |
| 9.69 | -8.585E-01 | 0.0953 | 1.078E-01 | 9.93 | -8.435E-01 | 0.0962 | 1.087E-01 |
| 10.18 | -7.990E-01 | 0.0990 | 1.096E-01 | 10.42 | -6.846E-01 | 0.1077 | 1.105E-01 |
| 10.67 | -4.858E-01 | 0.1304 | 1.114E-01 | 10.91 | -2.450E-01 | 0.1913 | 1.127E-01 |
| 11.16 | 0.000E+00 | 0.4370 | 1.127E-01 | | | | |

****************************** TIME = 6.000E+02 ******************************

ISTEP = 543 RAIN = 5.844E-02 TRAIN = 3.507E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 3.507E+01 SLTIN =-1.412E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.569E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 4.329E-01
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
„ „ SOLUTE: 1.2285 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.161E-09 | 0.23 | -7.796E-01 | 0.4127 | 2.371E-08 |
| 0.47 | -5.923E-01 | 0.4229 | 1.734E-07 | 0.70 | -3.823E-01 | 0.4374 | 9.824E-07 |
| 0.94 | -1.756E-01 | 0.4585 | 4.625E-06 | 1.18 | -1.753E-01 | 0.4585 | 1.667E-05 |
| 1.42 | -1.750E-01 | 0.4585 | 5.295E-05 | 1.66 | -1.747E-01 | 0.4586 | 1.523E-04 |
| 1.90 | -1.744E-01 | 0.4586 | 4.015E-04 | 2.14 | -1.741E-01 | 0.4586 | 9.782E-04 |
| 2.37 | -1.739E-01 | 0.4586 | 2.215E-03 | 2.61 | -1.736E-01 | 0.4587 | 4.674E-03 |
| 2.85 | -1.741E-01 | 0.4586 | 9.198E-03 | 3.09 | -1.818E-01 | 0.4578 | 1.679E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 2.817E-02 | 3.57 | -6.657E-01 | 0.4202 | 4.322E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 4.356E-02 | 4.06 | -8.550E-01 | 0.0955 | 4.394E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 4.433E-02 | 4.55 | -8.560E-01 | 0.0954 | 4.471E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 4.511E-02 | 5.04 | -8.571E-01 | 0.0954 | 4.550E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 4.590E-02 | 5.53 | -8.582E-01 | 0.0953 | 4.630E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 4.670E-02 | 6.02 | -8.592E-01 | 0.0952 | 4.711E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 4.752E-02 | 6.51 | -8.603E-01 | 0.0952 | 4.793E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 4.835E-02 | 7.00 | -8.614E-01 | 0.0951 | 4.877E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 4.919E-02 | 7.49 | -8.625E-01 | 0.0950 | 4.962E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 5.005E-02 | 7.98 | -8.635E-01 | 0.0950 | 5.048E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 5.092E-02 | 8.47 | -8.646E-01 | 0.0949 | 5.136E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 5.180E-02 | 8.96 | -8.657E-01 | 0.0948 | 5.225E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 5.270E-02 | 9.44 | -8.632E-01 | 0.0950 | 5.315E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 5.361E-02 | 9.93 | -8.435E-01 | 0.0962 | 5.407E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 5.454E-02 | 10.42 | -6.846E-01 | 0.1077 | 5.503E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 5.555E-02 | 10.91 | -2.450E-01 | 0.1913 | 5.625E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 5.625E-02 | | | | |

****************************** TIME = 7.000E+02 ******************************

ISTEP = 629 RAIN = 5.844E-02 TRAIN = 4.092E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 4.092E+01 SLTIN =-1.351E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.593E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.980E-01
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
„ „ SOLUTE: 2.6480 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 9.353E-10 | 0.23 | -7.796E-01 | 0.4127 | 1.014E-08 |
| 0.47 | -5.923E-01 | 0.4229 | 7.205E-08 | 0.70 | -3.823E-01 | 0.4374 | 3.982E-07 |
| 0.94 | -1.756E-01 | 0.4585 | 1.841E-06 | 1.18 | -1.753E-01 | 0.4585 | 6.552E-06 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1.42 | -1.750E-01 | 0.4585 | 2.068E-05 | 1.66 | -1.747E-01 | 0.4586 | 5.950E-05 |
| 1.90 | -1.744E-01 | 0.4586 | 1.582E-04 | 2.14 | -1.741E-01 | 0.4586 | 3.910E-04 |
| 2.37 | -1.739E-01 | 0.4586 | 9.034E-04 | 2.61 | -1.736E-01 | 0.4587 | 1.954E-03 |
| 2.85 | -1.741E-01 | 0.4586 | 3.955E-03 | 3.09 | -1.818E-01 | 0.4578 | 7.434E-03 |
| 3.33 | -2.505E-01 | 0.4507 | 1.285E-02 | 3.57 | -6.657E-01 | 0.4202 | 2.024E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 2.041E-02 | 4.06 | -8.550E-01 | 0.0955 | 2.059E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 2.078E-02 | 4.55 | -8.560E-01 | 0.0954 | 2.098E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 2.117E-02 | 5.04 | -8.571E-01 | 0.0954 | 2.136E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 2.156E-02 | 5.53 | -8.582E-01 | 0.0953 | 2.176E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 2.196E-02 | 6.02 | -8.592E-01 | 0.0952 | 2.216E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 2.236E-02 | 6.51 | -8.603E-01 | 0.0952 | 2.257E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 2.277E-02 | 7.00 | -8.614E-01 | 0.0951 | 2.298E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 2.319E-02 | 7.49 | -8.625E-01 | 0.0950 | 2.340E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 2.362E-02 | 7.98 | -8.635E-01 | 0.0950 | 2.383E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 2.405E-02 | 8.47 | -8.646E-01 | 0.0949 | 2.427E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 2.449E-02 | 8.96 | -8.657E-01 | 0.0948 | 2.471E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 2.494E-02 | 9.44 | -8.632E-01 | 0.0950 | 2.516E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 2.539E-02 | 9.93 | -8.435E-01 | 0.0962 | 2.562E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 2.586E-02 | 10.42 | -6.846E-01 | 0.1077 | 2.610E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 2.636E-02 | 10.91 | -2.450E-01 | 0.1913 | 2.672E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 2.672E-02 | | | | |

****************************** TIME = 8.000E+02 ******************************

ISTEP = 715 RAIN = 5.844E-02 TRAIN = 4.677E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 4.677E+01 SLTIN =-1.357E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.604E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 8.825E-02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 5.7509 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 3.899E-10 | 0.23 | -7.796E-01 | 0.4127 | 4.196E-09 |
| 0.47 | -5.923E-01 | 0.4229 | 2.931E-08 | 0.70 | -3.823E-01 | 0.4374 | 1.596E-07 |
| 0.94 | -1.756E-01 | 0.4585 | 7.300E-07 | 1.18 | -1.753E-01 | 0.4585 | 2.579E-06 |
| 1.42 | -1.750E-01 | 0.4585 | 8.109E-06 | 1.66 | -1.747E-01 | 0.4586 | 2.337E-05 |
| 1.90 | -1.744E-01 | 0.4586 | 6.253E-05 | 2.14 | -1.741E-01 | 0.4586 | 1.565E-04 |
| 2.37 | -1.739E-01 | 0.4586 | 3.675E-04 | 2.61 | -1.736E-01 | 0.4587 | 8.112E-04 |
| 2.85 | -1.741E-01 | 0.4586 | 1.679E-03 | 3.09 | -1.818E-01 | 0.4578 | 3.232E-03 |
| 3.33 | -2.505E-01 | 0.4507 | 5.713E-03 | 3.57 | -6.657E-01 | 0.4202 | 9.185E-03 |
| 3.81 | -8.544E-01 | 0.0955 | 9.263E-03 | 4.06 | -8.550E-01 | 0.0955 | 9.352E-03 |
| 4.30 | -8.555E-01 | 0.0955 | 9.441E-03 | 4.55 | -8.560E-01 | 0.0954 | 9.531E-03 |
| 4.79 | -8.566E-01 | 0.0954 | 9.622E-03 | 5.04 | -8.571E-01 | 0.0954 | 9.713E-03 |
| 5.28 | -8.576E-01 | 0.0953 | 9.806E-03 | 5.53 | -8.582E-01 | 0.0953 | 9.899E-03 |
| 5.77 | -8.587E-01 | 0.0953 | 9.993E-03 | 6.02 | -8.592E-01 | 0.0952 | 1.009E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 1.018E-02 | 6.51 | -8.603E-01 | 0.0952 | 1.028E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 1.038E-02 | 7.00 | -8.614E-01 | 0.0951 | 1.048E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 1.058E-02 | 7.49 | -8.625E-01 | 0.0950 | 1.068E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 1.078E-02 | 7.98 | -8.635E-01 | 0.0950 | 1.088E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 1.098E-02 | 8.47 | -8.646E-01 | 0.0949 | 1.109E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 1.119E-02 | 8.96 | -8.657E-01 | 0.0948 | 1.130E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 1.140E-02 | 9.44 | -8.632E-01 | 0.0950 | 1.151E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 1.162E-02 | 9.93 | -8.435E-01 | 0.0962 | 1.173E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 1.184E-02 | 10.42 | -6.846E-01 | 0.1077 | 1.196E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 1.208E-02 | 10.91 | -2.450E-01 | 0.1913 | 1.225E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 1.225E-02 | | | | |

****************************** TIME = 9.000E+02 ******************************

ISTEP = 801 RAIN = 5.844E-02 TRAIN = 5.262E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 5.262E+01 SLTIN =-1.332E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.609E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 3.858E-02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %

" " SOLUTE: 12.2478 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.590E-10 | 0.23 | -7.796E-01 | 0.4127 | 1.704E-09 |
| 0.47 | -5.923E-01 | 0.4229 | 1.178E-08 | 0.70 | -3.823E-01 | 0.4374 | 6.355E-08 |
| 0.94 | -1.756E-01 | 0.4585 | 2.889E-07 | 1.18 | -1.753E-01 | 0.4585 | 1.016E-06 |
| 1.42 | -1.750E-01 | 0.4585 | 3.190E-06 | 1.66 | -1.747E-01 | 0.4586 | 9.213E-06 |
| 1.90 | -1.744E-01 | 0.4586 | 2.480E-05 | 2.14 | -1.741E-01 | 0.4586 | 6.267E-05 |
| 2.37 | -1.739E-01 | 0.4586 | 1.492E-04 | 2.61 | -1.736E-01 | 0.4587 | 3.349E-04 |
| 2.85 | -1.741E-01 | 0.4586 | 7.062E-04 | 3.09 | -1.818E-01 | 0.4578 | 1.385E-03 |
| 3.33 | -2.505E-01 | 0.4507 | 2.493E-03 | 3.57 | -6.657E-01 | 0.4202 | 4.071E-03 |
| 3.81 | -8.544E-01 | 0.0955 | 4.107E-03 | 4.06 | -8.550E-01 | 0.0955 | 4.147E-03 |
| 4.30 | -8.555E-01 | 0.0955 | 4.188E-03 | 4.55 | -8.560E-01 | 0.0954 | 4.229E-03 |
| 4.79 | -8.566E-01 | 0.0954 | 4.270E-03 | 5.04 | -8.571E-01 | 0.0954 | 4.312E-03 |
| 5.28 | -8.576E-01 | 0.0953 | 4.354E-03 | 5.53 | -8.582E-01 | 0.0953 | 4.396E-03 |
| 5.77 | -8.587E-01 | 0.0953 | 4.439E-03 | 6.02 | -8.592E-01 | 0.0952 | 4.483E-03 |
| 6.26 | -8.598E-01 | 0.0952 | 4.526E-03 | 6.51 | -8.603E-01 | 0.0952 | 4.571E-03 |
| 6.75 | -8.609E-01 | 0.0951 | 4.615E-03 | 7.00 | -8.614E-01 | 0.0951 | 4.660E-03 |
| 7.24 | -8.619E-01 | 0.0951 | 4.705E-03 | 7.49 | -8.625E-01 | 0.0950 | 4.751E-03 |
| 7.73 | -8.630E-01 | 0.0950 | 4.797E-03 | 7.98 | -8.635E-01 | 0.0950 | 4.844E-03 |
| 8.22 | -8.641E-01 | 0.0949 | 4.891E-03 | 8.47 | -8.646E-01 | 0.0949 | 4.939E-03 |
| 8.71 | -8.651E-01 | 0.0949 | 4.987E-03 | 8.96 | -8.657E-01 | 0.0948 | 5.035E-03 |
| 9.20 | -8.653E-01 | 0.0949 | 5.084E-03 | 9.44 | -8.632E-01 | 0.0950 | 5.133E-03 |
| 9.69 | -8.585E-01 | 0.0953 | 5.183E-03 | 9.93 | -8.435E-01 | 0.0962 | 5.234E-03 |
| 10.18 | -7.990E-01 | 0.0990 | 5.285E-03 | 10.42 | -6.846E-01 | 0.1077 | 5.338E-03 |
| 10.67 | -4.858E-01 | 0.1304 | 5.395E-03 | 10.91 | -2.450E-01 | 0.1913 | 5.473E-03 |
| 11.16 | 0.000E+00 | 0.4370 | 5.473E-03 | | | | |

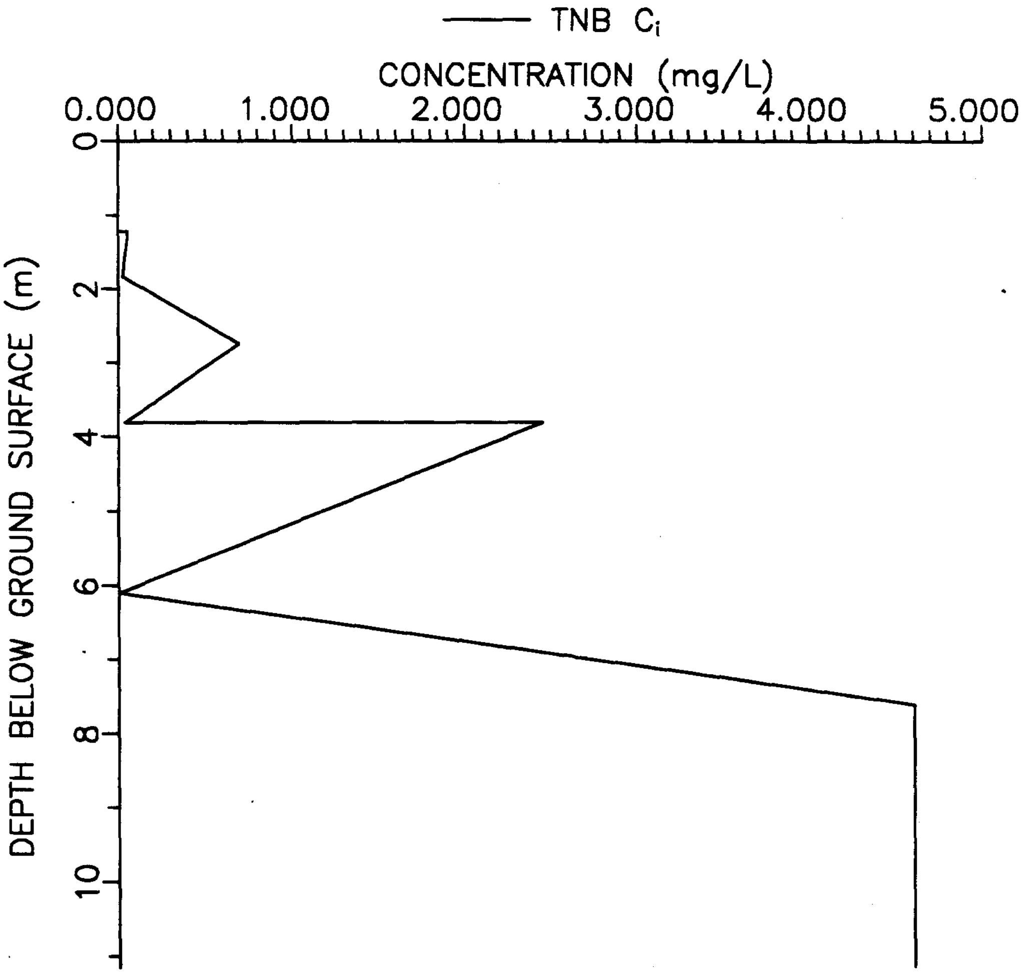
****************************** TIME = 1.000E+03 ******************************

ISTEP = 887 RAIN = 5.844E-02 TRAIN = 5.848E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 5.848E+01 SLTIN =-1.339E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.611E+01
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.661E-02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
" " SOLUTE: 24.4794 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 6.400E-11 | 0.23 | -7.796E-01 | 0.4127 | 6.840E-10 |
| 0.47 | -5.923E-01 | 0.4229 | 4.699E-09 | 0.70 | -3.823E-01 | 0.4374 | 2.522E-08 |
| 0.94 | -1.756E-01 | 0.4585 | 1.142E-07 | 1.18 | -1.753E-01 | 0.4585 | 4.009E-07 |
| 1.42 | -1.750E-01 | 0.4585 | 1.258E-06 | 1.66 | -1.747E-01 | 0.4586 | 3.643E-06 |
| 1.90 | -1.744E-01 | 0.4586 | 9.859E-06 | 2.14 | -1.741E-01 | 0.4586 | 2.513E-05 |
| 2.37 | -1.739E-01 | 0.4586 | 6.051E-05 | 2.61 | -1.736E-01 | 0.4587 | 1.377E-04 |
| 2.85 | -1.741E-01 | 0.4586 | 2.948E-04 | 3.09 | -1.818E-01 | 0.4578 | 5.873E-04 |
| 3.33 | -2.505E-01 | 0.4507 | 1.072E-03 | 3.57 | -6.657E-01 | 0.4202 | 1.772E-03 |
| 3.81 | -8.544E-01 | 0.0955 | 1.788E-03 | 4.06 | -8.550E-01 | 0.0955 | 1.806E-03 |
| 4.30 | -8.555E-01 | 0.0955 | 1.824E-03 | 4.55 | -8.560E-01 | 0.0954 | 1.842E-03 |
| 4.79 | -8.566E-01 | 0.0954 | 1.861E-03 | 5.04 | -8.571E-01 | 0.0954 | 1.879E-03 |
| 5.28 | -8.576E-01 | 0.0953 | 1.898E-03 | 5.53 | -8.582E-01 | 0.0953 | 1.917E-03 |
| 5.77 | -8.587E-01 | 0.0953 | 1.936E-03 | 6.02 | -8.592E-01 | 0.0952 | 1.955E-03 |
| 6.26 | -8.598E-01 | 0.0952 | 1.975E-03 | 6.51 | -8.603E-01 | 0.0952 | 1.994E-03 |
| 6.75 | -8.609E-01 | 0.0951 | 2.014E-03 | 7.00 | -8.614E-01 | 0.0951 | 2.034E-03 |
| 7.24 | -8.619E-01 | 0.0951 | 2.054E-03 | 7.49 | -8.625E-01 | 0.0950 | 2.075E-03 |
| 7.73 | -8.630E-01 | 0.0950 | 2.095E-03 | 7.98 | -8.635E-01 | 0.0950 | 2.116E-03 |
| 8.22 | -8.641E-01 | 0.0949 | 2.137E-03 | 8.47 | -8.646E-01 | 0.0949 | 2.158E-03 |
| 8.71 | -8.651E-01 | 0.0949 | 2.180E-03 | 8.96 | -8.657E-01 | 0.0948 | 2.201E-03 |
| 9.20 | -8.653E-01 | 0.0949 | 2.223E-03 | 9.44 | -8.632E-01 | 0.0950 | 2.245E-03 |
| 9.69 | -8.585E-01 | 0.0953 | 2.267E-03 | 9.93 | -8.435E-01 | 0.0962 | 2.290E-03 |
| 10.18 | -7.990E-01 | 0.0990 | 2.313E-03 | 10.42 | -6.846E-01 | 0.1077 | 2.337E-03 |
| 10.67 | -4.858E-01 | 0.1304 | 2.362E-03 | 10.91 | -2.450E-01 | 0.1913 | 2.397E-03 |
| 11.16 | 0.000E+00 | 0.4370 | 2.397E-03 | | | | |

***** NORMAL TERMINATION TIME = 1000.6279 AND STEP NUMBER = 887

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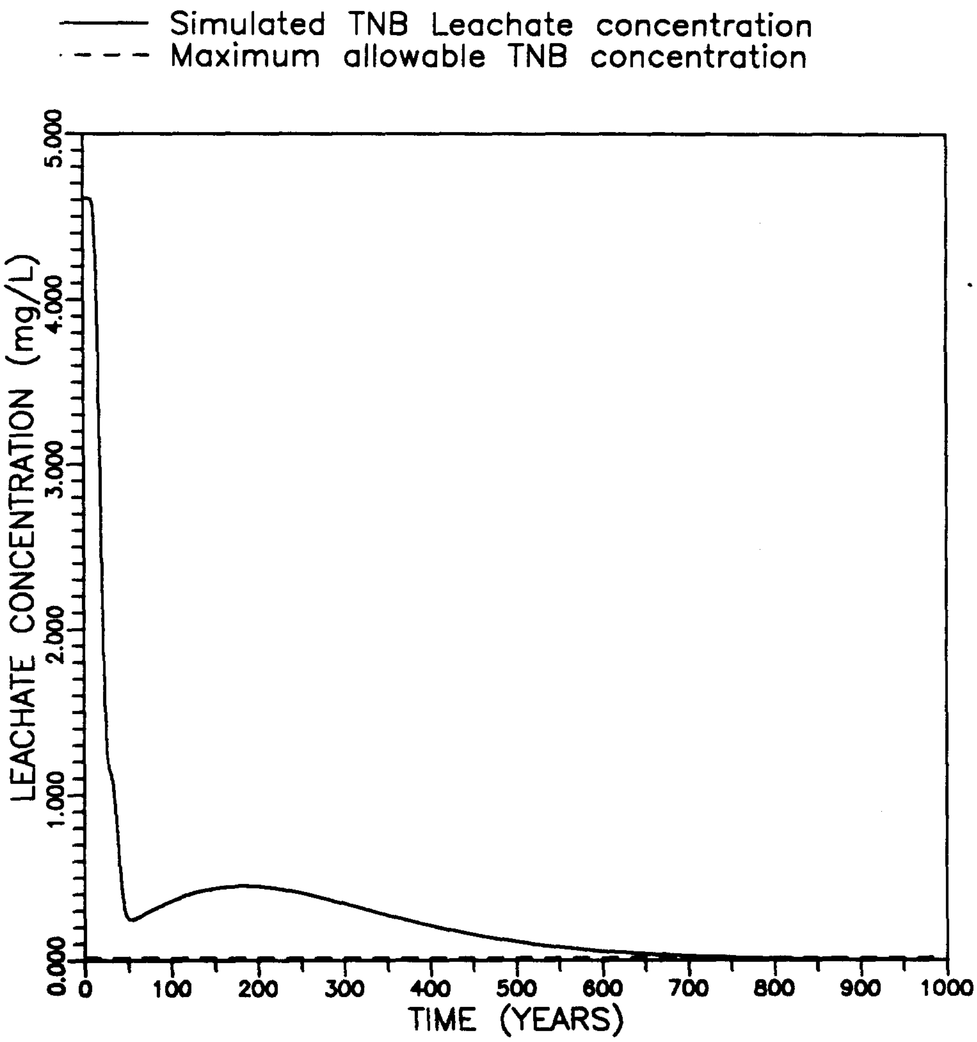
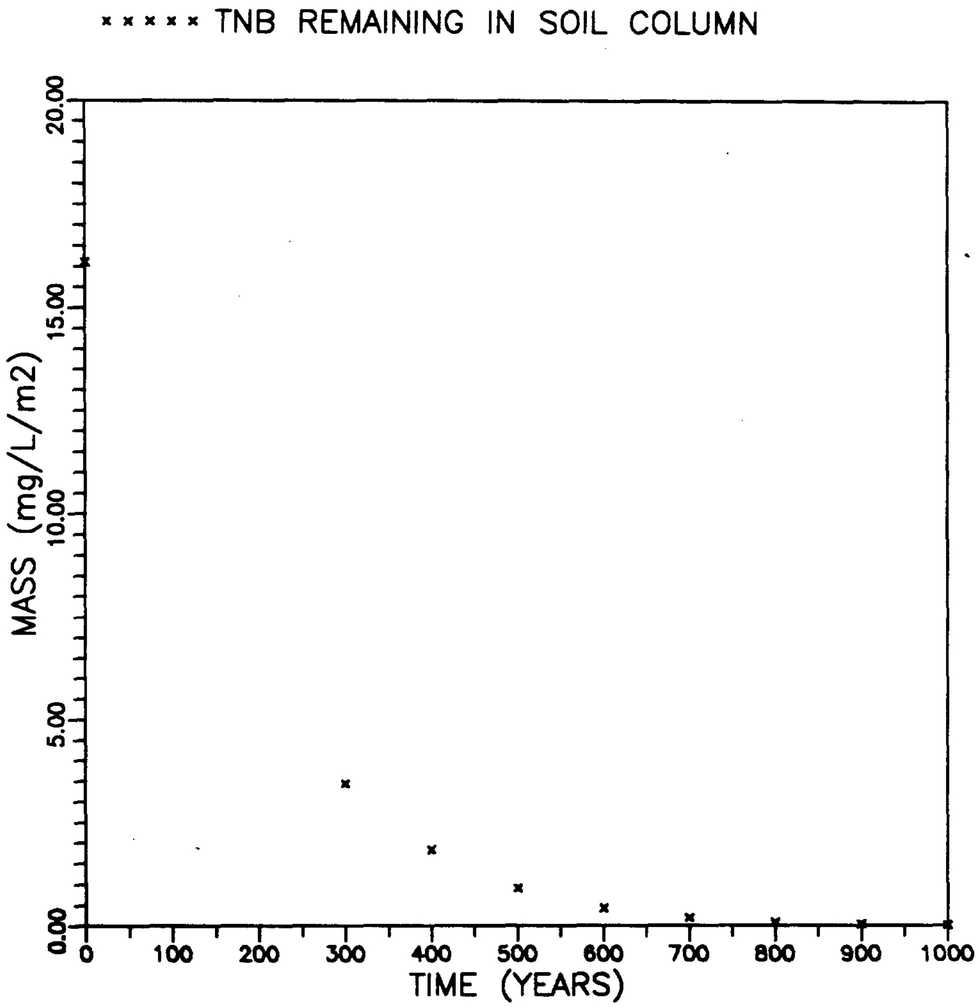


Simulated TNB Leachate concentration
Maximum allowable TNB concentration
LEACHATE CONCENTRATION (mg/L)
0.000
1.000
2.000
3.000
4.000
5.000
0
100
200
300
400
500
600
700
800
900
1000
TIME (YEARS)




B07NE003702-09268

**ATTACHMENT 2B**

**HYDRUS MODEL INPUT FILES, OUTPUT FILES AND ASSOCIATED GRAPHS FOR HYPOTHETICAL TNB EVALUATION (SECTION 5.4.1)**

```
hypothetical, time units = years, infiltration = 2.3 in/yr
TNB, Stnb=0.0121mg/kg (C=0.0911) from 12.5 to 13.5, 150.dat
  1   0   0   0   0   1   1   0   0   2
 7500   3   3   1   7   1      0.0
    .001   .00001    100.0    1000.     .010      .01 9900
   1   1      0.0      0.7      0.25
   2   2      0.7      3.81     0.25
   3   3      3.81     11.16    0.25
    2.681     1.17     0.475    0.090    98.55
    2.925     1.15     0.479    0.056    3.285
     13.8     1.69     0.437    0.020    3650.
   2.27e-2    0.10      1.4      0.0      0.0    7.748     1.0
   2.27e-2    0.10      1.4      0.0      0.0    8.84      1.0
   2.27e-2    0.10      1.4      0.0      0.0    0.1326    1.0
0.000E+00 -9.476E-01  0.4050  0.000E+00
2.333E-01 -7.876E-01  0.4123  0.000E+00
4.667E-01 -6.004E-01  0.4225  0.000E+00
7.000E-01 -3.903E-01  0.4368  0.000E+00
9.392E-01 -1.838E-01  0.4576  0.000E+00
1.220E+00 0.0        0.4576  0.000E+00
1.22      0.0        0.4576  0.
1.657E+00 -1.838E-01  0.4576  0.
1.83      0.0        0.4576  0.
1.896E+00 -1.838E-01  0.4576  0.
2.135E+00 -1.838E-01  0.4576  0.
2.375E+00 -1.838E-01  0.4576  0.
2.614E+00 -1.838E-01  0.4576  0.
2.74      0.0        0.4576  0.
2.853E+00 -1.845E-01  0.4575  0.
3.092E+00 -1.922E-01  0.4567  0.
3.332E+00 -2.607E-01  0.4497  0.
3.571E+00 -6.748E-01  0.4197  0.
3.810E+00 -8.628E-01  0.0950  0.
3.81      0.0        0.0950  0.0911
4.12      0.0        0.0950  0.0911
4.12      0.0        0.0950  0.
5.770E+00 -8.628E-01  0.0950  0.
6.015E+00 -8.628E-01  0.0950  0.
6.1       0.0        0.0950  0.
6.260E+00 -8.628E-01  0.0950  0.
6.505E+00 -8.628E-01  0.0950  0.
6.750E+00 -8.628E-01  0.0950  0.
6.995E+00 -8.628E-01  0.0950  0.
7.240E+00 -8.628E-01  0.0950  0.
7.485     0.0        0.0950  0.0
7.485E+00 -8.628E-01  0.0950  0.0
7.62      0.0        0.0950  0.0
7.730E+00 -8.628E-01  0.0950  0.0
7.975E+00 -8.628E-01  0.0950  0.0
8.220E+00 -8.628E-01  0.0950  0.0
8.465E+00 -8.628E-01  0.0950  0.0
8.955E+00 -8.625E-01  0.0950  0.0
9.200E+00 -8.621E-01  0.0951  0.0
9.445E+00 -8.605E-01  0.0952  0.0
9.690E+00 -8.557E-01  0.0954  0.0
9.935E+00 -8.407E-01  0.0964  0.0
1.018E+01 -7.961E-01  0.0992  0.0
1.042E+01 -6.837E-01  0.1078  0.0
1.067E+01 -4.851E-01  0.1305  0.0
1.091E+01 -2.450E-01  0.1913  0.0
1.116E+01  0.000E+00  0.4370  0.0
      0.0   1   0   .05844      0.0
      5.0     10.0     25.0     30.0     35.0     50.0     90.0
    11.159
```

```
**************************************************************
*                                                  *
*          ONE-DIMENSIONAL FLOW AND TRANSPORT MODEL          *
*                    HYDRUS  v. 3.4                 *
*                                                  *
*   DATA INPUT FILE: 150.dat                          *
*                                                  *
*  hypothetical, time units = years, infiltration = 2.3 in/yr     *
*  TNB, Stnb=0.0121mg/kg (C=0.0911) from 12.5 to 13.5, 150.dat    *
*                                                  *
**************************************************************
```

PROBLEM CONTROL PARAMETERS
======================

SIMULATION CONTROL CODE ...............(ITKOD) = 1
HYSTERESIS MODELING CODE .............(IHKOD) = 0
TRANSPORT BOUNDARY COND. CODE ........(ICOKOD) = 0
ROOT WATER UPTAKE CODE ...............(IRUKOD) = 0
CONDUCTIVITY UPSTREAM WEIGHTING ......(IUPKOD) = 0
FLOW MASS MATRIX OPTION ...............(ILKOD) = 1
FLOW INITIAL CONDITION CODE ...........(ICKOD) = 1
BOUNDARY CONDITION CODE ..............(IBCKOD) = 0
PLOT OUTPUT CODE .......................(IOKOD) = 0
RESTART OUTPUT CODE ..................(IRSKOD) = 2

TIME STEPPING PARAMETERS
=====================

INITIAL TIMESTEP .......................(DELIN) = 0.100E-02
MINIMUM TIMESTEP .....................(DELMIN) = 0.100E-04
MAXIMUM TIMESTEP ......................(DELMAX) = 100.
TOTAL SIMULATION TIME ..................(TMAX) = 0.100E+04
REL. PR. HEAD CONVERGENCE TOLERANCE ....(TOL1) = 0.100E-01
ABS. " " " ....(TOL2) = 0.100E-01
NUMBER OF NONLINEAR ITERATIONS .......(NITMAX) = 9900

PROBLEM SPECIFICATION PARAMETERS
============================

MAXIMUM NUMBER OF TIMESTEPS ..........(NSTEPS) = 7500
NUMBER OF SOIL MATERIALS ...............(NMAT) = 3
NUMBER OF SOIL LAYERS .................(NLAYR) = 3
NUMBER OF BOUNDARY COND. TIME VALUES ....(NBC) = 1
NUMBER OF OUTPUT TIME VALUES .........(NPRINT) = 7
NUMBER OF OBSERVATION POINTS ...........(NOBS) = 1
SOIL DEPTH ...........................(TDEPTH) = 11.2
GROUNDWATER SOLUTE CONCENTRATION ........(CNN) = 0.000

PROBLEM GEOMETRY
==============

LAYER NUMBER ......... 1
MATERIAL INDEX .........................(MATL) = 1
LAYER THICKNESS .......................(THICK) = 0.700
BEGINNING DEPTH ........................(TOPL) = 0.000
ENDING DEPTH ...........................(BOTL) = 0.700
NODAL SPACING ..........................(DELZ) = 0.233

LAYER NUMBER ......... 2
MATERIAL INDEX .........................(MATL) = 2
LAYER THICKNESS .......................(THICK) = 3.11
BEGINNING DEPTH ........................(TOPL) = 0.700
ENDING DEPTH ...........................(BOTL) = 3.81
NODAL SPACING ..........................(DELZ) = 0.239

LAYER NUMBER ......... 3
MATERIAL INDEX ..........................(MATL) = 3
LAYER THICKNESS ........................(THICK) = 7.35
BEGINNING DEPTH ........................(TOPL) = 3.81
ENDING DEPTH ............................(BOTL) = 11.2
NODAL SPACING ...........................(DELZ) = 0.245

SOIL HYDRAULIC AND TRANSPORT PROPERTIES

HYDRAULIC PROPERTIES FOR MATERIAL: 1

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.6810 | 1.1700 | 0.4750 | 0.0900 | 9.855E+01 |

HYDRAULIC PROPERTIES FOR MATERIAL: 2

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.9250 | 1.1500 | 0.4790 | 0.0560 | 3.285E+00 |

HYDRAULIC PROPERTIES FOR MATERIAL: 3

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 13.8000 | 1.6900 | 0.4370 | 0.0200 | 3.650E+03 |

TRANSPORT PROPERTIES FOR MATERIAL: 1

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 7.748 |

TRANSPORT PROPERTIES FOR MATERIAL: 2

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 8.840 |

TRANSPORT PROPERTIES FOR MATERIAL: 3

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 0.133 |

MAXIMUM VALUE OF GRID PÈCLET NUMBER IS 2.450 FOR LAYER NO. 3

BOUNDARY CONDITION DATA

| TIME | IRTYP | IDRTYP | BCN1 | BCNN | CN1 | POTET |
|---|---|---|---|---|---|---|
| 0.000 | 1 | 0 | 0.058 | 0.000 | 0.000 | 0.000 |

OUTPUT TIME VALUES

0.500E+01 0.100E+02 0.250E+02 0.300E+02 0.350E+02 0.500E+02 0.900E+02

OBSERVATION POINT COORDINATES

11.159

INITIAL CONDITIONS
================

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.482E-01 | 0.4050 | 0.000E+00 | 0.23 | -7.879E-01 | 0.4123 | 0.000E+00 |
| 0.47 | -5.997E-01 | 0.4225 | 0.000E+00 | 0.70 | -3.897E-01 | 0.4368 | 0.000E+00 |
| 0.94 | -1.835E-01 | 0.4576 | 0.000E+00 | 1.18 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.42 | -1.835E-01 | 0.4576 | 0.000E+00 | 1.66 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.90 | -1.835E-01 | 0.4576 | 0.000E+00 | 2.14 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 2.37 | -1.835E-01 | 0.4576 | 0.000E+00 | 2.61 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 2.85 | -1.844E-01 | 0.4575 | 0.000E+00 | 3.09 | -1.920E-01 | 0.4567 | 0.000E+00 |
| 3.33 | -2.611E-01 | 0.4497 | 0.000E+00 | 3.57 | -6.737E-01 | 0.4197 | 0.000E+00 |
| 3.81 | -8.631E-01 | 0.0950 | 9.110E-02 | 4.06 | -8.631E-01 | 0.0950 | 9.110E-02 |
| 4.30 | -8.631E-01 | 0.0950 | 0.000E+00 | 4.55 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 4.79 | -8.631E-01 | 0.0950 | 0.000E+00 | 5.04 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 5.28 | -8.631E-01 | 0.0950 | 0.000E+00 | 5.53 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 5.77 | -8.631E-01 | 0.0950 | 0.000E+00 | 6.02 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 6.26 | -8.631E-01 | 0.0950 | 0.000E+00 | 6.51 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 6.75 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.00 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 7.24 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.49 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 7.73 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.98 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 8.22 | -8.631E-01 | 0.0950 | 0.000E+00 | 8.47 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 8.71 | -8.631E-01 | 0.0950 | 0.000E+00 | 8.96 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 9.20 | -8.614E-01 | 0.0951 | 0.000E+00 | 9.44 | -8.597E-01 | 0.0952 | 0.000E+00 |
| 9.69 | -8.564E-01 | 0.0954 | 0.000E+00 | 9.93 | -8.399E-01 | 0.0964 | 0.000E+00 |
| 10.18 | -7.965E-01 | 0.0992 | 0.000E+00 | 10.42 | -6.788E-01 | 0.1083 | 0.000E+00 |
| 10.67 | -4.852E-01 | 0.1305 | 0.000E+00 | 10.91 | -2.339E-01 | 0.1962 | 0.000E+00 |
| 11.16 | -8.691E-10 | 0.4370 | 0.000E+00 | | | | |

INITIAL MOISTURE IN PROFILE : 2.44
INITIAL SALT IN PROFILE : 0.125E-01

STEADY STATE FLOW SOLUTION PERFORMED IN 1 ITERATIONS

****************************** TIME = 5.000E+00 ******************************

ISTEP = 32 RAIN = 5.844E-02 TRAIN = 2.948E-01 CIN = 0.000E+00
DELT = 1.010E+00 DRAIN = 5.844E-02 TDRAIN = 2.948E-01 SLTIN =-1.839E-62
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT=-6.585E-15
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.248E-02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.1784 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 8.888E-46 | 0.23 | -7.796E-01 | 0.4127 | 4.839E-43 |
| 0.47 | -5.923E-01 | 0.4229 | 4.689E-40 | 0.70 | -3.823E-01 | 0.4374 | 3.656E-37 |
| 0.94 | -1.756E-01 | 0.4585 | 2.482E-34 | 1.18 | -1.753E-01 | 0.4585 | 1.678E-31 |
| 1.42 | -1.750E-01 | 0.4585 | 1.135E-28 | 1.66 | -1.747E-01 | 0.4586 | 6.034E-26 |
| 1.90 | -1.744E-01 | 0.4586 | 3.024E-23 | 2.14 | -1.741E-01 | 0.4586 | 1.409E-20 |
| 2.37 | -1.739E-01 | 0.4586 | 5.992E-18 | 2.61 | -1.736E-01 | 0.4587 | 2.269E-15 |
| 2.85 | -1.741E-01 | 0.4586 | 7.398E-13 | 3.09 | -1.818E-01 | 0.4578 | 1.985E-10 |
| 3.33 | -2.505E-01 | 0.4507 | 4.211E-08 | 3.57 | -6.657E-01 | 0.4202 | 7.145E-06 |
| 3.81 | -8.544E-01 | 0.0955 | 3.368E-04 | 4.06 | -8.550E-01 | 0.0955 | 4.759E-03 |
| 4.30 | -8.555E-01 | 0.0955 | 1.627E-02 | 4.55 | -8.560E-01 | 0.0954 | 3.008E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 3.737E-02 | 5.04 | -8.571E-01 | 0.0954 | 3.474E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 2.579E-02 | 5.53 | -8.582E-01 | 0.0953 | 1.600E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 8.587E-03 | 6.02 | -8.592E-01 | 0.0952 | 4.090E-03 |
| 6.26 | -8.598E-01 | 0.0952 | 1.766E-03 | 6.51 | -8.603E-01 | 0.0952 | 7.031E-04 |
| 6.75 | -8.609E-01 | 0.0951 | 2.616E-04 | 7.00 | -8.614E-01 | 0.0951 | 9.202E-05 |
| 7.24 | -8.619E-01 | 0.0951 | 3.089E-05 | 7.49 | -8.625E-01 | 0.0950 | 9.970E-06 |
| 7.73 | -8.630E-01 | 0.0950 | 3.115E-06 | 7.98 | -8.635E-01 | 0.0950 | 9.467E-07 |
| 8.22 | -8.641E-01 | 0.0949 | 2.812E-07 | 8.47 | -8.646E-01 | 0.0949 | 8.194E-08 |
| 8.71 | -8.651E-01 | 0.0949 | 2.349E-08 | 8.96 | -8.657E-01 | 0.0948 | 6.642E-09 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9.20 | -8.653E-01 | 0.0949 | 1.857E-09 | 9.44 | -8.632E-01 | 0.0950 | 5.137E-10 |
| 9.69 | -8.585E-01 | 0.0953 | 1.409E-10 | 9.93 | -8.435E-01 | 0.0962 | 3.827E-11 |
| 10.18 | -7.990E-01 | 0.0990 | 1.026E-11 | 10.42 | -6.846E-01 | 0.1077 | 2.677E-12 |
| 10.67 | -4.858E-01 | 0.1304 | 6.584E-13 | 10.91 | -2.450E-01 | 0.1913 | 1.363E-13 |
| 11.16 | 0.000E+00 | 0.4370 | 1.363E-13 | | | | |

****************************** TIME = 1.000E+01 ******************************

ISTEP = 37 RAIN = 5.844E-02 TRAIN = 6.351E-01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 6.351E-01 SLTIN =-7.014E-58
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT=-1.174E-09
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.248E-02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.1784 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 5.500E-42 | 0.23 | -7.796E-01 | 0.4127 | 1.757E-39 |
| 0.47 | -5.923E-01 | 0.4229 | 1.488E-36 | 0.70 | -3.823E-01 | 0.4374 | 1.013E-33 |
| 0.94 | -1.756E-01 | 0.4585 | 5.992E-31 | 1.18 | -1.753E-01 | 0.4585 | 2.645E-28 |
| 1.42 | -1.750E-01 | 0.4585 | 8.210E-26 | 1.66 | -1.747E-01 | 0.4586 | 2.382E-23 |
| 1.90 | -1.744E-01 | 0.4586 | 6.382E-21 | 2.14 | -1.741E-01 | 0.4586 | 1.554E-18 |
| 2.37 | -1.739E-01 | 0.4586 | 3.369E-16 | 2.61 | -1.736E-01 | 0.4587 | 6.323E-14 |
| 2.85 | -1.741E-01 | 0.4586 | 9.864E-12 | 3.09 | -1.818E-01 | 0.4578 | 1.207E-09 |
| 3.33 | -2.505E-01 | 0.4507 | 1.083E-07 | 3.57 | -6.657E-01 | 0.4202 | 6.718E-06 |
| 3.81 | -8.544E-01 | 0.0955 | 7.824E-06 | 4.06 | -8.550E-01 | 0.0955 | 4.375E-05 |
| 4.30 | -8.555E-01 | 0.0955 | 3.278E-04 | 4.55 | -8.560E-01 | 0.0954 | 1.494E-03 |
| 4.79 | -8.566E-01 | 0.0954 | 4.522E-03 | 5.04 | -8.571E-01 | 0.0954 | 9.949E-03 |
| 5.28 | -8.576E-01 | 0.0953 | 1.692E-02 | 5.53 | -8.582E-01 | 0.0953 | 2.325E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 2.670E-02 | 6.02 | -8.592E-01 | 0.0952 | 2.634E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 2.281E-02 | 6.51 | -8.603E-01 | 0.0952 | 1.767E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 1.244E-02 | 7.00 | -8.614E-01 | 0.0951 | 8.052E-03 |
| 7.24 | -8.619E-01 | 0.0951 | 4.850E-03 | 7.49 | -8.625E-01 | 0.0950 | 2.742E-03 |
| 7.73 | -8.630E-01 | 0.0950 | 1.467E-03 | 7.98 | -8.635E-01 | 0.0950 | 7.479E-04 |
| 8.22 | -8.641E-01 | 0.0949 | 3.652E-04 | 8.47 | -8.646E-01 | 0.0949 | 1.717E-04 |
| 8.71 | -8.651E-01 | 0.0949 | 7.802E-05 | 8.96 | -8.657E-01 | 0.0948 | 3.440E-05 |
| 9.20 | -8.653E-01 | 0.0949 | 1.476E-05 | 9.44 | -8.632E-01 | 0.0950 | 6.181E-06 |
| 9.69 | -8.585E-01 | 0.0953 | 2.530E-06 | 9.93 | -8.435E-01 | 0.0962 | 1.013E-06 |
| 10.18 | -7.990E-01 | 0.0990 | 3.960E-07 | 10.42 | -6.846E-01 | 0.1077 | 1.493E-07 |
| 10.67 | -4.858E-01 | 0.1304 | 5.287E-08 | 10.91 | -2.450E-01 | 0.1913 | 1.566E-08 |
| 11.16 | 0.000E+00 | 0.4370 | 1.566E-08 | | | | |

****************************** TIME = 2.500E+01 ******************************

ISTEP = 50 RAIN = 5.844E-02 TRAIN = 1.520E+00 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 1.520E+00 SLTIN = 2.721E-53
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 2.995E-04
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.218E-02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: -0.1828 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.097E-36 | 0.23 | -7.796E-01 | 0.4127 | 1.688E-34 |
| 0.47 | -5.923E-01 | 0.4229 | 1.429E-31 | 0.70 | -3.823E-01 | 0.4374 | 9.726E-29 |
| 0.94 | -1.756E-01 | 0.4585 | 1.591E-26 | 1.18 | -1.753E-01 | 0.4585 | 2.391E-24 |
| 1.42 | -1.750E-01 | 0.4585 | 3.302E-22 | 1.66 | -1.747E-01 | 0.4586 | 4.144E-20 |
| 1.90 | -1.744E-01 | 0.4586 | 4.663E-18 | 2.14 | -1.741E-01 | 0.4586 | 4.629E-16 |
| 2.37 | -1.739E-01 | 0.4586 | 3.970E-14 | 2.61 | -1.736E-01 | 0.4587 | 2.858E-12 |
| 2.85 | -1.741E-01 | 0.4586 | 1.659E-10 | 3.09 | -1.818E-01 | 0.4578 | 7.332E-09 |
| 3.33 | -2.505E-01 | 0.4507 | 2.313E-07 | 3.57 | -6.657E-01 | 0.4202 | 4.935E-06 |
| 3.81 | -8.544E-01 | 0.0955 | 5.043E-06 | 4.06 | -8.550E-01 | 0.0955 | 5.167E-06 |
| 4.30 | -8.555E-01 | 0.0955 | 5.294E-06 | 4.55 | -8.560E-01 | 0.0954 | 5.426E-06 |
| 4.79 | -8.566E-01 | 0.0954 | 5.580E-06 | 5.04 | -8.571E-01 | 0.0954 | 5.858E-06 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5.28 | -8.576E-01 | 0.0953 | 6.763E-06 | 5.53 | -8.582E-01 | 0.0953 | 1.027E-05 |
| 5.77 | -8.587E-01 | 0.0953 | 2.266E-05 | 6.02 | -8.592E-01 | 0.0952 | 6.060E-05 |
| 6.26 | -8.598E-01 | 0.0952 | 1.610E-04 | 6.51 | -8.603E-01 | 0.0952 | 3.923E-04 |
| 6.75 | -8.609E-01 | 0.0951 | 8.608E-04 | 7.00 | -8.614E-01 | 0.0951 | 1.700E-03 |
| 7.24 | -8.619E-01 | 0.0951 | 3.035E-03 | 7.49 | -8.625E-01 | 0.0950 | 4.934E-03 |
| 7.73 | -8.630E-01 | 0.0950 | 7.343E-03 | 7.98 | -8.635E-01 | 0.0950 | 1.007E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 1.278E-02 | 8.47 | -8.646E-01 | 0.0949 | 1.509E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 1.668E-02 | 8.96 | -8.657E-01 | 0.0948 | 1.731E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 1.694E-02 | 9.44 | -8.632E-01 | 0.0950 | 1.570E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 1.382E-02 | 9.93 | -8.435E-01 | 0.0962 | 1.159E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 9.268E-03 | 10.42 | -6.846E-01 | 0.1077 | 7.049E-03 |
| 10.67 | -4.858E-01 | 0.1304 | 5.039E-03 | 10.91 | -2.450E-01 | 0.1913 | 3.114E-03 |
| 11.16 | 0.000E+00 | 0.4370 | 3.114E-03 | | | | |

****************************** TIME = 3.000E+01 ******************************

ISTEP = 54 RAIN = 5.844E-02 TRAIN = 1.792E+00 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 1.792E+00 SLTIN =-1.358E-51
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.892E-03
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.058E-02
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
„ „ SOLUTE: -0.2104 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 3.164E-35 | 0.23 | -7.796E-01 | 0.4127 | 5.340E-33 |
| 0.47 | -5.923E-01 | 0.4229 | 4.523E-30 | 0.70 | -3.823E-01 | 0.4374 | 8.442E-28 |
| 0.94 | -1.756E-01 | 0.4585 | 1.154E-25 | 1.18 | -1.753E-01 | 0.4585 | 1.450E-23 |
| 1.42 | -1.750E-01 | 0.4585 | 1.670E-21 | 1.66 | -1.747E-01 | 0.4586 | 1.742E-19 |
| 1.90 | -1.744E-01 | 0.4586 | 1.626E-17 | 2.14 | -1.741E-01 | 0.4586 | 1.335E-15 |
| 2.37 | -1.739E-01 | 0.4586 | 9.456E-14 | 2.61 | -1.736E-01 | 0.4587 | 5.611E-12 |
| 2.85 | -1.741E-01 | 0.4586 | 2.682E-10 | 3.09 | -1.818E-01 | 0.4578 | 9.754E-09 |
| 3.33 | -2.505E-01 | 0.4507 | 2.534E-07 | 3.57 | -6.657E-01 | 0.4202 | 4.463E-06 |
| 3.81 | -8.544E-01 | 0.0955 | 4.559E-06 | 4.06 | -8.550E-01 | 0.0955 | 4.670E-06 |
| 4.30 | -8.555E-01 | 0.0955 | 4.783E-06 | 4.55 | -8.560E-01 | 0.0954 | 4.900E-06 |
| 4.79 | -8.566E-01 | 0.0954 | 5.020E-06 | 5.04 | -8.571E-01 | 0.0954 | 5.144E-06 |
| 5.28 | -8.576E-01 | 0.0953 | 5.283E-06 | 5.53 | -8.582E-01 | 0.0953 | 5.485E-06 |
| 5.77 | -8.587E-01 | 0.0953 | 5.951E-06 | 6.02 | -8.592E-01 | 0.0952 | 7.406E-06 |
| 6.26 | -8.598E-01 | 0.0952 | 1.205E-05 | 6.51 | -8.603E-01 | 0.0952 | 2.566E-05 |
| 6.75 | -8.609E-01 | 0.0951 | 6.142E-05 | 7.00 | -8.614E-01 | 0.0951 | 1.455E-04 |
| 7.24 | -8.619E-01 | 0.0951 | 3.231E-04 | 7.49 | -8.625E-01 | 0.0950 | 6.619E-04 |
| 7.73 | -8.630E-01 | 0.0950 | 1.248E-03 | 7.98 | -8.635E-01 | 0.0950 | 2.171E-03 |
| 8.22 | -8.641E-01 | 0.0949 | 3.497E-03 | 8.47 | -8.646E-01 | 0.0949 | 5.236E-03 |
| 8.71 | -8.651E-01 | 0.0949 | 7.317E-03 | 8.96 | -8.657E-01 | 0.0948 | 9.579E-03 |
| 9.20 | -8.653E-01 | 0.0949 | 1.179E-02 | 9.44 | -8.632E-01 | 0.0950 | 1.370E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 1.506E-02 | 9.93 | -8.435E-01 | 0.0962 | 1.572E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 1.561E-02 | 10.42 | -6.846E-01 | 0.1077 | 1.474E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 1.319E-02 | 10.91 | -2.450E-01 | 0.1913 | 1.053E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 1.053E-02 | | | | |

****************************** TIME = 3.500E+01 ******************************

ISTEP = 58 RAIN = 5.844E-02 TRAIN = 2.064E+00 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 2.064E+00 SLTIN = 1.687E-50
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 5.387E-03
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 7.089E-03
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
„ „ SOLUTE: -0.3144 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 3.296E-34 | 0.23 | -7.796E-01 | 0.4127 | 4.080E-32 |
| 0.47 | -5.923E-01 | 0.4229 | 3.456E-29 | 0.70 | -3.823E-01 | 0.4374 | 5.066E-27 |
| 0.94 | -1.756E-01 | 0.4585 | 5.967E-25 | 1.18 | -1.753E-01 | 0.4585 | 6.440E-23 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1.42 | -1.750E-01 | 0.4585 | 6.358E-21 | 1.66 | -1.747E-01 | 0.4586 | 5.678E-19 |
| 1.90 | -1.744E-01 | 0.4586 | 4.527E-17 | 2.14 | -1.741E-01 | 0.4586 | 3.173E-15 |
| 2.37 | -1.739E-01 | 0.4586 | 1.914E-13 | 2.61 | -1.736E-01 | 0.4587 | 9.667E-12 |
| 2.85 | -1.741E-01 | 0.4586 | 3.929E-10 | 3.09 | -1.818E-01 | 0.4578 | 1.215E-08 |
| 3.33 | -2.505E-01 | 0.4507 | 2.687E-07 | 3.57 | -6.657E-01 | 0.4202 | 4.039E-06 |
| 3.81 | -8.544E-01 | 0.0955 | 4.126E-06 | 4.06 | -8.550E-01 | 0.0955 | 4.225E-06 |
| 4.30 | -8.555E-01 | 0.0955 | 4.326E-06 | 4.55 | -8.560E-01 | 0.0954 | 4.431E-06 |
| 4.79 | -8.566E-01 | 0.0954 | 4.538E-06 | 5.04 | -8.571E-01 | 0.0954 | 4.647E-06 |
| 5.28 | -8.576E-01 | 0.0953 | 4.760E-06 | 5.53 | -8.582E-01 | 0.0953 | 4.877E-06 |
| 5.77 | -8.587E-01 | 0.0953 | 5.003E-06 | 6.02 | -8.592E-01 | 0.0952 | 5.156E-06 |
| 6.26 | -8.598E-01 | 0.0952 | 5.413E-06 | 6.51 | -8.603E-01 | 0.0952 | 6.027E-06 |
| 6.75 | -8.609E-01 | 0.0951 | 7.754E-06 | 7.00 | -8.614E-01 | 0.0951 | 1.258E-05 |
| 7.24 | -8.619E-01 | 0.0951 | 2.515E-05 | 7.49 | -8.625E-01 | 0.0950 | 5.518E-05 |
| 7.73 | -8.630E-01 | 0.0950 | 1.208E-04 | 7.98 | -8.635E-01 | 0.0950 | 2.522E-04 |
| 8.22 | -8.641E-01 | 0.0949 | 4.943E-04 | 8.47 | -8.646E-01 | 0.0949 | 9.053E-04 |
| 8.71 | -8.651E-01 | 0.0949 | 1.551E-03 | 8.96 | -8.657E-01 | 0.0948 | 2.488E-03 |
| 9.20 | -8.653E-01 | 0.0949 | 3.752E-03 | 9.44 | -8.632E-01 | 0.0950 | 5.330E-03 |
| 9.69 | -8.585E-01 | 0.0953 | 7.155E-03 | 9.93 | -8.435E-01 | 0.0962 | 9.102E-03 |
| 10.18 | -7.990E-01 | 0.0990 | 1.101E-02 | 10.42 | -6.846E-01 | 0.1077 | 1.269E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 1.398E-02 | 10.91 | -2.450E-01 | 0.1913 | 1.441E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 1.441E-02 | | | | |

****************************** TIME = 5.000E+01 ******************************

ISTEP = 71 RAIN = 5.844E-02 TRAIN = 2.949E+00 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 2.949E+00 SLTIN =-1.176E-47
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.229E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.897E-04
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
,, ,, SOLUTE: -13.2699 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.123E-31 | 0.23 | -7.796E-01 | 0.4127 | 2.101E-29 |
| 0.47 | -5.923E-01 | 0.4229 | 2.918E-27 | 0.70 | -3.823E-01 | 0.4374 | 2.969E-25 |
| 0.94 | -1.756E-01 | 0.4585 | 2.455E-23 | 1.18 | -1.753E-01 | 0.4585 | 1.850E-21 |
| 1.42 | -1.750E-01 | 0.4585 | 1.273E-19 | 1.66 | -1.747E-01 | 0.4586 | 7.897E-18 |
| 1.90 | -1.744E-01 | 0.4586 | 4.367E-16 | 2.14 | -1.741E-01 | 0.4586 | 2.119E-14 |
| 2.37 | -1.739E-01 | 0.4586 | 8.838E-13 | 2.61 | -1.736E-01 | 0.4587 | 3.084E-11 |
| 2.85 | -1.741E-01 | 0.4586 | 8.662E-10 | 3.09 | -1.818E-01 | 0.4578 | 1.855E-08 |
| 3.33 | -2.505E-01 | 0.4507 | 2.854E-07 | 3.57 | -6.657E-01 | 0.4202 | 3.014E-06 |
| 3.81 | -8.544E-01 | 0.0955 | 3.076E-06 | 4.06 | -8.550E-01 | 0.0955 | 3.148E-06 |
| 4.30 | -8.555E-01 | 0.0955 | 3.221E-06 | 4.55 | -8.560E-01 | 0.0954 | 3.296E-06 |
| 4.79 | -8.566E-01 | 0.0954 | 3.373E-06 | 5.04 | -8.571E-01 | 0.0954 | 3.453E-06 |
| 5.28 | -8.576E-01 | 0.0953 | 3.534E-06 | 5.53 | -8.582E-01 | 0.0953 | 3.617E-06 |
| 5.77 | -8.587E-01 | 0.0953 | 3.703E-06 | 6.02 | -8.592E-01 | 0.0952 | 3.790E-06 |
| 6.26 | -8.598E-01 | 0.0952 | 3.880E-06 | 6.51 | -8.603E-01 | 0.0952 | 3.973E-06 |
| 6.75 | -8.609E-01 | 0.0951 | 4.068E-06 | 7.00 | -8.614E-01 | 0.0951 | 4.165E-06 |
| 7.24 | -8.619E-01 | 0.0951 | 4.265E-06 | 7.49 | -8.625E-01 | 0.0950 | 4.370E-06 |
| 7.73 | -8.630E-01 | 0.0950 | 4.483E-06 | 7.98 | -8.635E-01 | 0.0950 | 4.615E-06 |
| 8.22 | -8.641E-01 | 0.0949 | 4.801E-06 | 8.47 | -8.646E-01 | 0.0949 | 5.128E-06 |
| 8.71 | -8.651E-01 | 0.0949 | 5.814E-06 | 8.96 | -8.657E-01 | 0.0948 | 7.350E-06 |
| 9.20 | -8.653E-01 | 0.0949 | 1.077E-05 | 9.44 | -8.632E-01 | 0.0950 | 1.814E-05 |
| 9.69 | -8.585E-01 | 0.0953 | 3.320E-05 | 9.93 | -8.435E-01 | 0.0962 | 6.252E-05 |
| 10.18 | -7.990E-01 | 0.0990 | 1.169E-04 | 10.42 | -6.846E-01 | 0.1077 | 2.167E-04 |
| 10.67 | -4.858E-01 | 0.1304 | 3.874E-04 | 10.91 | -2.450E-01 | 0.1913 | 8.596E-04 |
| 11.16 | 0.000E+00 | 0.4370 | 8.596E-04 | | | | |

****************************** TIME = 9.000E+01 ******************************

ISTEP = 105 RAIN = 5.844E-02 TRAIN = 5.262E+00 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 5.262E+00 SLTIN =-9.582E-44
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.247E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 9.733E-06
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %

" " SOLUTE: -13.2699 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 7.136E-28 | 0.23 | -7.796E-01 | 0.4127 | 3.781E-26 |
| 0.47 | -5.923E-01 | 0.4229 | 2.822E-24 | 0.70 | -3.823E-01 | 0.4374 | 1.597E-22 |
| 0.94 | -1.756E-01 | 0.4585 | 7.350E-21 | 1.18 | -1.753E-01 | 0.4585 | 3.052E-19 |
| 1.42 | -1.750E-01 | 0.4585 | 1.157E-17 | 1.66 | -1.747E-01 | 0.4586 | 3.954E-16 |
| 1.90 | -1.744E-01 | 0.4586 | 1.203E-14 | 2.14 | -1.741E-01 | 0.4586 | 3.214E-13 |
| 2.37 | -1.739E-01 | 0.4586 | 7.387E-12 | 2.61 | -1.736E-01 | 0.4587 | 1.424E-10 |
| 2.85 | -1.741E-01 | 0.4586 | 2.219E-09 | 3.09 | -1.818E-01 | 0.4578 | 2.661E-08 |
| 3.33 | -2.505E-01 | 0.4507 | 2.329E-07 | 3.57 | -6.657E-01 | 0.4202 | 1.438E-06 |
| 3.81 | -8.544E-01 | 0.0955 | 1.466E-06 | 4.06 | -8.550E-01 | 0.0955 | 1.497E-06 |
| 4.30 | -8.555E-01 | 0.0955 | 1.529E-06 | 4.55 | -8.560E-01 | 0.0954 | 1.562E-06 |
| 4.79 | -8.566E-01 | 0.0954 | 1.596E-06 | 5.04 | -8.571E-01 | 0.0954 | 1.631E-06 |
| 5.28 | -8.576E-01 | 0.0953 | 1.666E-06 | 5.53 | -8.582E-01 | 0.0953 | 1.702E-06 |
| 5.77 | -8.587E-01 | 0.0953 | 1.739E-06 | 6.02 | -8.592E-01 | 0.0952 | 1.777E-06 |
| 6.26 | -8.598E-01 | 0.0952 | 1.816E-06 | 6.51 | -8.603E-01 | 0.0952 | 1.856E-06 |
| 6.75 | -8.609E-01 | 0.0951 | 1.897E-06 | 7.00 | -8.614E-01 | 0.0951 | 1.939E-06 |
| 7.24 | -8.619E-01 | 0.0951 | 1.982E-06 | 7.49 | -8.625E-01 | 0.0950 | 2.026E-06 |
| 7.73 | -8.630E-01 | 0.0950 | 2.071E-06 | 7.98 | -8.635E-01 | 0.0950 | 2.117E-06 |
| 8.22 | -8.641E-01 | 0.0949 | 2.164E-06 | 8.47 | -8.646E-01 | 0.0949 | 2.212E-06 |
| 8.71 | -8.651E-01 | 0.0949 | 2.262E-06 | 8.96 | -8.657E-01 | 0.0948 | 2.313E-06 |
| 9.20 | -8.653E-01 | 0.0949 | 2.365E-06 | 9.44 | -8.632E-01 | 0.0950 | 2.418E-06 |
| 9.69 | -8.585E-01 | 0.0953 | 2.473E-06 | 9.93 | -8.435E-01 | 0.0962 | 2.529E-06 |
| 10.18 | -7.990E-01 | 0.0990 | 2.587E-06 | 10.42 | -6.846E-01 | 0.1077 | 2.649E-06 |
| 10.67 | -4.858E-01 | 0.1304 | 2.715E-06 | 10.91 | -2.450E-01 | 0.1913 | 2.808E-06 |
| 11.16 | 0.000E+00 | 0.4370 | 2.808E-06 | | | | |

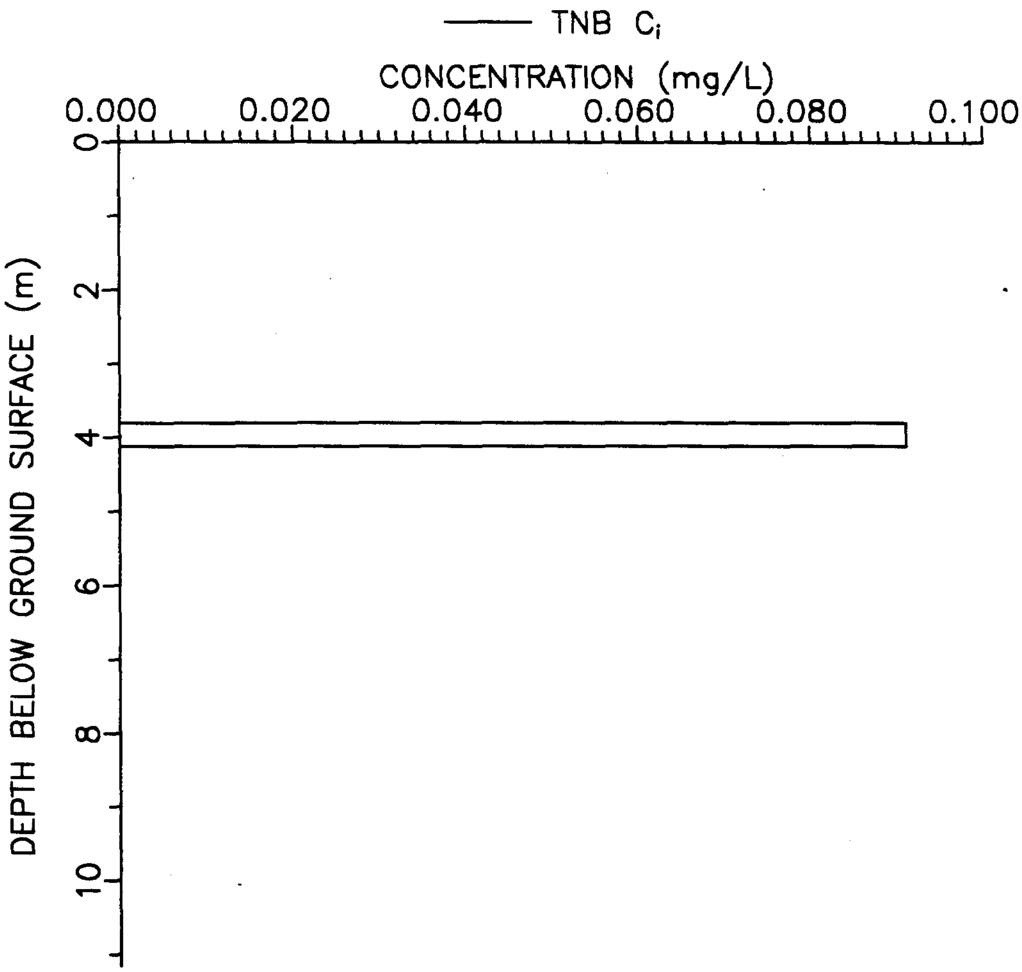
****************************** TIME = 1.000E+03 ******************************

ISTEP = 887 RAIN = 5.844E-02 TRAIN = 5.848E+01 CIN = 0.000E+00
DELT = 1.164E+00 DRAIN = 5.844E-02 TDRAIN = 5.848E+01 SLTIN = 2.501E-35
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 1.248E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.739E-10
QDECAY= 0.000E+00

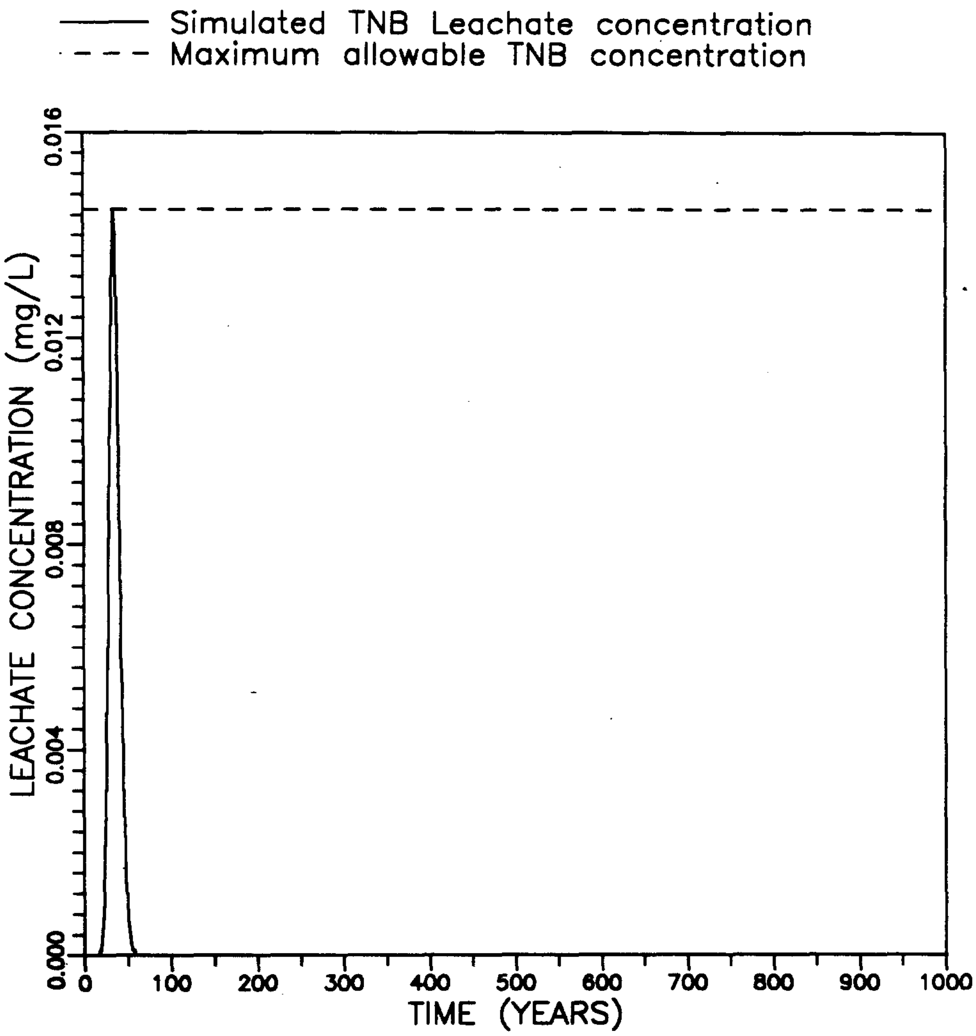
MASS BALANCE ERROR WATER : 0.0000 %
" " SOLUTE: -13.2699 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 7.664E-21 | 0.23 | -7.796E-01 | 0.4127 | 9.196E-20 |
| 0.47 | -5.923E-01 | 0.4229 | 8.372E-19 | 0.70 | -3.823E-01 | 0.4374 | 6.062E-18 |
| 0.94 | -1.756E-01 | 0.4585 | 3.710E-17 | 1.18 | -1.753E-01 | 0.4585 | 1.845E-16 |
| 1.42 | -1.750E-01 | 0.4585 | 8.542E-16 | 1.66 | -1.747E-01 | 0.4586 | 3.705E-15 |
| 1.90 | -1.744E-01 | 0.4586 | 1.503E-14 | 2.14 | -1.741E-01 | 0.4586 | 5.677E-14 |
| 2.37 | -1.739E-01 | 0.4586 | 1.984E-13 | 2.61 | -1.736E-01 | 0.4587 | 6.365E-13 |
| 2.85 | -1.741E-01 | 0.4586 | 1.849E-12 | 3.09 | -1.818E-01 | 0.4578 | 4.770E-12 |
| 3.33 | -2.505E-01 | 0.4507 | 1.072E-11 | 3.57 | -6.657E-01 | 0.4202 | 2.078E-11 |
| 3.81 | -8.544E-01 | 0.0955 | 2.101E-11 | 4.06 | -8.550E-01 | 0.0955 | 2.126E-11 |
| 4.30 | -8.555E-01 | 0.0955 | 2.152E-11 | 4.55 | -8.560E-01 | 0.0954 | 2.179E-11 |
| 4.79 | -8.566E-01 | 0.0954 | 2.206E-11 | 5.04 | -8.571E-01 | 0.0954 | 2.233E-11 |
| 5.28 | -8.576E-01 | 0.0953 | 2.260E-11 | 5.53 | -8.582E-01 | 0.0953 | 2.288E-11 |
| 5.77 | -8.587E-01 | 0.0953 | 2.316E-11 | 6.02 | -8.592E-01 | 0.0952 | 2.344E-11 |
| 6.26 | -8.598E-01 | 0.0952 | 2.373E-11 | 6.51 | -8.603E-01 | 0.0952 | 2.402E-11 |
| 6.75 | -8.609E-01 | 0.0951 | 2.431E-11 | 7.00 | -8.614E-01 | 0.0951 | 2.461E-11 |
| 7.24 | -8.619E-01 | 0.0951 | 2.491E-11 | 7.49 | -8.625E-01 | 0.0950 | 2.522E-11 |
| 7.73 | -8.630E-01 | 0.0950 | 2.553E-11 | 7.98 | -8.635E-01 | 0.0950 | 2.584E-11 |
| 8.22 | -8.641E-01 | 0.0949 | 2.616E-11 | 8.47 | -8.646E-01 | 0.0949 | 2.648E-11 |
| 8.71 | -8.651E-01 | 0.0949 | 2.681E-11 | 8.96 | -8.657E-01 | 0.0948 | 2.714E-11 |
| 9.20 | -8.653E-01 | 0.0949 | 2.747E-11 | 9.44 | -8.632E-01 | 0.0950 | 2.781E-11 |
| 9.69 | -8.585E-01 | 0.0953 | 2.815E-11 | 9.93 | -8.435E-01 | 0.0962 | 2.850E-11 |
| 10.18 | -7.990E-01 | 0.0990 | 2.885E-11 | 10.42 | -6.846E-01 | 0.1077 | 2.922E-11 |
| 10.67 | -4.858E-01 | 0.1304 | 2.961E-11 | 10.91 | -2.450E-01 | 0.1913 | 3.015E-11 |
| 11.16 | 0.000E+00 | 0.4370 | 3.015E-11 | | | | |

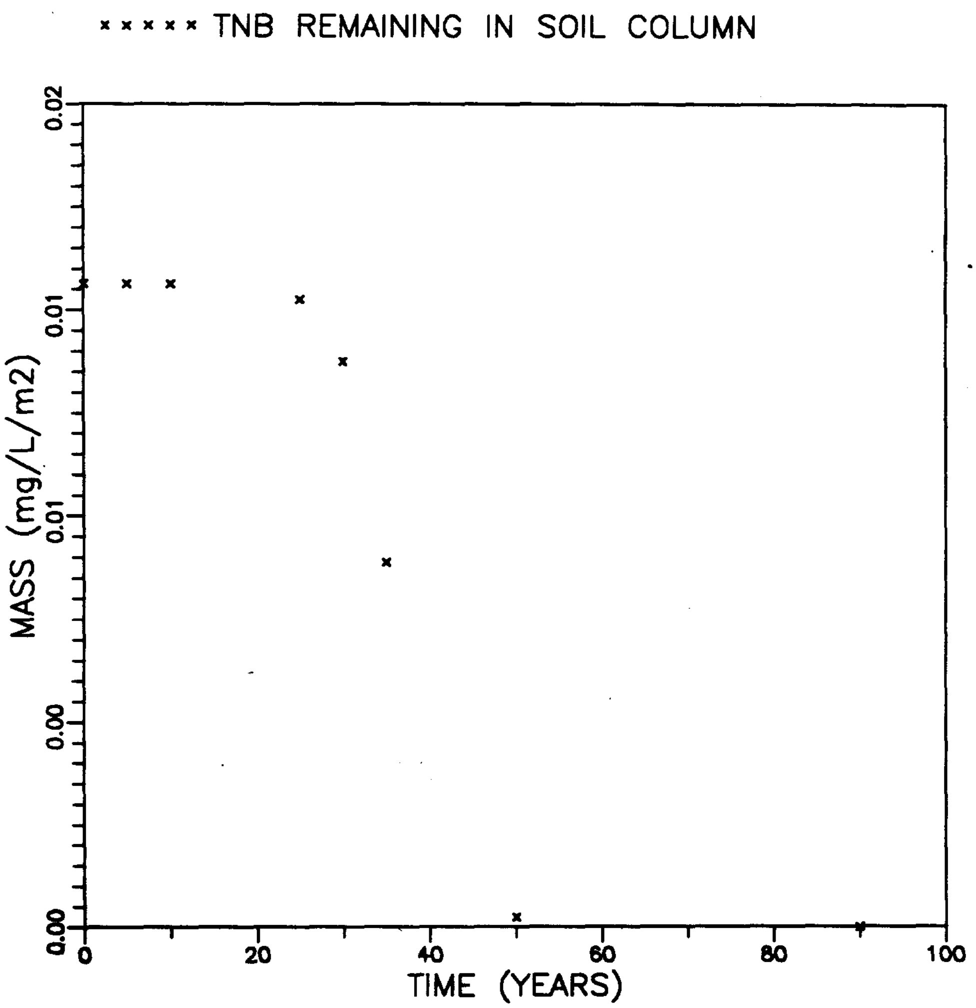
***** NORMAL TERMINATION TIME = 1000.6279 AND STEP NUMBER = 887



TNB $C_i$
CONCENTRATION (mg/L)
0.000
0.020
0.040
0.060
0.080
0.100
DEPTH BELOW GROUND SURFACE (m)
0
2
4
6
8
10



Simulated TNB Leachate concentration
Maximum allowable TNB concentration
LEACHATE CONCENTRATION (mg/L)
0.000
0.004
0.008
0.012
0.016
0
100
200
300
400
500
600
700
800
900
1000
TIME (YEARS)




B07NE003702-09280

**ATTACHMENT 2C**
**HYDRUS MODEL INPUT FILES, OUTPUT FILES**
**AND ASSOCIATED GRAPHS FOR LL2[C(1)]**

---

LL2C1, time units = years, infiltration = 2.3 in/yr
TNT, clean up to 4 ft, 78.dat

```
  1   0   0   0   0   1   1   0   0   2
7500   3   3   1   7   1      0.0
   .001   .00001   100.0   1000.   .010   .01 9900
  1   1    0.0    0.7    0.25
  2   2    0.7    3.81   0.25
  3   3    3.81   11.16  0.25
   2.681   1.17   0.475   0.090   98.55
   2.925   1.15   0.479   0.056   3.285
   13.8    1.69   0.437   0.020   3650.
  2.12e-2   0.10   1.4   0.0   0.0   12.000   1.0
  2.12e-2   0.10   1.4   0.0   0.0   13.000   1.0
  2.12e-2   0.10   1.4   0.0   0.0   0.2000   1.0
0.000E+00 -9.476E-01  0.4050  0.000E+00
2.333E-01 -7.876E-01  0.4123  0.000E+00
4.667E-01 -6.004E-01  0.4225  0.000E+00
7.000E-01 -3.903E-01  0.4368  0.000E+00
9.392E-01 -1.838E-01  0.4576  0.000E+00
1.220E+00 0.0         0.4576  0.000E+00
1.22      0.0         0.4576  0.1995
1.657E+00 -1.838E-01  0.4576  0.0720
1.83      0.0         0.4576  0.0215
1.896E+00 -1.838E-01  0.4576  0.0215
2.135E+00 -1.838E-01  0.4576  0.0215
2.375E+00 -1.838E-01  0.4576  0.0215
2.614E+00 -1.838E-01  0.4576  0.0215
2.74      0.0         0.4576  0.0215
2.853E+00 -1.845E-01  0.4575  0.0215
3.092E+00 -1.922E-01  0.4567  0.0215
3.332E+00 -2.607E-01  0.4497  0.0215
3.571E+00 -6.748E-01  0.4197  0.0215
3.810E+00 -8.628E-01  0.0950  0.0215
3.81      0.0         0.0950  1.4
4.055E+00 -8.628E-01  0.0950  1.4
4.545E+00 -8.628E-01  0.0950  1.4
5.280E+00 -8.628E-01  0.0950  1.4
5.770E+00 -8.628E-01  0.0950  1.4
6.015E+00 -8.628E-01  0.0950  1.4
6.1       0.0         0.0950  1.4
6.260E+00 -8.628E-01  0.0950  1.4
6.505E+00 -8.628E-01  0.0950  1.4
6.750E+00 -8.628E-01  0.0950  1.4
6.995E+00 -8.628E-01  0.0950  1.4
7.240E+00 -8.628E-01  0.0950  1.4
7.485E+00 -8.628E-01  0.0950  1.4
7.62      0.0         0.0950  1.4
7.730E+00 -8.628E-01  0.0950  1.4
7.975E+00 -8.628E-01  0.0950  1.4
8.220E+00 -8.628E-01  0.0950  1.4
8.465E+00 -8.628E-01  0.0950  1.4
8.955E+00 -8.625E-01  0.0950  1.4
9.200E+00 -8.621E-01  0.0951  1.4
9.445E+00 -8.605E-01  0.0952  1.4
9.690E+00 -8.557E-01  0.0954  1.4
9.935E+00 -8.407E-01  0.0964  1.4
1.018E+01 -7.961E-01  0.0992  1.4
1.042E+01 -6.837E-01  0.1078  1.4
1.067E+01 -4.851E-01  0.1305  1.4
1.091E+01 -2.450E-01  0.1913  1.4
1.116E+01  0.000E+00  0.4370  1.4
     0.0   1   0   .05844    0.0
   300.0   400.0   500.0   600.0   700.0   800.0   900.0
   11.159
```

```
*******************************************************************
*                                                         *
*        ONE-DIMENSIONAL FLOW AND TRANSPORT MODEL                 *
*                 HYDRUS  v. 3.4                              *
*                                                         *
*   DATA INPUT FILE: 78.dat                                     *
*                                                         *
*  LL2C1, time units = years, infiltration = 2.3 in/yr          *
*  TNT, clean up to 4 ft, 78.dat                              *
*                                                         *
*******************************************************************
```

PROBLEM CONTROL PARAMETERS
======================

SIMULATION CONTROL CODE ...............(ITKOD) = 1
HYSTERESIS MODELING CODE ..............(IHKOD) = 0
TRANSPORT BOUNDARY COND. CODE ........(ICOKOD) = 0
ROOT WATER UPTAKE CODE ...............(IRUKOD) = 0
CONDUCTIVITY UPSTREAM WEIGHTING ......(IUPKOD) = 0
FLOW MASS MATRIX OPTION ...............(ILKOD) = 1
FLOW INITIAL CONDITION CODE ...........(ICKOD) = 1
BOUNDARY CONDITION CODE ..............(IBCKOD) = 0
PLOT OUTPUT CODE ......................(IOKOD) = 0
RESTART OUTPUT CODE ..................(IRSKOD) = 2

TIME STEPPING PARAMETERS
======================

INITIAL TIMESTEP ......................(DELIN) = 0.100E-02
MINIMUM TIMESTEP .....................(DELMIN) = 0.100E-04
MAXIMUM TIMESTEP .....................(DELMAX) = 100.
TOTAL SIMULATION TIME .................(TMAX) = 0.100E+04
REL. PR. HEAD CONVERGENCE TOLERANCE ....(TOL1) = 0.100E-01
ABS. ,, ,, ,, ....(TOL2) = 0.100E-01
NUMBER OF NONLINEAR ITERATIONS .......(NITMAX) = 9900

PROBLEM SPECIFICATION PARAMETERS
==============================

MAXIMUM NUMBER OF TIMESTEPS ..........(NSTEPS) = 7500
NUMBER OF SOIL MATERIALS ...............(NMAT) = 3
NUMBER OF SOIL LAYERS .................(NLAYR) = 3
NUMBER OF BOUNDARY COND. TIME VALUES ....(NBC) = 1
NUMBER OF OUTPUT TIME VALUES .........(NPRINT) = 7
NUMBER OF OBSERVATION POINTS ...........(NOBS) = 1
SOIL DEPTH ..........................(TDEPTH) = 11.2
GROUNDWATER SOLUTE CONCENTRATION ........(CNN) = 0.000

PROBLEM GEOMETRY
==============

LAYER NUMBER ......... 1
MATERIAL INDEX .........................(MATL) = 1
LAYER THICKNESS .......................(THICK) = 0.700
BEGINNING DEPTH ........................(TOPL) = 0.000
ENDING DEPTH ...........................(BOTL) = 0.700
NODAL SPACING ..........................(DELZ) = 0.233

LAYER NUMBER ......... 2
MATERIAL INDEX .........................(MATL) = 2
LAYER THICKNESS .......................(THICK) = 3.11

BEGINNING DEPTH ........................(TOPL) = 0.700
ENDING DEPTH ............................(BOTL) = 3.81
NODAL SPACING ..........................(DELZ) = 0.239

LAYER NUMBER ......... 3
MATERIAL INDEX ..........................(MATL) = 3
LAYER THICKNESS .......................(THICK) = 7.35
BEGINNING DEPTH ........................(TOPL) = 3.81
ENDING DEPTH ............................(BOTL) = 11.2
NODAL SPACING ..........................(DELZ) = 0.245

SOIL HYDRAULIC AND TRANSPORT PROPERTIES
==================================

HYDRAULIC PROPERTIES FOR MATERIAL: 1

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.6810 | 1.1700 | 0.4750 | 0.0900 | 9.855E+01 |

HYDRAULIC PROPERTIES FOR MATERIAL: 2

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.9250 | 1.1500 | 0.4790 | 0.0560 | 3.285E+00 |

HYDRAULIC PROPERTIES FOR MATERIAL: 3

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 13.8000 | 1.6900 | 0.4370 | 0.0200 | 3.650E+03 |

TRANSPORT PROPERTIES FOR MATERIAL: 1

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.021 | 0.100 | 1.400 | 0.000 | 0.000 | 12.000 |

TRANSPORT PROPERTIES FOR MATERIAL: 2

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.021 | 0.100 | 1.400 | 0.000 | 0.000 | 13.000 |

TRANSPORT PROPERTIES FOR MATERIAL: 3

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.021 | 0.100 | 1.400 | 0.000 | 0.000 | 0.200 |

MAXIMUM VALUE OF GRID PECLET NUMBER IS 2.450 FOR LAYER NO. 3

BOUNDARY CONDITION DATA
=====================

| TIME | IRTYP | IDRTYP | BCN1 | BCNN | CN1 | POTET |
|---|---|---|---|---|---|---|
| 0.000 | 1 | 0 | 0.058 | 0.000 | 0.000 | 0.000 |

OUTPUT TIME VALUES
=================

0.300E+03 0.400E+03 0.500E+03 0.600E+03 0.700E+03 0.800E+03 0.900E+03

OBSERVATION POINT COORDINATES

==========================
11.159

INITIAL CONDITIONS
================

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.482E-01 | 0.4050 | 0.000E+00 | 0.23 | -7.879E-01 | 0.4123 | 0.000E+00 |
| 0.47 | -5.997E-01 | 0.4225 | 0.000E+00 | 0.70 | -3.897E-01 | 0.4368 | 0.000E+00 |
| 0.94 | -1.835E-01 | 0.4576 | 0.000E+00 | 1.18 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.42 | -1.835E-01 | 0.4576 | 1.418E-01 | 1.66 | -1.835E-01 | 0.4576 | 7.202E-02 |
| 1.90 | -1.835E-01 | 0.4576 | 2.150E-02 | 2.14 | -1.835E-01 | 0.4576 | 2.150E-02 |
| 2.37 | -1.835E-01 | 0.4576 | 2.150E-02 | 2.61 | -1.835E-01 | 0.4576 | 2.150E-02 |
| 2.85 | -1.844E-01 | 0.4575 | 2.150E-02 | 3.09 | -1.920E-01 | 0.4567 | 2.150E-02 |
| 3.33 | -2.611E-01 | 0.4497 | 2.150E-02 | 3.57 | -6.737E-01 | 0.4197 | 2.150E-02 |
| 3.81 | -8.631E-01 | 0.0950 | 1.400E+00 | 4.06 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 4.30 | -8.631E-01 | 0.0950 | 1.400E+00 | 4.55 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 4.79 | -8.631E-01 | 0.0950 | 1.400E+00 | 5.04 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 5.28 | -8.631E-01 | 0.0950 | 1.400E+00 | 5.53 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 5.77 | -8.631E-01 | 0.0950 | 1.400E+00 | 6.02 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 6.26 | -8.631E-01 | 0.0950 | 1.400E+00 | 6.51 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 6.75 | -8.631E-01 | 0.0950 | 1.400E+00 | 7.00 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 7.24 | -8.631E-01 | 0.0950 | 1.400E+00 | 7.49 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 7.73 | -8.631E-01 | 0.0950 | 1.400E+00 | 7.98 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 8.22 | -8.631E-01 | 0.0950 | 1.400E+00 | 8.47 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 8.71 | -8.631E-01 | 0.0950 | 1.400E+00 | 8.96 | -8.631E-01 | 0.0950 | 1.400E+00 |
| 9.20 | -8.614E-01 | 0.0951 | 1.400E+00 | 9.44 | -8.597E-01 | 0.0952 | 1.400E+00 |
| 9.69 | -8.564E-01 | 0.0954 | 1.400E+00 | 9.93 | -8.399E-01 | 0.0964 | 1.400E+00 |
| 10.18 | -7.965E-01 | 0.0992 | 1.400E+00 | 10.42 | -6.788E-01 | 0.1083 | 1.400E+00 |
| 10.67 | -4.852E-01 | 0.1305 | 1.400E+00 | 10.91 | -2.339E-01 | 0.1962 | 1.400E+00 |
| 11.16 | -8.691E-10 | 0.4370 | 1.400E+00 | | | | |

INITIAL MOISTURE IN PROFILE : 2.44
INITIAL SALT IN PROFILE : 5.76

STEADY STATE FLOW SOLUTION PERFORMED IN 1 ITERATIONS

****************************** TIME = 3.000E+02 ******************************

ISTEP = 222 RAIN = 5.844E-02 TRAIN = 1.756E+01 CIN = 0.000E+00
DELT = 1.556E+00 DRAIN = 5.844E-02 TDRAIN = 1.756E+01 SLTIN = 8.224E-24
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.353E+00
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.402E+00
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
" " SOLUTE: 0.0537 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.909E-08 | 0.23 | -7.796E-01 | 0.4127 | 3.197E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 4.626E-06 | 0.70 | -3.823E-01 | 0.4374 | 4.636E-05 |
| 0.94 | -1.756E-01 | 0.4585 | 3.366E-04 | 1.18 | -1.753E-01 | 0.4585 | 1.659E-03 |
| 1.42 | -1.750E-01 | 0.4585 | 5.935E-03 | 1.66 | -1.747E-01 | 0.4586 | 1.478E-02 |
| 1.90 | -1.744E-01 | 0.4586 | 2.682E-02 | 2.14 | -1.741E-01 | 0.4586 | 3.770E-02 |
| 2.37 | -1.739E-01 | 0.4586 | 4.341E-02 | 2.61 | -1.736E-01 | 0.4587 | 4.304E-02 |
| 2.85 | -1.741E-01 | 0.4586 | 3.863E-02 | 3.09 | -1.818E-01 | 0.4578 | 3.306E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 2.832E-02 | 3.57 | -6.657E-01 | 0.4202 | 2.509E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 2.503E-02 | 4.06 | -8.550E-01 | 0.0955 | 2.495E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 2.488E-02 | 4.55 | -8.560E-01 | 0.0954 | 2.481E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 2.474E-02 | 5.04 | -8.571E-01 | 0.0954 | 2.467E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 2.461E-02 | 5.53 | -8.582E-01 | 0.0953 | 2.454E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 2.447E-02 | 6.02 | -8.592E-01 | 0.0952 | 2.440E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 2.434E-02 | 6.51 | -8.603E-01 | 0.0952 | 2.428E-02 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6.75 | -8.609E-01 | 0.0951 | 2.421E-02 | 7.00 | -8.614E-01 | 0.0951 | 2.415E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 2.409E-02 | 7.49 | -8.625E-01 | 0.0950 | 2.403E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 2.397E-02 | 7.98 | -8.635E-01 | 0.0950 | 2.391E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 2.385E-02 | 8.47 | -8.646E-01 | 0.0949 | 2.379E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 2.373E-02 | 8.96 | -8.657E-01 | 0.0948 | 2.368E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 2.362E-02 | 9.44 | -8.632E-01 | 0.0950 | 2.357E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 2.351E-02 | 9.93 | -8.435E-01 | 0.0962 | 2.346E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 2.341E-02 | 10.42 | -6.846E-01 | 0.1077 | 2.335E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 2.330E-02 | 10.91 | -2.450E-01 | 0.1913 | 2.323E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 2.323E-02 | | | | |

****************************** TIME = 4.000E+02 ******************************

ISTEP = 286 RAIN = 5.844E-02 TRAIN = 2.338E+01 CIN = 0.000E+00
DELT = 1.556E+00 DRAIN = 5.844E-02 TDRAIN = 2.338E+01 SLTIN =-1.018E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.500E+00
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.255E+00
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
" " SOLUTE: 0.0600 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.211E-08 | 0.23 | -7.796E-01 | 0.4127 | 3.256E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 3.756E-06 | 0.70 | -3.823E-01 | 0.4374 | 3.079E-05 |
| 0.94 | -1.756E-01 | 0.4585 | 1.890E-04 | 1.18 | -1.753E-01 | 0.4585 | 8.158E-04 |
| 1.42 | -1.750E-01 | 0.4585 | 2.739E-03 | 1.66 | -1.747E-01 | 0.4586 | 7.092E-03 |
| 1.90 | -1.744E-01 | 0.4586 | 1.441E-02 | 2.14 | -1.741E-01 | 0.4586 | 2.364E-02 |
| 2.37 | -1.739E-01 | 0.4586 | 3.238E-02 | 2.61 | -1.736E-01 | 0.4587 | 3.815E-02 |
| 2.85 | -1.741E-01 | 0.4586 | 3.986E-02 | 3.09 | -1.818E-01 | 0.4578 | 3.811E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 3.450E-02 | 3.57 | -6.657E-01 | 0.4202 | 3.059E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 3.051E-02 | 4.06 | -8.550E-01 | 0.0955 | 3.042E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 3.033E-02 | 4.55 | -8.560E-01 | 0.0954 | 3.024E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 3.015E-02 | 5.04 | -8.571E-01 | 0.0954 | 3.006E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 2.997E-02 | 5.53 | -8.582E-01 | 0.0953 | 2.988E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 2.979E-02 | 6.02 | -8.592E-01 | 0.0952 | 2.970E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 2.960E-02 | 6.51 | -8.603E-01 | 0.0952 | 2.951E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 2.942E-02 | 7.00 | -8.614E-01 | 0.0951 | 2.933E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 2.924E-02 | 7.49 | -8.625E-01 | 0.0950 | 2.915E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 2.906E-02 | 7.98 | -8.635E-01 | 0.0950 | 2.897E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 2.888E-02 | 8.47 | -8.646E-01 | 0.0949 | 2.879E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 2.869E-02 | 8.96 | -8.657E-01 | 0.0948 | 2.860E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 2.851E-02 | 9.44 | -8.632E-01 | 0.0950 | 2.842E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 2.833E-02 | 9.93 | -8.435E-01 | 0.0962 | 2.824E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 2.815E-02 | 10.42 | -6.846E-01 | 0.1077 | 2.806E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 2.796E-02 | 10.91 | -2.450E-01 | 0.1913 | 2.784E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 2.784E-02 | | | | |

****************************** TIME = 5.000E+02 ******************************

ISTEP = 351 RAIN = 5.844E-02 TRAIN = 2.929E+01 CIN = 0.000E+00
DELT = 1.556E+00 DRAIN = 5.844E-02 TDRAIN = 2.929E+01 SLTIN = 3.546E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.681E+00
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.074E+00
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
" " SOLUTE: 0.0701 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.872E-08 | 0.23 | -7.796E-01 | 0.4127 | 2.550E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 2.530E-06 | 0.70 | -3.823E-01 | 0.4374 | 1.821E-05 |
| 0.94 | -1.756E-01 | 0.4585 | 1.008E-04 | 1.18 | -1.753E-01 | 0.4585 | 4.032E-04 |
| 1.42 | -1.750E-01 | 0.4585 | 1.308E-03 | 1.66 | -1.747E-01 | 0.4586 | 3.461E-03 |
| 1.90 | -1.744E-01 | 0.4586 | 7.531E-03 | 2.14 | -1.741E-01 | 0.4586 | 1.370E-02 |
| 2.37 | -1.739E-01 | 0.4586 | 2.122E-02 | 2.61 | -1.736E-01 | 0.4587 | 2.858E-02 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2.85 | -1.741E-01 | 0.4586 | 3.413E-02 | 3.09 | -1.818E-01 | 0.4578 | 3.688E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 3.689E-02 | 3.57 | -6.657E-01 | 0.4202 | 3.502E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 3.498E-02 | 4.06 | -8.550E-01 | 0.0955 | 3.494E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 3.489E-02 | 4.55 | -8.560E-01 | 0.0954 | 3.485E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 3.480E-02 | 5.04 | -8.571E-01 | 0.0954 | 3.475E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 3.470E-02 | 5.53 | -8.582E-01 | 0.0953 | 3.465E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 3.460E-02 | 6.02 | -8.592E-01 | 0.0952 | 3.455E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 3.450E-02 | 6.51 | -8.603E-01 | 0.0952 | 3.444E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 3.439E-02 | 7.00 | -8.614E-01 | 0.0951 | 3.433E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 3.427E-02 | 7.49 | -8.625E-01 | 0.0950 | 3.421E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 3.415E-02 | 7.98 | -8.635E-01 | 0.0950 | 3.409E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 3.403E-02 | 8.47 | -8.646E-01 | 0.0949 | 3.397E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 3.391E-02 | 8.96 | -8.657E-01 | 0.0948 | 3.385E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 3.378E-02 | 9.44 | -8.632E-01 | 0.0950 | 3.372E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 3.365E-02 | 9.93 | -8.435E-01 | 0.0962 | 3.358E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 3.351E-02 | 10.42 | -6.846E-01 | 0.1077 | 3.344E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 3.337E-02 | 10.91 | -2.450E-01 | 0.1913 | 3.327E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 3.327E-02 | | | | |

****************************** TIME = 6.000E+02 ******************************

```
ISTEP =     415   RAIN  = 5.844E-02   TRAIN  = 3.511E+01   CIN    = 0.000E+00
DELT  = 1.556E+00   DRAIN = 5.844E-02   TDRAIN = 3.511E+01   SLTIN = 2.263E-23
NIT   =       1   PET   = 0.000E+00   TRUPTK = 0.000E+00   SLTOUT= 4.884E+00
RELAXF=     1.000   ACTET = 0.000E+00   STORW  = 0.000E+00   STORS = 8.714E-01
                                        QDECAY= 0.000E+00
```

MASS BALANCE ERROR WATER :   0.0000 %
 ..   .. SOLUTE:   0.0864 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.326E-08 | 0.23 | -7.796E-01 | 0.4127 | 1.720E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 1.539E-06 | 0.70 | -3.823E-01 | 0.4374 | 1.014E-05 |
| 0.94 | -1.756E-01 | 0.4585 | 5.251E-05 | 1.18 | -1.753E-01 | 0.4585 | 2.005E-04 |
| 1.42 | -1.750E-01 | 0.4585 | 6.380E-04 | 1.66 | -1.747E-01 | 0.4586 | 1.711E-03 |
| 1.90 | -1.744E-01 | 0.4586 | 3.898E-03 | 2.14 | -1.741E-01 | 0.4586 | 7.617E-03 |
| 2.37 | -1.739E-01 | 0.4586 | 1.292E-02 | 2.61 | -1.736E-01 | 0.4587 | 1.929E-02 |
| 2.85 | -1.741E-01 | 0.4586 | 2.567E-02 | 3.09 | -1.818E-01 | 0.4578 | 3.092E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 3.422E-02 | 3.57 | -6.657E-01 | 0.4202 | 3.547E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 3.549E-02 | 4.06 | -8.550E-01 | 0.0955 | 3.552E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 3.554E-02 | 4.55 | -8.560E-01 | 0.0954 | 3.557E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 3.559E-02 | 5.04 | -8.571E-01 | 0.0954 | 3.561E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 3.563E-02 | 5.53 | -8.582E-01 | 0.0953 | 3.565E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 3.567E-02 | 6.02 | -8.592E-01 | 0.0952 | 3.569E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 3.571E-02 | 6.51 | -8.603E-01 | 0.0952 | 3.572E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 3.574E-02 | 7.00 | -8.614E-01 | 0.0951 | 3.575E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 3.576E-02 | 7.49 | -8.625E-01 | 0.0950 | 3.577E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 3.578E-02 | 7.98 | -8.635E-01 | 0.0950 | 3.579E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 3.580E-02 | 8.47 | -8.646E-01 | 0.0949 | 3.581E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 3.581E-02 | 8.96 | -8.657E-01 | 0.0948 | 3.582E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 3.582E-02 | 9.44 | -8.632E-01 | 0.0950 | 3.582E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 3.582E-02 | 9.93 | -8.435E-01 | 0.0962 | 3.582E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 3.582E-02 | 10.42 | -6.846E-01 | 0.1077 | 3.582E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 3.582E-02 | 10.91 | -2.450E-01 | 0.1913 | 3.581E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 3.581E-02 | | | | |

****************************** TIME = 7.000E+02 ******************************

```
ISTEP =     479   RAIN  = 5.844E-02   TRAIN  = 4.093E+01   CIN    = 0.000E+00
DELT  = 1.556E+00   DRAIN = 5.844E-02   TDRAIN = 4.093E+01   SLTIN = 2.575E-23
NIT   =       1   PET   = 0.000E+00   TRUPTK = 0.000E+00   SLTOUT= 5.089E+00
RELAXF=     1.000   ACTET = 0.000E+00   STORW  = 0.000E+00   STORS = 6.662E-01
                                        QDECAY= 0.000E+00
```

MASS BALANCE ERROR WATER :   0.0000 %
 ..   .. SOLUTE:   0.1129 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 8.422E-09 | 0.23 | -7.796E-01 | 0.4127 | 1.057E-07 |
| 0.47 | -5.923E-01 | 0.4229 | 8.812E-07 | 0.70 | -3.823E-01 | 0.4374 | 5.466E-06 |
| 0.94 | -1.756E-01 | 0.4585 | 2.705E-05 | 1.18 | -1.753E-01 | 0.4585 | 1.003E-04 |
| 1.42 | -1.750E-01 | 0.4585 | 3.153E-04 | 1.66 | -1.747E-01 | 0.4586 | 8.545E-04 |
| 1.90 | -1.744E-01 | 0.4586 | 2.012E-03 | 2.14 | -1.741E-01 | 0.4586 | 4.142E-03 |
| 2.37 | -1.739E-01 | 0.4586 | 7.524E-03 | 2.61 | -1.736E-01 | 0.4587 | 1.217E-02 |
| 2.85 | -1.741E-01 | 0.4586 | 1.768E-02 | 3.09 | -1.818E-01 | 0.4578 | 2.332E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 2.823E-02 | 3.57 | -6.657E-01 | 0.4202 | 3.182E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 3.189E-02 | 4.06 | -8.550E-01 | 0.0955 | 3.197E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 3.205E-02 | 4.55 | -8.560E-01 | 0.0954 | 3.213E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 3.221E-02 | 5.04 | -8.571E-01 | 0.0954 | 3.229E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 3.236E-02 | 5.53 | -8.582E-01 | 0.0953 | 3.244E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 3.252E-02 | 6.02 | -8.592E-01 | 0.0952 | 3.259E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 3.267E-02 | 6.51 | -8.603E-01 | 0.0952 | 3.274E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 3.281E-02 | 7.00 | -8.614E-01 | 0.0951 | 3.289E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 3.296E-02 | 7.49 | -8.625E-01 | 0.0950 | 3.303E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 3.310E-02 | 7.98 | -8.635E-01 | 0.0950 | 3.317E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 3.324E-02 | 8.47 | -8.646E-01 | 0.0949 | 3.331E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 3.337E-02 | 8.96 | -8.657E-01 | 0.0948 | 3.344E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 3.351E-02 | 9.44 | -8.632E-01 | 0.0950 | 3.357E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 3.364E-02 | 9.93 | -8.435E-01 | 0.0962 | 3.370E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 3.376E-02 | 10.42 | -6.846E-01 | 0.1077 | 3.383E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 3.389E-02 | 10.91 | -2.450E-01 | 0.1913 | 3.397E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 3.397E-02 | | | | |

****************************** TIME = 8.000E+02 ******************************

```
ISTEP =      544  RAIN  = 5.844E-02  TRAIN  = 4.684E+01  CIN   = 0.000E+00
DELT  = 1.556E+00  DRAIN = 5.844E-02  TDRAIN = 4.684E+01  SLTIN = 2.495E-23
NIT   =        1  PET   = 0.000E+00  TRUPTK = 0.000E+00  SLTOUT= 5.276E+00
RELAXF=    1.000  ACTET = 0.000E+00  STORW  = 0.000E+00  STORS = 4.793E-01
                                     QDECAY= 0.000E+00

MASS BALANCE ERROR WATER :   0.0000 %
    ..    .. SOLUTE:   0.1569 %
```

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 4.987E-09 | 0.23 | -7.796E-01 | 0.4127 | 6.126E-08 |
| 0.47 | -5.923E-01 | 0.4229 | 4.856E-07 | 0.70 | -3.823E-01 | 0.4374 | 2.887E-06 |
| 0.94 | -1.756E-01 | 0.4585 | 1.385E-05 | 1.18 | -1.753E-01 | 0.4585 | 5.036E-05 |
| 1.42 | -1.750E-01 | 0.4585 | 1.572E-04 | 1.66 | -1.747E-01 | 0.4586 | 4.299E-04 |
| 1.90 | -1.744E-01 | 0.4586 | 1.037E-03 | 2.14 | -1.741E-01 | 0.4586 | 2.224E-03 |
| 2.37 | -1.739E-01 | 0.4586 | 4.259E-03 | 2.61 | -1.736E-01 | 0.4587 | 7.337E-03 |
| 2.85 | -1.741E-01 | 0.4586 | 1.145E-02 | 3.09 | -1.818E-01 | 0.4578 | 1.628E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 2.127E-02 | 3.57 | -6.657E-01 | 0.4202 | 2.580E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 2.589E-02 | 4.06 | -8.550E-01 | 0.0955 | 2.599E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 2.609E-02 | 4.55 | -8.560E-01 | 0.0954 | 2.620E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 2.630E-02 | 5.04 | -8.571E-01 | 0.0954 | 2.640E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 2.650E-02 | 5.53 | -8.582E-01 | 0.0953 | 2.660E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 2.671E-02 | 6.02 | -8.592E-01 | 0.0952 | 2.681E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 2.691E-02 | 6.51 | -8.603E-01 | 0.0952 | 2.701E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 2.711E-02 | 7.00 | -8.614E-01 | 0.0951 | 2.721E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 2.731E-02 | 7.49 | -8.625E-01 | 0.0950 | 2.741E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 2.751E-02 | 7.98 | -8.635E-01 | 0.0950 | 2.761E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 2.771E-02 | 8.47 | -8.646E-01 | 0.0949 | 2.781E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 2.791E-02 | 8.96 | -8.657E-01 | 0.0948 | 2.801E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 2.811E-02 | 9.44 | -8.632E-01 | 0.0950 | 2.820E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 2.830E-02 | 9.93 | -8.435E-01 | 0.0962 | 2.840E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 2.850E-02 | 10.42 | -6.846E-01 | 0.1077 | 2.860E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 2.870E-02 | 10.91 | -2.450E-01 | 0.1913 | 2.884E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 2.884E-02 | | | | |

****************************** TIME = 9.000E+02 ******************************

```
ISTEP =      608  RAIN  = 5.844E-02  TRAIN  = 5.266E+01  CIN   = 0.000E+00
DELT  = 1.556E+00  DRAIN = 5.844E-02  TDRAIN = 5.266E+01  SLTIN = 2.644E-23
```

NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 5.425E+00
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 3.300E-01
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.2277 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.818E-09 | 0.23 | -7.796E-01 | 0.4127 | 3.411E-08 |
| 0.47 | -5.923E-01 | 0.4229 | 2.610E-07 | 0.70 | -3.823E-01 | 0.4374 | 1.506E-06 |
| 0.94 | -1.756E-01 | 0.4585 | 7.074E-06 | 1.18 | -1.753E-01 | 0.4585 | 2.538E-05 |
| 1.42 | -1.750E-01 | 0.4585 | 7.894E-05 | 1.66 | -1.747E-01 | 0.4586 | 2.175E-04 |
| 1.90 | -1.744E-01 | 0.4586 | 5.354E-04 | 2.14 | -1.741E-01 | 0.4586 | 1.184E-03 |
| 2.37 | -1.739E-01 | 0.4586 | 2.366E-03 | 2.61 | -1.736E-01 | 0.4587 | 4.291E-03 |
| 2.85 | -1.741E-01 | 0.4586 | 7.096E-03 | 3.09 | -1.818E-01 | 0.4578 | 1.074E-02 |
| 3.33 | -2.505E-01 | 0.4507 | 1.496E-02 | 3.57 | -6.657E-01 | 0.4202 | 1.930E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 1.939E-02 | 4.06 | -8.550E-01 | 0.0955 | 1.948E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 1.958E-02 | 4.55 | -8.560E-01 | 0.0954 | 1.968E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 1.978E-02 | 5.04 | -8.571E-01 | 0.0954 | 1.988E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 1.998E-02 | 5.53 | -8.582E-01 | 0.0953 | 2.008E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 2.018E-02 | 6.02 | -8.592E-01 | 0.0952 | 2.028E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 2.038E-02 | 6.51 | -8.603E-01 | 0.0952 | 2.048E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 2.058E-02 | 7.00 | -8.614E-01 | 0.0951 | 2.069E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 2.079E-02 | 7.49 | -8.625E-01 | 0.0950 | 2.089E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 2.099E-02 | 7.98 | -8.635E-01 | 0.0950 | 2.109E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 2.119E-02 | 8.47 | -8.646E-01 | 0.0949 | 2.129E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 2.140E-02 | 8.96 | -8.657E-01 | 0.0948 | 2.150E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 2.160E-02 | 9.44 | -8.632E-01 | 0.0950 | 2.170E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 2.180E-02 | 9.93 | -8.435E-01 | 0.0962 | 2.191E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 2.201E-02 | 10.42 | -6.846E-01 | 0.1077 | 2.212E-02 |
| 10.67 | -4.858E-01 | 0.1304 | 2.223E-02 | 10.91 | -2.450E-01 | 0.1913 | 2.237E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 2.237E-02 | | | | |

****************************** TIME = 1.000E+03 ******************************

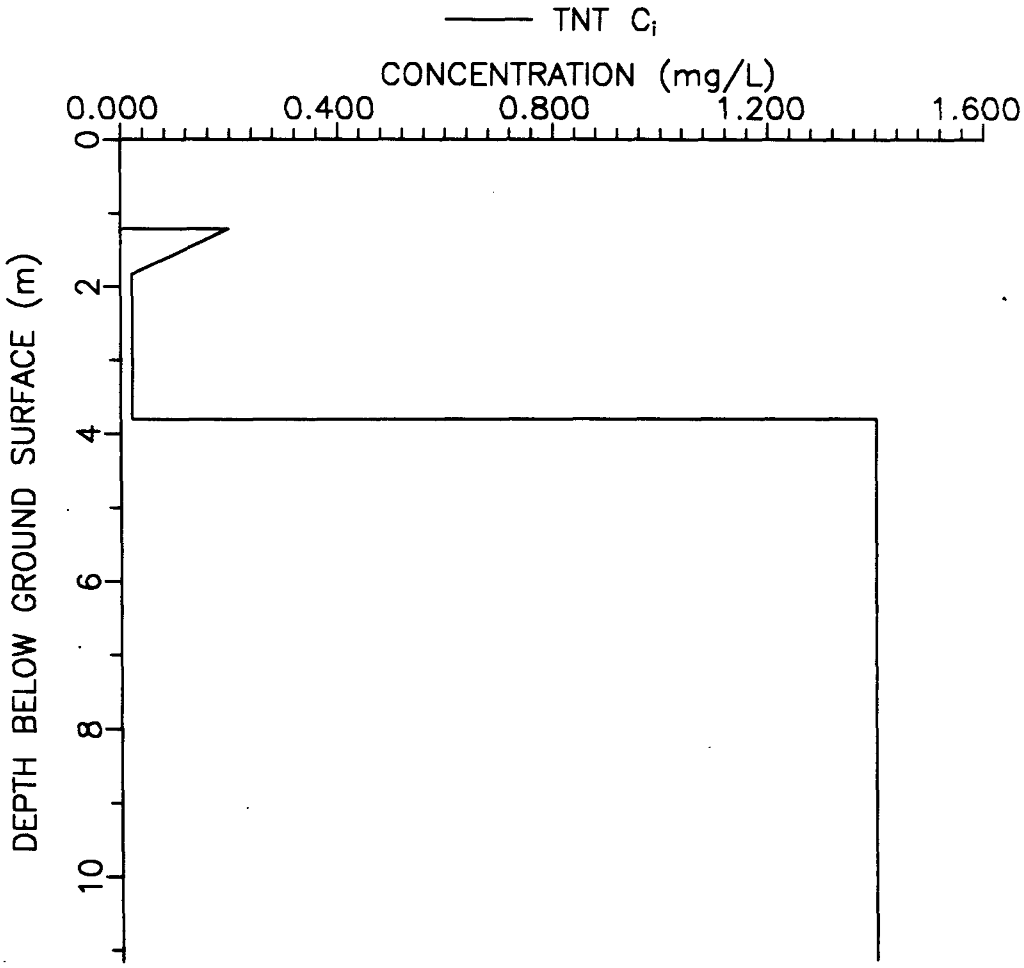
ISTEP = 672 RAIN = 5.844E-02 TRAIN = 5.848E+01 CIN = 0.000E+00
DELT = 1.556E+00 DRAIN = 5.844E-02 TDRAIN = 5.848E+01 SLTIN = 2.757E-23
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 5.537E+00
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 2.181E-01
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.3443 %

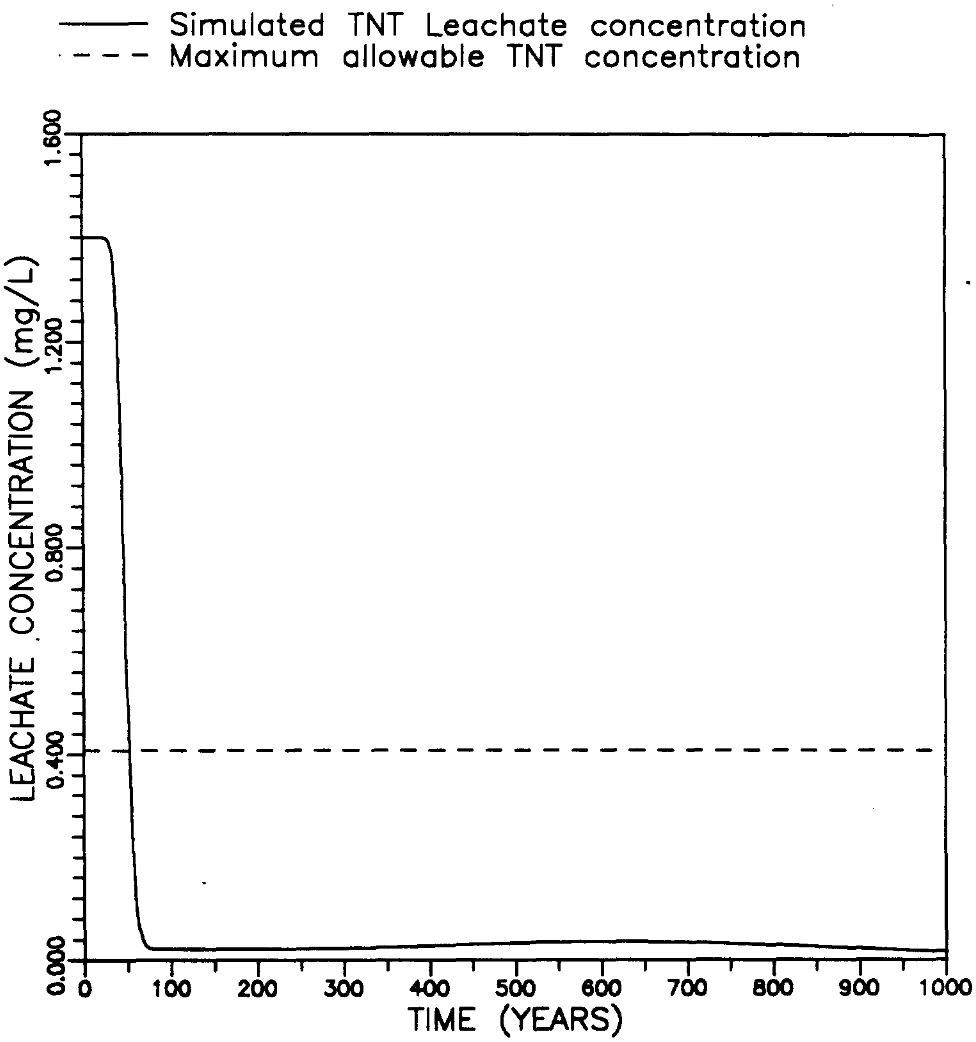
| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.543E-09 | 0.23 | -7.796E-01 | 0.4127 | 1.849E-08 |
| 0.47 | -5.923E-01 | 0.4229 | 1.380E-07 | 0.70 | -3.823E-01 | 0.4374 | 7.791E-07 |
| 0.94 | -1.756E-01 | 0.4585 | 3.606E-06 | 1.18 | -1.753E-01 | 0.4585 | 1.283E-05 |
| 1.42 | -1.750E-01 | 0.4585 | 3.983E-05 | 1.66 | -1.747E-01 | 0.4586 | 1.105E-04 |
| 1.90 | -1.744E-01 | 0.4586 | 2.765E-04 | 2.14 | -1.741E-01 | 0.4586 | 6.277E-04 |
| 2.37 | -1.739E-01 | 0.4586 | 1.298E-03 | 2.61 | -1.736E-01 | 0.4587 | 2.455E-03 |
| 2.85 | -1.741E-01 | 0.4586 | 4.260E-03 | 3.09 | -1.818E-01 | 0.4578 | 6.795E-03 |
| 3.33 | -2.505E-01 | 0.4507 | 9.978E-03 | 3.57 | -6.657E-01 | 0.4202 | 1.355E-02 |
| 3.81 | -8.544E-01 | 0.0955 | 1.362E-02 | 4.06 | -8.550E-01 | 0.0955 | 1.371E-02 |
| 4.30 | -8.555E-01 | 0.0955 | 1.379E-02 | 4.55 | -8.560E-01 | 0.0954 | 1.387E-02 |
| 4.79 | -8.566E-01 | 0.0954 | 1.395E-02 | 5.04 | -8.571E-01 | 0.0954 | 1.404E-02 |
| 5.28 | -8.576E-01 | 0.0953 | 1.412E-02 | 5.53 | -8.582E-01 | 0.0953 | 1.420E-02 |
| 5.77 | -8.587E-01 | 0.0953 | 1.429E-02 | 6.02 | -8.592E-01 | 0.0952 | 1.437E-02 |
| 6.26 | -8.598E-01 | 0.0952 | 1.445E-02 | 6.51 | -8.603E-01 | 0.0952 | 1.454E-02 |
| 6.75 | -8.609E-01 | 0.0951 | 1.462E-02 | 7.00 | -8.614E-01 | 0.0951 | 1.471E-02 |
| 7.24 | -8.619E-01 | 0.0951 | 1.480E-02 | 7.49 | -8.625E-01 | 0.0950 | 1.488E-02 |
| 7.73 | -8.630E-01 | 0.0950 | 1.497E-02 | 7.98 | -8.635E-01 | 0.0950 | 1.505E-02 |
| 8.22 | -8.641E-01 | 0.0949 | 1.514E-02 | 8.47 | -8.646E-01 | 0.0949 | 1.523E-02 |
| 8.71 | -8.651E-01 | 0.0949 | 1.532E-02 | 8.96 | -8.657E-01 | 0.0948 | 1.540E-02 |
| 9.20 | -8.653E-01 | 0.0949 | 1.549E-02 | 9.44 | -8.632E-01 | 0.0950 | 1.558E-02 |
| 9.69 | -8.585E-01 | 0.0953 | 1.567E-02 | 9.93 | -8.435E-01 | 0.0962 | 1.576E-02 |
| 10.18 | -7.990E-01 | 0.0990 | 1.585E-02 | 10.42 | -6.846E-01 | 0.1077 | 1.594E-02 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10.67 | -4.858E-01 | 0.1304 | 1.604E-02 | 10.91 | -2.450E-01 | 0.1913 | 1.616E-02 |
| 11.16 | 0.000E+00 | 0.4370 | 1.616E-02 | | | | |

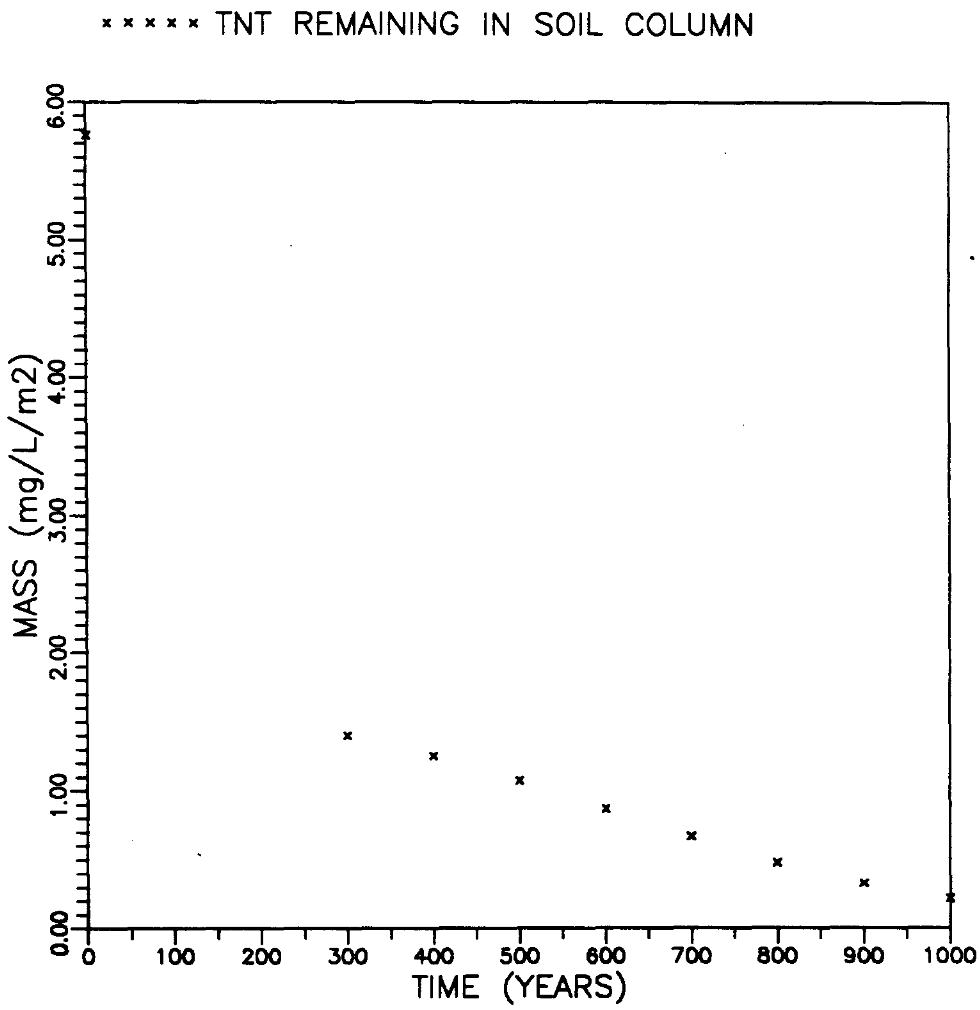
***** NORMAL TERMINATION TIME = 1000.6882 AND STEP NUMBER = 672



TNT $C_i$
CONCENTRATION (mg/L)
0.000
0.400
0.800
1.200
1.600
0
2
4
6
8
10
DEPTH BELOW GROUND SURFACE (m)




B07NE003702-09292



××××× TNT REMAINING IN SOIL COLUMN
MASS (mg/L/m2)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
100
200
300
400
500
600
700
800
900
1000
TIME (YEARS)

**ATTACHMENT 2D**

**HYDRUS MODEL INPUT FILES, OUTPUT FILES AND ASSOCIATED GRAPHS FOR HYPOTHETICAL RDX EVALUATION (SECTION 5.4.3)**

```
time units = years, infiltration = 2.3 in/yr
RDX, clean except for 12.5-13.5 ft S=0.0195mg/kg (C=0.7235mg/L), 154.dat
   1   0   0   0   0   1   1   0   0   2
 7500   3   3   1   7   1      0.0
     .001    .00001    100.0    1000.    .010    .01 9900
   1   1     0.0     0.7     0.25
   2   2     0.7     3.81    0.25
   3   3     3.81    11.16   0.25
    2.681    1.17    0.475   0.090   98.55
    2.925    1.15    0.479   0.056   3.285
    13.8     1.69    0.437   0.020   3650.
   2.26e-2   0.10    1.4     0.0     0.0    1.6     1.0
   2.26e-2   0.10    1.4     0.0     0.0    1.8     1.0
   2.26e-2   0.10    1.4     0.0     0.0    0.027   1.0
0.000E+00 -9.476E-01  0.4050  0.000E+00
2.333E-01 -7.876E-01  0.4123  0.000E+00
4.667E-01 -6.004E-01  0.4225  0.000E+00
7.000E-01 -3.903E-01  0.4368  0.000E+00
9.392E-01 -1.838E-01  0.4576  0.000E+00
1.220E+00 0.0         0.4576  0.000E+00
1.657E+00 -1.838E-01  0.4576  0.
1.83      0.0         0.4576  0.
1.896E+00 -1.838E-01  0.4576  0.
2.135E+00 -1.838E-01  0.4576  0.
2.375E+00 -1.838E-01  0.4576  0.
2.614E+00 -1.838E-01  0.4576  0.
2.74      0.0         0.4576  0.
2.853E+00 -1.845E-01  0.4575  0.
3.092E+00 -1.922E-01  0.4567  0.
3.332E+00 -2.607E-01  0.4497  0.
3.571E+00 -6.748E-01  0.4197  0.
3.81      0.0         0.0950  0.
3.81      0.0         0.0950  0.7235
4.12      0.0         0.0950  0.7235
4.12      0.0         0.0950  0.0
4.545E+00 -8.628E-01  0.0950  0.
5.280E+00 -8.628E-01  0.0950  0.
5.770E+00 -8.628E-01  0.0950  0.
6.015E+00 -8.628E-01  0.0950  0.
6.1       0.0         0.0950  0.
6.260E+00 -8.628E-01  0.0950  0.
6.505E+00 -8.628E-01  0.0950  0.
6.750E+00 -8.628E-01  0.0950  0.
6.995E+00 -8.628E-01  0.0950  0.
7.240E+00 -8.628E-01  0.0950  0.
7.485E+00 -8.628E-01  0.0950  0.
7.62      0.0         0.0950  0.0
7.730E+00 -8.628E-01  0.0950  0.0
7.975E+00 -8.628E-01  0.0950  0.0
8.220E+00 -8.628E-01  0.0950  0.0
8.465E+00 -8.628E-01  0.0950  0.0
8.955E+00 -8.625E-01  0.0950  0.0
9.200E+00 -8.621E-01  0.0951  0.0
9.445E+00 -8.605E-01  0.0952  0.0
9.690E+00 -8.557E-01  0.0954  0.0
9.935E+00 -8.407E-01  0.0964  0.0
1.018E+01 -7.961E-01  0.0992  0.0
1.042E+01 -6.837E-01  0.1078  0.0
1.067E+01 -4.851E-01  0.1305  0.0
1.091E+01 -2.450E-01  0.1913  0.0
1.116E+01  0.000E+00  0.4370  0.0
     0.0   1   0   .05844     0.0
    300.0    400.0    500.0    600.0    700.0    800.0    900.0
    11.159
```

B07NE003702-09295

```
*******************************************************************
*                                              *
*        ONE-DIMENSIONAL FLOW AND TRANSPORT MODEL          *
*                 HYDRUS v. 3.4·              *
*                                              *
*    DATA INPUT FILE: 154.dat                          *
*                                              *
*   time units = years, infiltration = 2.3 in/yr        *
*   RDX, clean except for 12.5-13.5 ft S=0.0195mg/kg (C=0.7235mg   *
*                                              *
*******************************************************************
```

PROBLEM CONTROL PARAMETERS
=======================

SIMULATION CONTROL CODE ...............(ITKOD) = 1
HYSTERESIS MODELING CODE ..............(IHKOD) = 0
TRANSPORT BOUNDARY COND. CODE ........(ICOKOD) = 0
ROOT WATER UPTAKE CODE ...............(IRUKOD) = 0
CONDUCTIVITY UPSTREAM WEIGHTING ......(IUPKOD) = 0
FLOW MASS MATRIX OPTION ...............(ILKOD) = 1
FLOW INITIAL CONDITION CODE ...........(ICKOD) = 1
BOUNDARY CONDITION CODE ..............(IBCKOD) = 0
PLOT OUTPUT CODE .......................(IOKOD) = 0
RESTART OUTPUT CODE ..................(IRSKOD) = 2

TIME STEPPING PARAMETERS
=====================

INITIAL TIMESTEP ......................(DELIN) = 0.100E-02
MINIMUM TIMESTEP .....................(DELMIN) = 0.100E-04
MAXIMUM TIMESTEP .....................(DELMAX) = 100.
TOTAL SIMULATION TIME ..................(TMAX) = 0.100E+04
REL. PR. HEAD CONVERGENCE TOLERANCE ....(TOL1) = 0.100E-01
ABS. ,, ,, ,, ....(TOL2) = 0.100E-01
NUMBER OF NONLINEAR ITERATIONS .......(NITMAX) = 9900

PROBLEM SPECIFICATION PARAMETERS
============================

MAXIMUM NUMBER OF TIMESTEPS ..........(NSTEPS) = 7500
NUMBER OF SOIL MATERIALS ...............(NMAT) = 3
NUMBER OF SOIL LAYERS .................(NLAYR) = 3
NUMBER OF BOUNDARY COND. TIME VALUES ....(NBC) = 1
NUMBER OF OUTPUT TIME VALUES .........(NPRINT) = 7
NUMBER OF OBSERVATION POINTS ...........(NOBS) = 1
SOIL DEPTH ...........................(TDEPTH) = 11.2
GROUNDWATER SOLUTE CONCENTRATION ........(CNN) = 0.000

PROBLEM GEOMETRY
===============

LAYER NUMBER ......... 1
MATERIAL INDEX .........................(MATL) = 1
LAYER THICKNESS .......................(THICK) = 0.700
BEGINNING DEPTH ........................(TOPL) = 0.000
ENDING DEPTH ...........................(BOTL) = 0.700
NODAL SPACING ..........................(DELZ) = 0.233

LAYER NUMBER ......... 2
MATERIAL INDEX .........................(MATL) = 2
LAYER THICKNESS .......................(THICK) = 3.11
BEGINNING DEPTH ........................(TOPL) = 0.700
ENDING DEPTH ...........................(BOTL) = 3.81
NODAL SPACING ..........................(DELZ) = 0.239

LAYER NUMBER ......... 3
MATERIAL INDEX ..........................(MATL) = 3
LAYER THICKNESS ........................(THICK) = 7.35
BEGINNING DEPTH ........................(TOPL) = 3.81
ENDING DEPTH ............................(BOTL) = 11.2
NODAL SPACING ...........................(DELZ) = 0.245

SOIL HYDRAULIC AND TRANSPORT PROPERTIES
=====================================

HYDRAULIC PROPERTIES FOR MATERIAL: 1

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.6810 | 1.1700 | 0.4750 | 0.0900 | 9.855E+01 |

HYDRAULIC PROPERTIES FOR MATERIAL: 2

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 2.9250 | 1.1500 | 0.4790 | 0.0560 | 3.285E+00 |

HYDRAULIC PROPERTIES FOR MATERIAL: 3

| ALPHA | BETA | WCS | WCR | SATK |
|---|---|---|---|---|
| 13.8000 | 1.6900 | 0.4370 | 0.0200 | 3.650E+03 |

TRANSPORT PROPERTIES FOR MATERIAL: 1

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 1.600 |

TRANSPORT PROPERTIES FOR MATERIAL: 2

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 1.800 |

TRANSPORT PROPERTIES FOR MATERIAL: 3

| DIF | DISP | RHO | DONE | DSONE | KD |
|---|---|---|---|---|---|
| 0.023 | 0.100 | 1.400 | 0.000 | 0.000 | 0.027 |

MAXIMUM VALUE OF GRID PECLET NUMBER IS 2.450 FOR LAYER NO. 3

BOUNDARY CONDITION DATA
=======================

| TIME | IRTYP | IDRTYP | BCN1 | BCNN | CN1 | POTET |
|---|---|---|---|---|---|---|
| 0.000 | 1 | 0 | 0.058 | 0.000 | 0.000 | 0.000 |

OUTPUT TIME VALUES
==================

0.300E+03 0.400E+03 0.500E+03 0.600E+03 0.700E+03 0.800E+03 0.900E+03

OBSERVATION POINT COORDINATES
============================

11.159

INITIAL CONDITIONS
================

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.482E-01 | 0.4050 | 0.000E+00 | 0.23 | -7.879E-01 | 0.4123 | 0.000E+00 |
| 0.47 | -5.997E-01 | 0.4225 | 0.000E+00 | 0.70 | -3.897E-01 | 0.4368 | 0.000E+00 |
| 0.94 | -1.835E-01 | 0.4576 | 0.000E+00 | 1.18 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.42 | -1.835E-01 | 0.4576 | 0.000E+00 | 1.66 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 1.90 | -1.835E-01 | 0.4576 | 0.000E+00 | 2.14 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 2.37 | -1.835E-01 | 0.4576 | 0.000E+00 | 2.61 | -1.835E-01 | 0.4576 | 0.000E+00 |
| 2.85 | -1.844E-01 | 0.4575 | 0.000E+00 | 3.09 | -1.920E-01 | 0.4567 | 0.000E+00 |
| 3.33 | -2.611E-01 | 0.4497 | 0.000E+00 | 3.57 | -6.737E-01 | 0.4197 | 0.000E+00 |
| 3.81 | -8.631E-01 | 0.0950 | 7.235E-01 | 4.06 | -8.631E-01 | 0.0950 | 7.235E-01 |
| 4.30 | -8.631E-01 | 0.0950 | 0.000E+00 | 4.55 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 4.79 | -8.631E-01 | 0.0950 | 0.000E+00 | 5.04 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 5.28 | -8.631E-01 | 0.0950 | 0.000E+00 | 5.53 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 5.77 | -8.631E-01 | 0.0950 | 0.000E+00 | 6.02 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 6.26 | -8.631E-01 | 0.0950 | 0.000E+00 | 6.51 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 6.75 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.00 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 7.24 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.49 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 7.73 | -8.631E-01 | 0.0950 | 0.000E+00 | 7.98 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 8.22 | -8.631E-01 | 0.0950 | 0.000E+00 | 8.47 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 8.71 | -8.631E-01 | 0.0950 | 0.000E+00 | 8.96 | -8.631E-01 | 0.0950 | 0.000E+00 |
| 9.20 | -8.614E-01 | 0.0951 | 0.000E+00 | 9.44 | -8.597E-01 | 0.0952 | 0.000E+00 |
| 9.69 | -8.564E-01 | 0.0954 | 0.000E+00 | 9.93 | -8.399E-01 | 0.0964 | 0.000E+00 |
| 10.18 | -7.965E-01 | 0.0992 | 0.000E+00 | 10.42 | -6.788E-01 | 0.1083 | 0.000E+00 |
| 10.67 | -4.852E-01 | 0.1305 | 0.000E+00 | 10.91 | -2.339E-01 | 0.1962 | 0.000E+00 |
| 11.16 | -8.691E-10 | 0.4370 | 0.000E+00 | | | | |

INITIAL MOISTURE IN PROFILE : 2.44
INITIAL SALT IN PROFILE : 0.468E-01

STEADY STATE FLOW SOLUTION PERFORMED IN 1 ITERATIONS

****************************** TIME = 3.000E+02 ******************************

ISTEP = 570 RAIN = 5.844E-02 TRAIN = 1.756E+01 CIN = 0.000E+00
DELT = 5.507E-01 DRAIN = 5.844E-02 TDRAIN = 1.756E+01 SLTIN =-4.973E-35
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.698E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 4.725E-11
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
" " SOLUTE: 0.0000 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.197E-20 | 0.23 | -7.796E-01 | 0.4127 | 2.526E-19 |
| 0.47 | -5.923E-01 | 0.4229 | 2.064E-18 | 0.70 | -3.823E-01 | 0.4374 | 1.334E-17 |
| 0.94 | -1.756E-01 | 0.4585 | 7.289E-17 | 1.18 | -1.753E-01 | 0.4585 | 3.220E-16 |
| 1.42 | -1.750E-01 | 0.4585 | 1.319E-15 | 1.66 | -1.747E-01 | 0.4586 | 5.088E-15 |
| 1.90 | -1.744E-01 | 0.4586 | 1.849E-14 | 2.14 | -1.741E-01 | 0.4586 | 6.321E-14 |
| 2.37 | -1.739E-01 | 0.4586 | 2.020E-13 | 2.61 | -1.736E-01 | 0.4587 | 5.993E-13 |
| 2.85 | -1.741E-01 | 0.4586 | 1.629E-12 | 3.09 | -1.818E-01 | 0.4578 | 3.977E-12 |
| 3.33 | -2.505E-01 | 0.4507 | 8.545E-12 | 3.57 | -6.657E-01 | 0.4202 | 1.595E-11 |
| 3.81 | -8.544E-01 | 0.0955 | 1.630E-11 | 4.06 | -8.550E-01 | 0.0955 | 1.670E-11 |
| 4.30 | -8.555E-01 | 0.0955 | 1.711E-11 | 4.55 | -8.560E-01 | 0.0954 | 1.753E-11 |
| 4.79 | -8.566E-01 | 0.0954 | 1.796E-11 | 5.04 | -8.571E-01 | 0.0954 | 1.840E-11 |
| 5.28 | -8.576E-01 | 0.0953 | 1.885E-11 | 5.53 | -8.582E-01 | 0.0953 | 1.931E-11 |
| 5.77 | -8.587E-01 | 0.0953 | 1.978E-11 | 6.02 | -8.592E-01 | 0.0952 | 2.027E-11 |
| 6.26 | -8.598E-01 | 0.0952 | 2.077E-11 | 6.51 | -8.603E-01 | 0.0952 | 2.128E-11 |
| 6.75 | -8.609E-01 | 0.0951 | 2.180E-11 | 7.00 | -8.614E-01 | 0.0951 | 2.233E-11 |
| 7.24 | -8.619E-01 | 0.0951 | 2.288E-11 | 7.49 | -8.625E-01 | 0.0950 | 2.344E-11 |
| 7.73 | -8.630E-01 | 0.0950 | 2.401E-11 | 7.98 | -8.635E-01 | 0.0950 | 2.460E-11 |
| 8.22 | -8.641E-01 | 0.0949 | 2.521E-11 | 8.47 | -8.646E-01 | 0.0949 | 2.582E-11 |
| 8.71 | -8.651E-01 | 0.0949 | 2.646E-11 | 8.96 | -8.657E-01 | 0.0948 | 2.710E-11 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9.20 | -8.653E-01 | 0.0949 | 2.777E-11 | 9.44 | -8.632E-01 | 0.0950 | 2.845E-11 |
| 9.69 | -8.585E-01 | 0.0953 | 2.915E-11 | 9.93 | -8.435E-01 | 0.0962 | 2.987E-11 |
| 10.18 | -7.990E-01 | 0.0990 | 3.062E-11 | 10.42 | -6.846E-01 | 0.1077 | 3.144E-11 |
| 10.67 | -4.858E-01 | 0.1304 | 3.238E-11 | 10.91 | -2.450E-01 | 0.1913 | 3.392E-11 |
| 11.16 | 0.000E+00 | 0.4370 | 3.392E-11 | | | | |

****************************** TIME = 4.000E+02 ******************************

ISTEP = 751 RAIN = 5.844E-02 TRAIN = 2.339E+01 CIN = 0.000E+00
DELT = 5.507E-01 DRAIN = 5.844E-02 TDRAIN = 2.339E+01 SLTIN =-5.062E-35
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.698E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 7.102E-13
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.0000 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 9.831E-22 | 0.23 | -7.796E-01 | 0.4127 | 1.092E-20 |
| 0.47 | -5.923E-01 | 0.4229 | 8.183E-20 | 0.70 | -3.823E-01 | 0.4374 | 4.835E-19 |
| 0.94 | -1.756E-01 | 0.4585 | 2.416E-18 | 1.18 | -1.753E-01 | 0.4585 | 9.671E-18 |
| 1.42 | -1.750E-01 | 0.4585 | 3.569E-17 | 1.66 | -1.747E-01 | 0.4586 | 1.241E-16 |
| 1.90 | -1.744E-01 | 0.4586 | 4.089E-16 | 2.14 | -1.741E-01 | 0.4586 | 1.277E-15 |
| 2.37 | -1.739E-01 | 0.4586 | 3.770E-15 | 2.61 | -1.736E-01 | 0.4587 | 1.044E-14 |
| 2.85 | -1.741E-01 | 0.4586 | 2.676E-14 | 3.09 | -1.818E-01 | 0.4578 | 6.239E-14 |
| 3.33 | -2.505E-01 | 0.4507 | 1.294E-13 | 3.57 | -6.657E-01 | 0.4202 | 2.352E-13 |
| 3.81 | -8.544E-01 | 0.0955 | 2.402E-13 | 4.06 | -8.550E-01 | 0.0955 | 2.459E-13 |
| 4.30 | -8.555E-01 | 0.0955 | 2.518E-13 | 4.55 | -8.560E-01 | 0.0954 | 2.577E-13 |
| 4.79 | -8.566E-01 | 0.0954 | 2.639E-13 | 5.04 | -8.571E-01 | 0.0954 | 2.701E-13 |
| 5.28 | -8.576E-01 | 0.0953 | 2.765E-13 | 5.53 | -8.582E-01 | 0.0953 | 2.831E-13 |
| 5.77 | -8.587E-01 | 0.0953 | 2.898E-13 | 6.02 | -8.592E-01 | 0.0952 | 2.967E-13 |
| 6.26 | -8.598E-01 | 0.0952 | 3.037E-13 | 6.51 | -8.603E-01 | 0.0952 | 3.109E-13 |
| 6.75 | -8.609E-01 | 0.0951 | 3.183E-13 | 7.00 | -8.614E-01 | 0.0951 | 3.258E-13 |
| 7.24 | -8.619E-01 | 0.0951 | 3.336E-13 | 7.49 | -8.625E-01 | 0.0950 | 3.415E-13 |
| 7.73 | -8.630E-01 | 0.0950 | 3.495E-13 | 7.98 | -8.635E-01 | 0.0950 | 3.578E-13 |
| 8.22 | -8.641E-01 | 0.0949 | 3.663E-13 | 8.47 | -8.646E-01 | 0.0949 | 3.750E-13 |
| 8.71 | -8.651E-01 | 0.0949 | 3.839E-13 | 8.96 | -8.657E-01 | 0.0948 | 3.930E-13 |
| 9.20 | -8.653E-01 | 0.0949 | 4.023E-13 | 9.44 | -8.632E-01 | 0.0950 | 4.118E-13 |
| 9.69 | -8.585E-01 | 0.0953 | 4.216E-13 | 9.93 | -8.435E-01 | 0.0962 | 4.317E-13 |
| 10.18 | -7.990E-01 | 0.0990 | 4.422E-13 | 10.42 | -6.846E-01 | 0.1077 | 4.536E-13 |
| 10.67 | -4.858E-01 | 0.1304 | 4.666E-13 | 10.91 | -2.450E-01 | 0.1913 | 4.881E-13 |
| 11.16 | 0.000E+00 | 0.4370 | 4.881E-13 | | | | |

****************************** TIME = 5.000E+02 ******************************

ISTEP = 933 RAIN = 5.844E-02 TRAIN = 2.924E+01 CIN = 0.000E+00
DELT = 5.507E-01 DRAIN = 5.844E-02 TDRAIN = 2.924E+01 SLTIN =-5.056E-35
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.698E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 1.152E-14
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.0000 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 2.918E-23 | 0.23 | -7.796E-01 | 0.4127 | 3.189E-22 |
| 0.47 | -5.923E-01 | 0.4229 | 2.295E-21 | 0.70 | -3.823E-01 | 0.4374 | 1.298E-20 |
| 0.94 | -1.756E-01 | 0.4585 | 6.200E-20 | 1.18 | -1.753E-01 | 0.4585 | 2.361E-19 |
| 1.42 | -1.750E-01 | 0.4585 | 8.240E-19 | 1.66 | -1.747E-01 | 0.4586 | 2.706E-18 |
| 1.90 | -1.744E-01 | 0.4586 | 8.439E-18 | 2.14 | -1.741E-01 | 0.4586 | 2.504E-17 |
| 2.37 | -1.739E-01 | 0.4586 | 7.056E-17 | 2.61 | -1.736E-01 | 0.4587 | 1.876E-16 |
| 2.85 | -1.741E-01 | 0.4586 | 4.651E-16 | 3.09 | -1.818E-01 | 0.4578 | 1.055E-15 |
| 3.33 | -2.505E-01 | 0.4507 | 2.143E-15 | 3.57 | -6.657E-01 | 0.4202 | 3.838E-15 |
| 3.81 | -8.544E-01 | 0.0955 | 3.918E-15 | 4.06 | -8.550E-01 | 0.0955 | 4.009E-15 |
| 4.30 | -8.555E-01 | 0.0955 | 4.102E-15 | 4.55 | -8.560E-01 | 0.0954 | 4.198E-15 |
| 4.79 | -8.566E-01 | 0.0954 | 4.296E-15 | 5.04 | -8.571E-01 | 0.0954 | 4.396E-15 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5.28 | -8.576E-01 | 0.0953 | 4.498E-15 | 5.53 | -8.582E-01 | 0.0953 | 4.602E-15 |
| 5.77 | -8.587E-01 | 0.0953 | 4.710E-15 | 6.02 | -8.592E-01 | 0.0952 | 4.819E-15 |
| 6.26 | -8.598E-01 | 0.0952 | 4.931E-15 | 6.51 | -8.603E-01 | 0.0952 | 5.046E-15 |
| 6.75 | -8.609E-01 | 0.0951 | 5.163E-15 | 7.00 | -8.614E-01 | 0.0951 | 5.283E-15 |
| 7.24 | -8.619E-01 | 0.0951 | 5.406E-15 | 7.49 | -8.625E-01 | 0.0950 | 5.531E-15 |
| 7.73 | -8.630E-01 | 0.0950 | 5.660E-15 | 7.98 | -8.635E-01 | 0.0950 | 5.791E-15 |
| 8.22 | -8.641E-01 | 0.0949 | 5.926E-15 | 8.47 | -8.646E-01 | 0.0949 | 6.063E-15 |
| 8.71 | -8.651E-01 | 0.0949 | 6.204E-15 | 8.96 | -8.657E-01 | 0.0948 | 6.348E-15 |
| 9.20 | -8.653E-01 | 0.0949 | 6.495E-15 | 9.44 | -8.632E-01 | 0.0950 | 6.646E-15 |
| 9.69 | -8.585E-01 | 0.0953 | 6.801E-15 | 9.93 | -8.435E-01 | 0.0962 | 6.960E-15 |
| 10.18 | -7.990E-01 | 0.0990 | 7.126E-15 | 10.42 | -6.846E-01 | 0.1077 | 7.306E-15 |
| 10.67 | -4.858E-01 | 0.1304 | 7.512E-15 | 10.91 | -2.450E-01 | 0.1913 | 7.850E-15 |
| 11.16 | 0.000E+00 | 0.4370 | 7.850E-15 | | | | |

****************************** TIME = 6.000E+02 ******************************

ISTEP = 1114 RAIN = 5.844E-02 TRAIN = 3.507E+01 CIN = 0.000E+00
DELT = 5.507E-01 DRAIN = 5.844E-02 TDRAIN = 3.507E+01 SLTIN =-5.056E-35
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.698E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 2.033E-16
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.0000 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 7.154E-25 | 0.23 | -7.796E-01 | 0.4127 | 7.756E-24 |
| 0.47 | -5.923E-01 | 0.4229 | 5.468E-23 | 0.70 | -3.823E-01 | 0.4374 | 3.020E-22 |
| 0.94 | -1.756E-01 | 0.4585 | 1.409E-21 | 1.18 | -1.753E-01 | 0.4585 | 5.223E-21 |
| 1.42 | -1.750E-01 | 0.4585 | 1.768E-20 | 1.66 | -1.747E-01 | 0.4586 | 5.619E-20 |
| 1.90 | -1.744E-01 | 0.4586 | 1.696E-19 | 2.14 | -1.741E-01 | 0.4586 | 4.879E-19 |
| 2.37 | -1.739E-01 | 0.4586 | 1.336E-18 | 2.61 | -1.736E-01 | 0.4587 | 3.464E-18 |
| 2.85 | -1.741E-01 | 0.4586 | 8.407E-18 | 3.09 | -1.818E-01 | 0.4578 | 1.875E-17 |
| 3.33 | -2.505E-01 | 0.4507 | 3.758E-17 | 3.57 | -6.657E-01 | 0.4202 | 6.666E-17 |
| 3.81 | -8.544E-01 | 0.0955 | 6.803E-17 | 4.06 | -8.550E-01 | 0.0955 | 6.959E-17 |
| 4.30 | -8.555E-01 | 0.0955 | 7.119E-17 | 4.55 | -8.560E-01 | 0.0954 | 7.283E-17 |
| 4.79 | -8.566E-01 | 0.0954 | 7.450E-17 | 5.04 | -8.571E-01 | 0.0954 | 7.621E-17 |
| 5.28 | -8.576E-01 | 0.0953 | 7.796E-17 | 5.53 | -8.582E-01 | 0.0953 | 7.975E-17 |
| 5.77 | -8.587E-01 | 0.0953 | 8.158E-17 | 6.02 | -8.592E-01 | 0.0952 | 8.346E-17 |
| 6.26 | -8.598E-01 | 0.0952 | 8.537E-17 | 6.51 | -8.603E-01 | 0.0952 | 8.733E-17 |
| 6.75 | -8.609E-01 | 0.0951 | 8.933E-17 | 7.00 | -8.614E-01 | 0.0951 | 9.138E-17 |
| 7.24 | -8.619E-01 | 0.0951 | 9.348E-17 | 7.49 | -8.625E-01 | 0.0950 | 9.562E-17 |
| 7.73 | -8.630E-01 | 0.0950 | 9.782E-17 | 7.98 | -8.635E-01 | 0.0950 | 1.001E-16 |
| 8.22 | -8.641E-01 | 0.0949 | 1.024E-16 | 8.47 | -8.646E-01 | 0.0949 | 1.047E-16 |
| 8.71 | -8.651E-01 | 0.0949 | 1.071E-16 | 8.96 | -8.657E-01 | 0.0948 | 1.095E-16 |
| 9.20 | -8.653E-01 | 0.0949 | 1.121E-16 | 9.44 | -8.632E-01 | 0.0950 | 1.146E-16 |
| 9.69 | -8.585E-01 | 0.0953 | 1.173E-16 | 9.93 | -8.435E-01 | 0.0962 | 1.200E-16 |
| 10.18 | -7.990E-01 | 0.0990 | 1.228E-16 | 10.42 | -6.846E-01 | 0.1077 | 1.259E-16 |
| 10.67 | -4.858E-01 | 0.1304 | 1.293E-16 | 10.91 | -2.450E-01 | 0.1913 | 1.351E-16 |
| 11.16 | 0.000E+00 | 0.4370 | 1.351E-16 | | | | |

****************************** TIME = 7.000E+02 ******************************

ISTEP = 1296 RAIN = 5.844E-02 TRAIN = 4.093E+01 CIN = 0.000E+00
DELT = 5.507E-01 DRAIN = 5.844E-02 TDRAIN = 4.093E+01 SLTIN =-5.056E-35
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.698E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 3.652E-18
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.0000 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.591E-26 | 0.23 | -7.796E-01 | 0.4127 | 1.717E-25 |
| 0.47 | -5.923E-01 | 0.4229 | 1.197E-24 | 0.70 | -3.823E-01 | 0.4374 | 6.530E-24 |
| 0.94 | -1.756E-01 | 0.4585 | 3.007E-23 | 1.18 | -1.753E-01 | 0.4585 | 1.098E-22 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1.42 | -1.750E-01 | 0.4585 | 3.649E-22 | 1.66 | -1.747E-01 | 0.4586 | 1.138E-21 |
| 1.90 | -1.744E-01 | 0.4586 | 3.368E-21 | 2.14 | -1.741E-01 | 0.4586 | 9.505E-21 |
| 2.37 | -1.739E-01 | 0.4586 | 2.557E-20 | 2.61 | -1.736E-01 | 0.4587 | 6.522E-20 |
| 2.85 | -1.741E-01 | 0.4586 | 1.561E-19 | 3.09 | -1.818E-01 | 0.4578 | 3.443E-19 |
| 3.33 | -2.505E-01 | 0.4507 | 6.842E-19 | 3.57 | -6.657E-01 | 0.4202 | 1.206E-18 |
| 3.81 | -8.544E-01 | 0.0955 | 1.231E-18 | 4.06 | -8.550E-01 | 0.0955 | 1.259E-18 |
| 4.30 | -8.555E-01 | 0.0955 | 1.287E-18 | 4.55 | -8.560E-01 | 0.0954 | 1.317E-18 |
| 4.79 | -8.566E-01 | 0.0954 | 1.347E-18 | 5.04 | -8.571E-01 | 0.0954 | 1.377E-18 |
| 5.28 | -8.576E-01 | 0.0953 | 1.409E-18 | 5.53 | -8.582E-01 | 0.0953 | 1.441E-18 |
| 5.77 | -8.587E-01 | 0.0953 | 1.474E-18 | 6.02 | -8.592E-01 | 0.0952 | 1.507E-18 |
| 6.26 | -8.598E-01 | 0.0952 | 1.541E-18 | 6.51 | -8.603E-01 | 0.0952 | 1.577E-18 |
| 6.75 | -8.609E-01 | 0.0951 | 1.612E-18 | 7.00 | -8.614E-01 | 0.0951 | 1.649E-18 |
| 7.24 | -8.619E-01 | 0.0951 | 1.687E-18 | 7.49 | -8.625E-01 | 0.0950 | 1.725E-18 |
| 7.73 | -8.630E-01 | 0.0950 | 1.764E-18 | 7.98 | -8.635E-01 | 0.0950 | 1.804E-18 |
| 8.22 | -8.641E-01 | 0.0949 | 1.845E-18 | 8.47 | -8.646E-01 | 0.0949 | 1.887E-18 |
| 8.71 | -8.651E-01 | 0.0949 | 1.930E-18 | 8.96 | -8.657E-01 | 0.0948 | 1.974E-18 |
| 9.20 | -8.653E-01 | 0.0949 | 2.019E-18 | 9.44 | -8.632E-01 | 0.0950 | 2.064E-18 |
| 9.69 | -8.585E-01 | 0.0953 | 2.111E-18 | 9.93 | -8.435E-01 | 0.0962 | 2.160E-18 |
| 10.18 | -7.990E-01 | 0.0990 | 2.210E-18 | 10.42 | -6.846E-01 | 0.1077 | 2.265E-18 |
| 10.67 | -4.858E-01 | 0.1304 | 2.327E-18 | 10.91 | -2.450E-01 | 0.1913 | 2.429E-18 |
| 11.16 | 0.000E+00 | 0.4370 | 2.429E-18 | | | | |

****************************** TIME = 8.000E+02 ******************************

```
ISTEP =      1478   RAIN  = 5.844E-02   TRAIN  = 4.678E+01   CIN   = 0.000E+00
DELT  = 5.507E-01   DRAIN = 5.844E-02   TDRAIN = 4.678E+01   SLTIN =-5.056E-35
NIT   =         1   PET   = 0.000E+00   TRUPTK = 0.000E+00   SLTOUT= 4.698E-02
RELAXF=     1.000   ACTET = 0.000E+00   STORW  = 0.000E+00   STORS = 6.738E-20
                                        QDECAY= 0.000E+00

MASS BALANCE ERROR WATER :   0.0000 %
     ..    .. SOLUTE:   0.0000 %
```

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 3.354E-28 | 0.23 | -7.796E-01 | 0.4127 | 3.613E-27 |
| 0.47 | -5.923E-01 | 0.4229 | 2.502E-26 | 0.70 | -3.823E-01 | 0.4374 | 1.355E-25 |
| 0.94 | -1.756E-01 | 0.4585 | 6.193E-25 | 1.18 | -1.753E-01 | 0.4585 | 2.240E-24 |
| 1.42 | -1.750E-01 | 0.4585 | 7.372E-24 | 1.66 | -1.747E-01 | 0.4586 | 2.272E-23 |
| 1.90 | -1.744E-01 | 0.4586 | 6.645E-23 | 2.14 | -1.741E-01 | 0.4586 | 1.853E-22 |
| 2.37 | -1.739E-01 | 0.4586 | 4.929E-22 | 2.61 | -1.736E-01 | 0.4587 | 1.245E-21 |
| 2.85 | -1.741E-01 | 0.4586 | 2.953E-21 | 3.09 | -1.818E-01 | 0.4578 | 6.465E-21 |
| 3.33 | -2.505E-01 | 0.4507 | 1.277E-20 | 3.57 | -6.657E-01 | 0.4202 | 2.242E-20 |
| 3.81 | -8.544E-01 | 0.0955 | 2.288E-20 | 4.06 | -8.550E-01 | 0.0955 | 2.339E-20 |
| 4.30 | -8.555E-01 | 0.0955 | 2.393E-20 | 4.55 | -8.560E-01 | 0.0954 | 2.447E-20 |
| 4.79 | -8.566E-01 | 0.0954 | 2.502E-20 | 5.04 | -8.571E-01 | 0.0954 | 2.559E-20 |
| 5.28 | -8.576E-01 | 0.0953 | 2.617E-20 | 5.53 | -8.582E-01 | 0.0953 | 2.676E-20 |
| 5.77 | -8.587E-01 | 0.0953 | 2.737E-20 | 6.02 | -8.592E-01 | 0.0952 | 2.798E-20 |
| 6.26 | -8.598E-01 | 0.0952 | 2.862E-20 | 6.51 | -8.603E-01 | 0.0952 | 2.927E-20 |
| 6.75 | -8.609E-01 | 0.0951 | 2.993E-20 | 7.00 | -8.614E-01 | 0.0951 | 3.060E-20 |
| 7.24 | -8.619E-01 | 0.0951 | 3.130E-20 | 7.49 | -8.625E-01 | 0.0950 | 3.200E-20 |
| 7.73 | -8.630E-01 | 0.0950 | 3.273E-20 | 7.98 | -8.635E-01 | 0.0950 | 3.346E-20 |
| 8.22 | -8.641E-01 | 0.0949 | 3.422E-20 | 8.47 | -8.646E-01 | 0.0949 | 3.499E-20 |
| 8.71 | -8.651E-01 | 0.0949 | 3.578E-20 | 8.96 | -8.657E-01 | 0.0948 | 3.659E-20 |
| 9.20 | -8.653E-01 | 0.0949 | 3.742E-20 | 9.44 | -8.632E-01 | 0.0950 | 3.826E-20 |
| 9.69 | -8.585E-01 | 0.0953 | 3.913E-20 | 9.93 | -8.435E-01 | 0.0962 | 4.002E-20 |
| 10.18 | -7.990E-01 | 0.0990 | 4.095E-20 | 10.42 | -6.846E-01 | 0.1077 | 4.195E-20 |
| 10.67 | -4.858E-01 | 0.1304 | 4.310E-20 | 10.91 | -2.450E-01 | 0.1913 | 4.498E-20 |
| 11.16 | 0.000E+00 | 0.4370 | 4.498E-20 | | | | |

****************************** TIME = 9.000E+02 ******************************

```
ISTEP =      1659   RAIN  = 5.844E-02   TRAIN  = 5.261E+01   CIN   = 0.000E+00
DELT  = 5.507E-01   DRAIN = 5.844E-02   TDRAIN = 5.261E+01   SLTIN =-5.056E-35
NIT   =         1   PET   = 0.000E+00   TRUPTK = 0.000E+00   SLTOUT= 4.698E-02
RELAXF=     1.000   ACTET = 0.000E+00   STORW  = 0.000E+00   STORS = 1.293E-21
                                        QDECAY= 0.000E+00

MASS BALANCE ERROR WATER :   0.0000 %
```

.. .. SOLUTE: 0.0000 %

| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 6.863E-30 | 0.23 | -7.796E-01 | 0.4127 | 7.381E-29 |
| 0.47 | -5.923E-01 | 0.4229 | 5.093E-28 | 0.70 | -3.823E-01 | 0.4374 | 2.747E-27 |
| 0.94 | -1.756E-01 | 0.4585 | 1.250E-26 | 1.18 | -1.753E-01 | 0.4585 | 4.497E-26 |
| 1.42 | -1.750E-01 | 0.4585 | 1.470E-25 | 1.66 | -1.747E-01 | 0.4586 | 4.500E-25 |
| 1.90 | -1.744E-01 | 0.4586 | 1.306E-24 | 2.14 | -1.741E-01 | 0.4586 | 3.617E-24 |
| 2.37 | -1.739E-01 | 0.4586 | 9.551E-24 | 2.61 | -1.736E-01 | 0.4587 | 2.396E-23 |
| 2.85 | -1.741E-01 | 0.4586 | 5.653E-23 | 3.09 | -1.818E-01 | 0.4578 | 1.232E-22 |
| 3.33 | -2.505E-01 | 0.4507 | 2.425E-22 | 3.57 | -6.657E-01 | 0.4202 | 4.244E-22 |
| 3.81 | -8.544E-01 | 0.0955 | 4.330E-22 | 4.06 | -8.550E-01 | 0.0955 | 4.428E-22 |
| 4.30 | -8.555E-01 | 0.0955 | 4.528E-22 | 4.55 | -8.560E-01 | 0.0954 | 4.630E-22 |
| 4.79 | -8.566E-01 | 0.0954 | 4.735E-22 | 5.04 | -8.571E-01 | 0.0954 | 4.841E-22 |
| 5.28 | -8.576E-01 | 0.0953 | 4.951E-22 | 5.53 | -8.582E-01 | 0.0953 | 5.062E-22 |
| 5.77 | -8.587E-01 | 0.0953 | 5.176E-22 | 6.02 | -8.592E-01 | 0.0952 | 5.293E-22 |
| 6.26 | -8.598E-01 | 0.0952 | 5.412E-22 | 6.51 | -8.603E-01 | 0.0952 | 5.534E-22 |
| 6.75 | -8.609E-01 | 0.0951 | 5.659E-22 | 7.00 | -8.614E-01 | 0.0951 | 5.787E-22 |
| 7.24 | -8.619E-01 | 0.0951 | 5.917E-22 | 7.49 | -8.625E-01 | 0.0950 | 6.050E-22 |
| 7.73 | -8.630E-01 | 0.0950 | 6.186E-22 | 7.98 | -8.635E-01 | 0.0950 | 6.325E-22 |
| 8.22 | -8.641E-01 | 0.0949 | 6.468E-22 | 8.47 | -8.646E-01 | 0.0949 | 6.613E-22 |
| 8.71 | -8.651E-01 | 0.0949 | 6.762E-22 | 8.96 | -8.657E-01 | 0.0948 | 6.914E-22 |
| 9.20 | -8.653E-01 | 0.0949 | 7.069E-22 | 9.44 | -8.632E-01 | 0.0950 | 7.228E-22 |
| 9.69 | -8.585E-01 | 0.0953 | 7.391E-22 | 9.93 | -8.435E-01 | 0.0962 | 7.559E-22 |
| 10.18 | -7.990E-01 | 0.0990 | 7.733E-22 | 10.42 | -6.846E-01 | 0.1077 | 7.923E-22 |
| 10.67 | -4.858E-01 | 0.1304 | 8.139E-22 | 10.91 | -2.450E-01 | 0.1913 | 8.493E-22 |
| 11.16 | 0.000E+00 | 0.4370 | 8.493E-22 | | | | |

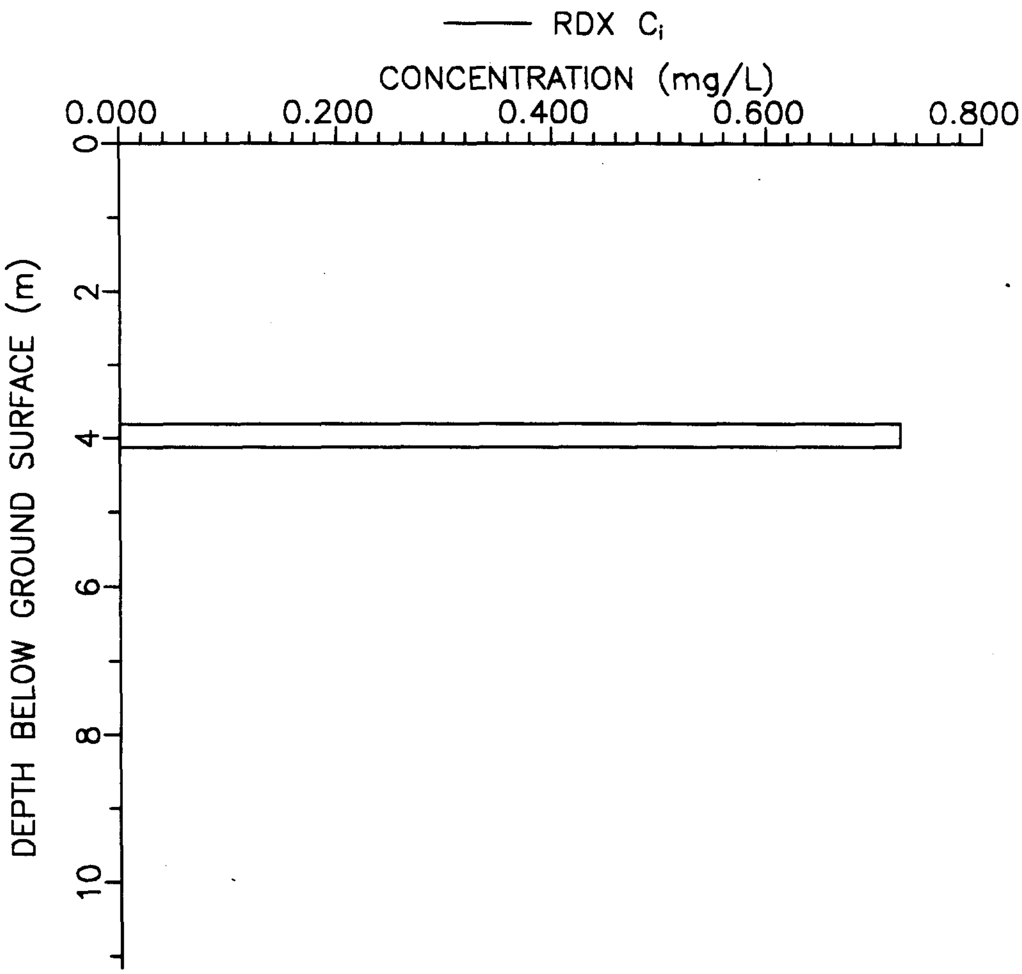
****************************** TIME = 1.000E+03 ******************************

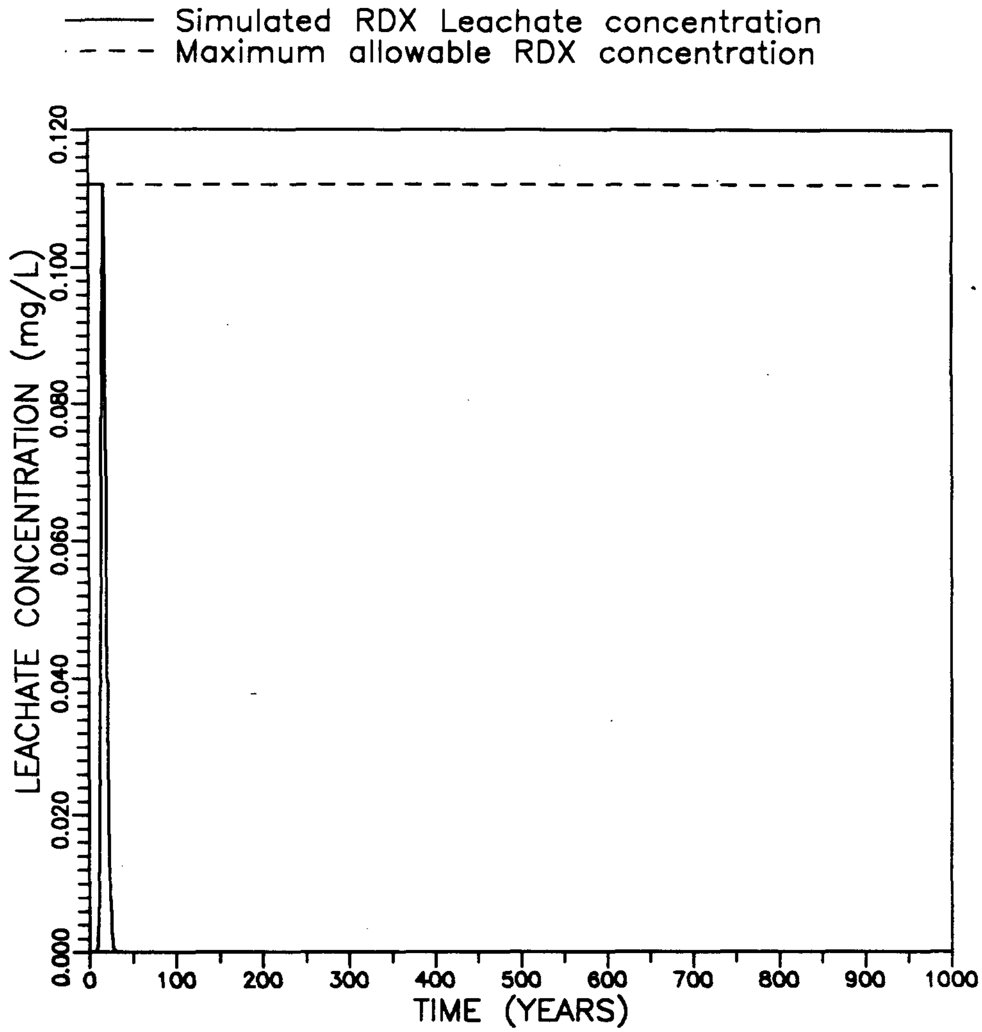
ISTEP = 1841 RAIN = 5.844E-02 TRAIN = 5.846E+01 CIN = 0.000E+00
DELT = 5.507E-01 DRAIN = 5.844E-02 TDRAIN = 5.846E+01 SLTIN =-5.056E-35
NIT = 1 PET = 0.000E+00 TRUPTK = 0.000E+00 SLTOUT= 4.698E-02
RELAXF= 1.000 ACTET = 0.000E+00 STORW = 0.000E+00 STORS = 2.456E-23
QDECAY= 0.000E+00

MASS BALANCE ERROR WATER : 0.0000 %
.. .. SOLUTE: 0.0000 %

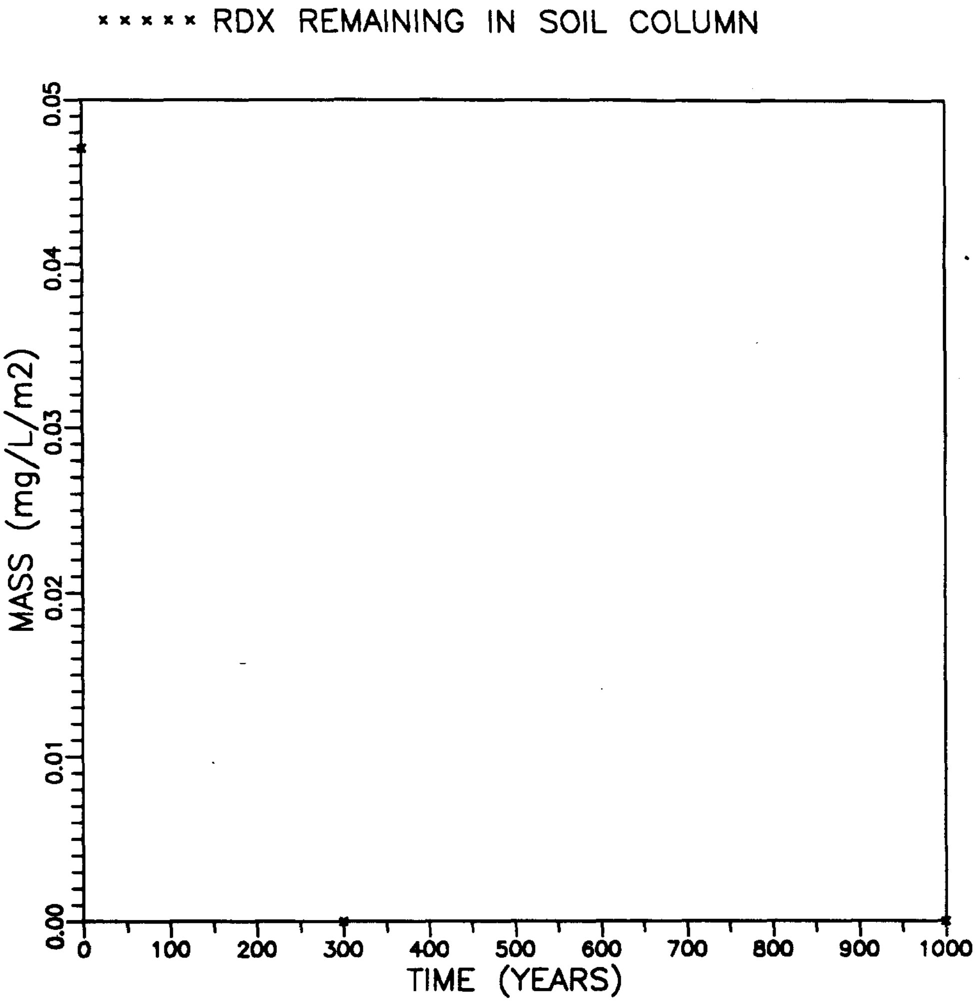
| Depth | P | WC | C | Depth | P | WC | C |
|---|---|---|---|---|---|---|---|
| 0.00 | -9.394E-01 | 0.4054 | 1.379E-31 | 0.23 | -7.796E-01 | 0.4127 | 1.482E-30 |
| 0.47 | -5.923E-01 | 0.4229 | 1.021E-29 | 0.70 | -3.823E-01 | 0.4374 | 5.490E-29 |
| 0.94 | -1.756E-01 | 0.4585 | 2.491E-28 | 1.18 | -1.753E-01 | 0.4585 | 8.936E-28 |
| 1.42 | -1.750E-01 | 0.4585 | 2.910E-27 | 1.66 | -1.747E-01 | 0.4586 | 8.870E-27 |
| 1.90 | -1.744E-01 | 0.4586 | 2.563E-26 | 2.14 | -1.741E-01 | 0.4586 | 7.063E-26 |
| 2.37 | -1.739E-01 | 0.4586 | 1.857E-25 | 2.61 | -1.736E-01 | 0.4587 | 4.639E-25 |
| 2.85 | -1.741E-01 | 0.4586 | 1.091E-24 | 3.09 | -1.818E-01 | 0.4578 | 2.369E-24 |
| 3.33 | -2.505E-01 | 0.4507 | 4.652E-24 | 3.57 | -6.657E-01 | 0.4202 | 8.129E-24 |
| 3.81 | -8.544E-01 | 0.0955 | 8.293E-24 | 4.06 | -8.550E-01 | 0.0955 | 8.480E-24 |
| 4.30 | -8.555E-01 | 0.0955 | 8.671E-24 | 4.55 | -8.560E-01 | 0.0954 | 8.866E-24 |
| 4.79 | -8.566E-01 | 0.0954 | 9.066E-24 | 5.04 | -8.571E-01 | 0.0954 | 9.270E-24 |
| 5.28 | -8.576E-01 | 0.0953 | 9.478E-24 | 5.53 | -8.582E-01 | 0.0953 | 9.692E-24 |
| 5.77 | -8.587E-01 | 0.0953 | 9.910E-24 | 6.02 | -8.592E-01 | 0.0952 | 1.013E-23 |
| 6.26 | -8.598E-01 | 0.0952 | 1.036E-23 | 6.51 | -8.603E-01 | 0.0952 | 1.059E-23 |
| 6.75 | -8.609E-01 | 0.0951 | 1.083E-23 | 7.00 | -8.614E-01 | 0.0951 | 1.107E-23 |
| 7.24 | -8.619E-01 | 0.0951 | 1.132E-23 | 7.49 | -8.625E-01 | 0.0950 | 1.158E-23 |
| 7.73 | -8.630E-01 | 0.0950 | 1.184E-23 | 7.98 | -8.635E-01 | 0.0950 | 1.210E-23 |
| 8.22 | -8.641E-01 | 0.0949 | 1.237E-23 | 8.47 | -8.646E-01 | 0.0949 | 1.265E-23 |
| 8.71 | -8.651E-01 | 0.0949 | 1.294E-23 | 8.96 | -8.657E-01 | 0.0948 | 1.323E-23 |
| 9.20 | -8.653E-01 | 0.0949 | 1.352E-23 | 9.44 | -8.632E-01 | 0.0950 | 1.383E-23 |
| 9.69 | -8.585E-01 | 0.0953 | 1.414E-23 | 9.93 | -8.435E-01 | 0.0962 | 1.446E-23 |
| 10.18 | -7.990E-01 | 0.0990 | 1.479E-23 | 10.42 | -6.846E-01 | 0.1077 | 1.515E-23 |
| 10.67 | -4.858E-01 | 0.1304 | 1.556E-23 | 10.91 | -2.450E-01 | 0.1913 | 1.624E-23 |
| 11.16 | 0.000E+00 | 0.4370 | 1.624E-23 | | | | |

***** NORMAL TERMINATION TIME = 1000.4123 AND STEP NUMBER = 1841


RDX $C_i$
CONCENTRATION (mg/L)
0.000
0.200
0.400
0.600
0.800
DEPTH BELOW GROUND SURFACE (m)
0
2
4
6
8
10



Simulated RDX Leachate concentration
Maximum allowable RDX concentration
LEACHATE CONCENTRATION (mg/L)
0.000
0.020
0.040
0.060
0.080
0.100
0.120
0
100
200
300
400
500
600
700
800
900
1000
TIME (YEARS)




B07NE003702-09305

# APPENDIX D
# GROUNDWATER VOLUME CALCULATIONS

# TABLE D-1

## AVERAGE AQUIFER THICKNESS CALCULATIONS

| Area | Monitoring Well Number | Aquifer Thickness (feet) | | |
|---|---|---|---|---|
| | | Shallow | Intermediate | Deep[5] |
| Load Line 1[1] | 16 | --- | --- | N/A[6] |
| | 22 | 49 | 21 | N/A |
| | 23 | 47 | 20 | N/A |
| | 12 | 48 | 30 | N/A |
| | 2 | 46 | 17 | N/A |
| | 21 | 42 | 44 | N/A |
| | 24 | 41 | 47 | N/A |
| | 3 | 34 | 48 | N/A |
| | 25 | 40 | 71 | N/A |
| Average Thickness | | 44 | 38 | N/A |
| Load Lines 2 and 3[2] | 30 | 31 | 32 | N/A |
| | 31 | 20 | 43 | N/A |
| | 32 | 38 | 17 | N/A |
| | 14 | --- | --- | N/A |
| | 7 | 49 | 9 | N/A |
| | 13 | --- | --- | N/A |
| | 5 | 47 | 21 | N/A |
| | 4 | 47 | 20 | N/A |
| | 28 | 30 | 48 | N/A |
| | 29 | 41 | 49 | N/A |
| Average Thickness | | 38 | 30 | N/A |
| Atlas Missile/Burning Ground/ Load Line 4/Johnson Creek[3] | 58 | 48 | 50 | N/A |
| | 40 | 22 | 61 | 10 |
| | 52 | 39 | 41 | N/A |
| | 53 | 37 | 36 | N/A |
| | 18 | 30 | 30 | N/A |
| | 43 | 22 | 35 | N/A |
| | 44 | 24 | 23 | 12 |
| | 45 | 15 | 22 | 11 |
| | 36 | 17 | 22 | N/A |
| | 15 | 21 | 55 | N/A |
| | 9 | 39 | 30 | N/A |
| | 35 | 19 | 25 | N/A |
| | 37 | --- | 17 | N/A |

**Notes:**

1 As represented on cross-sections A-A', F-F', and G-G' (OU2 RI Report; WCC, 1993C).
2 As represented on cross-sections C-C', H-H', and I-I' (OU2 RI Report; WCC, 1993C).
3 As represented on cross-sections B-B', K-K', and L-L' (OU2 RI Report; WCC, 1993C).
4 The 30-foot thickness reflects the thickness of the Omadi Sandstone which is estimated to be impacted by groundwater cleanup activities.
5 The thickness of the Omadi Sandstone penetrated by monitoring wells is listed.
6 N/A - Not Applicable

**TABLE D-2.** **SUMMARY OF GROUNDWATER VOLUME CALCULATIONS (Target Cleanup Goal I)**

| | AREAL EXTENT (SQ. FT.) | | | AQUIFER THICKNESS (FT.) | | | ASSUMED | PLUME VOLUME |
|---|---|---|---|---|---|---|---|---|
| AREA NAME | SHALLOW | INTER. | DEEP | SHALLOW | INTER. | DEEP | POROSITY | (GALS.) |
| Load Line 1 | 10,095,159 | 2,568,207 | 0 | 44 | 38 | NA | 0.25 | 1.01E+09 |
| Load Lines 2 and 3 | 9,797,725 | 4,242,455 | 0 | 38 | 30 | NA | 0.25 | 9.34E+08 |
| Atlas/Burning/LL4/Johnson Cr. | 79,238,124 | 63,867,511 | 29,799,685 | 28 | 35 | 30 | 0.25 | 1.00E+10 |
| | 99,131,008 | 70,678,173 | 29,799,685 | 2.00E+08 | | TOTAL PLUME VOLUME | | 1.19E+10 |

**TABLE D-3.** **SUMMARY OF GROUNDWATER VOLUME CALCULATIONS (Target Cleanup Goal II)**

| | AREAL EXTENT (SQ. FT.) | | | AQUIFER THICKNESS (FT.) | | | ASSUMED | PLUME VOLUME |
|---|---|---|---|---|---|---|---|---|
| AREA NAME | SHALLOW | INTER. | DEEP | SHALLOW | INTER. | DEEP | POROSITY | (GALS.) |
| Load Line 1 | 13,993,518 | 2,568,207 | 0 | 44 | 38 | NA | 0.25 | 1.33E+09 |
| Load Lines 2 and 3 | 74,987,139 | 102,619,269 | 0 | 38 | 30 | NA | 0.25 | 1.11E+10 |
| Atlas/Burning/LL4/Johnson Cr. | 80,855,297 | 65,061,188 | 29,799,685 | 28 | 35 | 30 | 0.25 | 1.02E+10 |
| | 169,835,954 | 170,248,664 | 29,799,685 | 3.70E+08 | | TOTAL PLUME VOLUME | | 2.26E+10 |

**TABLE D-4.** **SUMMARY OF GROUNDWATER VOLUME CALCULATIONS (Target Cleanup Goal III)**

| | AREAL EXTENT (SQ. FT.) | | | AQUIFER THICKNESS (FT.) | | | ASSUMED | PLUME VOLUME |
|---|---|---|---|---|---|---|---|---|
| AREA NAME | SHALLOW | INTER. | DEEP | SHALLOW | INTER. | DEEP | POROSITY | (GALS.) |
| Load Line 1 | 13,993,518 | 3,010,368 | 0 | 44 | 38 | NA | 0.25 | 1.37E+09 |
| Load Lines 2 and 3 | 124,130,736 | 115,042,214 | 0 | 38 | 30 | NA | 0.25 | 1.53E+10 |
| Atlas/Burning/LL4/Johnson Cr. | 83,924,531 | 65,061,188 | 29,799,685 | 28 | 35 | 30 | 0.25 | 1.03E+10 |
| | 222,048,785 | 183,113,770 | 29,799,685 | 4.35E+08 | | TOTAL PLUME VOLUME | | 2.70E+10 |

**NOTES:**

(1) Composite areal extents measured using Microstation Version 4.03.
(2) Calculations of average aquifer thickness are shown on Table D-1.
(3) Assumed porosity of fine sand unit adopted from Freeze and Cherry, 1979.

# APPENDIX E
# SOIL VOLUME CALCULATIONS

**Attachment E1** contains a memorandum from RUST Environment and Infrastructure (RUST) dated September 22, 1994. The memo contains the procedures and assumptions used to calculate the soil volume to be excavated and treated under OU1. As discussed in the memorandum, the assumptions and estimated volume of soil to be excavated are as follows.

<u>Excavation Depths</u>

- Excavation from 4 feet to 12.5 feet below ground surface (bgs) underneath OU1 excavations (OU1 remediation includes the top 4 feet.

- Excavation from ground surface to 12.5 feet bgs at locations outside OU1 remediation locations.

<u>Soil Remediation Goals</u>

- Soils containing greater than 5 mg/kg of TNB at depths 0 to 9 feet bgs.

- Soils containing greater than 1 mg/kg of TNB at depths 9 to 12.5 feet bgs.

Rationale for these assumptions is that contaminants in soil types at greater than approximately 12.5 feet bgs will completely migrate through the more porous soil before groundwater remediation is completed. Therefore, these contaminants cease to be a source of leaching to groundwater prior to the estimated completion of the groundwater remediation (Refer to **Appendix C - Unsaturated Zone Modeling Results**). TNB concentrations are the controlling soil concentrations for excavation since the mobility of TNB in soils is such that TNB has the lowest allowable leachate concentration.

RUST calculated the estimated soil volumes to be removed to meet the requirements stated above **(2,600 cubic yards (cy)** total). Specific details are contained in **Attachment E1.** Excavation to meet the remediation goals of 5 mg/kg of TNB at 0 to 9 feet bgs and 1 mg/kg of TNB at 9 to 12.5 feet bgs will occur in the vicinity of Load Lines 1,2 and 3 (LL-1, LL-2, LL-3). Aerial views of these excavations are shown in **Drawings 4-6A, 4-6B** and **4-6C** of Volume I.

**ATTACHMENT E1**

MEMORANDUM

DATE: September 22, 1994

TO: Rosemary Gilbertson - USACE
Lori Lynch - USACE
Mead OU1 Files

FROM: Chandler Taylor - RUST

SUBJECT: **OU2 Soil Volumes: TNB > 5,0-9 Feet;TNB > 1,9-12.5 Feet**
**Former Nebraska Ordnance Plant**

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This memorandum summarizes the procedures, assumptions and results used to calculate OU2 soil volumes for the former Nebraska Ordnance Plant.

**Procedures:**

1) USACE provided the following OU2 preliminary remediation goals (PRGs):

- TNB detected greater than 5 mg/kg between 0 and 9 feet below ground surface.
- TNB detected greater than 1 mg/kg between 9 and 12.5 feet below ground surface.

2) RUST estimated the in-place volume of contaminated soil based on the OU2 PRGs using procedures similar to OU1. Volumes were estimated for the following criteria:

- directly below OU1 remediation areas between 4 and 12.5 feet.
- not directly below OU1 remediation areas between 0 and 12.5 feet.

**Assumptions:**

The volume of soil containing detected concentrations of explosives compounds was estimated using assumptions and methods similar to those used to calculate the OU1 FS volumes (April 1993 OU1 FS Appendix C1). The assumptions used include the following:

- if samples were located in the vicinity of one another (for an isolated area) or along the same ditch (for ditch segments), contamination was assumed to extend halfway from a sample above PRGs to a sample below PRGs.
- building and concrete pads were used, where appropriate to delineate contaminated areas.
- topography was used, in the absence of other information, to delineate contamination.
- contamination between two adjacent ditches was assumed, in the absence of other information to extend to the ditches.
- ditch widths were assumed to be 8 feet unless data indicated otherwise.
- sumps were considered as contamination sources but some sumps sampled were below

PRGs, probably due to the reported excavation of source sumps. The area between buildings and sumps was assumed to be above PRGs unless specific data indicates otherwise.

- areas will be excavated to a maximum depth of 12.5 feet.
- if there was a sample interval below PRGs below a sample interval above PRGs, the contamination depth was assumed to extend halfway between the bottom depth of the interval above PRGs and the top depth of the sample interval below PRGs.
- for multiple samples within an area, the depth was assumed to be an average of several borings (with clean intervals below contaminated intervals).
- if one contaminated boring and several contaminated surficial samples were located in an area, the assumed boring depth was used for the entire area.
- all cuts are vertical and any sideslopes are assumed to be clean.

**Results**

The estimated volumes (cy) based on the assumptions and procedures above are shown in the following table:

| Depth | Volume Under OU1 Area | Volume Outside of OU1 Area |
|---|---|---|
| 0-9 feet | | 940 |
| 4-9 feet | 760 | |
| 9-12.5 feet | 560 | 340 |
| All depths | 1300 | 1300 |

Note: Volumes are rounded to two significant figures.

The total OU2 volume based on the criteria in this memorandum is 2600 cy.

# APPENDIX F
# BIOREMEDIATION LITERATURE SURVEY

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ATTACHMENT F1 PRG FOR TNB IN SOIL

# 1.0
# INTRODUCTION

The Mead Site has been organized into Operable Unit 1 (OU1), Operable Unit 2 (OU2) and Operable Unit 3 (OU3). After remediation of soil in OU1, there will be soils remaining which will contain explosive compounds. If not removed, these compounds may continue to leach into the groundwater and be a source of explosive compounds in groundwater. OU2 groundwater remediation alternatives have been developed and include some alternatives with excavation of additional soils containing explosives. Excavation would reduce the potential for explosives to leach to groundwater which may raise concentrations of explosives in groundwater above Target Groundwater Cleanup Goals.

Target Groundwater Cleanup Goals for OU2 include four explosive Chemicals of Concern (COCs), 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), 1,3,5-trinitrobenzene (TNB) and 2,4-dinitroluene (2,4-DNT). A preliminary remediation goal (PRG) for soils which may be removed as part of OU2 remediation has been established for TNB. This PRG, referenced in **Attachment F1**, is as follows:

| Depth Below Ground Surface | PRG |
|---|---|
| 0 to 9 feet | 5 mg/kg |
| 9 to 12.5 feet | 1 mg/kg |

This PRG information is also contained in **Appendix E - Soil Volume Calculations**, and is repeated in this appendix for reader convenience.

Once soils containing explosives are excavated, they would be treated to remove the explosives. Biological treatment is one of the soil treatment technologies evaluated. As part of the technology evaluation process, a literature survey of biological treatment of explosive compounds in soil was conducted. Information from the following literature survey is used to assist in soil treatment technology evaluation.

## 2.0 OBJECTIVES

There are two primary objectives of the literature survey. The first is to determine if bioremediation is currently commercially available as a full-scale process. The second objective is to determine if any of the literature references available document that bioremediation has achieved the lowest soils PRC concentration of 1 mg/kg of TNB in remediated soils.

## 3.0
## SUMMARY OF RESULTS

Sixteen applicable references were found, with 10 references reporting ranges of specific concentrations reached after bioremediation (post-bioremediation concentrations) for a variety of explosive compounds. The values listed in **Table F-1** are the lowest concentrations achieved by specific types of bioremediation reported in the 10 references.

The seven additional references, which are listed in **Table F-2,** contained general information on bioremediation of explosives, without any specific post-bioremediation concentrations. These seven additional references are included in this appendix to provide useful auxiliary information such as descriptions of the biotransformation scheme, limiting conditions, process descriptions, system design and operation, and cost.

**Tables F-1** and **F-2** include the reference citation, the type of study or report, a description of the type of bioremediation studied, and a brief summary of the results or a general description of the study.

All of the studies reviewed were either laboratory or pilot studies. The compost study at Umatilla Depot, Oregon (References No. 7 and 8) contained the most details on bioremediation results. No references were found for commercially available bioremediation processes with a history of commercial use. The three vendors found in the literature survey (Reference Nos. 11, 12 and 14) are, according to the references, in the demonstration stage of development.

**Table F-1** lists post-remediation concentrations for all of the explosive COCs.

## TABLE F-1

## SUMMARY OF EXPLOSIVES BIOTREATMENT DATA FROM LITERATURE REVIEW

| Ref. | Type of Study | Type of Bioremediation | Compound | Study Results: Beginning Concentration | Study Results: Ending Concentration | Study Results: Treatment Time | Comments |
|---|---|---|---|---|---|---|---|
| F.1 | Laboratory | Activated-sludge | TNT | NA | 5 mg/L | NA | |
| F.2 | Laboratory | White rot fungus | TNT | 30 mg/L | 60 μg/L | 96 hours | |
| F.3 | Laboratory | Sewage Treatment Microbes | TNT | 100 ppm | 1.25 ppm | 5 days | |
| F.4 | Laboratory | Composting | RDX | NA | 21.6% of initial conc. | 6 weeks | |
| | | | TNT | NA | 16.63% of initial conc. | 6 weeks | |
| | Greenhouse-scale | Composting | RDX | 9,327 μg/g | 2,209.5 mg/kg | 3 weeks | Results averaged from two tests. |
| | | | TNT | 19,041 μg/g | > 17 mg/kg | | |
| F.5 | Laboratory | Bio-slurry | TNT | 1,300 mg/L | < 10 mg/L | 15 days | |
| F.6 | Bench | Bioslurry | TNT | 1,730 mg/kg | 901 mg/kg | 4 weeks | Concentration of TNB and 2,6-DNT increased during bioremediation. |
| | | | RDX | 539 mg/kg | 433 mg/kg | | |
| | | | HMX | 80 mg/kg | 79 mg/kg | | |
| | | | Tetryl | 72 mg/kg | 3.3 mg/kg | | |
| | | | TNB | 53 mg/kg | 137 mg/kg | | |
| | | | 2,4-DNT | 1.6 mg/kg | 1.1 mg/kg | | |
| | | | 2,6-DNT | 0.3 mg/kg | 1.4 mg/kg | | |
| | | | DNB | 1.5 mg/kg | 7.0 mg/kg | | |
| | | | *o*-NT | 1.3 mg/kg | 0.6 mg/kg | | |
| | Laboratory | Bioslurry | TNT | 1,730 mg/kg | 116 mg/kg | 32 days | Results from the best treatment conditions are presented. The concentration of 2,6-DNT increased during bioremediation. |
| | | | RDX | 539 mg/kg | 235 mg/kg | | |
| | | | HMX | 80 mg/kg | 59 mg/kg | | |
| | | | Tetryl | 72 mg/kg | 0.3 mg/kg | | |
| | | | TNB | 53 mg/kg | 6.5 mg/kg | | |

## TABLE F-1
## (Continued)

## SUMMARY OF EXPLOSIVES BIOTREATMENT DATA FROM LITERATURE REVIEW

| Ref. | Type of Study | Type of Bioremediation | Compound | Study Results: Beginning Concentration | Study Results: Ending Concentration | Study Results: Treatment Time | Comments |
|---|---|---|---|---|---|---|---|
| F.6 (Con't) | | | 2,4-DNT | 1.6 mg/kg | 1.5 mg/kg | | |
| | | | 2,6-DNT | 0.3 mg/kg | 4.2 mg/kg | | |
| | | | DNB | 1.5 mg/kg | 1.3 mg/kg | | |
| | | | o-NT | 1.3 mg/kg | 0.6 mg/kg | | |
| F.7 | Pilot | Composting - aerated static pile | TNT | 7,908 mg/kg | 174 mg/kg | 90 days | Results from the 30% soil aerated static pile are presented (Test No. SP-5). |
| | | | RDX | 776 mg/kg | 213 mg/kg | 90 days | Results from the 7% soil aerated static pile are presented (Test No. SP-1) |
| | | | HMX | 120 mg/kg | 73 mg/kg | | |
| | | Composting - Mechanically agitated in-vessel (MAIV) | TNT | 3,126 mg/kg | 5.6 mg/kg | 90 days | Results from a 10% soil MAIV test are presented (Test No. MAIV-2) |
| | | | RDX | 575 mg/kg | 3.8 mg/kg | | |
| | | | HMX | 119 mg/kg | 6.1 mg/kg | | |
| F.8 | Pilot | Composting - Windrow | TNT | 1,574 μg/g | 10 mg/kg | 20 days | Results from unaerated windrow are presented |
| | | | RDX | 944 μg/g | 5 mg/kg | | |
| | | | HMX | 159 μg/g | 1 mg/kg | | |
| | | | TNB | 8.88 μg/g | 2.04 mg/kg | | |
| | | | 2,6-DNT | 1.61 μg/g | 0.39 mg/kg | | |
| | | | 2,4-DNT | 2.48 μg/g | 0.41 mg/kg | | |
| F.9 | Laboratory | Metabolic oxidation | TNT | 100 μg/ml | < 1 μg/ml | 24 hours | Test was performed on water matrix |

## TABLE F-1
## (Continued)

## SUMMARY OF EXPLOSIVES BIOTREATMENT DATA FROM LITERATURE REVIEW

| Ref. | Type of Study | Type of Bioremediation | Compound | Study Results | | | Comments |
|---|---|---|---|---|---|---|---|
| | | | | Beginning Concentration | Ending Concentration | Treatment Time | |
| F.10 | Laboratory | Naturally-occurring Microbes from surface soils and aquifer materials | TNT<br>2,4-DNT<br>2,6-DNT | 22.7 mg/kg<br>18.2 mg/kg<br>18.2 mg/kg | (<0.05 μM)<br>(<0.05 μM)<br>(<0.05 μM) | 70 days | Best results presented |

Note: NA = information not available.
μM = micromolar (no. of moles/liter)

Reference :


F.1 Bell, B.A., W.D. Burrows, and J.A. Carrazza. 1984. Prototype (Pilot Scale) Testing of a Semi-Continuous Activated Sludge Treatment System. Prepared under Contract DMAD-17-85-C-5801. Prepared by Carpenter Environmental Associates, Inc., Northvale, N.J. for U.S. Army Medical and Bioengineering Research and Development Laboratory, Federick, MD.

F.2 Bumpus, J.A., and M. Tatarko. 1994. "Biodegradation of 2,4,6-Trinitrotoluene by *Phanerochaete chrysosporium*: Identification of Initial Degradation Products and the Discovery of a TNT Metabolite That Inhibits Lignin Peroxidases". Current Microbiology. Vol. 28, pp. 185-190.

F.3 Enzinger, R.M. 1970. Special Study of the Effect of Alpha TNT on Microbiological Systems and the Determination of the Biodegradability of Alpha TNT. U.S. Army Environmental Hygiene Agency Report DTIC AD 728497. January-August.

F.4 Isbister, J. D., G. L. Anspach, J. F. Kitchens, and R. C. Doyle. 1984. "Composting for Decontamination of Soils Containing Explosives". Microbiologica. 7, 47-73. Supported in part by the U.S. Army Toxic and Hazardous Materials Agency under Contract No. DAAK11-81-C-0027. (Ames assay and analytical methods development was supported by Atlantic Research Corporation.)

F.5 Montemagno, C.D. 1991. Evaluation of the Feasibility of Biodegrading Explosives-Contaminated Soils and Groundwater at the Newport Army Ammunition Plant. Prepared for U.S. Army Toxic and Hazardous Materials Agency. Prepared by Argonne National Laboratory, Environmental Research Division.

F.6 RUST Environment & Infrastructure. 1993. Draft Treatability Study Report, Remedial Alternative Feasibility Study, Operable Unit 1, Former NOP Site, Mead, Nebraska. Prepared for Department of the Army, U.S. Army Engineer District, Kansas City Corps of Engineers, Kansas City, MO. Contract DACW 41-90-D-0009. June.

F.7 Roy F. Weston, Inc. 1991. Optimization of Composting for Explosives Contaminated Soil. Contract No. DAAA15-88-D-0010, Task Order Number 10, Work Order 2281-08-10. Prepared for U.S. Army Toxic and Hazardous Materials Agency. November.

F.8 Roy F. Weston, Inc. 1993. Windrow Composting Demonstration for Explosives-Contaminated Soils at Umatilla Depot Activity, Hermiston, Oregon. Report No. CETHA-TS-CR-93043. Prepared for U.S. Army Environmental Center, Contract No. DACA31-91-D-0079. August.

F.9 Won, W. D., R. J. Heckly, D. J. Glover, and J. C. Hoffsommer. 1974. "Metabolic Disposition of 2,4,6-Trinitrotoluene". Applied Microbiology. Volume 27, No.3, p513-516. Sponsored by the Naval Ordnance Systems Command through a contract between the Regents of University of California and the Office of Naval Research. March.

F.10 Bradley, P.M., F.H. Chapelle, J.E. Landmeyer, and J.G. Schumacher 1994. "Microbial Transformation of Nitroaromatics in Surface Soils". Applied and Environmental Microbiology. Volume 60, No. 6, p.2170-2175. Sponsored by the U.S. Geological Survey - Water Resources Division, Stephenson Center, Columbia, South Carolina, and U.S. Geological Survey - Water Resources Division, Rolla Missouri.

# TABLE F-2
# SUMMARY OF GENERAL EXPLOSIVES BIOTREATMENT REFERENCES

| Ref. | Type of Study or Report | Type of Bioremediation | Compound | Description |
|---|---|---|---|---|
| F.11 | EPA VISITT Vendor: Earthfax Engineering | White Rot Fungus System | Not specific. Includes explosive compounds. | Overview description of technology. No specific claims on explosive compound reduction. Field implementation claimed to have begun in 1993. |
| F.12 | EPA VISITT Vendor: EODT Services | Amoeba-bacteria slurry system | Not specific. Includes explosive compounds. | Overview description of technology. 75% reduction of solid propellants claimed at demonstration test at Lone Star Army Ammunition Plant. No specific explosive concentrations or compounds reported. |
| F.13 | Laboratory Study | Compost | TNT | Determined biotransformation scheme for TNT in compost. Fact that TNT will degrade in compost proven, but no ending TNT concentrations reported. |
| F.14 | EPA VISITT Vendor: MYCOTECH Corp. | In-situ or ex-situ White Rot Fungus system for soils | Not specific. Includes explosive compounds. | Prototype system claimed operational. No specific explosive concentrations or compounds reported. |
| F.15 | Field Observation | Compost | Not specified. | Addressed compost volume changes as result of compost process. No description of explosive concentrations. |
| F.16 | Engineering Study | Compost | Not specified. | Engineering report on system design, operations and cost. No discussion of explosive concentrations. |
| F.17 | Laboratory Study | White Rot Fungus | TNT | Growth of White Rot Fungus is inhibited at TNT concentrations above approximately 20 ppm. White Rot Fungus will degrade TNT if beginning TNT concentrations below critical level. Conclusions of final TNT concentrations not clear from report. |

References:

F.11 Earthfax Engineering, Inc. 1994. Vendor Information System for Innovative Treatment Technologies (VISITT) database Version 3.0. U.S. Environmental Protection Agency. October.

F.12 EODT Services, Inc. 1994. Vendor Information System for Innovative Treatment Technologies (VISITT) database Version 3.0. U.S. Environmental Protection Agency. October.

F.13 Kaplan, D.L., A.M. Kaplan. 1982. U.S. Army Natick Research and Development Command. "Thermophilic Biotransformations of 2,4,6-Trinitrotoluene Under Simulated Composting Conditions". Environmental Microbiology, p. 757-760. September.

F.14 MYCOTECH Corp. 1994. Vendor Information System for Innovative Treatment Technologies (VISITT) database Version 3.0. U.S. Environmental Protection Agency. October.

# TABLE F-2
# (Continued)

## SUMMARY OF GENERAL EXPLOSIVES BIOTREATMENT REFERENCES


F.15 Roy F. Weston, Inc. 1993. Compost Compaction Evaluation. Prepared for U.S. Army Environmental Center, Contract No. DACA 31-9-D-0079. July.

F.16 Roy F. Weston, Inc. 1993. Windrow Composting Engineering/Economic Evaluation. Report No. CETHA-TS-CE-93050. Prepared for U.S. Army Environmental Center. May.

F.17 Spiker, J.K., D.L. Crawford, R.L. Crawford. 1992. "Influence of 2,4,6-Trinitrotoluene (TNT) concentration on the Degradation of TNT in Explosive-contaminated Soils by the White Rot Fungus Phanerochaete Chrysopium." Applied and Environmental Microbiology. 589: 3199-3202.

| Explosive Chemical of Concern | Reference No. | Lowest Post-Bioremediation Concentration Reported in Reference (mg/kg) |
|---|---|---|
| TNT | 7 | 5.6 |
| | 8 | 10 |
| | 4 | 17 |
| | 6 | 116 |
| RDX | 7 | 3.8 |
| | 8 | 5 |
| TNB | 8 | 2 |
| | 6 | 6.5 |
| 2,4-DNT | 8 | 0.4 |

In summary, the literature survey resulted in the following lowest achievable concentrations.

- TNT 5.6 mg/kg
- RDX 3.8 mg/kg
- TNB 2 mg/kg
- 2,4 DNT 0.4 mg/kg

These lowest results are all from the Umatilla pilot project using approximately 14 cubic yards of explosive contaminated soil for an aerated static pile and a mechanically agitated in-vessel compost study (Reference No. 7) and approximately 18 cubic yards of explosive contaminated soil for a windrow compost study (Reference No. 8).

Reference B.10 presents the results of a U.S. Geological Survey study to evaluate the biodegradation of nitroaromatics in surface soils by indigenous microorganisms. In this study, native microorganisms from Weldon Spring, Missouri were amended to laboratory microcosms containing approximately 18.2 mg/kg 2,4-DNT and 2,6-DNT, each. The initial TNT concentration in these microcosms was approximately 22.7 mg/kg.

Only those studies in which post-bioremediation concentrations were expressed in weight of explosives per weight of soil could be evaluated. Five of the laboratory studies (Reference Nos. 1, 2, 3, 5, and 10) reported post-remediation values in mg/L, ppm or $\mu$M with no conversions to weight of explosives per weight of soil (i.e. μg/g or mg/kg, etc.). Therefore these five studies, while showing a decrease in explosive concentrations through bioremediation, cannot be directly compared to the Site soil PRGs.

The only known bioremediation study specific to the Site is a treatability study (Reference No. 6) which included slurry based biological treatment for OU1. During the treatability study, explosive contaminated soils collected from the Site were treated in 500 mL flasks (termed Laboratory study) and 30L vessels (termed Bench-Scale study). The lowest post-bioremediation concentrations reported were:

- TNT 116 mg/kg
- RDX 451 mg/kg
- TNB 6.5 mg/kg
- 2,4 DNT 1.6 mg/kg

These concentrations are higher than those reported in the Umatilla compost study (Reference Nos. 7 and 8).

# 4.0
# CONCLUSIONS

## 4.1 FIRST OBJECTIVE - COMMERCIAL AVAILABILITY

None of the references surveyed depicted bioremediation as commercially available. None of the studies in the references surveyed included data to demonstrate that bioremediation will reduce the Site explosive COCs to non-detectable levels.

## 4.2 SECOND OBJECTIVE - MEETING PRGs FOR TNB

The lowest TNB concentration reported in the literature surveyed is 2 mg/kg. This will meet the PRG of 5 mg/kg for depths of 0 to 9 feet below ground surface (bgs), but will not meet the PRG of 1 mg/kg for depths of 9 to 12.5 feet bgs.

## 4.3 RECOMMENDATIONS

Due to the fact that none of the literature references demonstrated that bioremediation is commercially available, or that all of the PRGs for TNB in soil could be met, bioremediation cannot be recommended for OU2 remediation without additional treatability and pilot scale studies.

## 4.4 TREATABILITY AND PILOT SCALE STUDIES

For any treatability and pilot study, the following parameters should be evaluated:

- The duration of treatment to achieve site-specific goals
- The density of the indigenous microbial population required to effect bioremediation
- The ability of the indigenous microbial population to degrade the range of contaminant concentrations present at the site
- The potential formation of hazardous intermediate compounds resulting from the biodegradation of contaminants
- The availability of required growth factors (i.e. nutrients, oxygen)

- The possibility of amending non-indigenous microorganisms (bioaugmentation).

## 5.0 REFERENCES WITH SPECIFIC EXPLOSIVES CONCENTRATION INFORMATION

This section contains summaries of the nine references from the literature survey which contain explosive compound concentration information. Explosive concentration reduction results are contained in **Table F-1**.

**F.1** **Bell, B.A., W.D. Burrows, and J.A. Carrazza. 1984. Prototype (Pilot Scale) Testing of a Semi-Continuous Activated Sludge Treatment System. Prepared under Contract DMAD-17-85-C-5801. Prepared by Carpenter Environmental Associates, Inc., Northvale, N.J. for U.S. Army Medical and Bioengineering Research and Development Laboratory, Federick, MD.**

Objective

Feasibility of bioremediation of explosives in wastewater.

Description

Laboratory bench- and pilot-scale studies of a semicontinuous activated sludge wastewater treatment system proposed for cleaning wastewater from the Holston Army Ammunition Plant.

Summary

Bell found that, in semicontinuous activated-sludge treatment systems, no significant TNT reduction was seen in anoxic conditions when TNT concentration fell below 5 mg/L. The bench-scale model was run for 30 months and the pilot model was run for 6 months under aerobic and anaerobic conditions. The rate of TNT removal was a function of available (biodegradable) COD, with the rate of removal being reduced to extremely low levels or ceasing when COD was exhausted. TNT removal was to below detectable levels. Much of RDX and TAX was removed.

**F.2** **Bumpus, J.A., and M. Tatarko. 1994. "Biodegradation of 2,4,6-Trinitrotoluene by *Phanerochaete chrysosporium*: Identification of Initial Degradation Products and the Discovery of a TNT Metabolite That Inhibits Lignin Peroxidases". Current Microbiology. Vol. 28, pp. 185-190.**

Objective

Demonstrate that TNT can be degraded by White Rot Fungus and identify products of biodegradation.

Description

Laboratory tests using membrane bioreactor and pelleted culture.

Summary

Bumpus and Tatarko found that TNT at concentration of 30 mg/L was reduced to less than 60 µg/L by ligninolytic culture of *Phanerochaete chrysosporirum* in 2-L silicone membrane bioreactor at the end of a 96-hour incubation.

**F.3** **Enzinger, R.M. 1970. Special Study of the Effect of Alpha TNT on Microbiological Systems and the Determination of the Biodegradability of Alpha TNT. U.S. Army Environmental Hygiene Agency Report DTIC AD 728497. January-August.**

Summary

Enzinger acclimated sewage treatment microbes to TNT. When cultured in a nutrient broth (trypticase soy), these microbes decreased TNT from 100 to 1.25 ppm in 5 days.

**F.4** **Isbister, J. D., G. L. Anspach, J. F. Kitchens, and R. C. Doyle. 1984. "Composting for Decontamination of Soils Containing Explosives". Microbiologica. 7, 47-73. Supported in part by the U.S. Army Toxic and Hazardous Materials Agency under Contract No. DAAK11-81-C-0027. (Ames assay and analytical methods development was supported by Atlantic Research Corporation.)**

Objective

Evaluate compost process for degrading TNT and RDX.

Description

- Laboratory and larger-scale greenhouse composting of TNT and RDX.
- Amendments mixture contained hay and horsefeed.

Summary

Extractable TNT and RDX concentrations in the composts rapidly declined in the six weeks of composting. The results from the greenhouse-scale compost studies confirmed the laboratory-scale experiments.

In the laboratory compost, solvent extractable RDX decreased from an average of 112.3% at time zero to 68.9% at three weeks and 21.6% at six weeks (RDX concentrations at initiation were 10,000 µg/g on dry weight basis). The rapid loss of $^{14}$C-RDX with the concurrent evolution of $^{14}CO_2$ suggests that the RDX molecule was rapidly metabolized with a substantial portion of carbon released as $CO_2$. In the greenhouse-scale compost testings, 55% of RDX was degraded after three weeks of composting. RDX concentration in the greenhouse-scale compost testing are as follows:

| | RDX concentration, µg/g (dry weight) | | |
|---|---|---|---|
| Length of Composting (weeks) | 0 | 3 | 6 |
| Test 1 | 9,240 | 3,284 | 3,142 |
| Test 2 | 9,414 | 5,093 | 1,277 |

In the laboratory composts, TNT was rapidly transformed into non-extractable compounds that resemble humus materials. Extractable $^{14}$C-TNT decreased from an average of 93.46% at the initiation of the study to an average of 46.63% after three weeks and an average of 16.63% after six weeks of composting (TNT concentrations at initiation were 10,000 µg/g on dry weight basis). Extractable TNT concentrations in the greenhouse-scale TNT compost was reduced from an average of 19,041 µg/g at week zero to below the detection limit (17 µg/g) after three weeks of composting. No evidence for cleavage of the TNT benzene ring was found. The reductive transformation products normally associated with microbial action on TNT were found only in very small quantities.

**F.5** **Montemagno, C.D. 1991. <u>Evaluation of the Feasibility of Biodegrading Explosives-Contaminated Soils and Groundwater at the Newport Army Ammunition Plant</u>. Prepared for U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD. Prepared by Argonne National Laboratory, Environmental Research Division.**

Objective

Feasibility of biodegrading explosives in soil and groundwater.

Description

Laboratory study of soil slurry sequencing batch reactor.

Summary

Aerobic reactors (soil slurry-sequencing batch reactor system) reduced TNT concentrations from about 1,300 mg/L to less than 10 mg/L in 15 days. Anoxic reactors achieved the same kind of reduction but at an apparently slower rate. Bioaugmentation, the addition of microorganisms isolated from soil and having the ability to degrade TNT, did not improve the degradation rate observed in the reactors.

**F.6 RUST Environment & Infrastructure. 1993. Draft Treatability Study Report, Remedial Alternative Feasibility Study, Operable Unit 1, Former NOP Site, Mead, Nebraska. Prepared for Department of the Army, U.S. Army Engineer District, Kansas City Corps of Engineers, Kansas City, MO. Contract DACW 41-90-D-0009. June.**

Objective

Treatability study of explosives compounds in soil.

Description

- Laboratory-scale studies were used to screen for biotreatment conditions which favor destruction of the explosives compounds in the contaminated soils.
- Bench-scale treatability studies were primarily used to evaluate the quantity of material necessary for conducting a range of post-treatment analyses.

Summary

Laboratory-scale treatability studies demonstrated better than 90% destruction of TNT in four-week batch aerobic treatment and 32-day, two stage continuous flow aerobic treatment. Tetryl concentrations were decreased to nondetectable levels (<5 mg/kg) in all aerobic treatments. The highest treatment reductions achieved for RDX and HMX were approximately 50% reduction in contaminant concentrations. The success in treating TNT is attributed to bioaugmentation with an inocula which had demonstrated capabilities for degrading TNT. Based on literature, inocula with similar capabilities for degrading RDX and HMX probably exist.

Studies with $^{14}C$-labeled TNT demonstrated that TNT was not being fully mineralized to $CO_2$, suggesting that the TNT was bioconverted without cleavage of the aromatic ring. However, assays demonstrated a substantial reduction in toxicity between the untreated soil and the biotreated residue.

**F.7** **Roy F. Weston, Inc. 1991. <u>Optimization of Composting for Explosives Contaminated Soil</u>. Contract No. DAAA15-88-D-0010, Task Order Number 10, Work Order 2281-08-10. Prepared for U.S. Army Toxic and Hazardous Materials Agency. November.**

<u>Objective</u>

To evaluate key parameters that have the potential to increase the quantity of soil processed in a compost treatment system per unit time.

<u>Description</u>

- Field scale pilot studies.
- Composting systems evaluated : mechanically agitated in-vessel (MAIV) system and aerated static pile (SP) system.
- Key composting parameters investigated : soil loading percentage and overall amendment composition.
- Explosives compound analyzed : TNT, RDX, and HMX.

<u>Summary</u>

Percent Reduction for TNT, RDX, and HMX are summarized in **Table F-3** for the eight SP and four MAIV test conducted. Average explosives concentrations during each test are summarized in **Table F-4**. Composition of amendments mixtures used for the pilot studies are summarized in **Table F-5**.

In terms of removal percentage, TNT was consistently degraded to the greatest extent, followed by RDX. HMX generally was degraded to a much lesser extent than either TNT or RDX. Degradation was much more rapid and extensive in the MAIV tests than in the SP tests.

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TABLE F-3

**Percent Reduction of Explosives in UMDA Compost Experiments**

| Test | % Soil/ Amendment Mix* | Percent Reduction HMX | RDX | TNT |
|---|---|---|---|---|
| SP-1 | 7/A | 39 | 73 | 91 |
| SP-2 | 10/A | 21 | 46 | 96 |
| SP-3 | 20/A | 5 | 16 | 94 |
| SP-4 | 80/inoculated | 2 | 4 | 6 |
| SP-5 | 30/A | 11 | 22 | 98 |
| SP-6 | 40/A | 2 | 0 | 79 |
| SP-7 | 10 UC/A | n/a | n/a | n/a |
| SP-8 | 10/C | 80 | 93 | 99 |
| MAIV-1 | 10/A | 29 | 90 | 97 |
| MAIV-2 | 10/B | 95 | 99 | 99 |
| MAIV-3 | 25/C | 68 | 97 | 99 |
| MAIV-4 | 40/C | 0 | 18 | 97 |

n/a - Uncontaminated soil pilot unit, no explosives present.
* - See Table 4-2

From Roy F. Weston. 1991 "Optimization of Composting for Explosives Contaminated Soil". November.

TABLE F-4

**Average Concentrations and Standard Deviations of Explosives Data From UMDA Composting Pilot Studies**

| Reactor | | Average HMX mg/kg | Average RDX mg/kg | Average 2,4,6-TNT mg/kg | Standard Deviation HMX Std Dev | Standard Deviation RDX Std Dev | Standard Deviation 2,4,6-TNT Std Dev |
|---|---|---|---|---|---|---|---|
| Static 1 | Day 0 | 120 | 776 | 1,144 | 5.9 | 79 | 106 |
| 7% Soil | Day 10 | 124 | 647 | 270 | 22 | 150 | 63 |
| | Day 20 | 70 | 428 | 271 | 16 | 85 | 84 |
| | Day 44 | 84 | 324 | 173 | 27 | 131 | 157 |
| | Day 90 | 73 | 213 | 107 | 14 | 125 | 90 |
| Static 2 | Day 0 | 180 | 1,008 | 4,984 | 11 | 58 | 551 |
| 10% Soil | Day 10 | 125 | 973 | 1,114 | 12 | 205 | 249 |
| | Day 20 | 127 | 723 | 719 | 15 | 85 | 378 |
| | Day 44 | 181 | 939 | 241 | 27 | 167 | 147 |
| | Day 90 | 142 | 542 | 200 | 20 | 186 | 115 |

From Roy F. Weston. 1991. "Optimization of Composting for Explosives Contaminated Soil". November.

TABLE F-4

**(continued)**

| Reactor | | Average HMX mg/kg | Average RDX mg/kg | Average 2,4,6-TNT mg/kg | Standard Deviation HMX Std Dev | Standard Deviation RDX Std Dev | Standard Deviation 2,4,6-TNT Std Dev |
|---|---|---|---|---|---|---|---|
| Static 3 20% Soil | Day 0 | 194 | 1,076 | 5,716 | 9.6 | 38 | 491 |
| | Day 10 | 175 | 1,178 | 3,322 | 33 | 198 | 372 |
| | Day 20 | 174 | 961 | 2,370 | 23 | 125 | 534 |
| | Day 44 | 195 | 964 | 517 | 27 | 199 | 58 |
| | Day 90 | 184 | 902 | 331 | 33 | 222 | 238 |
| Static 4 microbes added 80% Soil | Day 0 | 243 | 1,234 | 11,320 | 16 | 64 | 808 |
| | Day 2 | 255 | 1,258 | 11,580 | 30 | 130 | 909 |
| | Day 4 | 250 | 1,222 | 11,700 | 17 | 97 | 387 |
| | Day 8 | 247 | 1,236 | 11,880 | 12 | 69 | 327 |
| | Day 16 | 274 | 1,246 | 11,740 | 35 | 165 | 1,494 |
| | Day 20 | 265 | 1,184 | 10,900 | 18 | 68 | 791 |
| | Day 90 | 238 | 1,180 | 10,640 | 32 | 199 | 978 |

From Roy F. Weston. 1991. "Optimization of Composting for Explosives Contaminated Soil". November.

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TABLE F-4

**(continued)**

| Reactor | | Average HMX mg/kg | Average RDX mg/kg | Average 2,4,6-TNT mg/kg | Standard Deviation HMX Std Dev | Standard Deviation RDX Std Dev | Standard Deviation 2,4,6-TNT Std Dev |
|---|---|---|---|---|---|---|---|
| Static 5 | Day 0 | 236 | 1,178 | 7,908 | 14 | 53 | 336 |
| 30% Soil | Day 10 | 216 | 1,278 | 5,058 | 41 | 192 | 901 |
| | Day 20 | 175 | 1,003 | 3,242 | 45 | 183 | 695 |
| | Day 44 | 230 | 741 | 526 | 19 | 209 | 337 |
| | Day 90 | 210 | 924 | 174 | 33 | 122 | 117 |
| Static 6 | Day 0 | 310 | 1,572 | 9,858 | 29 | 136 | 1,014 |
| 40% Soil | Day 10 | 372 | 1,974 | 9,440 | 24 | 119 | 596 |
| | Day 20 | 290 | 1,556 | 5,956 | 57 | 258 | 1,313 |
| | Day 44 | 310 | 1,192 | 1,736 | 29 | 508 | 416 |
| | Day 90 | 305 | 1,674 | 2,086 | 30 | 174 | 442 |

From Roy F. Weston. 1991. "Optimization of Composting for Explosives Contaminated Soil". November.

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TABLE F-4

**(continued)**

| Reactor | | Average HMX mg/kg | Average RDX mg/kg | Average 2,4,6-TNT mg/kg | Standard Deviation HMX Std Dev | Standard Deviation RDX Std Dev | Standard Deviation 2,4,6-TNT Std Dev |
|---|---|---|---|---|---|---|---|
| Static 7 | Day 0 | 2.54 | 1.96 | 3.84 | 0.00 | 0.00 | 0.00 |
| 10% UC | Day 10 | 4.96 | 16.5 | 17.7 | 4.96 | 28.8 | 28.1 |
| | Day 20 | 2.54 | 1.96 | 3.84 | 0.00 | 0.00 | 0.00 |
| | Day 44 | 2.54 | 2.00 | 3.84 | 0.00 | 0.09 | 0.00 |
| | Day 90 | 2.54 | 1.96 | 5.82 | 0.00 | 0.00 | 0.42 |
| Static 8* | Day 0 | 307 | 618 | 3,850 | 67 | 100 | 650 |
| 10% Soil | Day 10 | 203 | 386 | 1,078 | 52 | 96 | 536 |
| | Day 20 | 92 | 112 | 117 | 50 | 54 | 104 |
| | Day 44 | 55 | 43 | 39 | 26 | 32 | 30 |
| | Day 90 | 61 | 46 | 41 | 26 | 15 | 31 |

* Analyses and data reduction done by Oak Ridge National Laboratory.

From Roy F. Weston. 1991. "Optimization of Composting for Explosives Contaminated Soil". November.

TABLE F-4

**(continued)**

| Reactor | | Average HMX mg/kg | Average RDX mg/kg | Average 2,4,6-TNT mg/kg | Standard Deviation HMX Std Dev | Standard Deviation RDX Std Dev | Standard Deviation 2,4,6-TNT Std Dev |
|---|---|---|---|---|---|---|---|
| MAIV-1 10% Soil | Day 0 | 169 | 1,011 | 3,452 | 11 | 61 | 255 |
| | Day 10 | 140 | 1,009 | 165 | 13 | 96 | 73 |
| | Day 20 | 71 | 74 | 63 | 15 | 33 | 70 |
| | Day 44 | 120 | 104 | 90 | 22 | 18 | 119 |
| MAIV-2 10% Soil | Day 0 | 119 | 575 | 3,126 | 5 | 37 | 257 |
| | Day 10 | 34 | 33 | 61 | 8 | 13 | 18 |
| | Day 20 | 6.5 | 6.3 | 16 | 1 | 4 | 9.1 |
| | Day 44 | 6.1 | 3.8 | 5.6 | 2 | 2.6 | 3.0 |
| MAIV-3 25% Soil | Day 0 | 161 | 597 | 5,208 | 47.6 | 190 | 1872 |
| | Day 10 | 133 | 464 | 1,145 | 4.9 | 30 | 424 |
| | Day 20 | 81 | 89 | 27 | 8.6 | 29 | 35 |
| | Day 44 | 51 | 18 | 14 | 13.1 | 11 | 11 |

From Roy F. Weston. 1991. "Optimization of Composting for Explosives Contaminated Soil". November.

TABLE F-4

**(continued)**

| Reactor | | Average HMX mg/kg | Average RDX mg/kg | Average 2,4,6-TNT mg/kg | Standard Deviation HMX Std Dev | Standard Deviation RDX Std Dev | Standard Deviation 2,4,6-TNT Std Dev |
|---|---|---|---|---|---|---|---|
| MAIV-4* | Day 0 | 456 | 754 | 6,950 | 20 | 44 | 190 |
| 40% Soil | Day 10 | 522 | 843 | 5,100 | 48 | 58 | 760 |
| | Day 20 | 627 | 840 | 1,785 | 37 | 148 | 536 |
| | Day 44 | 601 | 621 | 209 | 79 | 114 | 188 |

* Analyses and data reduction done by Oak Ridge National Laboratory.

Note: All explosives concentrations in Table 5-3 are expressed on a dry weight basis.

From Roy F. Weston. 1991. "Optimization of Composting for Explosives Contaminated Soil". November.

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TABLE F-5

**Non-Soil Amendments Used in UMDA Composting Tests**

| | Amendment Mix | | |
|---|---|---|---|
| | A | B | C |
| Test | SP-1 | MAIV-2 | MAIV-3 |
| Test | SP-2 | | MAIV-4 |
| Test | SP-3 | | SP-8 |
| Test | SP-5 | | |
| Test | SP-6 | | |
| Test | SP-7 | | |
| Test | MAIV-1 | | |
| Amendments | | | |
| Sawdust | 30% | | 22% |
| Apple pomace | 15% | | 6% |
| Chicken manure | 20% | | |
| Chopped potato waste | 35% | | 17% |
| Horse manure/straw | | 50% | |
| Buffalo manure | | 10% | |
| Alfalfa | | 32% | 22% |
| Horse feed | | 8% | |
| Cow manure | | | 33% |

From Roy F. Weston. 1991. "Optimization of Composting for Explosives Contaminated Soil". November.

**F.8** **Roy F. Weston, Inc. 1993. <u>Windrow Composting Demonstration for Explosives-Contaminated Soils at Umatilla Depot Activity, Hermiston, Oregon</u>. Report No. CETHA-TS-CR-93043, Contract No. DACA31-91-D-0079, Task Order No. 01. Prepared for U.S. Army Environmental Center, CET-HA-TD-5, Aberdeen Proving Ground, MD. August.**

Objective

To evaluate the performance of windrow composting in terms of explosives removal.

Description

- Field demonstration of windrow composting.
- Six windrow testings using uncontaminated soils were conducted to evaluate soil loading percentages and turning frequencies.
- Two windrows testings using contaminated soils were conducted to compare explosives removal in aerated and unaerated windrow. Soil loading rate in the contaminated windrow testing is 30%.
- Amendments used in the windrow studies included sawdust, wood chips, alfalfa, cow manure, chicken manure, and potato processing waste.

Summary

The results of the contaminated windrow testings are summarized as follows. In the aerated windrow, the overall removal efficiencies for HMX, RDX, and TNT were 76.6%, 99.2%, and 99.8% respectively after 40 days. For the unaerated windrow, HMX, RDX, and TNT reduction were 96.8%, 99.8%, and 99.7% respectively after 40 days. TNT removal appears to have commenced upon initiation of windrows, while a delay or lag was observed for HMX and RDX. In both windrows, the maximum removals were achieved on or about Day 20. The initial rate of TNT removal and the overall extent of HMX removal were higher in the unaerated windrow than in the aerated windrow. In addition, compost samples from the contaminated windrows were analyzed for the following explosives intermediates:

- 2-amino-4,6-dinitrotoluene (2A-4,6-DNT)
- 4-amino-2,6-dinitrotoluene (4A-2,6-DNT)
- 2,4-diamino-6-nitrotoluene (2,4D-6-NT)
- 2,6-diamino-4-nitrotoluene (2,6D-4-NT)

Near complete removal or transformation of the four explosives intermediates were observed in the aerated and unaerated windrows. Explosives and explosives intermediates data for the aerated (CWR7) and unaerated (CWR8) windrows are summarized in **Table F-6**.

TABLE F-6

**Average[1] Explosives Concentrations for Contaminated Windrows**

| Test | Day | 2,4,6-TNT (ug/g) | RDX (ug/g) | HMX (ug/g) | 1,3,5-TNB (ug/g) | 2,6 DNT (ug/g) | 2,4-DNT (ug/g) |
|---|---|---|---|---|---|---|---|
| CWR7 | 0 | 1,869 | 1,069 | 175 | 7.27 | 1.63 | 2.67 |
| CWR7 | 5 | 719 | 937 | 126 | 2.11 | 0.56 | 1.64 |
| CWR7 | 10 | 20 | 406 | 114 | 2.12 | 0.40 | 0.43 |
| CWR7 | 15 | 11 | 65 | 96 | 2.09 | 0.40 | 0.42 |
| CWR7 | 20 | 9 | 11 | 58 | 2.04 | 0.39 | 0.41 |
| CWR7 | 40 | 4 | 8 | 47 | 2.04 | 0.39 | 0.41 |
| CWR7 | 41 | 5 | 7 | 43 | 2.10 | 0.40 | 0.42 |
| CWR7 | 53 | 3 | 1 | 7 | 2.07 | 0.40 | 0.42 |
| CWR8 | 0 | 1,574 | 944 | 159 | 8.88 | 1.61 | 2.48 |
| CWR8 | 5 | 101 | 1,124 | 158 | 2.11 | 0.39 | 0.66 |
| CWR8 | 10 | 26 | 710 | 120 | 2.14 | 0.41 | 0.43 |
| CWR8 | 15 | 16 | 75 | 100 | 2.05 | 0.39 | 0.41 |
| CWR8 | 20 | 10 | 5 | 1 | 2.04 | 0.39 | 0.41 |
| CWR8 | 40 | 4 | 2 | 5 | 2.07 | 0.40 | 0.42 |
| CWR8 | 41 | 11 | 2 | 2 | 2.10 | 0.40 | 0.42 |
| CWR8 | 53 | 14 | 5 | 1 | 2.09 | 0.40 | 0.42 |

[1]Calculation of averages included actual values present below detection limits (J values) and one-half of lower detection limit for non-detected (U values).

**F.9** **Won, W. D., R. J. Heckly, D. J. Glover, and J. C. Hoffsommer. 1974. "Metabolic Disposition of 2,4,6-Trinitrotoluene". Applied Microbiology. Volume 27, No.3, p513-516. Sponsored by the Naval Ordnance Systems Command through a contract between the Regents of University of California and the Office of Naval Research. March.**

Objective

Evaluate bio-degrading TNT in water.

Description

Bench-scale laboratory study

Summary

Three pseudomonas-like organisms have been shown to metabolically oxidized TNT dissolved in water with oxidation proceeded without a lag. For accelerated TNT degradation, addition of glucose or nitrogenous substance was essential. In culture supplemented with yeast extract, TNT concentration was reduced from 100μg/ml to less than 1 μg/ml in 24 hours. TNT was metabolized to yield

- 2,2',6,6'-tetranitro-4-azoxytoluene
- 2,2',4,4'-tetranitro-6-azoxytoluene
- 4,6-dinitro-2-aminotoluene
- 2,6-dintro-4-hydroxylaminotoluene
- nitrodiaminotoluene

After depletion of TNT, the azoxy compounds were shown to degrade gradually, approaching complete disappearance at 96 hour. However, the organisms used seam incapable of oxidizing intermediates 4,6-dintro-2-aminotoulene and nitroaminotoluene.

**F.10** **Bradley, P.M., F.H. Chapelle, J.E. Landmeyer, and J.G. Schumacher 1994. "Microbial Transformation of Nitroaromatics in Surface Soils". Applied and Environmental Microbiology. Volume 60, No.6, p.2170-2175. Sponsored by the U.S. Geological Survey - Water Resources Division, Stephenson Center, Columbia, South Carolina, and U.S. Geological Survey - Water Resources Division, Rolla, Missouri.**

Objective

Evaluate the microbial transformation of nitroaromatics in surface soils and the aquifer.

Description

Bench-scale laboratory study

Summary

The ability of microorganisms indigenous to Weldon Spring, Missouri to transform TNT, 2,4-DNT, and 2,6-DNT was investigated by using contaminated surface soil, uncontaminated surface soil, fractured carbonate bedrock material, and material from a weathered, semiconsolidated, water-bearing zone that occurs on top of the bedrock. Core material was dissolved in microcosms to yield a 100 μM concentration of TNT, 2,4-DNT, or 2,6-DNT within the microcosms. The potential for microbial mineralization of nitroaromatic compounds was investigated. Results indicate that the microbial communities associated with surface soils and aquifer materials at Weldon Spring are capable of transforming TNT, 2,4-DNT, and 2,6-DNT. In most cases, complete disappearance of the source compound from the dissolved phase was achieved in 20 to 70 days. Decreases in the dissolved concentrations of the TNT or DNT test substrates were accompanied by accumulation of amino-DNT or amino-mononitrotoluene compounds, respectively.

## 6.0
## REFERENCES WITH NO EXPLOSIVE CONCENTRATION INFORMATION

This section contains seven additional references from the literature survey in which the feasibility of biological treatment of explosives compounds is discussed without including explosive concentration reduction results. These auxiliary references are included to present information as to biodegradation pathways, process description, status, and costs. A summary of the contents are contained in **Table F-2**.

**F.11** **Vendor: EarthFax Engineering, Inc.**
**Technology Type: Bioremediation - Solid Phase**
**7324 South Union Park Avenue, Suite 100**
**Midvale, Utah 84047**
**(USA)**
**Ray Conners, Larry DuShane**
**Business Development**
**(801) 561-1555**
**(801) 561-1861**
**Pilot Scale**

### DESCRIPTION OF TECHNOLOGY

White rot fungi ("WRF") are naturally-occurring organisms that cause the decay of fallen trees by degrading cellulose and lignin, a complex, three-dimensional, heterogenous polymer that provides structural support for plants and is resistant to degradation by most microbes. White rot fungi evolved to degrade lignin using a non-specific, extracellular, oxidative, free radical process that is initiated by limiting nitrogen, carbohydrates, or sulfur. The fungi degrade lignin to gain access to cellulose which they utilize as an energy (carbon) source.

Research has shown that WRF use the same biochemical processes required for lignin degradation to break down a broad variety of carbon-based chemicals, including polycyclic aromatic hydrocarbons, PCBs, coal tars, wood preservatives, chlorinated solvents, explosives, pesticides, herbicides, cyanide, dyes, and others. This research has shown that the fungi possess the ability to not degrade (i.e., cause the disappearance of) a variety of contaminants but also mineralize those contaminants to carbon dioxide, water, and basic elements.

This technology can be applied as a batch process in most ex-situ and some in-situ cases. To apply the technology, a fungus-inoculated substrate (e.g., sawdust, straw, etc.) is mixed with the contaminated soil at a ratio which is dependent upon the contaminant and its concentration. The soil/substrate mixture is moistened during blending to provide an adequate environment for biological activity. The soil/substrate mixture is placed in a biocell (for ex-situ applications) or covered with a synthetic liner (for in-situ applications) and aerated.

The air retrieved from the cell is periodically monitored for oxygen and carbon dioxide, with fresh air added as needed to maintain adequate oxygen levels for fungal growth. Soil samples are collected every 2 to 4 weeks to monitor treatment success.

## TECHNOLOGY HIGHLIGHTS

White rot fungi ("WRF") utilize an extracellular mode of chemical degradation. This makes a greatly expanded list of contaminants amenable to biodegradation that cannot be addressed by bacteria (which generally utilize an intracellular degradation mechanism). WRF degrade carbon-based chemicals, including polycyclic aromatic hydrocarbons, PCBs, wood preservatives, chlorinated solvents, explosives, pesticides, herbicides, cyanide, dyes, and others. The fungi secrete a variety of enzymes and chemicals to promote the extracellular degradation of environmental contaminants. The extracellular degradation mechanism employed by WRF permits the fungi to degrade chemicals that are both soluble and insoluble as well as in both dissolved and adsorbed forms. No preconditioning of the fungi to the contaminant is required.

The extracellular mode of degradation also allows WRF to survive in environments that would otherwise be considered biotoxic, since the fungi detoxify as they degrade. In environments that are initially toxic to the fungi, the toxicity can be controlled, thus permitting degradation to continue.

Another major advantage of fungal bioremediation is that the synthesis of enzymes and other degradative chemicals continues as long as the substrate is present. Therefore, high concentrations of contaminant residuals do not normally remain as usually occurs with bacterial degradation.

The degradative mechanisms utilized by WRF are non-selective. In addition, the enzymes produced by the fungi have a very high oxidation potential. Thus, complex mixtures of contaminants can be remediated. This permits the fungi to survive and function in mixed-chemical environments that are typical of contaminated sites.

Finally, remediation can be accomplished on site, with the remediation mechanism relying on degradation of the contaminant to innocuous byproducts, rather than merely containing or stabilizing the contaminated material. This limits the cost and liability associated with off-site transportation and disposal.

## TECHNOLOGY LIMITATIONS

White rot fungi are biological organisms which can exist in an environment where temperature, moisture, and oxygen content are maintained within certain parameters. They are, however, generally quite tolerant of pH variations. Although the fungi are ubiquitous, they contaminated material must be augmented with additional fungi and substrate to provide an adequate quantity of the organisms to promote degradation.

This technology is currently being used for remediation of carbon-based compounds. Research on other compounds which may be amenable to the WRF technology continues. Although the fungi do not appear to be affected by the presence of metals, they also probably do not assist in metals recovery.

## OTHER COMMENTS ON TECHNOLOGY

Research on the use of WRF for the degradation of environmental contaminants was initially conducted by Dr. Steven D. Aust at Michigan State University in the early 1980s. In 1987, Dr. Aust left MSU to become the director of the Biotechnology Center at Utah State University, continuing his research on WRF in this capacity. This research has resulted in one issued patent and additional patent applications.

In December 1992, the Utah State University Foundation licensed the rights to the WRF technology to Intech One-Eighty Corporation, a Utah corporation that was co-founded by Dr. Aust for the commercialization of the technology. In February 1993, Intech sublicensed the environmental portions of the technology to EarthFax.

Significant laboratory research has been performed on the technology for the past 10 years. Field implementation of the Intech technology began in 1993.

**F.12** **Vendor Name: EODT Services, Inc.**
**Technology Type: Bioremediation - Slurry Phase**
**10511 Hardin Valley Road**
**Knoxville, Tennessee 37932**
**USA**
**Paul Greene, Monirul Haque**
**Project Manager, Program Engineer**
**(615) 690-6061**
**(615) 690-6065**
**Full Scale**

## DESCRIPTION OF TECHNOLOGY

EODT Services, Inc., in association with Oak Ridge National Laboratory, has developed several amoeba-bacteria consortia and methods for altering and degrading organic and explosive wastes and contaminants. More practically, this invention relates to protozoan derived consortia comprised of protozoa and bacteria, methods for using protozoa/bacteria for consortia for altering or degrading wastes and production and use of biodispersants derived from protozoa.bacteria consortia.

One of the unique features of this technology, other than those new bacteria consortia, is the invention of "biodispersant". The biodispersant is a nonreactive chemical substance produced by the microorganisms. It enhances the biodegradation process by stimulating indigenous bacteria. It provides the bioremediation technology with the capability of treating contaminants from the soil-matrix and many other solid wastes. This makes this technology more practical in the real field of application. The biodispersant is safe to use and is biodegradable.

In addition to slurry phase biodegradation, several other methods can be offered for site restoration depending on the nature of the contamination, soil type, composition, etc.

Primarily, this technology treats soils and liquids contaminated with TNT, napalm, nitrocellular, nitroglycerin, single and double base propellants, and other explosives, etc. With some pretreatment, soils containing explosive wastes are fed to the slurry phase bioreactor where water and biodispersant are fed with bacteria-consortia. The reaction rate is kept high by properly adjusting pH, temperature, and nutrient supply. The whole batch operation is very cost and time effective since the total degradation process takes from 1 to 5 days. After the operation, the liquid phase is separated and, with some treatment, recycled into the reactor or used to pretreat the excavated soils. The treated soils are dumped on site. The technology has completed pilot-scale engineering and has also finished a full-scale remediation of explosive propellants at a site in Texas.

EODT also offers a liquid phase biotreatment technology in which the soil/solid wastes are put into an absorption column. Liquid biodispersants and water are fed into the column to dissolve the contaminant and leach them from the soil. The liquid effluent is then pumped to a bioreactor for the necessary target level of biodegradation.

## TECHNOLOGY HIGHLIGHTS

1. This technology is ready, in terms of process, bacteria or biodispersant production, to treat/remediate soils and water and other wastes contaminated with TNT, napalm, nitrocellulose (NC), nitroglycerin (NG), single, double base propellants and other explosive substances. This technology is also ready to treat TCE, halogenated hydrocarbons, volatiles and semivolatiles.

2. This technology is much more cost-effective than incineration, open burn/open detonation, thermal desorption or any other chemical treatment process that uses chemicals and expensive chemical processes.

3. Production units for bacteria-consortia and biodispersant are already in operation at Oak Ridge, Tennessee.

4. There is no use of chemicals in this process. The biodispersant is passive and inert and naturally degradable.

CONTAMINANTS TREATED: A demonstration of the technology is recently performed at Lone Star Army Ammunition Plant (LSAAP) at Texarckana, Texas in November, 1993. Pure double base propellants were processed in the mobile Biotechnical Processing Unit into nonhazardous aqueous solution of nitro-compounds. About 75 percent of the solid propellants was completely conversed to nonhazardous aqueous compounds. The remaining 25 percent of the solid product from the process was a nitro-rich solid which has less burning hazard than starting virgin propellants and has a potential for fertilizer.

## TECHNOLOGY LIMITATIONS

Amoeba-bacteria consortia, though highly resistant to environmental conditions, is vulnerable to metal ions, especially chromium, copper and similar highly oxidized ions.

Effectiveness of the whole process depends on types of contaminants and their concentrations in soils and wastes. Before any field application of the process, some batch experiments are performed with the samples to establish field protocols.

The biodispersant is effective in degrading organic contaminants although no test has been conducted toward its efficiency in removing inorganic contaminants.

## OTHER COMMENTS ON TECHNOLOGY

The slurry phase bioremediation technology of EODT-S has finished its bench-scale and pilot scale demonstration. It has now the capability of full-scale remediation of hazardous contaminated soils, water, and explosives. As part of the full-scale capability, EODT-S has built its own mobile Biotechnical Processing Unit which is capable of degrading any soil, water, and pure/contaminated explosives and their wastes.

The capacity of this unit is 2 to 3 tons of explosives per month and can be upscaled to meet any requirement.

**F.13** **Kaplan, D. L., and A. M. Kaplan. "Thermophilic Biotransformation of 2,4,6-Trinitrotoluene Under Simulated Composting Conditions" Applied and Environmental Microbiology. September 1982. PP. 757-760.**

Objective

To define the biodegradation pathway for TNT in compost.

Description

Bench-scale study.

Summary

Some TNT in a compost mixture will degrade into a variety of degradation compounds. Starting TNT concentration was 1.5 percent dry weight of compost. No ending TNT concentration was reported.

**F.14** **Vendor Name: MycoTech Corporation**
**Technology Type: Bioremediation - Solid Phase**
**P.O. Box 4109**
**Butte, Montana 59701**
**USA**
**Kevin Harvey**
**Director of Environmental Services**
**(406) 782-2386**
**(406) 782-9912**
**Full Scale**

**DESCRIPTION OF TECHNOLOGY**

Enzymes produced by various forms of fungi have the ability to degrade many hazardous organic compounds via an oxidation reaction. End products are simple compounds, primarily carbon dioxide and water, leaving free radicals such as chlorine to dissipate or combine in very low concentrations.

The technology can be applied in-situ for shallow contaminants in soil (up to 18 inches), or ex-situ for deep contaminants by excavation, soil-substrate blending, and land farming type operations. Fungal enzymes are produced on a solid substrate which is introduced to the contaminated solid without separation. The fungi used by the technology are naturally occurring microorganisms which are non-soil fungi, and are selected by screening various isolated strains for optimum contaminant degrading capabilities.

Fungal substrates are grown in controlled conditions involving a batch process of substrate preparation, substrate inoculation, and growth-phase. Production equipment can be readily mobilized. The end product is 10 percent moist, solid substrate mass which transported to the contaminated site and introduced into soils by roto-tilling or other blending machinery. Fungi continue to grow in the soil mixture until growth substrates are fully consumed, producing extracellular enzymes which degrade hazardous compounds in a period of 4 to 12 weeks depending upon concentration and soil conditions.

## TECHNOLOGY HIGHLIGHTS

Advantages of fungal enzyme degradation over typical bacterial metabolic transformation are that is faster acting, it results in more complete contaminant degradation, it is less susceptible to toxicity and shock, and it acts on higher molecular weight organic compounds.

White rot fungi enzymes are capable of degrading PCBs, chlorinated pesticides and herbicides, dioxins, explosives, and coal tar. Insulated non-white rot fungi are able to degrade high concentrations of heavy petroleum hydrocarbons in a period of 4 to 6 weeks.

Cost of fungal enzyme degradation compares very favorable to alternatives such as incineration and solvent extraction. Effectiveness of enzyme degradation is appreciably better than bacterial processes for the more recalcitrant hazardous compounds and hence more cost effective.

## TECHNOLOGY LIMITATIONS

Limitations of fungal enzyme degradation are related to climatic condition, soil characteristics, such as permeability and pH, and the presence of competing microbes.

Fungi require 10 to 30 percent moisture for optimum growth. At temperatures below 40 degrees Fahrenheit and above 120 degrees Fahrenheit, fungi will go dormant or may die off.

Soil pH is most favorable in lower ranges of 4 to 8.

Tight clay soils restrict mobility and further inhibit mechanical blending to distribute fungal substrates uniformly in soils. Saturated soils and deep in-situ conditions must be excavated and treated under aerobic conditions.

## OTHER COMMENTS ON TECHNOLOGY

The first full-scale prototype production system is completed and operation. This is a fixed plant facility and, fungal substrates must be shipped to site locations. Production for the first large-scale remediation of 6,000 cubic yards of soil began in early September 1991.

Production capacity will be increased during early 1992, and mobilized equipment is scheduled for completion by late 1994.

**F.15** **Roy F. Weston, Inc. 1993. "Compost Compaction Evaluation". Prepared for U.S. Army Environmental Center. Contract No. DACA31-9-D-0079. July.**

Objective

Estimate final compacted volume of treated compost to be backfilled at the Umatilla Depot Activity following full-scale remediation of the washout lagoons soil.

Description

Field observations.

Summary

Up to 30 to 40 percent volume reduction can occur during composting. Reference contained no discussion of chemical concentrations.

**F.16** **Roy F. Weston, Inc. 1993. "Windrow Composting Engineering/Economic Evaluation". Report No. CETHA-TS-CR-93050, Contract No. DACA31-91-R-0009, Task Order No. 01. Prepared for U.S. Army Environmental Center, CET-HA-TD-5, Aberdeen Proving Ground, MD. May.**

Objective

Conceptual level facility design and economic evaluation.

Description

Brief system description and costs are also presented for aerated static pile and mechanically agitated in-vessel composting technologies.

Summary

Compost system design and operation and system cost per ton are presented. No specific chemical concentration reported.

**F.17** **Spiker, J.K., D.L. Crawford, and R.L. Crawford. 1992. "Influence of 2,4,6-Trinitrotoluene (TNT) Concentration on the Degradation of TNT in Explosive-Contaminated Soils by the White Rot Fungus *Phanerochaete chrysosporium*". Applied and Environmental Microbiology. 58 (9): 3199-3202.**

Objective

Determine ability of White Rot Fungus to bioremediate TNT in soil.

Description

Laboratory study.

Summary

Spiker et al. examined the influence of TNT concentrations on the degradation of TNT in explosive-contaminated soils by the white rot fungus. The ability of the white rot fungus to bioremediate TNT in a soil containing 12,000 ppm of TNT and the explosives RDX (3,000 ppm) and HMX (300 ppm) was investigated. The fungus did not grow in malt extract broth containing more than 0.02 percent wt/vol (24 ppm TNT) soil. Pure TNT or explosives extracted from the soil were degraded by P. chrysosporium spore-inoculated cultures at TNT concentrations up to 20 ppm.

Inhibited growth was observed in Mycelium-inoculated cultures at TNT concentrations above 20 ppm.

Attached is RUST memorandum dated September 22, 1994 containing the PRG for TNB in soil.

**MEMORANDUM**

**DATE:** September 22, 1994

**TO:** Rosemary Gilbertson - USACE
Lori Lynch - USACE
Mead OU1 Files

**FROM:** Chandler Taylor - RUST

**SUBJECT:** **OU2 Soil Volumes: TNB>5,0-9 Feet;TNB>1,9-12.5 Feet**
**Former Nebraska Ordnance Plant**

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This memorandum summarizes the procedures, assumptions and results used to calculate OU2 soil volumes for the former Nebraska Ordnance Plant.

**Procedures:**

1) USACE provided the following OU2 preliminary remediation goals (PRGs):

- TNB detected greater than 5 mg/kg between 0 and 9 feet below ground surface.
- TNB detected greater than 1 mg/kg between 9 and 12.5 feet below ground surface.

2) RUST estimated the in-place volume of contaminated soil based on the OU2 PRGs using procedures similar to OU1. Volumes were estimated for the following criteria:

- directly below OU1 remediation areas between 4 and 12.5 feet.
- not directly below OU1 remediation areas between 0 and 12.5 feet.

**Assumptions:**

The volume of soil containing detected concentrations of explosives compounds was estimated using assumptions and methods similar to those used to calculate the OU1 FS volumes (April 1993 OU1 FS Appendix C1). The assumptions used include the following:

- if samples were located in the vicinity of one another (for an isolated area) or along the same ditch (for ditch segments), contamination was assumed to extend halfway from a sample above PRGs to a sample below PRGs.
- building and concrete pads were used, where appropriate to delineate contaminated areas.
- topography was used, in the absence of other information, to delineate contamination.
- contamination between two adjacent ditches was assumed, in the absence of other information to extend to the ditches.
- ditch widths were assumed to be 8 feet unless data indicated otherwise.
- sumps were considered as contamination sources but some sumps sampled were below

PRGs, probably due to the reported excavation of source sumps. The area between buildings and sumps was assumed to be above PRGs unless specific data indicates otherwise.

- areas will be excavated to a maximum depth of 12.5 feet.
- if there was a sample interval below PRGs below a sample interval above PRGs, the contamination depth was assumed to extend halfway between the bottom depth of the interval above PRGs and the top depth of the sample interval below PRGs.
- for multiple samples within an area, the depth was assumed to be an average of several borings (with clean intervals below contaminated intervals).
- if one contaminated boring and several contaminated surficial samples were located in an area, the assumed boring depth was used for the entire area.
- all cuts are vertical and any sideslopes are assumed to be clean.

**Results**

The estimated volumes (cy) based on the assumptions and procedures above are shown in the following table:

| Depth | Volume Under OU1 Area | Volume Outside of OU1 Area |
|---|---|---|
| 0-9 feet | | 940 |
| 4-9 feet | 760 | |
| 9-12.5 feet | 560 | 340 |
| All depths | 1300 | 1300 |

Note: Volumes are rounded to two significant figures.

The total OU2 volume based on the criteria in this memorandum is 2600 cy.

# APPENDIX G
# CAPTURE ZONE AND DRAWDOWN ESTIMATIONS

## APPENDIX G
## CAPTURE ZONE AND DRAWDOWN ESTIMATIONS

---

### INTRODUCTION

The extraction well locations and flowrates developed in this appendix will be used for cost comparison purposes. The number of extraction wells, the extraction well locations, and the extraction well flowrates will be developed during remedial design.

This appendix contains capture zone width calculations for the groundwater extraction system of the former Mead NOP Plant, Mead, Nebraska. Aquifer parameter and methods used to calculate capture zone widths are discussed in the following sections.

Aquifer parameters were obtained from Hydrologic Investigations, Atlas HA-266 (Sounders, 1967) and information presented in the OU2 RI (WCC, 1993).

### AQUIFER PARAMETERS

The aquifer parameters used to estimate capture zone widths are transmissivity (T), aquifer saturated thickness (h), hydraulic gradient (i), hydraulic conductivity (k), and effective porosity ($\phi$).

### METHODS

Capture zone widths can be estimated for a homogenous and isotropic aquifer with a uniform thickness under steady state regional flow using a method developed by Keely and Tsang (1983). A refinement of the capture zone analysis was performed using Javandel and Tsang (1986) method. A complete discussion of this method is presented in the Removal Action Groundwater Technical Memorandum (WCC, 1994).

The capture zone is defined as the area surrounding a pumping well that supplies groundwater recharge to the well. Capture zone width calculations were performed for a single pumping well using Keely and Tsang method. The following steps were followed:

Step 1 Aquifer parameters such as hydraulic conductivity, transmissivity, aquifer saturated thickness, groundwater hydraulic gradient, aquifer natural groundwater velocity, and effective porosity were obtained from the OU2 RI (WCC, 1993).

Step 2 Pumping rates selected were 100, 250, 500, and 700 gallons per minute (gpm).

Step 3 The distance to the stagnation point from a single pumping well was calculated **(Table G-1)**. The stagnation point is defined as the distance from the pumping well on the downgradient side at which no water will be pulled back towards the well.

Step 4 Capture zone maximum widths were calculated on the basis of the stagnation point distance. The maximum capture zone width of the upgradient inflow zone is equal to $2\pi$ times the stagnation distance immediately downgradient **(Table G-1)**.

Step 5 Drawdowns were estimated using Theis non-equilibrium equation (Driscoll, 1986) to establish "sustainable" pumping rates for a given aquifer thickness **(Tables G-2 through G-5)**.

Step 6 Safe operating pumping rates were selected using the results of the Theis analysis.

Step 7 Capture zone information for a single pumping well was superimposed over plume maps to identify number, location, and pumping rates for each proposed alternative.

The Removal Action Groundwater Modeling Technical Memorandum (WCC, 1994) used the Javandel and Tsang (1986) method and a two-dimensional groundwater model (Quick Flow®) to estimate extraction well locations and flowrates for hydraulic containment. The Removal Action groundwater modeling may be revised pending analysis of the pumping rate.

The aquifer unit analyzed in this appendix corresponds to the sand and gravel unit. The sand and gravel unit has a larger hydraulic conductivity value than the fine sand; therefore, a smaller capture zone would be expected. The smaller capture zone width results in a more conservative number of extraction wells. Additionally, it was expected that drawdowns in shallower portions of the unconfined aquifer would be a limiting factor to aquifer pumping. Thus, it was necessary to evaluate expected drawdown of the most critical area of the aquifer.

## RESULTS

Aquifer drawdowns were estimated using Theis non-equilibrium equation (Driscoll, 1986). Calculated drawdowns for single well pumping rates of 100, 250, 500 and 700 gpm are presented in **Tables G-2 through G-5.** A summary of selected aquifer parameters, well radius, pumping rates and drawdowns are presented below.

### Assumptions

Hydraulic conductivity: 857 gpd/$ft^2$
Well diameter: 1.0 ft.
Well efficiency: 75 percent
Average aquifer thickness: 35 ft (See Appendix D)

### Calculated Capture Zone and Drawdown

| Pumping Rate (gpm) | Capture Zone Maximum width (ft) | Adjusted Drawdown (ft) |
|---|---|---|
| 100 | 2,114 | 11 |
| 250 | 5,286 | 28 |
| 500 | 10,573 | 55 |
| 700 | 14,802 | 77 |

Drawdown is the controlling factor in aquifer pumping. The maximum recommended drawdown should not exceed two-thirds of saturated thickness for an unconfined aquifer because it reduces needed minimum inlet pump submergence required for efficient pumping (Driscoll, 1989).

Aquifer drawdown estimations are based on an average aquifer thickness of 35 feet and hydraulic conductivity of 115 feet per day. **Figure G-1** presents ranges of adjusted aquifer drawdowns (for a 75 percent well efficiency) and pumping rates between 100 and 700 gpm.

This combination of aquifer parameters and pumping rates suggests that aquifer pumping rates greater than approximately 210 gpm will generate aquifer drawdowns that will exceed the maximum recommended drawdown within the Platte River Valley aquifer area where the aquifer is thin.

Groundwater extraction rates and locations for the containment and pump and treat alternatives were estimated using the Javandel and Tsang method. Single well pumping rate estimations are presented in **Tables G-6** to **G-8**.

The capture zone estimations and aquifer drawdowns presented herein are limited by the following assumptions:

- Aquifer thickness is considered uniform and of infinite areal extent
- The hydraulic conductivity is the same in all directions
- The aquifer recharge has no recharge from any source
- Pumping wells are fully penetrating and receive water from the entire aquifer thickness
- The potentiometric surface has no slope (the groundwater surface is flat)
- Drawdowns are calculated for a single pumping well

REFERENCES


Driscoll, F. G. 1989. Groundwater and Wells. St. Paul, Minnesota.

Keely, J. F. and Tsang, C. F. 1983. "Velocity Plots and Capture Zones of Pumping Centers for Groundwater Investigations." Journal of Groundwater. Nov-Dec.

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Sounders, V. L. 1967. Availability of Water in Eastern Saunders County, Nebraska. Atlas HA-266. United States Geological Survey. Washington, D.C.

Woodward-Clyde Consultants. 1993. Remedial Investigation Report Operable Unit No. 2 (Groundwater) for Former Nebraska Ordnance Plant, Mead, Nebraska. Draft Final. Prepared for U. S. Army Corps of Engineers, Kansas City District. May.

Woodward-Clyde Consultants. 1994. Removal Action Groundwater Modeling Technical Memorandum Operable Unit No. 2 (Groundwater) for Former Nebraska Ordnance

Plant, Mead, Nebraska. Draft. Prepared for U.S. Army Corps of Engineers, Kansas City District. May.

## Table G-1

# Mead Former NOP
# Groundwater Extraction System
# Capture Zone Estimation

**Methodology: Keely and Tsang, 1983**

**Q = 100 gpm**

| | | Units |
|---|---|---|
| Volumetric Flow Rate | = 100 | gpm |
| | = 144,000 | gpd |
| | = 19,251 | ft^3 / day |
| **Aquifer Parameters** | | |
| Effective Saturated Thickness | = 35 | ft |
| Hydraulic Conductivity , K = 0.08 ft / min, from RI Report | = 115.2 | ft / day |
| Hydraulic Gradient, i = 12 ft / Mile, from RI Report | = 0.00227 | ft / ft |
| Effective Porosity, from RI Report | = 0.145 | |
| Computed groundwater Velocity, v = (K * i )/ effective porosity | = 1.80 | ft / day (1) |

**Solve for Stagnation Point**

r = Q/(2 * Pi * h * Ø * v)

| | |
|---|---|
| Q = Volumetric flow rate | ft^3 / day |
| h = Effective saturated thickness | ft |
| Ø = Effective porosity | |
| v = Groundwater velocity | ft / day |
| Pi = 3.141592 | |

r = Distance from the pumping well on downgradient side at which no water will be pulled back towards the well (stagnation distance, ft.)

r = 335 feet

Maximum width of the upgradient inflow zone is 2* Pi * r

Max Width = 2103 feet

Note:
1. The groundwater velocity estimate is reported with three significant figures; however, the groundwater velocity value is considered to be accurate to one significant figure. See RI Report. (WCC, 1993)

## Table G-1

# Mead Former NOP
# Groundwater Extraction System
# Capture Zone Estimation

**Methodology: Keely and Tsang, 1983**

**Q = 250 gpm**

| | | Units |
|---|---|---|
| Volumetric Flow Rate | = 250 | gpm |
| | = 360,000 | gpd |
| | = 48,128 | ft^3 / day |
| **Aquifer Parameters** | | |
| Effective Saturated Thickness | = 35 | ft |
| Hydraulic Conductivity , K = 0.08 ft / min, from RI Report | = 115.2 | ft / day |
| Hydraulic Gradient, i = 12 ft / Mile, from RI Report | = 0.00227 | ft / ft |
| Effective Porosity, from RI Report | = 0.145 | |
| Computed groundwater Velocity, v = (K * i )/ effective porosity | = 1.80 | ft / day (1) |

**Solve for Stagnation Point**

r = Q/(2 * Pi * h * Ø * v)

| | |
|---|---|
| Q = Volumetric flow rate | ft^3 / day |
| h = Effective saturated thickness | ft |
| Ø = Effective porosity | |
| v = Groundwater velocity | ft / day |
| Pi = 3.141592 | |

r = Distance from the pumping well on downgradient side at which no water will be pulled back towards the well (stagnation distance, ft.)

r = 837 feet

Maximum width of the upgradient inflow zone is 2* Pi * r

Max Width = 5258 feet

Note:
1. The groundwater velocity estimate is reported with three significant figures; however, the groundwater velocity value is considered to be accurate to one significant figure. See RI Report. (WCC, 1993)

## Table G-1

# Mead Former NOP
# Groundwater Extraction System
# Capture Zone Estimation

**Methodology: Keely and Tsang, 1983**

**Q = 500 gpm**

| | | Units |
|---|---|---|
| Volumetric Flow Rate | = 500 | gpm |
| | = 720,000 | gpd |
| | = 96,257 | ft^3 / day |
| **Aquifer Parameters** | | |
| Effective Saturated Thickness | = 35 | ft |
| Hydraulic Conductivity , K = 0.08 ft / min, from RI Report | = 115.2 | ft / day |
| Hydraulic Gradient, i = 12 ft / Mile, from RI Report | = 0.00227 | ft / ft |
| Effective Porosity, from RI Report | = 0.145 | |
| Computed groundwater Velocity, v = (K * i )/ effective porosity | = 1.80 | ft / day (1) |

**Solve for Stagnation Point**

r = Q/(2 * Pi * h * Ø * v)

| | |
|---|---|
| Q = Volumetric flow rate | ft^3 / day |
| h = Effective saturated thickness | ft |
| Ø = Effective porosity | |
| v = Groundwater velocity | ft / day |
| Pi = 3.141592 | |

r = Distance from the pumping well on downgradient side at which no water will be pulled back towards the well (stagnation distance, ft.)

r = 1674 feet

Maximum width of the upgradient inflow zone is 2* Pi * r

Max Width = 10517 feet

Note:
1. The groundwater velocity estimate is reported with three significant figures; however, the groundwater velocity value is considered to be accurate to one significant figure. See RI Report. (WCC, 1993)

## Table G-1

# Mead Former NOP
# Groundwater Extraction System
# Capture Zone Estimation

**Methodology: Keely and Tsang, 1983**

**Q = 700 gpm**

| | | Units |
|---|---|---|
| Volumetric Flow Rate | = 700 | gpm |
| | = 1,008,000 | gpd |
| | = 134,759 | ft^3 / day |
| **Aquifer Parameters** | | |
| Effective Saturated Thickness | = 35 | ft |
| Hydraulic Conductivity , K = 0.08 ft / min, from RI Report | = 115.2 | ft / day |
| Hydraulic Gradient, i = 12 ft / Mile, from RI Report | = 0.00227 | ft / ft |
| Effective Porosity, from RI Report | = 0.145 | |
| Computed groundwater Velocity, v = (K * i )/ effective porosity | = 1.80 | ft / day (1) |

**Solve for Stagnation Point**

r = Q/(2 * Pi * h * Ø * v)

| | |
|---|---|
| Q = Volumetric flow rate | ft^3 / day |
| h = Effective saturated thickness | ft |
| Ø = Effective porosity | |
| v = Groundwater velocity | ft / day |
| Pi = 3.141592 | |

r = Distance from the pumping well on downgradient side at which no water will be pulled back towards the well (stagnation distance, ft.)

r = 2343 feet

Maximum width of the upgradient inflow zone is 2* Pi * r

Max Width = 14724 feet

Note:

1. The groundwater velocity estimate is reported with three significant figures; however, the groundwater velocity value is considered to be accurate to one significant figure. See RI Report (WCC, 1993).

# Table G-2

## Mead, Former NOP
## Estimated and Adjusted Drawdowns at 100 gpm

Theis Equation
Platte River Valley

| | | |
|---|---|---|
| 30000 | [ T ] | Transmissivity (gpd/ft) |
| 0.145 | [ S ] | Sto. Coef. |
| 100 | [ Q ] | Flow rate (gpm) |
| 10000 | [ t ] | Time (days) |
| 75 | [ e ] | Well efficiency (percent) |

| [ r ] distance (ft.) | u | W(u) | Theis drawdown (ft.) | [ s ] Adjusted drawdown (ft) |
|---|---|---|---|---|
| 0.5 | 2.2596E-10 | 21.633 | 8.3 | 11.0 |
| 1 | 9.0383E-10 | 20.247 | 7.7 | 10.3 |
| 10 | 9.0383E-08 | 15.642 | 6.0 | 8.0 |
| 50 | 2.2596E-06 | 12.423 | 4.7 | 6.3 |
| 100 | 9.0383E-06 | 11.037 | 4.2 | 5.6 |
| 1000 | 9.0383E-04 | 6.433 | 2.5 | 3.3 |
| 10000 | 9.0383E-02 | 1.915 | 0.7 | 1.0 |
| 20000 | 3.6153E-01 | 0.771 | 0.3 | 0.4 |

## Table G-2

**Mead, Former NOP**
**Estimated and Adjusted Drawdowns at 100 gpm**

Theis Equation (Driscoll, 1989)

s = 114.6 * Q * W (u) / T

where

s = drawdown, in feet
Q = pumping rate, in gpm
T = coefficient of transmissivity of the aquifer, gpd/ft
W (u) = well function of u

u = 1.87 * r** 2 * S/ T * t

where

r = distance, in ft, from the center of a pumped well to
a point where the drawdown is measured
S = coefficient of storage (dimensionless)
T = coefficient of transmissivity, in gpd/ft
t = time since pumping started, in days

## Table G-3

**Mead, NOP**
**Estimated and Adjusted Drawdowns at 250 gpm**

Theis Equation
Platte River Valley

| | | |
|---|---|---|
| 30000 | [ T ] | Transmissivity (gpd/ft) |
| 0.145 | [ S ] | Sto. Coef. |
| 250 | [ Q ] | Flow rate (gpm) |
| 10000 | [ t ] | Time (days) |
| 75 | [ e ] | Well efficiency (percent) |

| [ r ] distance (ft.) | u | W(u) | Theis drawdown (ft.) | [ s ] Adjusted drawdown (ft) |
|---|---|---|---|---|
| 0.5 | 2.2596E-10 | 21.633 | 20.7 | 27.5 |
| 1 | 9.0383E-10 | 20.247 | 19.3 | 25.8 |
| 10 | 9.0383E-08 | 15.642 | 14.9 | 19.9 |
| 50 | 2.2596E-06 | 12.423 | 11.9 | 15.8 |
| 100 | 9.0383E-06 | 11.037 | 10.5 | 14.1 |
| 1000 | 9.0383E-04 | 6.433 | 6.1 | 8.2 |
| 10000 | 9.0383E-02 | 1.915 | 1.8 | 2.4 |
| 20000 | 3.6153E-01 | 0.771 | 0.7 | 1.0 |

## Table G-4

**Mead, NOP**
**Estimated and Adjusted Drawdowns at 500 gpm**

Theis Equation
Platte River Valley

| | | |
|---|---|---|
| 30000 | [ T ] | Transmissivity (gpd/ft) |
| 0.145 | [ S ] | Sto. Coef. |
| 500 | [ Q ] | Flow rate (gpm) |
| 10000 | [ t ] | Time (days) |
| 75 | [ e ] | Well efficiency (percent) |

| [ r ] distance (ft.) | u | W(u) | Theis drawdown (ft.) | [ s ] Adjusted drawdown (ft) |
|---|---|---|---|---|
| 0.5 | 2.2596E-10 | 21.633 | 41.3 | 55.1 |
| 1 | 9.0383E-10 | 20.247 | 38.7 | 51.6 |
| 10 | 9.0383E-08 | 15.642 | 29.9 | 39.8 |
| 50 | 2.2596E-06 | 12.423 | 23.7 | 31.6 |
| 100 | 9.0383E-06 | 11.037 | 21.1 | 28.1 |
| 1000 | 9.0383E-04 | 6.433 | 12.3 | 16.4 |
| 10000 | 9.0383E-02 | 1.915 | 3.7 | 4.9 |
| 20000 | 3.6153E-01 | 0.771 | 1.5 | 2.0 |

# Table G-5

## Mead, NOP
## Estimated and Adjusted Drawdowns at 700 gpm

Theis Equation
Platte River Valley

| | | |
|---|---|---|
| 30000 | [ T ] | Transmissivity (gpd/ft) |
| 0.145 | [ S ] | Sto. Coef. |
| 700 | [ Q ] | Flow rate (gpm) |
| 10000 | [ t ] | Time (days) |
| 75 | [ e ] | Well efficiency (percent) |

| [ r ] distance (ft.) | u | W(u) | Theis drawdown (ft.) | [ s ] Adjusted drawdown (ft) |
|---|---|---|---|---|
| 0.5 | 2.2596E-10 | 21.633 | 57.8 | 77.1 |
| 1 | 9.0383E-10 | 20.247 | 54.1 | 72.2 |
| 10 | 9.0383E-08 | 15.642 | 41.8 | 55.8 |
| 50 | 2.2596E-06 | 12.423 | 33.2 | 44.3 |
| 100 | 9.0383E-06 | 11.037 | 29.5 | 39.3 |
| 1000 | 9.0383E-04 | 6.433 | 17.2 | 22.9 |
| 10000 | 9.0383E-02 | 1.915 | 5.1 | 6.8 |
| 20000 | 3.6153E-01 | 0.771 | 2.1 | 2.8 |

# Table G-6

**Extraction Wells**
**Pumping Rates**
**Target Cleanup Goal I**

Sand and Gravel Unit
Pumping Rate for U=0.26 ft/day
Containment Wells

| Extraction Well | Q / B * U (ft) | B (ft) | U (ft) | Q (cubic feet/day) | Q (gpm) | Number of Pumping Wells | Pumpage (gpm) |
|---|---|---|---|---|---|---|---|
| EW-1 | 2115 | 38 | 0.26 | 20896.20 | 108.6 | 1 | 109 |
| EW-2 | 2115 | 67 | 0.26 | 36843.30 | 191.4 | 1 | 191 |
| EW-3 | 2115 | 90 | 0.26 | 49491.00 | 257.1 | 1 | 257 |
| EW-4 | 2115 | 58 | 0.26 | 31894.20 | 165.7 | 1 | 166 |
| EW-5 | 2115 | 83 | 0.26 | 45641.70 | 237.1 | 1 | 237 |
| Wells within plume | | | | | | | |
| EW-6 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-7 | 3173 | 58 | 0.26 | 47848.84 | 248.6 | 1 | 249 |
| EW-8 | 5289 | 70 | 0.26 | 96259.80 | 500.0 | 1 | 500 |
| EW-9 | 5289 | 86 | 0.26 | 118262.04 | 614.3 | 1 | 614 |
| Total Pumpage (gpm) | | | | | | | 2486 |

# Table G-7

**Extraction Wells**
**Pumping Rates**
Target Cleanup Goal II

Sand and Gravel Unit
Pumping Rate for U=0.26 ft/day
Containment Wells

| Extraction Well | Q / B * U (ft) | B (ft) | U (ft) | Q (cubic feet/day) | Q (gpm) | Number of Pumping Wells | Pumpage (gpm) |
|---|---|---|---|---|---|---|---|
| EW-1 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-2 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-3 | 3173 | 44 | 0.26 | 36299.12 | 188.6 | 1 | 189 |
| EW-4 | 3173 | 58 | 0.26 | 47848.84 | 248.6 | 1 | 249 |
| EW-5 | 3173 | 55 | 0.26 | 45373.90 | 235.7 | 1 | 236 |
| EW-6 | 3173 | 55 | 0.26 | 45373.90 | 235.7 | 1 | 236 |
| EW-7 | 3173 | 55 | 0.26 | 45373.90 | 235.7 | 1 | 236 |
| EW-8 | 3173 | 68 | 0.26 | 56098.64 | 291.4 | 1 | 291 |
| EW-9 | 3173 | 83 | 0.26 | 68473.34 | 355.7 | 1 | 356 |
| Wells within plume | | | | | | | |
| EW-10 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-11 | 3173 | 58 | 0.26 | 47848.84 | 248.6 | 1 | 249 |
| EW-12 | 5289 | 70 | 0.26 | 96259.80 | 500.0 | 1 | 500 |
| EW-13 | 5289 | 86 | 0.26 | 118262.04 | 614.3 | 1 | 614 |
| EW-14 | 3173 | 67 | 0.26 | 55273.66 | 287.1 | 1 | 287 |
| EW-15 | 3173 | 68 | 0.26 | 56098.64 | 291.4 | 1 | 291 |
| | | | | | | | ------- |
| Total Pumpage (gpm) | | | | | | | 4221 |

## Table G-8

**Extraction Wells**

**Pumping Rates**

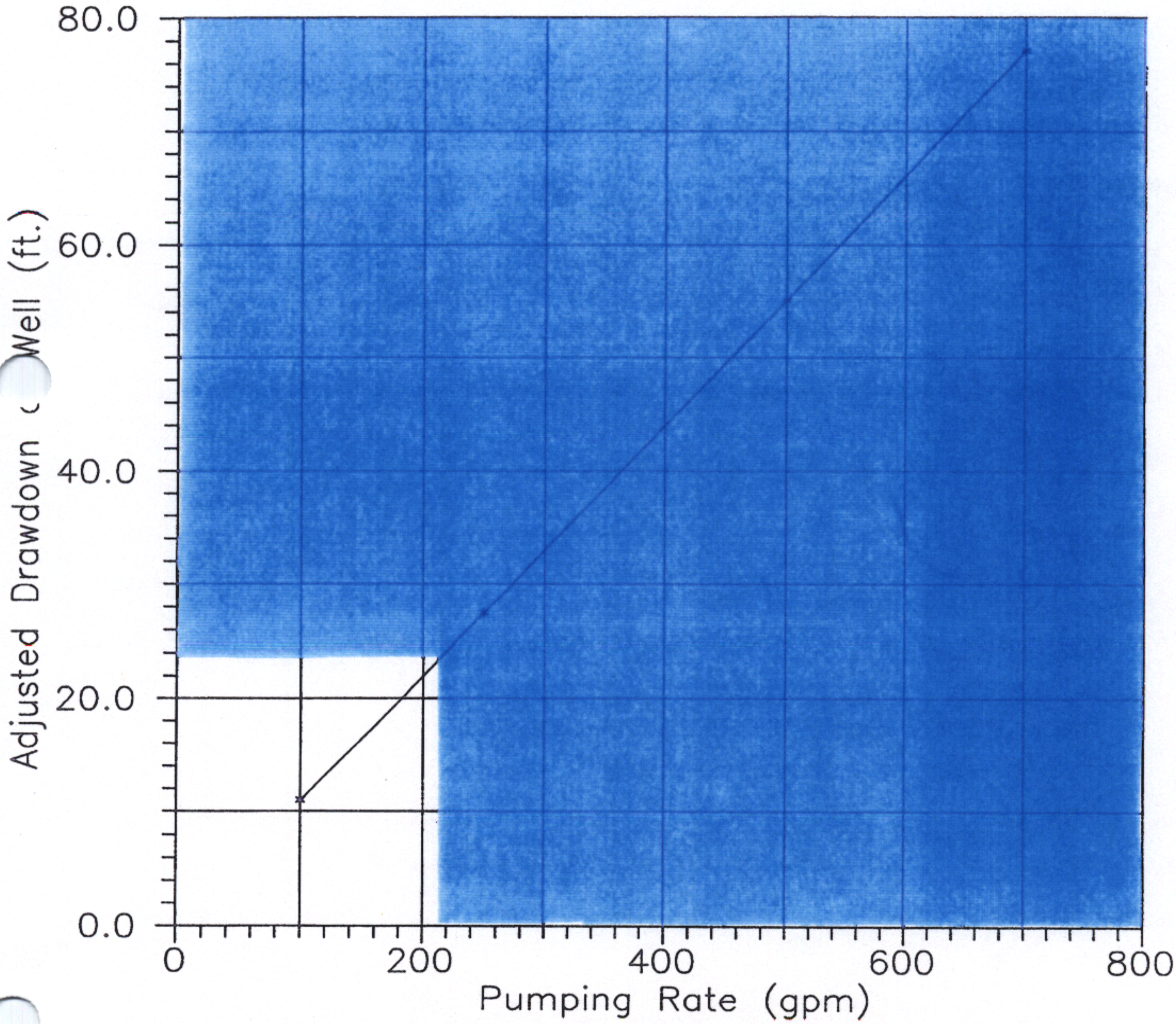
Target Cleanup Goal III

Sand and Gravel Unit
Pumping Rate for U=0.26 ft/day
Containment Wells

| Extraction Well | Q / B * U (ft) | B (ft) | U (ft) | Q (cubic feet/day) | Q (gpm) | Number of Pumping Wells | Pumpage (gpm) |
|---|---|---|---|---|---|---|---|
| EW-1 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-2 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-3 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-4 | 3173 | 44 | 0.26 | 36299.12 | 188.6 | 1 | 189 |
| EW-5 | 3173 | 58 | 0.26 | 47848.84 | 248.6 | 1 | 249 |
| EW-6 | 3173 | 81 | 0.26 | 66823.38 | 347.1 | 1 | 347 |
| EW-7 | 3173 | 81 | 0.26 | 66823.38 | 347.1 | 1 | 347 |
| EW-8 | 3173 | 81 | 0.26 | 66823.38 | 347.1 | 1 | 347 |
| EW-9 | 3173 | 83 | 0.26 | 68473.34 | 355.7 | 1 | 356 |
| Wells within plume | | | | | | | |
| EW-10 | 3173 | 38 | 0.26 | 31349.24 | 162.9 | 1 | 163 |
| EW-11 | 3173 | 58 | 0.26 | 47848.84 | 248.6 | 1 | 249 |
| EW-12 | 5289 | 70 | 0.26 | 96259.80 | 500.0 | 1 | 500 |
| EW-13 | 5289 | 86 | 0.26 | 118262.04 | 614.3 | 1 | 614 |
| EW-14 | 3173 | 53 | 0.26 | 43723.94 | 227.1 | 1 | 227 |
| EW-15 | 3173 | 67 | 0.26 | 55273.66 | 287.1 | 1 | 287 |
| EW-16 | 3173 | 58 | 0.26 | 47848.84 | 248.6 | 1 | 249 |
| EW-17 | 3173 | 68 | 0.26 | 56098.64 | 291.4 | 1 | 291 |
| | | | | | | | ------- |
| Total Pumpage (gpm) | | | | | | | 4903 |

## Figure G-1

Pumping Rate versus Drawdown
T = 30,000 gpd/ft
Average Aquifer Thickness = 35 ft.
Well Efficiency (75 %)




***** Adjusted drawdowns (100, 250, 500, and 700 gpm)

**NOTE: Maximum recommended drawdowns are exceeded in shaded area (Q > 210 gpm)**

# APPENDIX H
# GAC VENDOR ANALYSIS

In the process of evaluating remediation alternatives, Woodward-Clyde Consultants contacted the three GAC vendors listed below:

- Wheelabrator Clean Air Systems, Inc.
- Calgon Carbon Corporation
- Carbtrol Corporation

An example letter of correspondence with the vendors is included in this appendix along with recent responses from the following vendors:

- Calgon Carbon Corporation
- Carbtrol Corporation

As of the issuance of this report, a response has not been received from Wheelabrator Clean Air Systems Inc.

**Woodward-Clyde**

Engineering & sciences applied to the earth & its environment

December 2, 1994
WCC Project 92KW030R

Mr. Matt Phillips
Wheelabrator Clean Air Systems, Inc.
Westates Carbon
10 East Willow Street
Millburn, New Jersey 07041

Dear Mr. Phillips:

Woodward-Clyde (W-C) is evaluating potential remedial alternatives for a client who operated a military ordnance plant near Omaha, Nebraska. The site was in operation for approximately 20 years, and historic waste management practices have impacted the soil and groundwater.

Our client is planning to remediate groundwater at the site in the near future. Based on an evaluation of remedial alternatives, carbon adsorption is a candidate groundwater treatment technology.

The proposed design is to remove groundwater using several groundwater extraction wells and pump the extracted groundwater through a piping network to one central location where it will be treated to meet effluent standards. Estimated flow rates of the groundwater to be treated range from 970 to 4910 gallons per minute (GPM) for the various remedial alternatives being considered. Effluent standards to be met are EPA Drinking Water Standards.

The major groundwater contaminants of concern, and therefore the bulk of the contaminants to be removed from the groundwater to meet site remediation cleanup goals, are TCE and RDX. Estimated influent concentrations for TCE and RDX have been calculated from groundwater monitoring well data using a weighted average concentration for each proposed total groundwater extraction flow rate. This information, plus the effluent concentrations to be met, is listed in Table 1 attached to this letter.

In addition to the data on TCE and RDX concentrations, we have also included data on the average metals concentrations, as well as general water quality parameters (Table 2). The concentrations presented in Table 2 are average concentrations for the groundwater at the site, and have not been adjusted for specific flow rates. Therefore, as a conservative estimate, the concentrations in Table 2 should be considered the same for all flow rates.

**Woodward-Clyde Consultants** - A subsidiary of Woodward-Clyde Group, Inc.
10975 El Monte, Suite 100 · Overland Park, Kansas 66211
(913) 344-1000 · Fax (913) 344-1011

As mentioned above, TCE and RDX are the primary contaminants of concern at the site. However, numerous other contaminants have been sporadically detected at low concentrations, typically below the cleanup levels. A list of the additional compounds detected at the site is presented in Table 3. The list is intended to be used to determine whether any of the compounds present may affect the overall design of the treatment system. If any of the compounds on the list potentially complicate or present particular design problems, please notify us, and we may be able to provide more specific data on the particular contaminant. It should be noted that while these compounds have been detected in individual monitoring wells, we anticipate the concentrations in the combined flow from the extraction system will be insignificant (i.e., below detectable levels).

Please provide the following information for possible treatment of the above described groundwater:

- The ability of processes to attain the potential groundwater treatment requirements.

- Any pretreatment requirements prior to the actual remediation treatment process.

- Process operations restrictions, if any. For example: influent flow rate, chemical concentrations, groundwater chemistry parameters, temperature, etc.

- General system specifications, including requirements for power, space, etc.

- A description of the standard treatment system sizes and the typical flow rate capacity of these standard sizes (e.g. Standard System A is typically selected when the anticipated flow rate ranges from ____ gpm to ____ gpm and Standard System B is typically selected where the anticipated flow rates range from ____ gpm to ____ gpm, etc.).

- Typical costs, including bench and pilot scale treatability studies if needed and system design, equipment, construction, operation, and maintenance. Please include descriptions of estimated carbon usage rates (with supporting calculations), type of carbon, current estimated carbon costs and carbon disposal costs.

**Woodward-Clyde Consultants**



Please submit your information and cost estimates by **December 15, 1994** to:

Curt Elmore, Ph.D., P.E.
Woodward-Clyde
10975 El Monte, Suite 100
Overland Park, Kansas 66211
Phone: (913) 344-1154
Fax: (913) 344-1012

If you foresee that you would be unable to meet the December 15, 1994 target date, please contact us as soon as possible to discuss an alternate date for the submittal of your information.

Please do not hesitate to contact us if you have any questions.

Very truly yours,

Curt Elmore, Ph.D., P.E.
Project Engineer

Douglas E. Fiscus, P.E.
Senior Project Engineer

Attachments

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**Table 1**

**Design Influent and Effluent Concentrations for Groundwater Treatment of TCE and RDX**

| Groundwater Flow Rate (gpm) | TCE (1) | | RDX (2) | |
|---|---|---|---|---|
| | Influent (ug/L) | Effluent (3) (ug/L) | Influent (ug/L) | Effluent (4) (ug/L) |
| 970 | 21 | 5 | 53 | 2 |
| 2,100 | 14 | 5 | 5 | 2 |
| 2,330 | 13 | 5 | 5 | 2 |
| 1,980 | 350 | 5 | 27 | 2 |
| 3,300 | 209 | 5 | 18 | 2 |
| 3,530 | 195 | 5 | 18 | 2 |
| 1,450 | 51 | 5 | 36 | 2 |
| 2,770 | 30 | 5 | 23 | 2 |
| 3,000 | 23 | 5 | 21 | 2 |
| 2,490 | 338 | 5 | 18 | 2 |
| 4,200 | 204 | 5 | 23 | 2 |
| 4,910 | 173 | 5 | 21 | 2 |

Notes: EPA Drinking water Standards From:
Drinking Water Regulations and Health Advisories, May 1994. Office of Water, U.S. Environmental Protection Agency.

1. TCE = Trichloroethene
2. RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
3. EPA Drinking Water Maximum Contaminant Level (MCL)
4. EPA Health Advisory - Because no MCL has been established for this chemical

## Table 2
## Summary of Metals Concentrations and General Water Quality Parameters

| | Average Concentration in | Comments |
|---|---|---|
| TOTAL METALS (ug/l) | Groundwater Samples | |
| Aluminum | 1,066 | Detected in 15 of 15 monitoring wells |
| Arsenic | 13 | Detected in 9 of 15 monitoring wells |
| Barium | 218 | Detected in 15 of 15 monitoring wells |
| Beryllium | 1 | Detected in 1 of 15 monitoring wells |
| Calcium | 63,187 | Detected in 15 of 15 monitoring wells |
| Chromium | 14 | Detected in 3 of 15 monitoring wells |
| Cobalt | 13 | Detected in 1 of 15 monitoring wells |
| Copper | 15 | Detected in 2 of 15 monitoring wells |
| Iron | 1,200 | Detected in 15 of 15 monitoring wells |
| Lead | 9 | Detected in 2 of 15 monitoring wells |
| Magnesium | 15,238 | Detected in 15 of 15 monitoring wells |
| Manganese | 196 | Detected in 15 of 15 monitoring wells |
| Mercury | 0.33 | Detected in 1 of 15 monitoring wells |
| Nickel | 20 | Detected in 2 of 15 monitoring wells |
| Potassium | 8,758 | Detected in 15 of 15 monitoring wells |
| Selenium | 38 | Detected in 1 of 15 monitoring wells |
| Sodium | 20,847 | Detected in 15 of 15 monitoring wells |
| Thallium | 2 | Detected in 1 of 15 monitoring wells |
| Vanadium | 18 | Detected in 2 of 15 monitoring wells |
| Zinc | 12 | Detected in 12 of 15 monitoring wells |
| WATER QUALITY (mg/l) | | |
| Alkalinity as Calcium Carbonate | 198 | |
| Biochemical Oxygen Demand (BOD) | 6 | |
| Hardness as Calcium Carbonate | 241 | |
| Nitrate-Nitrite-N | 28 | |
| Total Chlorides | 24 | |
| Total Dissolved Solids (TDS) | 439 | |
| Total Kjeldahl Nitrogen (TKN) | 0.41 | |
| Total Microbial Count (cells/ml) | 22,650 | |
| Total Organic Carbon (TOC) | 2 | |
| Total Organic Halides (TOX) (ug/L) | 227 | |
| Total Sulfates | 88 | |
| Total Suspended Solids (TSS) | 52 | |
| Dissolved Oxygen (mg/L) | 4 | |
| Oxidation Reduction Potential (mV) | 73 | |
| pH | 7 | |
| Specific Conductance (umhos/cm) | 450 | |
| Temperature (Celsius) | 12 | |

12/2/94
3:02 PM

# Table 3

## Summary of Additional Compounds Detected at Low Concentrations (1) in Groundwater Samples

| |
|---|
| **EXPLOSIVES (ug/l)** |
| 1,3,5-Trinitrobenzene (TNB) |
| 2,4,6-Trinitrotoluene (TNT) |
| 2,4-Dinitrotoluene (24DNT) |
| 4-Nitrotoluene (4NT) |
| HMX |
| Tetryl |
| **GROSS Alpha/Beta (pCi/l)** |
| Gross Alpha |
| Gross Beta |
| **SEMIVOLATILES (ug/l)** |
| bis(2-Ethylhexyl)phthalate |
| Butyl benzyl phthalate |
| Di-n-butyl phthalate |
| Diethyl phthalate |
| N-Nitrosodiphenylamine(1) |
| Phenol |
| **PESTICIDES/PCB (ug/l)** |
| 4,4'-DDT |
| Aldrin |
| Alpha chlordane |
| Alpha-BHC |
| Delta-BHC |
| Dieldrin |
| Endrin |
| Gamma chlordane |
| Heptachlor |
| Heptachlor epoxide |
| p,p'-Methoxychlor |
| **VOLATILES (ug/l)** |
| 1,1,1-Trichloroethane |
| 1,1-Dichloroethane |
| 1,2-Dichloroethane |
| 1,2-Dichloroethene(Total) |
| 1,2-Dichloropropane |
| 1,4-Dichlorobenzene |
| 2-Butanone |
| Acetone |
| Carbon disulfide |
| Carbon tetrachloride |
| Chloroform |
| Cis-1,2-Dichloroethene |
| Ethylbenzene |
| Methylene chloride |
| Toluene |
| Xylenes (Total) |

(1) The compounds listed above were detected sporadically in groundwater samples, therefore, the average concentrations in the total groundwater flow to the groundwater treatment system are expected to be below the cleanup goals.

CALGON CARBON CORPORATION

CALGON CARBON CORPORATION 4343 COMMERCE COURT, SUITE 400, LISLE, IL 60532 (708) 505-1919

December 14, 1994

Dr. Curt Elmore
Woodward-Clyde Consultants
10975 El Monte
Suite 100
Overland Park, KS 66211
Fax: (913) 344-1012

SUBJECT: Mead Nebraska AAP Remediation Project

Dear Dr. Elmore:

Based on your letter dated December 2, 1994, it is our understanding that Woodward-Clyde is evaluating remediation alternatives for the remediation of an Army Ammunition Plant in Mead, Nebraska. As part of your evaluation you are considering activated carbon to treat anywhere between 970 to 4910 gallons per minute for the removal of TCE and RDX.

Below is listed the information you requested as the project relates to activated carbon treatment.

1. **Ability to Attain Groundwater Treatment Requirements** - The Model 10 Adsorption System proposed in this letter is able to attain non-detectable levels of TCE and RDX in the effluent.

2. **Pretreatment Requirements** - The presence of 52 ppm of suspended solids is high enough that prefilter be used or backwashable Model 10 Adsorption Systems be required.

3. **Process Operations Restrictions** - A minimum empty bed contact time (EBCT) of 15 minutes is required for efficient use of the activated carbon when used for the removal of TCE and RDX from groundwater. The Model 10 Adsorption System provides 15 minutes EBCT at a flow of 700 gpm.

4. **General System Specifications** - See attachments.

5. **Description of Standard System** - See Model 10 Adsorption System product bulletin.

6. **Budgetary Cost and Activated Carbon Usage Rates** - Due to the large flow rates present in this project, we recommend the use of as multiple number of Model 10 Adsorption Systems. Table I has been developed to show the number of Model 10's required for each flow rate. The table also provides the carbon usage rate per our Filtrasorb 300 Granular Activated Carbon based on the flows and contaminant concentrations provided in your letter.

   For your use in estimating the cost of treatment for each flow rate, use a budgetary price of $165,000 for each Model 10 Adsorption System required. This price includes delivery and the initial Filtrasorb 300 Granular Activated Carbon fill. Activated carbon exchanges are performed 20,000 lbs. at a time for the Model 10. The budget price for an exchange is $24,000 which includes delivery of Filtrasorb 300 Granular Activated Carbon and disposal via reactivation of spent carbon.

Calgon Carbon Corporation can provide services including bench and pilot scale treatability studies. The costs for these services vary greatly based on the scope of work. Please contact us if you wish to discuss a treatability study.

If you have any questions regarding the information contained in this letter, please do not hesitate to contact me.

Very truly yours,

Karl D Krause/sk

Karl D. Krause
Technical Sales Representative

KDK:sk
Enc.

## TABLE I

| Groundwater Flow Rate (gpm) | # of Model 10's | Carbon Usage (lb./1000 gal.) | Carbon Usage (lb./day) |
|---|---|---|---|
| 970 | 2 | <0.1 | <140 |
| 2,100 | 3 | <0.1 | <300 |
| 2,330 | 4 | <0.1 | <340 |
| 1,980 | 3 | 0.2 | 570 |
| 3,300 | 5 | 0.1 | 480 |
| 3,530 | 5 | 0.1 | 510 |
| 1,450 | 2 | <0.1 | <210 |
| 2,770 | 4 | <0.1 | <400 |
| 3,000 | 4 | <0.1 | <430 |
| 2,490 | 4 | 0.2 | 720 |
| 4,200 | 6 | 0.1 | 600 |
| 4,910 | 7 | 0.1 | 710 |

CALGON

CALGON CARBON CORPORATION

SYSTEM BULLETIN

# MODEL 10

## MODULAR CARBON ADSORPTION SYSTEM

## DESCRIPTION

The Calgon Carbon Model 10 is an adsorption system designed for the removal of dissolved organic contaminants from liquids using granular activated carbon. The modular design concept allows selection of options or alternate materials to best meet the requirements of the site and treatment application.

The Model 10 system is delivered as two adsorbers and a compact center piping network, requiring only minimal field assembly and site connections. An optional mounting skid is available to facilitate installation. The pre-engineered Model 10 design assures that all adsorption system functions can be performed with the provided equipment.

The process piping network for the Model 10 accommodates operation of the adsorbers in parallel or series (with either adsorber placed in first stage). The piping can also isolate either adsorber from the flow. This permits carbon exchange or backwash operations to be performed on one adsorber without interrupting treatment.

The unique internal cone underdrain design provides for the efficient collection of treated water and the distribution of backwash water. The internal cone also insures efficient and complete discharge of spent carbon from the adsorber. The Model 10 system is designed for use with Calgon Carbon's closed loop carbon exchange service. Using special designed trailers, spent carbon is removed from the adsorbers and returned to Calgon Carbon for reactivation. The trailers also recharge the adsorbers with fresh activated carbon.

## SYSTEM SPECIFICATIONS

**Carbon adsorbers:**

- Carbon steel ASME code pressure vessels.
- Internal vinyl ester lining (nominal 35 mil) where GAC contacts steel, for potable water and most liquid applications.
- Polypropylene slotted nozzles for water collection and backwash distribution.

**Standard adsorption system piping:**

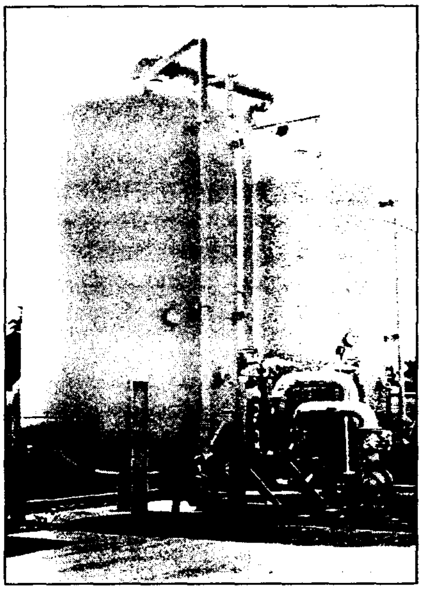
- Schedule 40 carbon steel process piping with cast iron fittings.
- Cast iron butterfly valves for process piping.
- PPL lined steel pipe for GAC discharge.
- Full bore stainless steel ball valves for GAC fill and discharge.

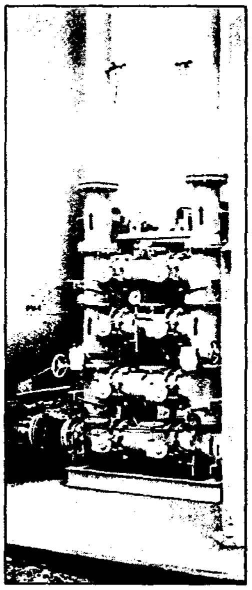
**System external coating:**

- Epoxy mastic paint system

**Available options:**

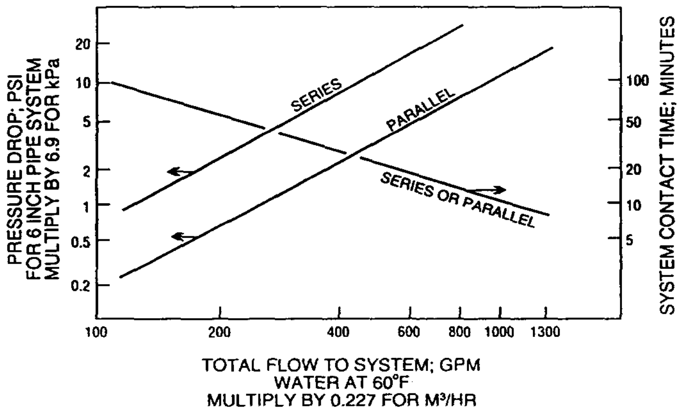
- Unifying system skid.
- In-bed water sample collection probes.





## OPERATING CONDITIONS

Carbon per adsorber: ............................ 20,000 lbs. (9080 kg)
Pressure rating: ........................................ 125 psig (862 kPa)
Pressure relief: ........................ Graphite rupture disk (94 psig)
Vacuum rating: ............................................................ 14 psig
Temperature rating: ........................... 150°F maximum (65°C)
Backwash rate: ............... Typical 1000 gpm (30% expansion)
Carbon transfer: ........................... Air pressure slurry transfer
Utility air: .................................................. 100 scfm at 30 psig
(reduce to 15 psig for trailer)
Utility water: ............................................ 100 gpm at 30 psig
Freeze protection: ...................... None provided; enclosure or protection recommended

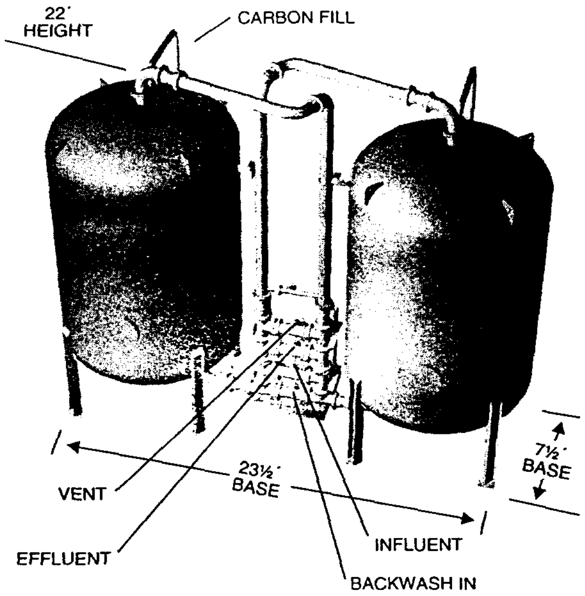


## DIMENSIONS AND FIELD CONNECTIONS

Adsorber vessel diameter: ............................ 10 ft (3050 mm)
Process Pipe: ...................................................... 6 in. or 8 in.
Process Pipe connection: ........................... 125# ANSI flange
Utility water connection: ...................... ¾ in. hose connection
Utility air connection: .......................... ¾ in. hose connection
Carbon hose connection: .......................... 4 in. Kamlock type
Carbon dry fill: .................................................. top 8" nozzle
Backwash connections: ........................... 6 in. or 8 in. flange
Drain/vent connection: ............................. 6 in. or 8 in. flange
Adsorber maintenance access ..20 in. round flanged manway
14 in. x 18 in. manway below cone
Adsorber shipping weight ......... 18,500 lbs. (empty) (8400 kg)
System operating weight .................. 215,000 lbs. (97,610 kg)

## CAUTION

Wet activated carbon preferentially removes oxygen from air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers are to enter a vessel containing carbon, appropriate sampling and work procedures for potentially low-oxygen spaces should be followed, including all applicable federal and state requirements.




Model 10 Adsorption System

For detailed information on the products described in this bulletin, please contact one of our Regional Sales Offices located nearest to you:


**New Jersey**
Bridgewater, NJ 08807
Tel (908) 526-4646
Fax (908) 526-2467

**Pennsylvania**
Pittsburgh, PA 15230-0717
Tel (412) 787-6700
800/4-CARBON
Fax (412) 787-6676

**Illinois**
Lisle, IL 60532
Tel (708) 505-1919
Fax (708) 505-1936

**California-North**
San Mateo, CA 94404
Tel (415) 572-9111
Fax (415) 574-4466

**Texas**
Houston, TX 77040-6071
Tel (713) 690-2000
Fax (713) 690-7909

**California-South**
Carlsbad, CA 92008
Tel (619) 431-5550
Fax (619) 431-8169

**Latin America/ Asia-Pacific**
Pittsburgh, PA 15230-0717
Tel (412) 787-4519
Fax (412) 787-4523

**Canada**
Calgon Carbon Canada, Inc.
Mississauga, Ontario
Canada L4V 1N3
Tel (416) 673-7137
Fax (416) 673-8883

**Europe**
Chemviron Carbon
Brussels, Belgium
Tel 32 2 773 02 11
Fax 32 2 770 93 94


If at any time our products or services do not meet your requirements or expectations, or if you would like to suggest any ideas for improvement, please call us at 1-800-548-1999. From outside the U.S. please call +1-412-787-6700.

CALGON

CALGON CARBON CORPORATION

CALGON CARBON MODULAR ADSORPTION SYSTEM

MODEL 10 X 8

( 10 ft dia. adsorbers / 8 in dia. process pipe )

## 1. SCOPE OF WORK

The following specification describes all equipment, materials and services necessary to provide a complete pre-engineered granular activated carbon adsorption system. The system is designed to allow for two-stage or parallel operation for efficient carbon usage, backwashing of the carbon bed to remove filterable solids and ease and completeness of carbon exchanges.

The adsorption system is identified as Calgon Carbon Corporation's Modular Adsorption System - Model 10 X 8; which specifies two 10 foot diameter carbon adsorbers and 8 inch piping for the water or other liquid to be treated. The Modular Adsorption System is designed to be used with selected grades of Calgon Carbon's granular activated carbon ( GAC ), and is specially designed to accommodate the removal of the spent carbon and recharge with fresh carbon using Calgon Carbon's exchange service and transport equipment.

Calgon Carbon Corporation will take complete responsibility for the design, fabrication, delivery and installation of the adsorption system, including the initial fill of GAC. Upon completion of installation, Calgon Carbon personnel will train site personnel in the operation of the adsorption system and provide Operating and Maintenance Manuals.

### 1.1. Adsorption System Design

The total adsorption system contains an installed capacity of 20,000 pounds of GAC in each of two adsorbers. Overall system design flow will be up to 700 gpm per adsorber, at a total pressure drop of less than or equal to 20 psig with the two adsorbers operated in series. The system flow rate should be verified with the design contact time, determined by the volume of the carbon bed divided by the flow rate; with the resultant contact time normally expressed in minutes. The system pressure drop is measured beginning with the influent piping and ending with the effluent piping at the system battery limits, based upon clean water and a clean carbon bed. The system is designed to treat water in the 7-9 pH range, or that is otherwise not corrosive to carbon steel or cast iron material.

Battery limits for the adsorption system are defined as the influent, effluent, backwash and vent connection flanges, all hose connections and the support skid. All equipment within these limits are provided by Calgon Carbon.

## 1.2. Work Included

The Scope of Work includes the furnishing of all equipment, materials and services to comprise a complete adsorption system:

1.2.1. Two 10 ft dia. downflow adsorbers including a water collection system ( underdrain ). Adsorbers are ASME code pressure vessels, with a corrosion resistant lining where GAC is in contact with the steel. Adsorbers include a cone design to facilitate complete removal of the spent GAC from the vessel.

1.2.2. Eight inch dia. carbon steel pipe with cast iron fittings for influent, effluent and backwash piping on the adsorption system. Piping allows placement of either adsorber in the lead position in a series arrangement, or allows both adsorbers to be operated as a single stage or in parallel. Valving allows either adsorber to be isolated for carbon exchange or backwash, while maintaining operation through the other adsorber if viable.

1.2.3. Independent GAC fill and discharge piping, including corrosion resistant valves and hose connections.

1.2.4. Vent and pressure relief piping, flush water connections, motive air connections for GAC transfers, pressure gauges and sample points.

1.2.5. Delivery and installation of the Adsorption System. System may include an optional steel support skid.

1.2.6. Delivery and installation of 20,000 pounds of granular activated carbon, as specified, per adsorber.

1.2.7. One complete set of technical specifications and six Operation and Maintenance Manuals.

1.2.8. Training of site operators by qualified Calgon Carbon personnel.

## 1.3. Work Not Included

The following work is not included by this Scope of Work and is to be the responsibility of others:

1.3.1. Foundation design, foundation and anchor bolts

1.3.2. Influent or backwash water supply, effluent or backwash disposition, utility water or air supply, including regulation or monitoring of such flows.

1.3.3. Any winterization, including insulation, heat tracing or building.

## 1.4. Services Required

The following services are to be supplied to the adsorption system to provide for carbon transfers:

1.4.1. Compressed air to provide motive force for carbon transfers; supplied at 100 scfm at 30 psig for adsorbers and 15 psig for transport trailers.

1.4.2. Uncontaminated water to provide for slurry of fresh GAC; supplied at 100 gpm and 30 psig ( minimum flow and pressure )

1.4.3. Uncontaminated water to provide for initial backwashing and classification of carbon bed; supplied to the adsorption system at 1000 gpm and 30 psig ( minimum ) for a minimum of 15 minutes per adsorber.

1.4.4. Drainage capability to allow for draining spent carbon of transfer ( slurry ) water prior to the transport trailer leaving the site. Transfer water will consist of approximately 4,000 gallons of slightly contaminated water.

1.4.5. Drainage capability for backwash water, after a fresh load of carbon is installed and when backwash is required. Backwash water typically amounts to 15,000 gallons per 1.4.3.

## 2. PROJECT SUBMITTALS

In order to assure that the Calgon Carbon Modular Adsorption System meets all the technical requirements of the site and treatment process, technical and design submittals will be provided at key points in the project. Any information provided by Calgon Carbon that is considered to be confidential, will be provided only after a confidentiality agreement is signed, and then will be clearly marked or designated.

### 2.1. Proposal Submittals

The following submittals will be made with the proposal;

2.1.1. Proposal Specification, including Scope of Work and general equipment or material specifications

2.1.2. Proposal Piping and Instrumentation Drawing indicating line sizes, valving, utility line sizes and all connections

2.1.3. Proposal Equipment Arrangement, including battery limit location, system dimensions and elevations, system weights and recommended foundation requirements.

2.1.4. Terms and Conditions for the Engineered System purchase

### 2.2. Contract Submittals

Two weeks after the receipt and acknowledgment of the purchase order by Calgon Carbon Corporation, the following submittal shall be made for approval. Any substantive changes from the Proposal Submittal as described in Section 2.1 may require a written change notice, a corresponding addendum to the purchase order pricing and adjustment of the system delivery date. All drawings and specifications will be updated, and issued as "as-built" documentation upon completion of the project, if necessary.

2.2.1. Piping and Instrumentation drawing; including all Calgon Carbon Specification notation for materials, valving, instrumentation and system accessories.

2.2.2. General Arrangement, Plans and Elevations; including detail and location of required interface connections, detail and location of base anchor bolt holes.

2.2.3. Adsorber Vessel and Underdrain drawing, including nozzle schedule and ASME Code information. ( Manufacturer's Data Sheet available upon request after vessel fabrication is complete )

2.2.4. Bill of Materials for specialty items, any extra material that may be supplied with the system and Specifications for all equipment items.

2.2.5. List of recommended spare parts, identifying those spare parts that are available through Calgon Carbon.

## 2.3. Operating Manual Submittal

Prior to delivery and startup of the Adsorption System, six ( 6 ) copies of the Operation and Maintenance Manual will be provided. This manual will incorporate all necessary information from prior submittals. Operating section will include complete instructions on staging the adsorbers, backwashing the carbon bed, unloading spent carbon, loading fresh carbon and conditioning the new bed. The manual will also include identification of Calgon Carbon personnel for on-going technical support.

# 3. PROCESS DESCRIPTION

## 3.1. Carbon Adsorption

The Adsorption System utilizes granular activated carbon ( GAC ) for efficient removal of dissolved organic chemical compounds from the water or liquid requiring treatment. Adsorption is a physical process in which the compounds adhere to the surface of the carbon particle. The large surface area contained within the internal structure of the granular carbon particle provides the Carbon Adsorption System with a substantial capacity for the organic chemical compounds to be removed. The Adsorption System provides effective exposure of the contaminated water to the GAC contained in the system.

The Carbon Adsorption System consists of two process vessels ( adsorbers ) operated in series or parallel. Each adsorber will contain twenty thousand ( 20,000 ) pounds of GAC. Water is conveyed to the adsorption system from the source, provided sufficient pressure is available, or it can be collected and repumped.

Water will enter the lead (or both) adsorber(s) at the top and flow downward through the bed. No internal distributor is required, as the space above the bed and the characteristics of flow through packed beds is sufficient to distribute the flow across the bed area. An internal collection system at the bottom of the adsorber is provided to collect the treated water equally from the cross sectional area of the bed and retain the granular carbon in the bed. The same system is used to introduce backwash water evenly across the bed to allow backwashing without disrupting the vertical classification of the packed bed. In series operation, the effluent from the lead adsorber, or first stage, is then directed to the polish, or second stage, adsorber. The water then flows downward through the second bed and is discharged from the adsorption system and the effluent connection battery limit.

The adsorption system design provides for a contact time of 7.5 minutes per adsorber given a flow of 700 gpm through each adsorber vessel. The contact time is calculated on a "superficial" or "empty bed contact time" basis, which is the time it takes a volume of water to pass through the same volume that would be occupied by the carbon bed. The pressure drop across each adsorber is estimated to be 10 psig or less, based upon clean water and clean carbon bed.

### 3.2. Carbon Exchange

When the carbon in an adsorber becomes saturated, or "spent", with contaminants adsorbed from the water, this adsorber will be taken out of service to replace the spent GAC with fresh GAC. The adsorber requiring GAC replacement can be isolated from the process flow for the exchange procedure. The flow is directed to the other adsorber, now to become the lead adsorber in series operation, or is reduced in half to allow the remaining adsorber to continue operation at design conditions if the system is being operated in parallel.

The adsorber is pressurized to 15-30 psig with compressed air and the spent GAC is displaced into a receiving trailer or transfer tank as a water-carbon slurry. The bottom of the carbon bed is contained in a coned section, so nearly complete removal of the spent carbon is possible in a single transfer procedure. Fresh carbon is transferred as a water-carbon slurry from a delivery container utilizing air pressure or an eductor system.

After the adsorber has been refilled with fresh GAC, dearated and backwashed, it can be returned to service as the second stage in series operation, or as a parallel adsorber after which full system flow can be resumed.

The transfer operation is fully compatible with Calgon Carbon's transfer trailers. The transfer trailer is designed to contain and transport 20,000 pounds of either dry or wet ( drained ) GAC, which means that the content of each single adsorber is contained in a single trailer. Hose connections easily connect the trailer to the adsorbers, and the transfer is made with air pressure to minimize water generation. The exchange is conducted in a "closed loop" to minimize loss of material and exposure of spent carbon to workers or the site. Spent GAC returned to Calgon Carbon is thermally reactivated and all contaminants are thermally destroyed in the process.

## 4. EQUIPMENT DESCRIPTION

### 4.1. Adsorber Vessels

Adsorbers are 10 ft. diameter vertical cylindrical pressure vessels with a semi-elliptical top head. The adsorber is designed such that the GAC is contained in a bottom cone with 45 degree slope, so that the GAC can be easily and completely discharged when spent. The vessels are designed, constructed and stamped in accordance with the ASME Code, Section VIII for a design pressure rating of 125 psig at 150 degrees F. The vessel is equipped with a 20" round, flanged manway on the lower side for maintenance access. There is an additional 14"x18" elliptical, quick opening manway on the bottom of the vessel for access to the underside of the cone.

The adsorber is provided with 4" nozzles for GAC fill and discharge, 8" nozzles for water and backwash connections, and 2" nozzles for optional bed sample probe. The bed sample probes can be added to allow drawing water samples from the carbon bed above the collection system. Sample probes would only extend approximately 12 inches into the bed. All nozzle connections are flush on the inside of the shell and are provided with 150 pound flat face flanges for connections.

The capacity of the adsorber is designed to contain 20,000 pounds of granular activated carbon, and allow for approximately 30% expansion of the GAC bed for backwash.

The adsorber is constructed of carbon steel, has all welds and any other sharp edges ground smooth and all imperfections such as skip welds, delaminations, scabs, slivers and slag corrected to allow for effective surface preparation. All surfaces are degreased prior to surface preparation. The adsorber internal surface that will be lined is blasted to a white metal surface ( SSPC-SP5 ) to provide an anchor pattern in the metal corresponding to a degree of profile of 4 mils, minimum. The exterior of the adsorber is sandblasted or power tool cleaned to the degree specified by SSPC-SP2-63.

The interior of the adsorber that is in contact with the GAC is lined in order to prevent corrosion that will occur when wet activated carbon is in contact with carbon steel. Immediately after sandblasting, the interior surface, is lined with light gray Plasite 4110 Abrasion-Resistant Protective Coating in two multi-pass spray coatings per manufacturer's instructions to produce a nominal 35 mil dry film thickness. This is a lining consisting of vinyl ester resin and inert flake pigment which exhibits excellent chemical resistance to a wide range of water solutions, provides excellent abrasion resistance to the movement of GAC and meets requirements of the U>S Federal Register, Food and Drug Regulations Title 21, Chapter 1, Paragraph 175.300.

In addition to the surfaces in contact with the GAC, the other vessel internal wetted surfaces under the cone section, ( not in contact with GAC ) are lined with a thin film vinyl ester coating to retard rust formation.

Following cleaning of the exterior, finish painting using an epoxy mastic coating system to a total dry film thickness of 6 mils in two applications is applied before rust can form. The two coat system is Sherwin Williams B58 Series consisting of a high solids, polyamine/bisphenol A epoxy formulation, which provides excellent resistance to condensation.

## 4.2. Underdrain Collection System

The cone section at the bottom of the carbon bed contains the underdrain collection system. The cone contains 80 nozzles to allow passage of water to the collection area below the cone and retain the GAC in the bed. The nozzles have been spaced to allow collection of the treated water from all zones of the cross sectional area. The nozzles also distribute backwash water at the bottom of the bed to evenly expand the bed without disrupting the classification of the GAC in the bed. The number of nozzles minimizes the face velocity at the nozzle, which if too high could cause either channeling at the nozzles or uneven backwash. The nozzles are constructed of polypropylene, and designed to withstand forward flow, backwash flow and movement of the GAC as it is discharged from the adsorber. With polypropylene nozzles, all bed internals are non-metallic.

### 4.3. Piping Network

A process piping network is provided for the pair of adsorbers that allows the following operations to be performed.

#### 4.3.1. Treatment

Under normal operation, the full flow of up to 700 gpm per adsorber is accepted at the system battery limits and directed to the lead adsorber if operated in series. The interconnecting piping allows for either adsorber to be operated in the lead position, and the effluent from that adsorber to be directed to the second adsorber. The effluent from the second adsorber is directed to the battery limits as the system effluent.

For parallel operation, flow of up to 1400 gpm is provided to the system battery limit and directed to both adsorbers. The effluent from both adsorbers is then combined in the pipe network for a single system effluent connection. Piping network valves isolate the influent from the treated water.

#### 4.3.2. Carbon Exchange

During carbon exchange, the adsorber being exchanged is isolated from the treatment process with valving in the piping network. The water flow is then reduced by 50% and directed solely to the other adsorber if the system is being operated in parallel, or directed completely to the second stage adsorber ( which will be the lead adsorber after exchange is completed ) in series operation.

For carbon discharge, the adsorber is isolated, pressurized with air, after which the GAC is discharged through the outlet piping. For fill, the adsorber vent is opened and GAC charged through the carbon fill line. After filling, the GAC bed is classified with a brief backwash procedure.

#### 4.3.3. Adsorber Backwash

The piping network enables the adsorber to be backwashed should an unacceptable pressure drop develop across the carbon bed due to the introduction of filterable suspended solids to the system. The adsorber being backwashed is isolated from the process flow as for carbon exchange, except for series flow, when the lead bed is backwashed the process flow should be stopped. Directing process flow to the polish bed prematurely will disrupt the adsorption characteristics and may cause premature breakthrough of contaminants to the system effluent.

An uncontaminated source of backwash water should be provided to the backwash water connection at the system battery limits. Backwash water is introduced at the bottom of the GAC bed at a rate of approximately 1000 gpm to effect a 30% bed expansion. Backwash water exits the top of the bed and is directed to the system battery limits at the "drain" connection; a single connection for backwash, vent and other drain sources.

## 4.4. Process and Utility Piping

The process and utility piping on the adsorption system includes influent water and backwash discharge to the top of the adsorber ( 8" ), treated water and backwash source water to the bottom of the adsorber ( 8" ), GAC fill and discharge lines ( 4" ). Connections are provided on these primary lines for venting, pressure relief, utility water and air, sample and flush connections, and pressure instrumentation.

With the exception of GAC discharge piping, all piping is carbon steel piping, fabricated using ASTM A53, Grade B carbon steel, rated for 150 psig @ 500 DEG F. For 2" and larger, piping is schedule 40 and provided with 150 pound ANSI B16.5, ASTM A105 forged steel slip-on or weld neck flanges. All piping welds are made in accordance with ANSI B31.3 by welders qualified under ASME Section IX.

Pipe fittings including tees, will be Class 125 pound flanged cast iron per ASTM A126, Class B. Piping less than 2" in diameter will be Schedule 80, threaded. Gaskets for the steel piping are red rubber. ( Manway gaskets are EPR type rubber )

The steel piping network will contain rubber expansion joints to allow for installation and operation without alignment problems or creating undue stress on piping between the adsorber vessels and the piping network. Expansion joints are double arch type, with 4 way movement and allowance for 30 DEG angular misalignment. Expansion joint is constructed of molded neoprene ( wetted surface ), reinforced with multiple plies of nylon, and is rated up to 225 psig at 170 DEG F.

Carbon discharge piping up to the discharge valve must be corrosion resistant as it is in contact with wet activated carbon, and therefore is polypropylene lined steel pipe rated at 150 psig to 225 DEG F. The steel pipe base is Schedule 40, ASTM A53 steel pipe with 125 pound ASTM A126, Class B cast iron flanges and fittings.

The exterior of the piping is power tool cleaned to the degree specified by SSPC-SP3-63 with a finish exterior painting of an epoxy mastic coating system. The two coat system results in a total 6 mil dry film thickness. Exterior paint is Sherwin Williams B58 Series coating, consisting of high solids, polyamine/bisphenol A epoxy formulation.

## 4.5. Process and Utility Valves

The process, backwash and utility piping, excluding GAC fill and discharge piping shall be equipped with butterfly valves for tight shut-off, isolation and flow control purposes. Butterfly valves are cast iron, one piece wafer type body with a bronze disc and stainless steel one piece through shaft, designed to mate with Class 125 ANSI flanges. Valves are rated for 200 psig in closed position at 180 DEG F, and meet or exceed all of the design strength, testing and performance requirements of AWWA Specification C-504 ( laying length may vary ).

Valves on the GAC fill and discharge need to withstand the corrosion and abrasion caused by the movement of wet GAC, and therefore are 316 stainless steel full bore ball valves with TFE seats and seals. Valves are wrench operated, and have 150 pound ANSI flanged ends.

Valving for small lines, including flush connections, sample points, pressure gauges and compressed air connections are bronze, forged brass or barstock brass body regular port ball valves, rated for 500 psig at 100 DEG F.

## 4.6. Piping System Accessories

### 4.6.1. Transfer Hose Connectors

The GAC piping is fitted with hose connectors, such that GAC transfer to and from the adsorbers can be facilitated with transfer hoses. Connectors are 4" Quick Disconnect Adaptors constructed of aluminum.

### 4.6.2. Flush and Air Connections

Two flush connections are provided on the GAC fill line on each side of the valve, one flush connection on the discharge line downstream of the valve and an air connection is provided on the adsorber influent line. Connections are welded into the steel pipe, or provided in polyproplylane "spacers", and shall consist of a short section of 3/4" pipe, a 3/4" ball valve as specified and a 3/4" quick disconnect adaptor for hose connection.

### 4.6.3. Pressure Relief

The system vent line ( connected to the adsorber influent line ) is equipped with a rupture disk for emergency pressure relief. The rupture disk is constructed of impervious graphite and is designed to relieve pressure at 94 psig +/- 5 percent, which is the recommended operating pressure for the system.

## 4.7. Instrumentation

### 4.7.1. Pressure Gauges

The adsorber piping network is equipped with pressure gauges to indicate the pressure of water entering and exiting each adsorber to provide information on pressure drops across each adsorber and the system. The pressure indicating gauges are 4 1/2" face diameter size with a stainless steel bourdon tube in a glycerin filled housing. The gauge reads 0-150 psig with an accuracy of 1% of full range.

4.7.2. Differential Pressure Switch

The Adsorption System is equipped with an indicating differential pressure switch to measure both the pressure drop across the adsorber and also across the cone at the bottom of the adsorber. The switches are connected to taps on the influent and effluent piping. The measuring element is diaphragm operated, with the differential pressure shown on a 4" diameter dial calibrated for 20-0-20 psi. The switch is provided with contacts for 10 amps @ 115 volts AC for remote indication. The switch is a Dwyer Instruments Capsu-photohelic Model 43000-B or equal. In order to protect the integrity of the cone section, it is the responsibility of the site operations to assure that the differential pressure switch is properly monitored or alarmed.

4.8. Steel Support Skid ( OPTIONAL )

The Adsorption System is provided with a steel skid for mounting of the adsorber vessels and the piping network ( not for transport of the system ). The skid provides a pre-engineered support structure for convenient installation of the vessels and piping. The skid consists of two lengthwise A36 steel beams ( W12X26, minimum ) and all necessary cross bracing. Slots are provided in the channels for installation on a foundation if required. The steel skid is finished painted similar to the exterior of the carbon steel piping as described in Section 4.4.

4.9. Sample Probes ( OPTIONAL )

The adsorption system may be provided with two sample probes per adsorber. Each sample probe is constructed of stainless steel, extends approximately one foot into the carbon bed and is equipped with a wedge wire screen end section to collect the water sample from the bed. The water exits the adsorber, and is directed by a 3/4" steel pipe to a sample valve at operating level.

5. GRANULAR ACTIVATED CARBON

5.1. General

Twenty thousand ( 20,000 ) pounds of Granular Activated Carbon will be provided and installed within each adsorber vessel.

5.2. GAC Specification

The activated carbon will be virgin grade material, manufactured in a domestic ( U.S. ) facility from domestic mined bituminous coal. The activated carbon will be Calgon Carbon Type Filtrasorb 300 and conform to the following specifications:

Iodine Number ( minimum ) ..................900
Abrasion Number ( minimum ) ..................75
Effective Size ....................0.8 - 1.0 mm
Screen Analysis
on 8 mesh ( maximum % ) ......................15
through 30 mesh ( maximum % ) .................4
Water Soluble Ash ( maximum % ) ...............1
Total Ash ( maximum % ) ......................10
Moisture, as packed ( maximum % ) ............2
Total Phosphate, as PO4 ( maximum % ) .........1

The delivered granular activated carbon will be accompanied by an analysis sheet upon request.

## 6. SERVICES

### 6.1. Adsorption System Installation

Calgon Carbon Corporation will make all necessary arrangements for and will provide supervision for the installation of the adsorption system including initial fill of GAC. Calgon Carbon's Project Manager will coordinate all necessary activities with the site personnel, including scheduling, site safety or other procedures, authorization of construction personnel and site responsibilities ( services not provided by Calgon Carbon Corporation but necessary for the installation and start-up of the adsorption system.

### 6.2. Operator Training and Start-Up Assistance

Calgon Carbon Corporation will provide the services of qualified company personnel who will be responsible for pre-startup inspection of the adsorption system, site operator training ( formal and informal ) and assistance to the site during system start-up. Two days of field service are provided for these activities, after which more technical assistance can be contracted for at per diem rates.

**CARBTROL**®
C O R P O R A T I O N

51 Riverside Avenue
Westport, Connecticut 06880
1-800-242-1150 • (203) 226-5642
FAX (203) 226-5322

December 6, 1994

Mr. Curt Elmore
WOODWARD-CLYDE CONSULTANTS
10975 El Monte - Suite 100
Overland Park, KS 66211

Re: Project 92KW030R

Dear Mr. Elmore:

With reference to the above project, please be advised that CARBTROL does not provide activated carbon treatment systems designed to handle flows in the range of 970 to 4,910 gpm.

Thank you for inviting us to submit cost information on this project. Please keep us in mind for applications that involve flows of up to 100 gpm.

Sincerely,

Charles E. O'Rourke
CEO:vlm
Enclosures

# APPENDIX I
# ADVANCED OXIDATION VENDOR ANALYSIS

In the process of evaluating remediation alternatives, Woodward-Clyde Consultants contacted the three advanced oxidation vendors listed below:

- Solarchem Environmental Systems, Inc.
- Ultrox
- Vulcan Peroxidation Systems, Inc.

An example letter of correspondence with the vendors is included in this appendix along with recent responses from each vendor.

December 2, 1994
WCC Project 92KW030R

T. P. O'Connor, P.E.
Solarchem Environmental Systems
7320 Smoke Ranch Road
Las Vegas, Nevada 89128

Dear Mr. O'Connor:

Woodward-Clyde (W-C) is evaluating potential remedial alternatives for a client who operated a military ordnance plant near Omaha, Nebraska. The site was in operation for approximately 20 years, and historic waste management practices have impacted the soil and groundwater.

Our client is planning to remediate groundwater at the site in the near future. Based on an evaluation of remedial alternatives, advanced oxidation is a candidate groundwater treatment technology.

The proposed design is to remove groundwater using several groundwater extraction wells and pump the extracted groundwater through a piping network to one central location where it will be treated to meet effluent standards. Estimated flow rates of the groundwater to be treated range from 970 to 4910 gallons per minute (GPM) for the various remedial alternatives being considered. Effluent standards to be met are EPA Drinking Water Standards.

The major groundwater contaminants of concern, and therefore the bulk of the contaminants to be removed from the groundwater to meet site remediation cleanup goals, are TCE and RDX. Estimated influent concentrations for TCE and RDX have been calculated from groundwater monitoring well data using a weighted average concentration for each proposed total groundwater extraction flow rate. This information, plus the effluent concentrations to be met, is listed in Table 1 attached to this letter.

In addition to the data on TCE and RDX concentrations, we have also included data on the average metals concentrations, as well as general water quality parameters (Table 2). The concentrations presented in Table 2 are average concentrations for the groundwater at the site, and have not been adjusted for specific flow rates. Therefore, as a conservative estimate, the concentrations in Table 2 should be considered the same for all flow rates.

As mentioned above, TCE and RDX are the primary contaminants of concern at the site. However, numerous other contaminants have been sporadically detected at low concentrations, typically below the cleanup levels. A list of the additional compounds detected at the site is presented in Table 3. The list is intended to be used to determine whether any of the compounds present may affect the overall design of the treatment system. If any of the compounds on the list potentially complicate or present particular design problems, please notify us, and we may be able to provide more specific data on the particular contaminant. It should be noted that while these compounds have been detected in individual monitoring wells, we anticipate the concentrations in the combined flow from the extraction system will be insignificant (i.e., below detectable levels).

Please provide the following information for possible treatment of the above described groundwater:

- The ability of processes to attain the potential groundwater treatment requirements.

- Any pretreatment requirements prior to the actual remediation treatment process.

- Process operations restrictions, if any. For example: influent flow rate, chemical concentrations, groundwater chemistry parameters, temperature, etc.

- General system specifications, including requirements for power, space, etc.

- A description of the standard treatment system sizes and the typical flow rate capacity of these standard sizes (e.g. Standard System A is typically selected when the anticipated flow rate ranges from ____ gpm to ____ gpm and Standard System B is typically selected where the anticipated flow rates range from ____ gpm to ____ gpm, etc.

- Typical costs, including bench and pilot scale treatability studies if needed and system design, equipment, construction, operation, and maintenance. Please include descriptions of the system power usage rates, chemical requirements, resonance times, frequency of lamp replacement and cost, and any potential intermediate compounds.

**Woodward-Clyde Consultants**



Please submit your information and cost estimates by **December 15, 1994** to:

Curt Elmore, Ph.D., P.E.
Woodward-Clyde
10975 El Monte, Suite 100
Overland Park, Kansas 66211
Phone: (913) 344-1154
Fax: (913) 344-1012

If you foresee that you would be unable to meet the December 15, 1994 target date, please contact us as soon as possible to discuss an alternate date for the submittal of your information.

Please do not hesitate to contact us if you have any questions.

Very truly yours,

Curt Elmore, Ph.D., P.E.
Project Engineer

Douglas E. Fiscus, P.E.
Senior Project Engineer

Attachments

## Table 1
## Design Influent and Effluent Concentrations for Groundwater Treatment of TCE and RDX

| Groundwater Flow Rate (gpm) | TCE (1) Influent (ug/L) | TCE (1) Effluent (3) (ug/L) | RDX (2) Influent (ug/L) | RDX (2) Effluent (4) (ug/L) |
|---|---|---|---|---|
| 970 | 21 | 5 | 53 | 2 |
| 2,100 | 14 | 5 | 5 | 2 |
| 2,330 | 13 | 5 | 5 | 2 |
| 1,980 | 350 | 5 | 27 | 2 |
| 3,300 | 209 | 5 | 18 | 2 |
| 3,530 | 195 | 5 | 18 | 2 |
| 1,450 | 51 | 5 | 36 | 2 |
| 2,770 | 30 | 5 | 23 | 2 |
| 3,000 | 23 | 5 | 21 | 2 |
| 2,490 | 338 | 5 | 18 | 2 |
| 4,200 | 204 | 5 | 23 | 2 |
| 4,910 | 173 | 5 | 21 | 2 |

Notes: EPA Drinking water Standards From:
Drinking Water Regulations and Health Advisories, May 1994. Office of Water, U.S. Environmental Protection Agency.

1. TCE = Trichloroethene
2. RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
3. EPA Drinking Water Maximum Contaminant Level (MCL)
4. EPA Health Advisory - Because no MCL has been established for this chemical

# Table 2
## Summary of Metals Concentrations and General Water Quality Parameters

| | Average Concentration in Groundwater Samples | Comments |
|---|---|---|
| TOTAL METALS (ug/l) | | |
| Aluminum | 1,066 | Detected in 15 of 15 monitoring wells |
| Arsenic | 13 | Detected in 9 of 15 monitoring wells |
| Barium | 218 | Detected in 15 of 15 monitoring wells |
| Beryllium | 1 | Detected in 1 of 15 monitoring wells |
| Calcium | 63,187 | Detected in 15 of 15 monitoring wells |
| Chromium | 14 | Detected in 3 of 15 monitoring wells |
| Cobalt | 13 | Detected in 1 of 15 monitoring wells |
| Copper | 15 | Detected in 2 of 15 monitoring wells |
| Iron | 1,200 | Detected in 15 of 15 monitoring wells |
| Lead | 9 | Detected in 2 of 15 monitoring wells |
| Magnesium | 15,238 | Detected in 15 of 15 monitoring wells |
| Manganese | 196 | Detected in 15 of 15 monitoring wells |
| Mercury | 0.33 | Detected in 1 of 15 monitoring wells |
| Nickel | 20 | Detected in 2 of 15 monitoring wells |
| Potassium | 8,758 | Detected in 15 of 15 monitoring wells |
| Selenium | 38 | Detected in 1 of 15 monitoring wells |
| Sodium | 20,847 | Detected in 15 of 15 monitoring wells |
| Thallium | 2 | Detected in 1 of 15 monitoring wells |
| Vanadium | 18 | Detected in 2 of 15 monitoring wells |
| Zinc | 12 | Detected in 12 of 15 monitoring wells |
| WATER QUALITY (mg/l) | | |
| Alkalinity as Calcium Carbonate | 198 | |
| Biochemical Oxygen Demand (BOD) | 6 | |
| Hardness as Calcium Carbonate | 241 | |
| Nitrate-Nitrite-N | 28 | |
| Total Chlorides | 24 | |
| Total Dissolved Solids (TDS) | 439 | |
| Total Kjeldahl Nitrogen (TKN) | 0.41 | |
| Total Microbial Count (cells/ml) | 22,650 | |
| Total Organic Carbon (TOC) | 2 | |
| Total Organic Halides (TOX) (ug/L) | 227 | |
| Total Sulfates | 88 | |
| Total Suspended Solids (TSS) | 52 | |
| Dissolved Oxygen (mg/L) | 4 | |
| Oxidation Reduction Potential (mV) | 73 | |
| pH | 7 | |
| Specific Conductance (umhos/cm) | 450 | |
| Temperature (Celsius) | 12 | |

## Table 3
## Summary of Additional Compounds Detected at Low Concentrations (1) in Groundwater Samples

| EXPLOSIVES (ug/l) |
|---|
| 1,3,5-Trinitrobenzene (TNB) |
| 2,4,6-Trinitrotoluene (TNT) |
| 2,4-Dinitrotoluene (24DNT) |
| 4-Nitrotoluene (4NT) |
| HMX |
| Tetryl |
| **GROSS Alpha/Beta (pCi/l)** |
| Gross Alpha |
| Gross Beta |
| **SEMIVOLATILES (ug/l)** |
| bis(2-Ethylhexyl)phthalate |
| Butyl benzyl phthalate |
| Di-n-butyl phthalate |
| Diethyl phthalate |
| N-Nitrosodiphenylamine(1) |
| Phenol |
| **PESTICIDES/PCB (ug/l)** |
| 4,4'-DDT |
| Aldrin |
| Alpha chlordane |
| Alpha-BHC |
| Delta-BHC |
| Dieldrin |
| Endrin |
| Gamma chlordane |
| Heptachlor |
| Heptachlor epoxide |
| p,p'-Methoxychlor |
| **VOLATILES (ug/l)** |
| 1,1,1-Trichloroethane |
| 1,1-Dichloroethane |
| 1,2-Dichloroethane |
| 1,2-Dichloroethene(Total) |
| 1,2-Dichloropropane |
| 1,4-Dichlorobenzene |
| 2-Butanone |
| Acetone |
| Carbon disulfide |
| Carbon tetrachloride |
| Chloroform |
| Cis-1,2-Dichloroethene |
| Ethylbenzene |
| Methylene chloride |
| Toluene |
| Xylenes (Total) |

(1) The compounds listed above were detected sporadically in groundwater samples, therefore, the average concentrations in the total groundwater flow to the groundwater treatment system are expected to be below the cleanup goals.

## Cost Estimate To

# WOODWARD-CLYDE

for the supply of a

## Rayox® UV/Oxidation

## Groundwater Treatment System

for

## Mead Army Depot
## Mead, NE

**DECEMBER 13, 1994**

Solarchem

# I. EXECUTIVE SUMMARY

In response to request, Solarchem is pleased to offer this cost estimate for a **Rayox®** UV/oxidation system to treat groundwater at the Mead Army Depot facility in Mead, NE. Solarchem has prepared this estimate for a system to destroy TCE and RDX at a design flowrate of 970 to 4910 gpm.

The **Rayox®** system uses UV light together with hydrogen peroxide to treat the water to the required levels. The optimal **Rayox®** system for the various options are shown in Tables 1 to 4 (pages 9 to 11 )

RDX is the controlling compound for all the options analyzed.

The following tables were developed in the following manner:

TABLE 1 is the system specific based on the twelve given flows and concentrations.

TABLE 2 is the system specifics for incremental reactors and its' flow capacities based on the average of the twelve concentrations given.

TABLE 3 is the system specifics for incremental reactors and its' flow capacities based on the average of the lowest six concentrations of RDX of the twelve concentrations given.

TABLE 4 is the system specifics for incremental reactors and its' flow capacities based on the average of the highest six concentrations of RDX of the twelve concentrations given.

The **Rayox®** system will come in skids of four reactors each. See page 13 for specifications. Depending on the actual number of reactors required, these skids will be run in parallel with three feet clearance needed between skids.

TABLE 5 shows the expected percent removal of additional compounds by the **Rayox®** system. See page 12

Based on the data provided there are no parameters that will complicate the treatment process or restrict its operation and therefore no pretreatment will be required.

Solarchem recommends a in-house treatability test in order to correctly size the required **Rayox®** system. From this testability test Solarchem will be able to offer a performance guarantee for the recommended system. The cost of this test will be free and the only cost that the client will be responsible for is that of the shipping of a 55 gallon drum of representative water and any outside analytical testing if required.

## II. SCOPE OF SUPPLY

### *SOLARCHEM SUPPLY*

Solarchem proposes to supply the following equipment and to provide the following services:

***Equipment:***

| | |
|---|---|
| One (1) | Pre-piped, pre-wired and fully shop-tested **Rayox®** skid(s) consisting of multiple 30 kW reactor(s) and power suppl(ies); flanged influent and effluent piping connections; system controller (PLC), fully programmed |
| One (1) | Hydrogen peroxide delivery system |
| One (1) | Operating and Maintenance Manual |

***Optional Equipment:***

| | |
|---|---|
| One (1) | Hydrogen peroxide storage tank with low level switch |
| One (1) | Air compressor |
| One (1) | Modem |
| One (1) | Autodialer |
| One (1) | Recycle system to equalization tank for start-up consisting of a automated 3-way valve, wiring and panel-mounted selector switch |
| One (1) | Batch Treatment System consisting of storage tank with three level switches, solenoid valves, one heat exchanger (water cooled), one feed pump and all necessary piping |
| One (1) | **ENOX** delivery system |
| One (1) | Acid delivery system |
| One (1) | Caustic delivery system |
| Two (2) | pH control systems consisting of probes, transmitters and controllers |

***SERVICES:***

1. Complete chemical and engineering operational design assistance.

2. Visit to a local **Rayox®** operational system for review.

3. References from similar projects.

4. Capital and Operational Costs guarantee if representative water analysis can be examined.

## *SUPPLY BY OTHERS*

In order to clarify the scope of Solarchem's supply, it has been assumed for the purposes of this proposal that the following items are supplied by others:

*Installation of the system including:*

- provision of an industrial indoor environment, 40°F to 95°F, sealed or painted concrete floor
- unloading, placing, leveling, and anchoring equipment
- electrical hook-up
- connecting piping to and from **Rayox®** system and between **Rayox®** skids
- Tubing between metering pump and peroxide storage tank, and between metering pump and **Rayox®** skid
- electrical wiring between metering pump and **Rayox®** skid
- provisional of a lockable electrical disconnect in vicinity of **Rayox®** system
- provision of utilities including power (480V/120V) and instrument air *(optional air compressor)*, and cooling water

## III. QUOTE

Solarchem proposes to supply the **Rayox®** system as described in this estimate under the commercial terms indicated below:

***EQUIPMENT PURCHASE***

| | |
|---|---|
| Selling price for **Rayox®** System as Described | See TABLES 1 to 4 |

Price does not include freight to the job site, site preparation, of installation.

***ESTIMATED OPERATING COST***

A breakdown of the operating cost per 1000 gallons and per year (350 days) are also shown in TABLES 1 to 4

Operating Costs includes electricity, lamp replacement and peroxide costs. Solarchem lamps are guaranteed to last 3000 hours of operation.

- Payment Terms: 40% of Purchase Price with Purchase Order<br>50% on notification of readiness to ship<br>10% 30 days after delivery
- Delivery: F.O.B. : Markham, Ontario<br>Taxes : Not included<br>Customs Clearance : Not included
- Delivery Schedule: 10 - 12 weeks from receipt of down payment<br>*To be confirmed at time of order*

## IV. GENERAL INFORMATION

**Rayox®** is a second generation enhanced oxidation process designed to **destroy** water borne toxic/hazardous organic contaminates. Its performance is based on the use of photons of a high intensity UV lamp of a proprietary design, oxidizing agents such as ozone or hydrogen peroxide, and, as necessary, a series of patented and proprietary catalyst additives. Target toxic contamination can be oxidized to carbon dioxide, water, chloride ion ($CL^-$) and simple, non-toxic organics suitable for surface or sewer discharge. This established technology is best used where toxic/hazardous contamination loadings in groundwater or process wastewater are less than 1% (10,000 ppm) and up to 99.999 + % contaminate destruction is desired.

Solarchem has developed a number of features that make **Rayox®** systems superior to the competing UV/Oxidation systems. Some of these features are:

Proprietary Low Wavelength UV Lamps

Destruction of target compounds during UV oxidation treatment occurs both by hydroxyl radical attack and direct photolysis. Therefore, it is critical for the UV lamp to have maximum energy output in the UV wavelengths where hydrogen peroxide and the target compounds absorb energy the greatest.

$H_2O_2$ and the target compounds have maximum UV absorbance peaks below 220 nm. Solarchem UV lamps have far greater output in these wavelengths than any other commercially available UV lamp. Since the light emitted below 225 nm will actually break bonds and destroy the molecule, the Solarchem Lamps are also uniquely able to provide destruction by direct photolysis. The strong output of the Solarchem Lamp below 225 nm also enables more efficient production of hydroxyl radicals from the splitting of peroxide. This means that a **Rayox®** system can be smaller, reducing equipment purchase and operating costs.

State-of-the-Art Lamp Power Supply

Solarchem has developed a sophisticated lamp power supply which controls the power fed to the lamp via the PLC through feedback control of the current and voltage. This ensures consistent control of lamp power throughout the life of the lamp, and automatically compensates for fluctuations in the main electrical supply and ambient temperature changes. This provides assurance that the lamp is operating correctly. In addition, linking the power supply to the PLC allows the total UV power to be varied automatically as a function of influent flowrate if so desired.

Proven Programmable Logic Controller

Solarchem has installed a PLC in every system we have built. Approximately one half of Solarchem's installed PLC's interface directly with plant controllers. A state-of-the-art operator interface mounted on the control panel enables on-line optimization of the **Rayox®** system performance.

Proven Lamp Cleaning Mechanism

Solarchem's patented lamp wiping mechanism has been included in all of our installations. The wiper mechanism is air-actuated, and does not rely on reverse flow of water. It, therefore, requires fewer replacement parts and no by-pass piping, which reduces complexity. Furthermore, its operation is continuously monitored and verified by the PLC system to ensure its integrity.

Inherently Simple Design

The **Rayox®** system is inherently simple by design. For example, a **Rayox®** system does not require a rupture disk to avoid an overpressure condition. Such a condition cannot occur through normal operation of the **Rayox®** system as it is designed to withstand a pressure of 50 psig. This avoids the need to register and maintain such a safety device.

Proprietary **ENOX** Photocatalysts

Solarchem has developed four proprietary **ENOX** photocatalysts which can be used, individually or in combination, to optimize the treatment process selected for a given application. One of these **ENOX** photocatalysts is at the heart of a unique photoreduction process, **Rayox®-R**, which significantly improves the treatment of halogenated alkanes like TCA, DCA, $CCl_4$, and $CHCl_3$, all of which treat slowly by conventional photooxidation technologies. A second **ENOX** photocatalyst is highly active in the visible light range, and has potential solar applications through Solarchem's **Solaqua®** process.

Solarchem utilize a family of treatment processes which can treat a wide range of water-borne contaminants. Using its proprietary **ENOX** photocatalysts, Solarchem is able to customize the advanced oxidation and/or reduction process for each application, thereby minimizing the capital and operating costs for the client.

Other **Rayox®** Advantages

Lamp turn-down capabilities to reduce future power costs
Vertical reactors with internal baffles for superior turbulence to increase mass and energy transfer
> 90% power efficiency
0.92 power factor at full power
Stainless steel parts, nuts, bolts
100 message alarm annunciator
High pressure tolerances (50 psig)
Lamp power control keeps lamp UV output constant over time

**TABLE 1 - System size and costs based on Table 1 of request**

| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent Concentration (ppb) | 53 | 5 | 5 | 27 | 18 | 18 | 36 | 23 | 21 | 18 | 23 | 21 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Flow (gpm) | 970 | 2100 | 2330 | 1980 | 3300 | 3530 | 1450 | 2770 | 3000 | 2490 | 4200 | 4910 |
| # of UV reactors | 8 | 5 | 5 | 12 | 18 | 18 | 10 | 16 | 16 | 12 | 24 | 28 |
| Capital Cost ($000's) | 253 | 172 | 172 | 355 | 503 | 503 | 278 | 429 | 429 | 355 | 651 | 725 |
| Operating Costs ($/1000 gals) | 0.32 | 0.12 | 0.11 | 0.24 | 0.22 | 0.21 | 0.27 | 0.23 | 0.21 | 0.2 | 0.23 | 0.23 |
| Operating Costs ($000's/year) | 156 | 127 | 129 | 239 | 365 | 373 | 197 | 321 | 317 | 250 | 486 | 569 |

**TABLE 2 - System size and capacity based on average of concentrations in Table 1 of request**

| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent Concentration (ppb) | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 200 | 385 | 570 | 755 | 940 | 1125 | 1310 | 1495 | 1680 | 1865 | 2050 | 2235 |
| # of UV reactors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Capital Cost ($000's) | 55 | 82 | 109 | 136 | 163 | 190 | 217 | 244 | 271 | 298 | 325 | 352 |
| Operating Costs ($/1000 gals) | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| Operating Costs ($000's/year) | 23 | 44 | 65 | 86 | 107 | 128 | 149 | 170 | 191 | 212 | 233 | 254 |

| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent Concentration (ppb) | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 2420 | 2605 | 2790 | 2975 | 3160 | 3345 | 3530 | 3715 | 3900 | 4085 | 4270 | 4455 |
| # of UV reactors | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Capital Cost ($000's) | 379 | 406 | 433 | 460 | 487 | 514 | 541 | 568 | 595 | 622 | 649 | 676 |
| Operating Costs ($/1000 gals) | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| Operating Costs ($000's/year) | 275 | 296 | 317 | 338 | 359 | 380 | 401 | 422 | 443 | 464 | 485 | 506 |

| Controlling Compound | RDX | RDX | RDX | RDX |
|---|---|---|---|---|
| Influent Concentration (ppb) | 22 | 22 | 22 | 22 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 4640 | 4825 | 5010 | 5195 |
| # of UV reactors | 25 | 26 | 27 | 28 |
| Capital Cost ($000's) | 703 | 730 | 757 | 784 |
| Operating Costs ($/1000 gals) | 0.23 | 0.23 | 0.23 | 0.23 |
| Operating Costs ($000's/year) | 527 | 548 | 569 | 590 |

**TABLE 3 - System size and capacity based on average of lower half concentrations in Table 1 of request**

| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nfluent Concentration (ppb) | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 245 | 470 | 695 | 920 | 1145 | 1370 | 1595 | 1820 | 2045 | 2270 | 2495 | 2720 |
| # of UV reactors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Capital Cost ($000's) | 55 | 82 | 109 | 136 | 163 | 190 | 217 | 244 | 271 | 298 | 325 | 352 |
| perating Costs ($/1000 gals) | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| perating Costs ($000's/year) | 25 | 47 | 69 | 91 | 113 | 135 | 157 | 179 | 201 | 223 | 245 | 267 |

| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent Concentration (ppb) | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 | 14.2 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 2945 | 3170 | 3395 | 3620 | 3845 | 4070 | 4295 | 4520 | 4745 | 4970 | 5195 | 5420 |
| # of UV reactors | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Capital Cost ($000's) | 379 | 406 | 433 | 460 | 487 | 514 | 541 | 568 | 595 | 622 | 649 | 676 |
| perating Costs ($/1000 gals) | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| perating Costs ($000's/year) | 289 | 311 | 333 | 355 | 377 | 399 | 421 | 443 | 465 | 487 | 509 | 531 |

**TABLE 4 - System size and capacity based on average of upper half concentrations in Table 1 of request**

| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nfluent Concentration (ppb) | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 |
| :ffluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 175 | 335 | 495 | 655 | 815 | 975 | 1135 | 1295 | 1455 | 1615 | 1775 | 1935 |
| # of UV reactors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Capital Cost ($000's) | 55 | 82 | 109 | 136 | 163 | 190 | 217 | 244 | 271 | 298 | 325 | 352 |
| )perating Costs ($/1000 gals) | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| )perating Costs ($000's/year) | 22 | 44 | 66 | 88 | 110 | 132 | 154 | 176 | 198 | 220 | 242 | 264 |

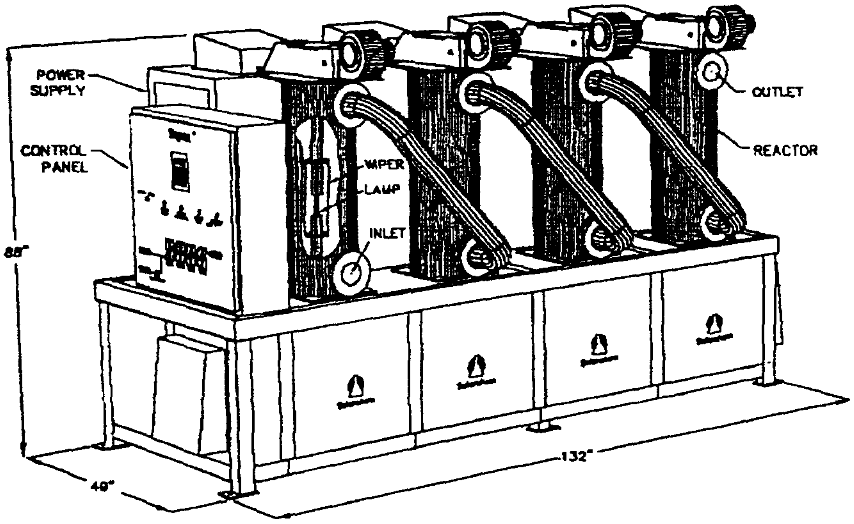
| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent Concentration (ppb) | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 2095 | 2255 | 2415 | 2575 | 2735 | 2895 | 3055 | 3215 | 3375 | 3535 | 3695 | 3855 |
| # of UV reactors | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Capital Cost ($000's) | 379 | 406 | 433 | 460 | 487 | 514 | 541 | 568 | 595 | 622 | 649 | 676 |
| )perating Costs ($/1000 gals) | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| )perating Costs ($000's/year) | 286 | 308 | 330 | 352 | 374 | 396 | 418 | 440 | 462 | 484 | 506 | 528 |

| Controlling Compound | RDX | RDX | RDX | RDX | RDX | RDX | RDX | RDX |
|---|---|---|---|---|---|---|---|---|
| Influent Concentration (ppb) | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 |
| Effluent Concentration (ppb) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Max. Flow (gpm) | 4015 | 4175 | 4335 | 4495 | 4655 | 4815 | 4975 | 5135 |
| # of UV reactors | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| Capital Cost ($000's) | 703 | 730 | 757 | 784 | 811 | 838 | 865 | 892 |
| )perating Costs ($/1000 gals) | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| )perating Costs ($000's/year) | 550 | 572 | 594 | 616 | 638 | 660 | 682 | 704 |

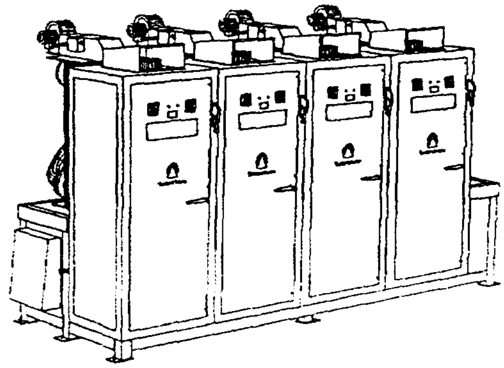
**TABLE 5 - Expected % Destruction of Additional Compounds Dectected at Low Concentrations in Groundwater Samples by Rayox system designed to treat TCE and RDX**

| Compound | Expected % Destruction of Influent Concentration |
|---|---|
| 1,3,5 - Trinitrobenzene(TNB) | 5 |
| 2,4,6 - Trinitrotoluene(TNT) | 90 |
| 2,4 - Dinitrotoluene(2,4DNT) | 90 |
| 4 - Nitrotoluene(4NT) | 90 |
| HMX | 90 |
| Tetryl | 75 |
| Gross Alpha | N.A. |
| Gross Beta | N.A. |
| bis(2 - Ethylexyl)phthalate | 75 |
| Butyl benzyl phthalate | 75 |
| Diethyl phthalate | 75 |
| N-nitrosodiphenylamine | 75 |
| Phenol | 75 |
| 4,4 - DDT | 75 |
| Aldrin | 15 |
| Alpha chlordane | 15 |
| Alpha-BHC | 15 |
| Delta-BHC | 15 |
| Dieldrin | 15 |
| Endrin | 15 |
| Gamma chlordane | 15 |
| Heptachlor | 15 |
| Heptachlor epoxide | 15 |
| p,p' - Methoxychlor | 30 |
| 1,1,1 - Trichloroethane | 10 |
| 1,1 - Dichloroethane | 30 |
| 1,2 - Dichloroethane | 30 |
| 1,2 - Dichloroethene(Total) | 90 |
| 1,2 - Dichloropropane | 30 |
| 1,4 - Dichlorobenzene | 50 |
| 2 - Butanone | 50 |
| Acetone | 15 |
| Carbon disulfide | 90 |
| Carbon Tetrachloride | 5 |
| Chloroform | 10 |
| Cis - 1,2 - Dichloroethene | 90 |
| Ethylbenzene | 90 |
| Methylene Chloride | 30 |
| Toluene | 90 |
| Xylenes(Total) | 90 |

# Model 30 - 4 (120 kW System)




Control Panel View



Power Supply View

### Model Features

- Fully Automated Control
- Proven Lamp Wiper
- Interactive Message Display
- Fully Adjustable Lamp Power
- OSHA Approved
- NEC Approved
- Safety Interlock Switches
- Modem/Auto Dialer (optional)
- Magnetic Flowmeters
- Factory Pretested
- Minimum Installation Requirements

### System Specifications

**Configuration:** 4 x 30 kW reactors

**Flowrate:** up to 300 gpm (4" piping)

**Electrical Requirements:**
(US) 480 VAC, 3ph, 215 amps
(Can) 600 VAC, 3ph, 172 amps

**Lamp Power:** 15 kW - 30 kW (adj.)

**PLC:** Siemens TI405 - 435 CPU

**Materials:**
Wetted Parts - 316SS, Quartz, Viton
External Parts - Epoxy Coated Steel

**Shipping Weight:** 9000 lbs / 4100 kg

Solarchem

OUTSHINING THE TREATMENT ALTERNATIVES

# ULTROX

*A Division of Zimpro Environmental, Inc.*

2435 South Anne Street
Santa Ana, CA 92704-5308
Phone: 714 545-5557
Fax: 714 557-5396

December 12, 1994

Curt Elmore, Ph.D., P.E.
Woodward-Clyde Consultants, Inc.
10975 El Monte, Ste. 100
Overland Park, KS 66211

Dear Dr. Elmore:

Thank you for your December 2nd inquiry regarding potential remedial alternatives for treating military ordnance. Ultrox has extensive experience in the treatment of both explosive compounds and chlorinated VOCs such as trichloroethylene (TCE). Our experiences with explosives treatment include the treatment of groundwaters at Milan Army Ammunition Plant, Savanna Army Depot, Umatilla Army Depot, Picatinny Arsenal and wastewaters at the Radford Army Depot and Louisiana Army Ammunition plant. Of these facilities, the one of most notoriety is the Milan Army Ammunition Plant. The Army Environmental Center and the U.S. Army Corps of Engineers evaluated the Ultrox® UV/Oxidation system in comparison with other UV/Oxidation approaches and granular activated carbon. Based upon the evaluation, an Ultrox system was purchased to treat 600 gpm of groundwater contaminated with 27 mg/l of explosives (including RDX). This system design was included in the Department of Defense letter to Congress.

Our experiences with TCE are equally as well documented and more numerous than those with explosives. TCE was one of the key compounds treated in our evaluation by the EPA as part of their SITE (Superfund Innovative Technology Evaluation) program. This was completed in 1989 with a favorable report (Report EPA 540/5-89/012) which concluded that the Ultrox® UV/Oxidation system was able to achieve the NPDES discharge requirements for numerous compounds including TCE. Further, no VOCs were detected in the off-gas.

While documented evidence exists that Ultrox® UV/Oxidation is very effective in the destruction of TCE and RDX, the economics of this treatment approach are quite attractive, especially at flow rates indicated in your December 2nd letter. The most beneficial factor in Ultrox® UV/Oxidation treatment is low operating and maintenance costs. This becomes even more significant at flow rates between 970 and 4,910 gpm. The U.S. Army Corps of Engineers has found this to be true when examining the life cycle costs of projects where Ultrox has been evaluated.

Having examined your "Table 2 - Summary of Metal Concentrations and General Water Quality Parameters", it is clear that your oxidizable metals (iron & manganese) are not of sufficient concentration to require pretreatment. While the hardness concentration indicates a moderately high concentration of carbonates, it is not likely that pH adjustment is warranted. However, this can be examined quite easily in bench scale or pilot treatability testing.

While you have indicated that additional compounds were detected in groundwater samples (Table 3), their net affect on the oxidation of the target compounds (TCE & RDX) is expected to be negligible with a total organic carbon (TOC) of 2 mg/l.

Our response to your inquiry is provided below:

1. Ultrox® UV/Oxidation systems can easily attain the potential groundwater treatment requirement. Further, they can be automated to reduce the oxidant and electrical power consumption proportional to reductions in flow rates.

2. No pretreatment is required. Reduction of pH may be evaluated for cost effectiveness to the process, but is not a requirement to achieve treatment objectives.

3. Ultrox® UV/Oxidation systems are typically designed with a hydraulic capacity capable of operating at 150% of design flow rate. The budgeted system (970 gpm) includes >50% additional ozone capacity. While reserve oxidant and UV exposures are limited to design capacities, flow rates may be increased at the expense of reduced treatment efficiencies. Temperature limitations range from the groundwater freezing point to 130°F. The actual temperature rise resulting from Ultrox® UV/Oxidation treatment is approximately 1°F. The pH of the untreated groundwater should not be less than 3 without equipment materials compatibility evaluation.

4. I have provided a general specification (based upon the 970 gpm system) for your review.

5. Ultrox® UV/Oxidation system equipment is designed specifically for each project. For smaller flow rates requiring short retention times, Ultrox® UV/Oxidation treatment tanks range in working capacities from 325 gallons to 3900 gallons. The treatment tank size is based upon the UV exposure (or retention) time required for the specific compounds being treated. The treatment tank working volume is determined by multiplying the retention time by the flow rate. For larger flow rates and retention times, multiple tanks are combined or customized UV treatment tanks are manufactured based upon the required UV power per volume of water to be treated over time.

6. Please see attached budget estimates for capital and operating costs associated with the two flow rates provided.

   While our budget estimates are generally within a reasonable margin of error, we will require empirical data in order to provide a performance guarantee. Should the client wish, a full laboratory and/or field pilot study can be conducted. However, with a relatively clean groundwater such as this, design parameters can be verified with less than 3 laboratory bench scale tests. A bench scale test to verify treatment parameters can be performed for analytical costs alone. Should a written report be required, the laboratory study would cost approximately $5,000.

Field pilot plant equipment is available for on-site treatment at the rate of $3,100 per week. A field engineer is available at the rate of $70 per hour plus travel and living expenses.

The destruction of TCE by advanced oxidation results in byproducts of dichloroethene, and possibly formic acid which are then immediately oxidized to carbon dioxide, water and chlorides. The destruction of RDX results in hydroxyquinones, catecols, resorcinol, followed by formic, oxalic and maleic acids. These in turn are oxidized to carbon dioxide and water. Other intermediaries may have been identified, but have not been detected in samples due to short life during the oxidation process. If you are interested in the oxidation pathways of various compounds, papers have been written for the Advanced Oxidation Technology Conference held in London, Ontario, Canada each year.

I hope this information assists you in your evaluation process. Should you have any questions, please give me a call.

Sincerely,

William S. Himebaugh
Sales Manager - Ultrox

WSH/gkr

enc. General Specification
Budget Quotation
Dimensioned Layout

cc. Steve Dzuro
Zimpro Environmental

# ULTROX

*A Division of Zimpro Environmental, Inc.*

2435 South Anne Street
Santa Ana, CA 92704-5308
Phone: 714 545-5557
Fax: 714 557-5396

December 12, 1994

**BUDGET CAPITAL AND O&M COSTS**
**FOR THE ULTROX® UV/OXIDATION SYSTEM**

**Woodward-Clyde Consultants, Inc.**
**Overland Park, KS**

## I. PARAMETERS

| PARAMETERS | CONCENTRATION (ug/l) | GOAL (ug/l) |
|---|---|---|
| TCE | 350 | 5 |
| RDX | 53 | 2 |

## II. UV/OXIDATION SYSTEM COMPONENTS (Flow rate = 970 gpm)

A. OXIDATION REACTOR
   1. Two (2) C-5000 Oxidation Treatment Tanks

B. OZONE GENERATOR
   1. 100 LB/DAY OZONE GENERATOR

C. OZONE GENERATOR AIR PREPARATION SYSTEM
   1. COMPRESSOR
   2. AIR DRYER (-70°F DEWPOINT)
   3. AIR FILTER

D. HYDROGEN PEROXIDE FEED SYSTEM
   1. CHEMICAL METERING PUMP (0.5 GPH)
   2. CALIBRATION CYLINDER
   3. PUMP STAND

E. VAPOR TREATMENT
   1. D-TOX™/DECOMPOZON™ CATALYTIC OZONE/VOC DESTRUCTION UNIT

F. POWER CONTROL UNIT
   1. PROGRAMMABLE LOGIC AUTOMATIC CONTROL UNIT

## III. UV/OXIDATION SYSTEM COMPONENTS (Flow rate = 4,910 gpm)

A. OXIDATION REACTOR
   1. Two (2) 50,000 Ultrox Oxidation Treatment Tanks

B. OZONE GENERATOR
   1. 300 LB/DAY OZONE GENERATOR

C. OZONE GENERATOR AIR PREPARATION SYSTEM
   1. COMPRESSOR
   2. AIR DRYER (-70°F DEWPOINT)
   3. AIR FILTER

D. HYDROGEN PEROXIDE FEED SYSTEM
   1. CHEMICAL METERING PUMP (0.5 GPH)
   2. CALIBRATION CYLINDER
   3. PUMP STAND

E. VAPOR TREATMENT
   1. D-TOX™/DECOMPOZON™ CATALYTIC OZONE/VOC DESTRUCTION UNIT

F. POWER CONTROL UNIT
   1. PROGRAMMABLE LOGIC AUTOMATIC CONTROL UNIT

## IV. ASSUMPTIONS

A. ELECTRICAL COSTS = $0.10/KWH

B. $H_2O_2$ COSTS = $0.70/LB

C. REPLACEMENT COSTS PER LAMP = $60 (lamp life = 1.2 yrs.)

## V. COSTS

Flow rate = 970 gpm

A. TOTAL BUDGET CAPITAL COST*: $ 265,000

B. TOTAL BUDGET O&M COSTS**: $ 0.04/1000 GALLONS

Flow Rate = 4,910 gpm

A. TOTAL BUDGET CAPITAL COST*: $ 450,000

B. TOTAL BUDGET O&M COSTS**: $ 0.04/1000 GALLONS

* Capital costs are estimated FOB Rothschild, WI, and do not include installation, start up or training. More detailed information will be required for integration into full-scale system design.

** O&M costs include electrical power costs, $H_2O_2$ costs, and amortized UV lamp replacement costs.

# ULTROX

# STANDARD TERMS AND FEE SCHEDULE FOR LABORATORY TREATABILITY AND PILOT PLANT STUDIES

## LABORATORY TREATABILITY STUDIES (Santa Ana, CA)

$700/day with a five day minimum

Analytical work at an independent laboratory will be billed at cost plus 20%

## FIELD PILOT PLANT STUDIES

Models P-75

$2,650/week, with a one week minimum

Models P-325, P-650, P-675

$3,100/week, with a one week minimum

| | |
|---|---|
| D-TOX CF-1 with G-14 lb/day ozone generator | $2,500/week |
| D-TOX CF-1 with G-28 lb/day ozone generator | $2,800/week |

An Ultrox field engineer will be provided at a charge of $2,400 (plus travel and living expenses) for the first five working days on site. A per diem charge of $575.00 (plus travel and living expenses) will be invoiced for each additional day an Ultrox field engineer is required. Rates for extended rental periods, i.e. greater than four weeks, will be quoted upon request.

A credit of 50% on up to 4 weeks laboratory work and pilot plant work will be given for purchase of an ULTROX® system purchased within six months of test completion. The credit does not apply to charges for living, travel and freight expenses or field engineer's time, or for analytical charges at an independent laboratory.

TERMS

- Payable upon receipt of invoice
- Invoices for laboratory tests are issued upon completion of tests or on a monthly basis for extended laboratory studies.
- Freight charges for shipment of samples and/or pilot plant units to and from Ultrox's facilities, are the customer's responsibility.
- Invoices for pilot plant rentals are issued on a monthly basis.
- First week's pilot plant rental due with purchase order.
- One third (1/3) payment due with purchase order on laboratory studies.
- Charges commence on the day the unit arrives at client's facility until it is returned to Ultrox's facilities. Federal holidays, Saturdays and Sundays that the unit is in transit are not billed to our clients.
- Any damage to the unit above normal operating wear is the responsibility of the customer.
- Actual travel and daily living expenses for Ultrox field engineers are billed to the customer.
- Prices are subject to change without notice.
- All samples will be returned to client after testing is completed.

Prices effective 4/1/91

# ULTROX

A Division of Zimpro Environmental, Inc.

2435 South Anne Street
Santa Ana, CA 92704-5308
Phone: 714 545-5557
Fax: 714 557-5396

S026
12/12/94

**SYSTEM SPECIFICATION**

**FOR**

**ULTROX® UV/OXIDATION SYSTEM**

**Prepared by: William S. Himebaugh**
**Date: 12/12/94**

| Date | Rev | Released for | Engineering Approval | Q.A. Approval |
|---|---|---|---|---|
| 12/12/94 | | | | |
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# 1.0 SCOPE

## 1.1 Purpose

This specification addresses the requirements for the design, fabrication and delivery of an Ultrox® oxidation system for the destruction of organic materials in groundwater. The system is covered by one or more of the following U.S. Patents: 4,941,957; 4,849,114; 4,792,407; 4,780,287. The system shall include equipment and accessories as required for the controlled addition of a combination of ozone and hydrogen peroxide to treat groundwater. The supplier of said equipment shall be Ultrox, hereafter referred to as the "vendor". The customer of said equipment shall be hereafter referred to as the "client".

## 1.2 Equipment

The oxidation system shall consist of the following major deliverable components:

a. Two (2) C-5000 Oxidation Process Tank
b. Master Control Center Assembly
c. Ozone Generator Assembly
d. Hydrogen Peroxide Feed Assembly
e. D-TOX™/Decompozon™ Assembly
f. Air Preparation System
g. Heat Exchanger System

# 2.0 APPLICABLE DOCUMENTS

## 2.1 Industry Standards

The following standards form a part of this specification as invoked by applicable requirements herein.

| | |
|---|---|
| Structural Welding Code - Steel | ANSI/AWS D1.1 |
| National Electric Code | NFPA 70 |
| Uniform Building Code | UBC 1991 |

# 3.0 REQUIREMENTS

## 3.1 Performance Requirements

The system is required to achieve the effluent standards listed under "Effluent Standards" in Table 1 at a flow rate no greater than 970 gpm provided that the organic and inorganic parameters are no greater than those listed under "Raw Influent" in Table 1. Where influent organic and inorganic constituents are not specified, it is assumed that they are not present.

**TABLE I**

| PARAMETERS | RAW INFLUENT ($\mu g/l$) | EFFLUENT STANDARD ($\mu g/l$) |
|---|---|---|
| TCE | 350 | 5 |
| RDX | 53 | 2 |
| Hardness (Ca and Mg) by Titration (as $CaCO_3$) | 241 mg/l | N/A |
| Alkalinity | 198 mg/l | N/A |
| Chloride $Cl^-$ | 24 mg/l | N/A |
| Total Suspended Solids (TSS) | 52 mg/l | N/A |
| Total Dissolved Solids (TDS) | 439 mg/l | N/A |
| Chromium, Total | 14 mg/l | N/A |
| Iron | 1.2 mg/l | N/A |
| Manganese | 0.2 mg/l | N/A |
| Total Organic Carbon | 2 mg/l | N/A |

ND-Non detectable; N/A-Not Applicable

## 3.2 Hydraulic Requirements

3.2.1 The system design influent flow rate shall be 970 gpm, with a hydraulic capacity of 1,455 gpm.

3.2.2. The C-5000 process tank shall operate near atmospheric pressure with an elevation head requirement of 109" W.C. and a head loss less than 36" W.C., as designed by the Vendor.

3.2.3 The effluent discharge shall be by gravity flow from a 109" high Weir assembly on the C-5000 oxidation process tank effluent port to client's sump.

## 3.3 Electrical Requirements

3.3.1 Wiring and electrical components provided shall be designed and fabricated in accordance with the latest edition of the National Electrical Code.

3.3.2 Wiring and electrical connections shall be adequately protected according to the environment in which the system is to be installed.

3.3.3 Client shall provide four separate electrical power services with the following voltage and circuit breaker trip ratings:

a. Ozone Generator: 480 VAC, 3$\phi$, 60A/60 Hz
b. Air Compressor: 480 VAC, 3$\phi$, 30A/60 Hz
c. DECOMPOZON/D-TOX™: 480 VAC, 3$\phi$, 10A/60 Hz
d. Master Control Center: 120 VAC/20A/60 Hz

## 3.4 Corrosion Resistance Requirements

3.4.1 Welded components which are wetted shall be 316L stainless steel.

3.4.2 Non-welded, metallic components which are wetted shall be 316 stainless steel or may be 316L.

3.4.3 Stainless steel surfaces shall not be painted.

3.4.4 Gaskets shall be silicone rubber, viton or teflon.

3.4.5 Iron and steel surfaces shall be painted.

3.4.5.1 Surface Preparation: Remove all mill scale, rust and other detrimental material and thoroughly clean with solvent.

3.4.5.2 Prime and paint with the manufacturer's standard coating system material. Coating system shall withstand ambient and equipment operational temperature swings without significant degradation.

3.5 Workmanship

All workmanship shall be performed in a professional manner. All materials shall be new and as specified by the documentation.

3.6 Reliability

The oxidation system shall be designed for continuous operation.

3.7 Design Documentation

3.7.1 Documentation shall be provided which shall include the following:

a. System Major Component Specifications
b. System Process and Instrumentation Diagram
c. System Mechanical Interface Specification
d. System Electrical Interface Specification
e. System Layout Plan
f. System Electrical Schematics
g. Assembly Drawings
h. Operations and Maintenance Manual to include product data sheets, PLC code listing and magnetic copy of PLC code.

3.7.2 A delivery schedule for documentation shall be provided within ten days of receipt of contract. Preliminary submittals of all documentation shall be submitted and approved by client before equipment is shipped. All drawings and data shall be submitted full size, 2 copies each. Final drawings shall be submitted on reproducible vellum or mylar. Final O&M manual shall include system O&M instructions, manufacturer O&M brochures and be submitted with equipment.

3.8 Master Control Center (MCC) Assembly.

3.8.1 MCC shall control the following:

a. Hydrogen Peroxide Feed Assembly
b. Ozone Generator Assembly
c. D-TOX™/DECOMPOZON Assembly
d. Heat Exchange Coolant Pumps

3.8.2 Control shall be provided to allow On/Off/Auto operation of the air preparation/ozone generation assembly. Operating in the automatic mode, the system shall control ozone production proportional to the groundwater flow rate within a range of 500 gpm to 1000 gpm.

3.8.3 Control shall be provided to allow On/Off/Auto operation of the hydrogen peroxide feed assembly. Operation in the automatic mode shall control $H_2O_2$ injection rate proportional to the groundwater flow rate within a range of 500 gpm to 1000 gpm.

3.8.4 Safety interlock indicating lamps shall be provided for each of the following failures:

a. Low D-TOX™/DECOMPOZON™ Temperature
b. Low Hydrogen Peroxide Flow
c. High Process Tank Pressure (atmospheric - not negative)
d. Ozone Generator Failure
e. Low Influent Water Flow
f. Spare (i.e., client's pumps)

3.8.5 All safety interlock failures shall include auxiliary normally closed contacts prewired through an interface terminal block for use by the client.

3.8.6 MCC shall have a system emergency shut down button which will stop all MCC controlled components.

3.8.7 MCC shall provide 120 VAC, 1 Amp rated dry contact closure control signal for client activation of influent transfer pumps and/or other client controlled equipment.

3.8.8 MCC shall not activate any of its components in the automatic mode of operation until it receives a 120 VAC, 1 Amp rated dry contact closure control signal from client controlled equipment.

3.8.9 Electrical input power to the MCC shall be 120 VAC, 3 wire, 20 Amp, 60 Hertz service.

## 3.9 Ozone Generator Assembly

3.9.1 Assembly shall require 47 SCFM of clean dry compressed air at a pressure between 10 and 15 psig.

3.9.2 Dial gages shall measure the temperature of the inlet and outlet cooling water.

3.9.3 Ozone generator shall produce minimum output of 100 lbs/day of ozone with 2.0% concentration by weight ozone with compressed air as feed gas.

3.9.4 Ozone production shall be based on a cooling water temperature into the ozone generator below 70°F at a flow rate of 40 gpm.

3.9.5 Electrical input power, shall be 480 VAC, 3 phase, 4 wire, 60 Amp, 60 hertz service, consisting of three (3) phase conductors and one (1) ground conductor.

3.9.6 Start-up and shutdown of ozone generator shall be controlled automatically by MCC and/or manually at the control panel of the ozone generator.

3.9.7 Safety interlocks shall be provided to identify a malfunction within the ozone generator and also to signal the MCC for a system shutdown. Dry contacts shall open when any of the following interlocks initiate a failure condition:

a. High dewpoint (DS1)
b. Low air flow (FS1)
c. Low air pressure (PSL1)
d. High air pressure (PSH1)
e. Low water flow (FS2)
f. High water temperature (TS1)
g. High ozone temperature (TS2)
h. High control center temperatures (TS3)

3.9.8 Ozone generator to have minimum ozone production turn down ratio of 10:1 based upon maximum recommended flow rate.

3.9.9 The ozone generator shall comply with NEMA Type 12 requirements.

3.10 D-TOX™/DECOMPOZON™ Assembly

3.10.1 The D-TOX™/Decompozon™ assembly shall reduce residual ozone concentration from the oxidation process tank off gas to below 0.1 ppm by weight using a proprietary metal-based catalyst. TCE shall be reduced to below method detection limits in the off gas.

3.10.2 The D-TOX™/Decompozon™ unit shall be fabricated from low carbon 300 series stainless steel.

3.10.3 The destruction unit shall be equipped with electrical inlet air preheater capable of heating 60 scfm of saturated air to 140°F.

3.10.4 Electrical input power shall be 480 VAC, 3 phase, 4 wire, 10 Ampere, 60 Hertz service, consisting of three (3) phase conductors and (1) one ground conductor.

3.10.5 The D-TOX™/Decompozon™ assembly shall be powered and controlled through an electrical cabinet containing appropriate motor starters, AC contactors, safety disconnect switch, phase loss detector and complementary hardware.

3.11 Hydrogen Peroxide Feed Assembly

3.11.1 The hydrogen peroxide feed pump shall have a nominal flow capacity of three (3) gph and shall be adjustable from 10% to 100% of full capacity.

3.11.2 Wetted pump materials shall be suitable for continuous contact with 50% hydrogen peroxide solution.

3.11.3 Connections for injection of 50% hydrogen peroxide solution in locations and quantities as required to achieve the specified requirements for the process shall be provided.

3.11.4 A Normally Closed (N.C.) pressure switch shall open if pump output pressure drops below applicable limits. (Limits to be established during start-up).

3.11.5 A hydrogen peroxide storage tank shall be provided by the client. Note: $H_2O_2$ vendors typically provide storage tanks with supply contract.

3.12 Air Preparation System

3.12.1 An air compressor is provided and shall supply sufficient compressed air for the dryer to provide 50 scfm at 15 psi.

3.12.2 A heatless regenerative dryer shall provide dry air with an acceptable dewpoint for continuous system operation.

3.12.3 A dewpoint monitor shall have a set of contacts which open should the dewpoint rises above acceptable limits.

3.12.4 An air filtration assembly shall remove oil and dirt from the compressed air for continuous system operation.

3.12.5 Electrical input power for compressor shall be 480VAC, 3$\phi$, 4 wire, 40 Amp, 60 Hertz service, consisting of three (3) 3 phase conductors and one (1) ground conductor.

3.12.6 Electrical input power for heatless regenerative dryer shall be provided by the ozone generator assembly.

3.13 C-5000 Process Tanks (2)

3.13.1 The C-5000 process tank shall be designed to efficiently and adequately distribute and collect the process water throughout the entire tank as necessary to eliminate any uneven flow pattern or short circuiting.

3.13.2 Tank shall be compatible with the untreated and treated solution and to the environment within it.

3.13.3 A manifold shall be used to supply ozone gas through distribution spargers at the bottom of the tank.

3.13.4 Means shall be provided to drain the tank.

3.13.5 The tank shall operate at 0.25 to 1.0" WG below atmospheric pressure. A pressure switch on the tank shall open its contacts if pressure exceeds atmospheric pressure.

3.13.6 A demister element shall remove water droplets from the effluent gas stream.

3.14 Heat Exchanger

A water/water heat exchanger shall be provided with a 40 gpm closed loop coolant to the ozone generator and compressor which is cooled to below 70°F. Cooling water for heat exchanger system shall enter heat exchanger below 65°F at a flow rate of 55-65 gpm. Heated process water shall return to equalization tank at effluent point. Heat exchanger pumps shall have stainless steel impellers and shall be powered by TEFC motors.

4.0 QUALITY ASSURANCE (QA) PROVISIONS

4.1 QA Measures by Vendor. Vendor shall be responsible for quality assurance of all deliverable items. Tests and examinations shall be performed at the discretion of Vendor to establish confidence in compliance with the treatment requirements.

4.1.1 Special tests and inspections. Vendor shall deliver copies of the certifications of materials used and passivation processes to establish compliance with 3.4.

4.1.2 Operational tests. Vendor shall complete operational tests on equipment to verify compliance with electrical and mechanical functional requirements.

4.1.3 Discrete Interfaces. Mechanical and electrical interfaces shall be visually inspected for compliance with Engineering Documentation.

4.2 QA Measures by Client. Client shall be responsible for verifying compliance with the treatment requirements.

4.2.1 Acceptance Test.

An Acceptance Test ("Test") shall be conducted to determine that the system, when operated under the design conditions and in accord with Vendor operating and maintenance practices, is functioning properly. Influent water quality shall contain organic and inorganic constituents no greater than those shown in Table 1. The Test will commence after completion of satisfactory system checkout and initial start-up operations. The system shall be operated for a four (4) hour period during which it will be tested to verify performance requirements. During the Test, Client personnel shall perform operation and maintenance under Vendor surveillance. Vendor shall provide a plan to define instrument calibration requirements, chemical addition rates and measurement points no later than ten (10) working days prior to the Test. The Test Plan shall include provisions for taking of split samples as requested by Vendor (any analysis of Vendor split is at Vendor expense). The client is responsible for any analytical expenses they incur during the acceptance test. The Acceptance Test shall be conducted within thirty (30) days of start-up of the system or the system shall be deemed to be accepted.

## 5.0 PREPARATION FOR DELIVERY AND INSTALLATION

### 5.1 Shipping and Packaging

The system shall be packaged by the vendor to avoid damage due to normal shipping and handling practices for intercontinental transportation of industrial hardware. The design and fabrication of the packaging containers shall be the responsibility of the vendor. The system may be shipped partially assembled as defined below.

a. MCC Assembly
b. Ozone Generator Assembly
c. Hydrogen Peroxide Feed Assembly
d. D-TOX™/DECOMPOZON™ Assembly
e. Air Preparation System
f. C-5000 Process Tanks Assembly Components
g. Heat Exchanger
h. Miscellaneous Hardware

### 5.2 Client and Vendor Responsibilities prior to and during delivery, installation and set-up.

5.2.1 Equipment Delivery. Client to provide transportation of equipment to client site. Shipments of equipment, except ozone generator, shall originate from vendor facility in Rothschild, WI.

5.2.2 Equipment Installation. Client shall arrange for arriving equipment at site to be transported from transport vehicle to location of operation and set to and secure same equipment in place. The C-5000 tanks shall require a 20 ton crane and operator for installation.

5.2.3 System Interface Connections. Vendor shall provide piping, tubing, and electrical connections internal to each major system component supplied by vendor. Client shall provide all other piping, tubing, and electrical connections between major system components, and shall provide all utilities to and from equipment as outlined below.

5.2.3.1 Plumbing by Client.

a. Copper pipe from compressor to air prep system

b. 316 stainless steel pipe from ozone generator to ozone manifold on C-5000 tanks.

c. Cooling water line from equalization tank to heat exchanger and from heat exchanger to equalization tank.

d. Cooling water line between heat exchanger, ozone generator and compressor.

e. Groundwater influent line from equalization tank to C-5000.

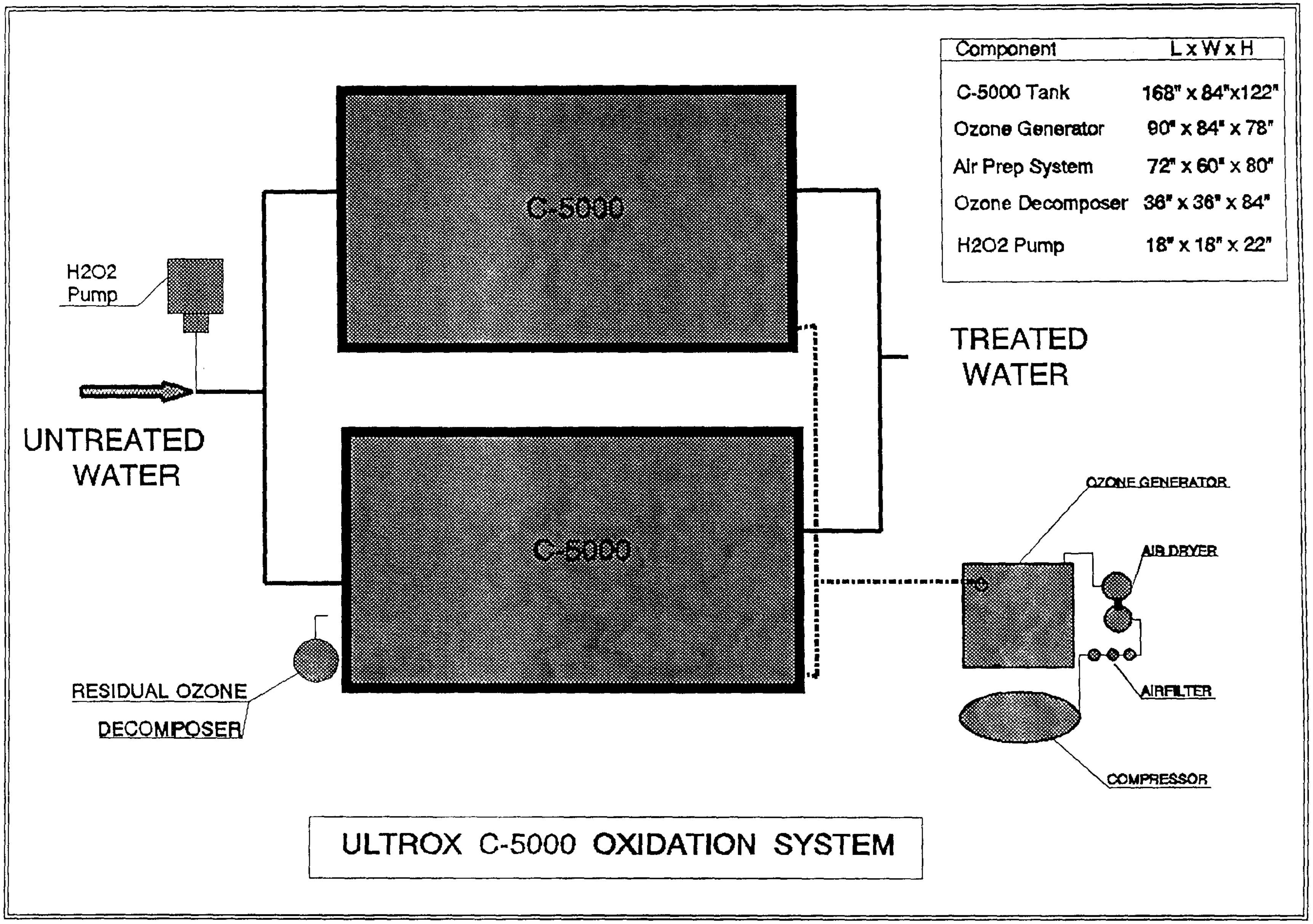
f. Hydrogen peroxide tubing from $H_2O_2$ feed pump to fitting on C-5000 inlet pipe.

5.2.3.2. Electrical Connections by Client.

a. 480 VAC, 3$\phi$, 40A service to air compressor
b. 480 VAC, 3$\phi$, 10A service to D-TOX/Decompozon
c. 120 VAC, 1$\phi$, 20A service to MCC
d. 480 VAC, 3$\phi$, 60A service to ozone generator
e. 480 VAC, 3$\phi$, 5A service to each heat exchanger pump
f. 120 VAC, 1$\phi$, 5A control wiring from MCC to ozone generator, to D-TOX/DECOMPOZON, to $H_2O_2$ feed pump, to coolant pumps and from ozone generator to compressor.

5.2.4 System Start-up. Technical assistance shall be made available by vendor at published rates.

5.2.5 Training. Vendor shall provide 16 man hours (2 days) of training for clients personnel on site.




| Component | L x W x H |
|---|---|
| C-5000 Tank | 168" x 84"x122" |
| Ozone Generator | 90" x 84" x 78" |
| Air Prep System | 72" x 60" x 80" |
| Ozone Decomposer | 36" x 36" x 84" |
| H2O2 Pump | 18" x 18" x 22" |

ULTROX C-5000 OXIDATION SYSTEM

December 15, 1994

Dr. Curt Elmore, Ph.D., P.E.
Woodward-Clyde
10975 El Monte, Suite 100
Overland Park, KS 66211

RE: **perox-pure**™ Information Regarding a Military Ordinance Plant near Omaha, Nebraska.
VPSI Proposal #DMW94039-18018-PN02

Dr. Elmore:

Thank you for your interest in the **perox-pure**™ UV oxidation system. We look forward to an opportunity to work with Woodward-Clyde and the Department of Defense in the remediation of both TCE and RDX at this site.

The following are direct responses to questions posed in Woodward-Clyde's request for information dated December 2, 1994.

1) The **perox-pure**™ process will have no difficulty destroying both RDX and TCE to below EPA Drinking Water Standards. This has been proven at numerous installations in the United States and Europe as well as in laboratory studies.

2) pH adjustment and filtration will be investigated as possible pretreatment steps. A bench scale or on-site demonstration will allow Vulcan Peroxidation Systems (VPSI) to determine whether pretreatment is beneficial both technically and economically.

3) Considering the information presented by Woodward-Clyde, there should not be any specific process operation restrictions. If process conditions vary significantly from the current data, VPSI may investigate additional pretreatment steps.

4) All **perox-pure**™ systems require a 480 volt, 3 phase, 60 hertz power supply. A potable water source is also necessary for the safety shower and eye wash station. Note that there are many possible equipment configurations that may be used for each different flow rate and contaminant combination. One possible configuration may include one to four individual units, each with a footprint of approximately 7 feet by 12 feet. In addition, one or two hydrogen peroxide feed modules (approx. 10 feet by 10 feet) will be required. Total height for all equipment is estimated to be below 10 feet. Note that this is a very general estimate of the space requirements. Once a specific case is selected, we can estimate the space requirements with greater precision.

5) VPSI equipment is typically not hydraulically limited. Equipment is selected based on the power required to destroy a 'rate limiting' contaminant to the desired effluent level. Attached is an equipment data sheet for a 540 kW unit (representative of units selected for this site). Note that the flow rate is primarily based on the size of inlet and outlet piping. The unit itself consists of banks of oxidation chambers that would operate in parallel, thereby not posing any flow rate restrictions. Multiples of this unit (capable of 540 kW) may be correlated to the kilowatt value calculated on the attached table.

6) A bench scale treatability study is available for $3,500 plus analytical costs. Analytical expenses would involve the testing of approximately 20-24 samples. A pilot scale treatability study is also available for $10,000 plus analytical and equipment delivery costs. This study would involve using VPSI's trailer mounted full scale unit on site for approximately one week. Capital, maintenance, and operations costs are described in the attached table. No hazardous intermediate products are expected to be created during the treatment process.

Please also find attached an equipment specifications document. This describes our **perox-pure**™ equipment in more detail. If we can be of any further assistance, please feel free to contact either Mr. Bruce Wilbee or I at (602) 790-8383. Thank you again for your interest in our products and services.

Sincerely,

David M. Wayne

David M. Wayne
Applications Specialist

enclosures: Preliminary Equipment Selection Chart
Model E-540 Equipment Data Sheet
Equipment Specifications Document

cc: Mr. Bruce Wilbee - VPSI



B07NE003702-09451

Woodward Clyde
Omaha, Nebraska
Ordnance Plant
(Preliminary Estimate)

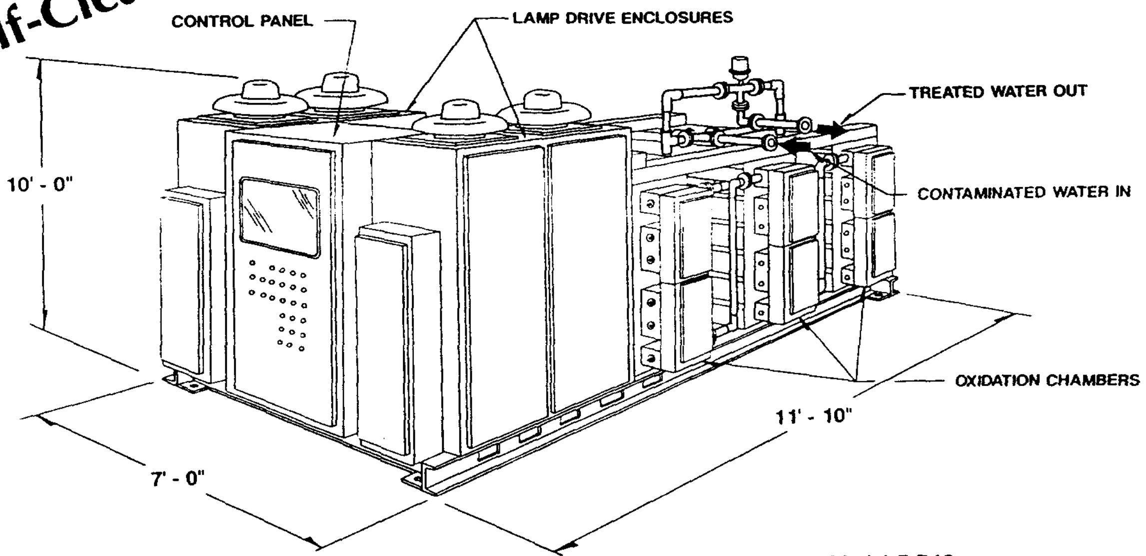
| Flow Rate | TCE Influent | Effluent (ppb) | RDX Influent | Effluent (ppb) | Kilowatts | H2O2 lbs/year | H2O2 $/year | Capital Cost | Maintenance $/year |
|---|---|---|---|---|---|---|---|---|---|
| 970 | 21 | 5 | 53 | 2 | 600 | 210,000 | $ 80,000 | $ 600,000 | $ 50,000 |
| 2,100 | 14 | 5 | 5 | 2 | 400 | 460,000 | $ 180,000 | $ 400,000 | $ 30,000 |
| 2,330 | 13 | 5 | 5 | 2 | 400 | 510,000 | $ 200,000 | $ 600,000 | $ 50,000 |
| 1,980 | 350 | 5 | 27 | 2 | 1,000 | 430,000 | $ 170,000 | $ 1,000,000 | $ 80,000 |
| 3,300 | 209 | 5 | 18 | 2 | 1,500 | 720,000 | $ 290,000 | $ 1,500,000 | $ 120,000 |
| 3,530 | 195 | 5 | 18 | 2 | 1,600 | 770,000 | $ 310,000 | $ 1,500,000 | $ 120,000 |
| 1,450 | 51 | 5 | 36 | 2 | 800 | 320,000 | $ 130,000 | $ 800,000 | $ 60,000 |
| 2,770 | 30 | 5 | 23 | 2 | 1,400 | 600,000 | $ 240,000 | $ 1,250,000 | $ 100,000 |
| 3,000 | 23 | 5 | 21 | 2 | 1,400 | 650,000 | $ 260,000 | $ 1,500,000 | $ 120,000 |
| 2,490 | 338 | 5 | 18 | 2 | 1,100 | 540,000 | $ 220,000 | $ 1,000,000 | $ 80,000 |
| 4,200 | 204 | 5 | 23 | 2 | 2,100 | 920,000 | $ 370,000 | $ 2,000,000 | $ 160,000 |
| 4,910 | 173 | 5 | 21 | 2 | 2,300 | 1,070,000 | $ 430,000 | $ 2,250,000 | $ 180,000 |

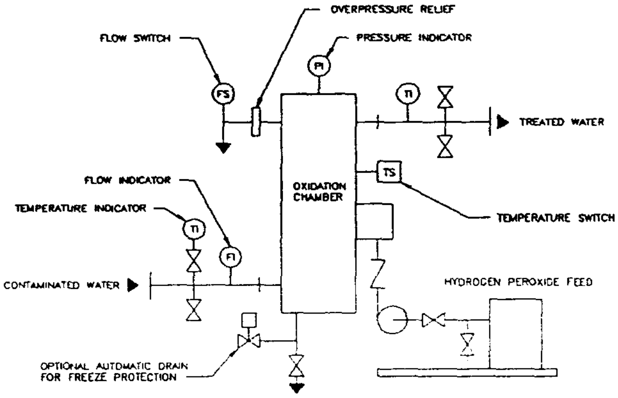
Note: RDX is rate limiting in all cases.

# MODULAR TREATMENT SYSTEM

## MODEL E-540

**Now Self-Cleaning**




| SPECIFICATIONS | Model E-540 | |
|---|---|---|
| Flow Rate: Maximum | 200 gpm | 1500 gpm |
| Connections: | 150# Flange | 150# Flang |
| Inlet: | 3" | 8" |
| Outlet: | 3" | 8" |
| Power Supply: | 3 pH/60Hz/480V, 540KW (2 @ 270 KV | |
| Electrical Encl.: | NEMA 3R | |
| Material - Wetted Parts: | Quartz, Fluoropolymers | |
| External Parts: | Enameled Steel | |
| Weight - Shipping: | 21000 lbs. | |
| Operating: | 23800 lbs. | |

The **perox-pure™** chemical oxidation system consists of modular, skid-mounted equipment designed to treat water contaminated by dissolved organic compounds. Bench-scale process evaluations will determine pretreatment requirements (if any) and the oxidation time necessary for the desired treatment level. Full-scale oxidation chamber volume, UV requirements and oxidant dosage are then selected.

The **perox-pure™** system incorporates corrosion resistant fluorocarbon-lined oxidation chambers and horizontally mounted medium pressure UV lamps. Indicators are provided to monitor performance of each lamp. A sequential hydrogen peroxide addition feature provides easy process optimization for maximum economy. In addition, a patented tube cleaning device maximizes performance and minimizes maintenance time. The cleaning device is automatic and self propelled, requiring no external actuating mechanism or sliding shaft seals. Other design features include shop-wired and tested control panels interlocked with personnel and process safety features to shut-off power and display the cause at preset conditions. Installation is quick and easy.

The **perox-pure™** system and its components are covered by numerous issued and pending patents.

# SPECIFICATION

## Ultraviolet Light/Hydrogen Peroxide Oxidation System

1. General

This specification describes the **perox-pure™** ultraviolet light (UV) - hydrogen peroxide ($H_2O_2$) oxidation system capable of destroying soluble toxic organic contaminants in water. These specifications are subject to change without notice.

Unloading, handling, installation, excavation, concrete work, finish painting, connecting piping, and electrical hookup are the responsibility of others.

2. Principle of Operation

The System utilizes the chemistry of UV/$H_2O_2$ reactions, which involves generation of hydroxyl radicals, and other reactive species, by the photochemical action of ultraviolet light on hydrogen peroxide. The hydroxyl radicals attack organic species.

The final products of the noted reaction are carbon dioxide, water, and inorganic ions.

3. Applicable Codes - (Latest Editions)

| | |
|---|---|
| Uniform Building Code | National Electric Code |
| Uniform Plumbing Code | NFPA |
| Uniform Mechanical Code | OSHA |

Note: Operating pressure is not to exceed 15 psig, ASME Code does not apply.

4. Equipment Description

UV/$H_2O_2$ Oxidation Module -

Maximum Inlet Pressure: 15 psig
Power Requirement: 3ph/60Hz/480V
Air Requirement: 80-120 psig, 4 ACFM (During tube cleaning operation only)

Materials of Construction -

UV/$H_2O_2$ oxidation chamber, fluorocarbon lined 6063-T6 aluminum or 316L stainless steel.
Chemical tubing - type 316 stainless steel with compression fittings.

UV/H2O2.SPC
Rev. 12/22/93 cmg

Process Piping - Sch. 80 CPVC.
Structural Steel Skids and Supports - carbon steel.
ASTM A-36 with chemical and weather resistant paint.
Electrical Enclosures - Enamelled carbon steel.
Wetted non-metallic components - Quartz, fluoroelastomers, or polymers resistant to UV, $H_2O_2$ and all chemicals present.

Design Features -

**Oxidation Chamber**

Lamps shall be horizontally mounted and removable without draining the oxidation chamber.

The lamp end enclosures shall be provided with hinged and gasketed doors.

All UV sensitive materials shall be shielded from the UV rays by material reflective of, or resistant to, UV.

The UV lamps shall be protected against contact with the fluid in the event of a leak.

Water shall be separated from contact with the UV lamps by quartz tubes sized for optimimum lamp operating temperature.

The UV oxidation chamber shall be designed to efficiently distribute and collect the process water throughout the entire oxidation chamber in order to eliminate an uneven flow pattern or short-circuiting. Piping connections shall be designed so that the UV oxidation chamber will remain full of fluid after shutdown.

The oxidation chamber shall not have chamber penetrations for automatic quartz tube cleaner actuation mechanism.

**Electrical Enclosures**

Electrical enclosures shall have hinged and lockable doors.

Electrical enclosure cabinets shall be weatherproof. Lamp drive enclosures will be provided with intake air cooling fans to control the inside temperature. The fans shall operate continuously when the unit is running.

Access doors shall have limit switches to shut the power off should the doors be opened.

## Circuitry

All wiring and electrical connections shall be protected against moisture to prevent electrical short or failure. Pressure indicators and temperature switches shall be in weatherproof housings.

All wiring and electrical components within the system shall be designed, constructed and installed in accordance with the latest edition of the National Electrical Code and all applicable State and local electrical codes.

Circuitry within the lamp drive enclosure shall be protected and disconnected by pre-wired circuit breaker rated at 30,000 amp minimum AIC with external ground fault sensor and shunt trip.

Lamp drives shall be of the high-power factor type.

## Instrumentation and Controls

The UV system shall be controlled via a touch-screen interface to a programmable logic controller (PLC). Standard PLC is Siemens Model TI 435 or TI 545. The Model of the PLC will vary with the size of the UV system. Controls shall be provided to allow on/off operation of individual UV lamps, on/off operation of (1) chemical feed pump, and shut-down of the UV system.

Alarm contact closures shall be provided on:

1) high temperature in lamp drive enclosure
2) low water flow (adjustable)
3) high water temperature
4) moisture in lamp end enclosure
5) access door opening
6) remote contact closure (10 amp, 120 VAC)
7) low peroxide pressure
8) low peroxide splitter flow (if splitter is provided)
9) overpressure relief flow
10) low oxidation chamber water level
11) tube cleaning system failure
12) lamp low current detection (shut-down optional)
13) lamp contactor failure
14) Emergency Stop
15) Primary Ground Fault
16) Secondary Ground Fault

Alarm conditions shall be displayed on the touchscreen with "First Out" indicator.
Flow indicator calibrated in gpm, with totalizer, shall be provided.
A system to indicate the operating status of each lamp shall be provided.

An elapsed timer meter shall be provided to indicate the number of hours of module operation. Timer shall be resettable with access codes.

**$H_2O_2$ Feed**

Connections for injection of $H_2O_2$ in quantities suitable for the process shall be provided. If required by the process, means for complete mixing of the $H_2O_2$ and process water, and for variable, staged injection shall be provided.

**Automatic Cleaner**

The UV oxidation system shall incorporate an automatic quartz tube cleaning system, programmable by the user for variable operation period frequency and duration dependent upon the requirements of the installation. Cleaner shall be constructed of stainless steel and/or UV resistant materials. The tube cleaner control system shall be capable of changes in both frequency of operation cycles and duration of each cycle. It shall also be capable of automatic variation of these cycles in response to changes in flow rate or signals from a remote control system based on, for example, effluent contaminant concentration.

The tube cleaner mechanism shall not require sliding shaft seals through the wall of the oxidation chamber. It shall effectively wipe the lamp tube to prevent accumulation of deposits that interfere with transmittance of UV light from the lamp. To prevent accumulation of deposits on the wall of the oxidation chamber the wiper shall also clean the inside of the oxidation chamber. The interior of the oxidation chamber shall be finished in a manner to minimize deposits of material.

The wiper mechanism shall wipe any point opposite the UV lamp a minimum of 4 times per pass. For extended tube wiper life, the wiper shall be retained in a recess away from the UV lamps so that it is shielded from UV light during the period between cycles. For even wiper wear distribution, the wiper shall be free to rotate around the longitudinal axis of the quartz tube.

**Assembly**

Oxidation chamber, control enclosures, instrumentation, controls, and piping shall be shop assembled on a skid and disassembled only as necessary for shipment. Lamps and supports to be shipped separately.

5. Installation, Start-up, and Operator Training

Supplier will supervise initial placement of all equipment provided in this specification.

The mechanical and electrical hookups by others shall be completed per schedule mutually agreed upon by all parties.

Upon completion of installation the equipment supplier shall hydrostatically test all pressure systems provided by this specification. If leaks occur, necessary corrections shall be made and retested until completed without any evidence of leakage. All electrical circuits and equipment shall be tested for continuity and functional performance.

All surfaces to be contacted by $H_2O_2$ shall be properly passivated by the equipment supplier.

In addition to the above, during a scheduled start-up period of five (5) calendar days, the equipment supplier shall provide start-up operation of the systems furnished by this specification. The Field Service Engineer shall operate the equipment, make all adjustments and calibrations necessary to allow operation at full load for a 24-hour period. Representative samples will be taken as required to determine performance. During this period, the owner's operating personnel are to be trained in the operation and maintenance of this equipment. Any materials deemed defective during this period are to be replaced.

6. Certified Dimension Drawings

Two (2) sets of certified dimension drawings will be furnished.

7. Operation and Maintenance Instructions

Three (3) complete Operation and Maintenance Instruction Manuals will be furnished.

8. Safety

Formal safety policies and procedures for laboratory, manufacturing and field operations activities shall be documented. Supplier shall have a Safety Committee which meets regularly to review and establish safety policies. All equipment shall be designed and constructed to adhere to regulatory requirements and practical consideration. Consideration shall be given to personnel safety during both operation and maintenance of the equipment. The following information outlines the safety features.

1. Changing Lamps and Quartz Tubes. Both lamps and tubes are reliable when handled by proper procedures. However, being quartz they are subject to breakage

if dropped or struck on another object. Accordingly, all maintenance on lamps and tubes is done by a technician without the need for ladders, scaffolds or other elevation means.

2. Changing ballasts. Ballasts which may weigh up to 250 pounds are quite reliable and are infrequently changed. If changing is necessary, the unit is to be equipped with a slide out mechanism to eliminate potential personnel problems with moving and securing the ballast.

3. Opening Enclosures. All electrical enclosures are to be built with interlock high voltage position switches which will shut down power to the unit if they are opened.

4. UV Exposure. The units shall be designed such that operators cannot be subjected to UV light.

5. Ground Fault Projection. In addition to conventional grounding and insulation, the unit shall employ an external groundfault sensor and a shunt trip. The shunt trip will activate when the primary or secondary exhibits a electrical short of 4 amps or greater.

6. Hydrogen Peroxide. $H_2O_2$ is a powerful oxidizing agent which is safe when handled properly. Safety training on handling and use of $H_2O_2$ is to be provided by Supplier to on-site personnel. In addition, standard $H_2O_2$ storage and feed equipment is to be equipped with a shower and eyewash station for personnel safety.

7. Equipment Protection. An extensive series or safety interlocks are to be designed into each module to guarantee the safety of the equipment if operating variables should significantly change during operation.

## 9. Quality

The equipment shall be produced under a versatile quality program that employs resolution inspections and pretested equipment which meets and complies with Quality Assurance/Quality Control Programs.

Supplier shall have a program in compliance with requirements of:

- NQA-1 - Nuclear Quality Assurance
- ANSI/ASME - American National Standard Institute/ American Society of Mechanical Engineers
- AWWS Specifications - American Water Works Standards
- NASA Specifications - National Aeronautics and Space Administration

- Military Specifications

Supplier's program shall be an on-going QA/QC program to satisfy the provisions and requirements of:

- ASQC Q90 - American Society for Quality Control
- ISO 9000 Series - International Standards Organization

Supplier shall have qualified QA/QC personnel and a system of procedures, checks, audits and corrective activities to ensure that all research, design and performance, environmental monitoring, sampling, plus other technical and reporting actions, are of the highest reasonably achievable quality.

# APPENDIX J
# AIR STRIPPING VENDOR ANALYSIS

In the process of evaluating remediation alternatives, Woodward-Clyde Consultants contacted the three air stripping vendors listed below:

- Carbonair Environmental Systems, Inc.
- Delta Cooling Towers, Inc.
- Rauschert Industries (who forwarded the WCC correspondence to Branch Environmental Corporation)

An example letter of correspondence with the vendors is included in this appendix along with recent responses from the following vendors:

- Carbonair Environmental Systems, Inc.
- Delta Cooling Towers, Inc.
- Branch Environmental Corporation

n:\fs2\vendorc.xls

**Woodward-Clyde**

Engineering & sciences applied to the earth & its environment

December 2, 1994
WCC Project 92KW030R

Mr. Vernon Christensen
Rauschert Industries, Inc.
Rt. 5
Industrial Park Highway 411 South
Madisonville, Tennessee 37354

Dear Mr. Christensen:

Woodward-Clyde (W-C) is evaluating potential remedial alternatives for a client who operated a military ordnance plant near Omaha, Nebraska. The site was in operation for approximately 20 years, and historic waste management practices have impacted the soil and groundwater.

Our client is planning to remediate groundwater at the site in the near future. Based on an evaluation of remedial alternatives, air stripping is a candidate groundwater treatment technology.

The proposed design is to remove groundwater using several groundwater extraction wells and pump the extracted groundwater through a piping network to one central location where it will be treated to meet effluent standards. Estimated flow rates of the groundwater to be treated range from 970 to 4910 gallons per minute (GPM) for the various remedial alternatives being considered. Effluent standards to be met are EPA Drinking Water Standards.

The major groundwater contaminants of concern, and therefore the bulk of the contaminants to be removed from the groundwater to meet site remediation cleanup goals, are TCE and RDX. Estimated influent concentrations for TCE and RDX have been calculated from groundwater monitoring well data using a weighted average concentration for each proposed total groundwater extraction flow rate. This information, plus the effluent concentrations to be met, is listed in Table 1 attached to this letter.

In addition to the data on TCE and RDX concentrations, we have also included data on the average metals concentrations, as well as general water quality parameters (Table 2). The concentrations presented in Table 2 are average concentrations for the groundwater at the site, and have not been adjusted for specific flow rates. Therefore, as a conservative estimate, the concentrations in Table 2 should be considered the same for all flow rates.

As mentioned above, TCE and RDX are the primary contaminants of concern at the site. However, numerous other contaminants have been sporadically detected at low concentrations, typically below the cleanup levels. A list of the additional compounds detected at the site is presented in Table 3. The list is intended to be used to determine whether any of the compounds present may affect the overall design of the treatment system. If any of the compounds on the list potentially complicate or present particular design problems, please notify us, and we may be able to provide more specific data on the particular contaminant. It should be noted that while these compounds have been detected in individual monitoring wells, we anticipate the concentrations in the combined flow from the extraction system will be insignificant (i.e., below detectable levels).

Please provide the following information for possible treatment of the above described groundwater:

- The ability of processes to attain the potential groundwater treatment requirements.

- Any pretreatment requirements prior to the actual remediation treatment process.

- Process operations restrictions, if any. For example: influent flow rate, chemical concentrations, groundwater chemistry parameters, temperature, etc.

- General system specifications, including requirements for power, space, etc.

- A description of the standard treatment system sizes and the typical flow rate capacity of these standard sizes (e.g. Standard System A is typically selected when the anticipated flow rate ranges from ____ gpm to ____ gpm and Standard System B is typically selected where the anticipated flow rates range from ____ gpm to ____ gpm, etc.).

- Typical costs, including bench and pilot scale treatability studies if needed and system design, equipment, construction, operation, and maintenance. Please include descriptions of the Tower Dimensions and packing geometry, any bio-fouling control and replacement frequency.

**Woodward-Clyde Consultants**



Please submit your information and cost estimates by **December 15, 1994** to:

Curt Elmore, Ph.D., P.E.
Woodward-Clyde
10975 El Monte, Suite 100
Overland Park, Kansas 66211
Phone: (913) 344-1154
Fax: (913) 344-1012

If you foresee that you would be unable to meet the December 15, 1994 target date, please contact us as soon as possible to discuss an alternate date for the submittal of your information.

Please do not hesitate to contact us if you have any questions.

Very truly yours,

Curt Elmore, Ph.D., P.E.
Project Engineer

Douglas E. Fiscus, P.E.
Senior Project Engineer

Attachments

## Table 1
## Design Influent and Effluent Concentrations for Groundwater Treatment of TCE and RDX

| Groundwater Flow Rate (gpm) | TCE (1) Influent (ug/L) | TCE (1) Effluent (3) (ug/L) | RDX (2) Influent (ug/L) | RDX (2) Effluent (4) (ug/L) |
|---|---|---|---|---|
| 970 | 21 | 5 | 53 | 2 |
| 2,100 | 14 | 5 | 5 | 2 |
| 2,330 | 13 | 5 | 5 | 2 |
| 1,980 | 350 | 5 | 27 | 2 |
| 3,300 | 209 | 5 | 18 | 2 |
| 3,530 | 195 | 5 | 18 | 2 |
| 1,450 | 51 | 5 | 36 | 2 |
| 2,770 | 30 | 5 | 23 | 2 |
| 3,000 | 23 | 5 | 21 | 2 |
| 2,490 | 338 | 5 | 18 | 2 |
| 4,200 | 204 | 5 | 23 | 2 |
| 4,910 | 173 | 5 | 21 | 2 |

Notes: EPA Drinking water Standards From:
Drinking Water Regulations and Health Advisories, May 1994. Office of Water, U.S. Environmental Protection Agency.

1. TCE = Trichloroethene
2. RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
3. EPA Drinking Water Maximum Contaminant Level (MCL)
4. EPA Health Advisory - Because no MCL has been established for this chemical

## Table 2
## Summary of Metals Concentrations and General Water Quality Parameters

| | Average Concentration in Groundwater Samples | Comments |
|---|---|---|
| TOTAL METALS (ug/l) | | |
| Aluminum | 1,066 | Detected in 15 of 15 monitoring wells |
| Arsenic | 13 | Detected in 9 of 15 monitoring wells |
| Barium | 218 | Detected in 15 of 15 monitoring wells |
| Beryllium | 1 | Detected in 1 of 15 monitoring wells |
| Calcium | 63,187 | Detected in 15 of 15 monitoring wells |
| Chromium | 14 | Detected in 3 of 15 monitoring wells |
| Cobalt | 13 | Detected in 1 of 15 monitoring wells |
| Copper | 15 | Detected in 2 of 15 monitoring wells |
| Iron | 1,200 | Detected in 15 of 15 monitoring wells |
| Lead | 9 | Detected in 2 of 15 monitoring wells |
| Magnesium | 15,238 | Detected in 15 of 15 monitoring wells |
| Manganese | 196 | Detected in 15 of 15 monitoring wells |
| Mercury | 0.33 | Detected in 1 of 15 monitoring wells |
| Nickel | 20 | Detected in 2 of 15 monitoring wells |
| Potassium | 8,758 | Detected in 15 of 15 monitoring wells |
| Selenium | 38 | Detected in 1 of 15 monitoring wells |
| Sodium | 20,847 | Detected in 15 of 15 monitoring wells |
| Thallium | 2 | Detected in 1 of 15 monitoring wells |
| Vanadium | 18 | Detected in 2 of 15 monitoring wells |
| Zinc | 12 | Detected in 12 of 15 monitoring wells |
| WATER QUALITY (mg/l) | | |
| Alkalinity as Calcium Carbonate | 198 | |
| Biochemical Oxygen Demand (BOD) | 6 | |
| Hardness as Calcium Carbonate | 241 | |
| Nitrate-Nitrite-N | 28 | |
| Total Chlorides | 24 | |
| Total Dissolved Solids (TDS) | 439 | |
| Total Kjeldahl Nitrogen (TKN) | 0.41 | |
| Total Microbial Count (cells/ml) | 22,650 | |
| Total Organic Carbon (TOC) | 2 | |
| Total Organic Halides (TOX) (ug/L) | 227 | |
| Total Sulfates | 88 | |
| Total Suspended Solids (TSS) | 52 | |
| Dissolved Oxygen (mg/L) | 4 | |
| Oxidation Reduction Potential (mV) | 73 | |
| pH | 7 | |
| Specific Conductance (umhos/cm) | 450 | |
| Temperature (Celsius) | 12 | |

## Table 3
### Summary of Additional Compounds Detected at Low Concentrations (1) in Groundwater Samples

| |
|---|
| **EXPLOSIVES (ug/l)** |
| 1,3,5-Trinitrobenzene (TNB) |
| 2,4,6-Trinitrotoluene (TNT) |
| 2,4-Dinitrotoluene (24DNT) |
| 4-Nitrotoluene (4NT) |
| HMX |
| Tetryl |
| **GROSS Alpha/Beta (pCi/l)** |
| Gross Alpha |
| Gross Beta |
| **SEMIVOLATILES (ug/l)** |
| bis(2-Ethylhexyl)phthalate |
| Butyl benzyl phthalate |
| Di-n-butyl phthalate |
| Diethyl phthalate |
| N-Nitrosodiphenylamine(1) |
| Phenol |
| **PESTICIDES/PCB (ug/l)** |
| 4,4'-DDT |
| Aldrin |
| Alpha chlordane |
| Alpha-BHC |
| Delta-BHC |
| Dieldrin |
| Endrin |
| Gamma chlordane |
| Heptachlor |
| Heptachlor epoxide |
| p,p'-Methoxychlor |
| **VOLATILES (ug/l)** |
| 1,1,1-Trichloroethane |
| 1,1-Dichloroethane |
| 1,2-Dichloroethane |
| 1,2-Dichloroethene(Total) |
| 1,2-Dichloropropane |
| 1,4-Dichlorobenzene |
| 2-Butanone |
| Acetone |
| Carbon disulfide |
| Carbon tetrachloride |
| Chloroform |
| Cis-1,2-Dichloroethene |
| Ethylbenzene |
| Methylene chloride |
| Toluene |
| Xylenes (Total) |

(1) The compounds listed above were detected sporadically in groundwater samples, therefore, the average concentrations in the total groundwater flow to the groundwater treatment system are expected to be below the cleanup goals.

Carbonair Environmental Systems, Inc.
8640 Monticello Lane
Maple Grove, MN 55369-4547
612-425-2992 800-526-4999
Fax Number 612-425-6882

CARBONAIR

Robert G. Bergsgaard
Regional Manager, Southeast
Direct Line 612-493-0231

PAGE 1 OF 8

**FAX MESSAGE**

DATE: 12-13-94

TO: Curt Elmore

FROM: Bob Bergsgaard

Re: Proposal # 204982

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Technical summary w/ budget pricing -

Sorry for lack of detail - We are extremely busy these last weeks of December.

Please call Chris Riddle here at our office w/ questions or comments.

I am out the rest of the week.

Thanks
Bob B.

If you have any questions or comments concerning this information, please feel free to give me a call.

Fax to: 913-244-1011

CARBONAIR ENVIRONMENTAL SYSTEMS
CARBONAIR ENVIRONMENTAL SYSTEMS, INC.
8640 MONTICELLO LANE
MAPLE GROVE, MINNESOTA
55369-4547
612•425•2892 800•526•4999
FAX 612•425•6882

December 12, 1994

Mr. Curt Elmore
Mr. Douglas E. Fiscus
Woodward-Clyde Consultants
10975 El Monte, Suite 100
Overland Park, KS 66211

Re: Proposal Number: 204982
Project Name: Remediation Project
Location: Omaha, NE

Dear Sirs:

Carbonair is pleased to quote products and services for the referenced project. The proposal is based on information received in the RFQ received last week. Detailed product specifications are attached.

**Technical Summary**

1. It is recommended that air stripping be used to remove TCE and carbon adsorption be used to removed RDX.

2. The recommended system for each water flow rate is shown in the table below. Since there is no data base for RDX available, it is recommended that pilot tests be conducted to determine the actual carbon bed life. The recommended carbon adsorption systems shown below are based on the hydraulic conditions and may be changed later based on the pilot test results.

| Flow Rate (GPM) | TCE Conc. (ppb) | RDX Conc. (ppb) | Recommended AirStrip System | Recommended Carbon System |
|---|---|---|---|---|
| 970 | 21 | 53 | System A - 2600 cfm | Four PC 78's Two parallel trains of two vessels in series |
| 1450 | 51 | 36 | System A - 11630 cfm | Six PC 78's Three parallel trains of two vessels in series |

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| | | | | |
|---|---|---|---|---|
| 1980 | 350 | 270 | System B - 3970 cfm | Eight PC 78's Four parallel trains of two vessels in series |
| 2100 | 14 | 5 | System A - 2808 cfm | Eight PC 78's Four parallel trains of two vessels in series |
| 2330 | 13 | 5 | System A - 3120 cfm | Eight PC 78's Four parallel trains of two vessels in series |
| 2490 | 338 | 18 | System B - 6,660 cfm | Ten PC 78's Five parallel trains of two vessels in series |
| 2770 | 30 | 23 | System A - 11,100 cfm | Ten PC 78's Ten parallel trains of two vessels in series |
| 3000 | 23 | 21 | System A - 8,020 cfm | Twelve PC 78's - Six parallel trains of two vessels in series |
| 3300 | 209 | 18 | System B - 6,620 cfm | Twelve PC 78's - Six parallel trains of two vessels in series |
| 3530 | 195 | 18 | System B - 7,080 cfm | Fourteen PC 78's - Seven parallel trains of two vessels in series |

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| | | | | |
|---|---|---|---|---|
| 4200 | 204 | 23 | System B - 11,230 cfm | Sixteen PC 78's - Eight parallel trains of two vessels in series |
| 4910 | 173 | 21 | System B - 9,850 cfm | Twenty PC 78's - Ten parallel trains of two vessels in series |

**Notes: System A = One airstripping tower eight (8) foot in diameter with ten (10) feet of packing height utilizing 3 1/2" Jaeger Tripacks packing media.**

**System B = Two airstripping towers operated in parallel, each eight (8) foot in diameter with twenty (20) feet of packing height utilizing 3 1/2 Jaeger Tripacks packing media.**

**Budget Pricing**

| | |
|---|---|
| Supply of the airstripper equipment for System A | $91,546.00 |
| Supply of the airstripping equipment for System B | $107,476.00 |
| Supply of each parallel train of two carbon vessels | $ 93,650.00 |
| Price per pound of reactivated liquid phase carbon | $0.70/POUND |

**General Conditions**

Terms of payment are Net 30 days with approved credit
Proposal and pricing valid for 60 days
The proposed equipment will be shipped within weeks after receipt of approved purchase order, approved submittals, if required, and an approved credit application.
This proposal is based on the attached **TERMS AND CONDITIONS**
Shipping charges are not included in the quoted prices. Shipping charges will be prepaid and added to invoice

CARBONAIR

If you have any questions or comments concerning this information, please feel free to give me (800-526-4999) a call. Thank you for the opportunity to bid on this project.

Sincerely,

Bob Bergsgaard

Bob Bergsgaard
Regional Manager, Southeast

CARBONAIR
Water
Treatment

# Liquid Phase Carbon Vessels

Carbonair carbon adsorbers are designed and manufactured in accordance with engineering standards set forth by the American Society of Mechanical Engineers. The materials used in construction are in accordance with standards established by AWWA, FDA and EPA.

**LPC 3** These low pressure drum-type adsorbers provide a simple, economical way to treat low-flow organic-laden water streams. The LPC 3 arrives ready to use; installation is quick and easy.

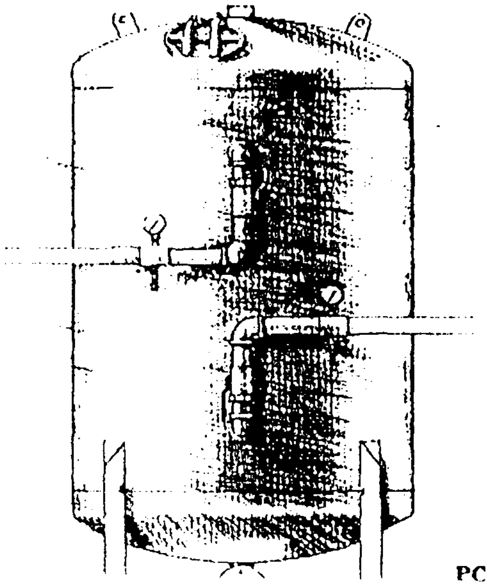
**PC 1, PC 3** Interiors of these vessels are lined with high density polyethylene for resistance to chemicals and abrasions. The reinforced fiberglass construction makes PC1 and PC3 units suitable for high pressure operation.

**PC 5, PC 7, PC 13, PC 20** The welded-steel construction of these popular models assures strength and durability. Interiors are double coated with a corrosion-resistant epoxy. Two-inch diameter influent/effluent couplings give greater connection flexibility. Large carbon slurry lines permit fast removal of spent carbon, and dual access ports provide easy inspection and maintenance.

**PC 28** Carbonair's PC 28 carbon adsorber offers above average value. The proportions of this vessel (six-foot diameter) and its capabilities make it adaptable to a variety of industrial, municipal and potable operations. Durability is built in with tough welded-steel construction and double-coated epoxy-lined interiors.

**PC 50** The rugged PC 50 is a proven performer. The conical bottom collection system allows full use of the carbon bed, while the carbon slurry piping permits complete removal of spent carbon. The unit is made of welded steel; vessel interiors are double coated with a corrosion-resistant epoxy. The large carbon slurry lines permit fast removal of spent carbon, and the 10,000-pound carbon capacity provides extended life at a full range of flow rates.

**PC 78** With a carbon capacity of 20,000 pounds, the PC 78 is one of the largest single-bed adsorbers available. The unit has an excellent track record in municipal, industrial and potable applications. Constructed of welded steel, the vessel interior's epoxy coating offers high chemical resistance.


PC 13

## OPTIONS

- Decon/3 piping package with quick connectors.
- Influent/effluent quick-connect kit.
- Influent/effluent sampling and pressure indicator kit.
- Interior sampling kit.
- Non-aerating sample ports.
- Flow instrumentation, including meters, gauges and valves.
- Carbon disposal and replacement program for full compliance with environmental regulations.
- ASME stamp.
- Skid (forkliftable).

## SPECIFICATIONS

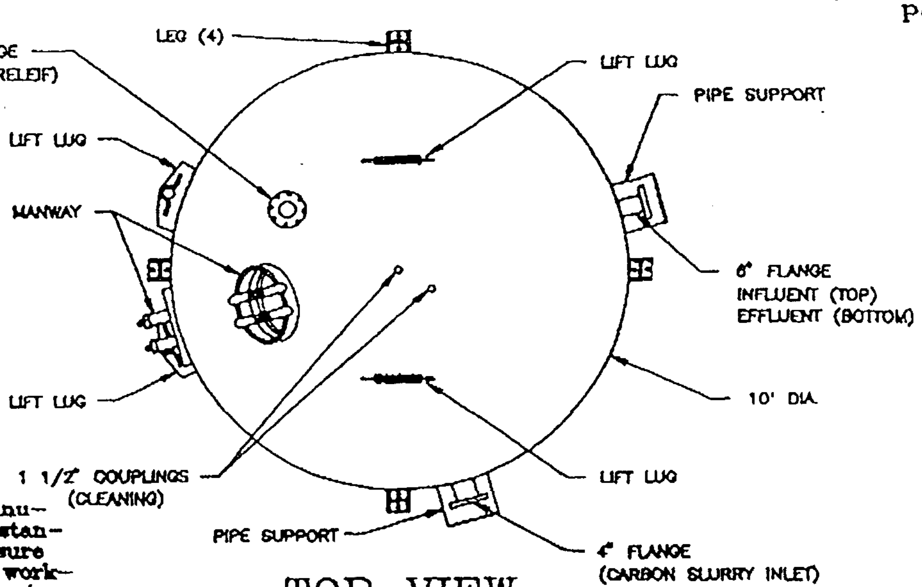
Listed on reverse.

CARBONAIR®
ENVIRONMENTAL SYSTEMS
8640 Monticello Lane
Maple Grove, MN 55369-4547
612-425-2992 800-526-4999
Fax 612-425-6882

## SPECIFICATIONS

| | LPC 3 | LPC 3.85 | LPC 5.110 | PC 1 | PC 3 | PC 5 | PC 7 | PC 13 | PC 20 | PC 28 | PC 50 | PC 78 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VESSEL DIAMETER | 1.8 ft. (0.55 m) | 2.16 ft. (0.66 m) | 2.5 ft. (0.76 m) | 1.2 ft. (0.37 m) | 1.8 ft. (0.55 m) | 2.5 ft. (0.76 m) | 3.0 ft. (0.91 m) | 4.0 ft. (1.22 m) | 5.0 ft. (1.52 m) | 6 ft. (1.83 m) | 8 ft. (2.44 m) | 10 ft. (3.05 m) |
| OVERALL HEIGHT | 2.8 ft. (0.85 m) | 3.02 ft. (0.92 m) | 3.4 ft. (1.04 m) | 3.9 ft. (1.19 m) | 4.5 ft. (1.37 m) | 7.3 ft. (2.23 m) | 7.3 ft. (2.23 m) | 7.5 ft. (2.29 m) | 7.5 ft. (2.29 m) | 15 ft. (4.57 m) | 17 ft. (5.19 m) | 18.5 ft. (5.64 m) |
| BED AREA | 2.6 ft² (0.24 m²) | 3.68 ft² (0.34 m²) | 4.9 ft² (0.46 m²) | 1.1 ft² (0.10 m2) | 2.4 ft² (0.22 m²) | 4.9 ft² (0.46 m²) | 7 ft² (0.65 m²) | 12.6 ft² (1.2 m²) | 19.6 ft² (1.82 m²) | 28 ft² (2.6 m²) | 50 ft² (4.7 m²) | 78.5 ft² (7.3 m²) |
| FLOW RANGE | 1-10 gpm (4-38 L/min) | 1-13 gpm (4-49 L/min) | 1-17 gpm (4-64 L/min) | 0.5-10 gpm (2-38 L/min) | 1-20 gpm (4-76 L/min) | 3-35 gpm (11-132 L/min) | 4-70 gpm (15-265 L/min) | 6-90 gpm (23-340 L/min) | 10-138 gpm (38-522 L/min) | 14-201 gpm (53-761 L/min) | 25-360 gpm (95-1363 L/min) | 40-550 gpm (150-2082 L/min) |
| CARBON CAPACITY | 150 lbs. (68 kg) | 250 lbs. (114 kg) | 350 lbs. (159 kg) | 90 lbs. (41 kg) | 250 lbs. (114 kg) | 575 lbs. (261 kg) | 900 lbs. (409 kg) | 1,500 lbs. (681 kg) | 2,500 lbs. (1,135 kg) | 5,000 lbs. (2,270 kg) | 10,000 lbs. (4,540 kg) | 20,000 lbs. (9,080 kg) |
| FITTINGS | Two 1½" influent/ effluent connections | Two 1½" influent/ effluent connections | Two 2" influent/ effluent connections | Two 1" influent/ effluent connections | Two 1" influent/ effluent connections | Two 2" influent/ effluent full couplings, one 12" x 16" and one 6" x 8" access port One 3" air pressure relief coupling | Two 2" influent/ effluent full couplings, one 12" x 16" and one 6" x 8" access port One 3" air pressure relief coupling | Two 2" influent/ effluent full couplings, two 12" x 16" access ports One 3" air pressure relief coupling One 3" carbon slurry flange | Two 3" influent/ effluent full couplings, two 12" x 16" access ports One 3" air pressure relief coupling One 3" carbon slurry flange | Two 4" influent/ effluent flanges, four 12" x 16" access ports, one 4" carbon slurry flange | Two 4" influent/ effluent flanges, four 12" x 16" access ports, one 4" carbon slurry flange | Two 6" influent/ effluent flanges, four 12" x 16" access ports, one 4" carbon slurry flange |
| DESIGN PRESSURE | 15 psi (0.2 bar) | 15 psi (0.2 bar) | 15 psi (0.2 bar) | 150 psi (10 bar) | 150 psi (10 bar) | 100 psi (6.9 bar) | 91 psi (6.3 bar) | 91 psi, optional ASME inspected and stamped (6.3 bar) | 70 psi, optional ASME inspected and stamped (4.8 bar) | 70 psi, optional ASME inspected and stamped (4.8 bar) | 66 psi, optional ASME inspected and stamped (4.6 bar) | 80 psi, optional ASME inspected and stamped (5.5 bar) |
| EMPTY WEIGHT | 50 lbs. (23 kg) | 100 lbs. (45 kg) | 120 lbs. (55 kg) | 23 lbs. (10 kg) | 53 lbs. (24 kg) | 1,200 lbs. (545 kg) | 1,400 lbs. (635 kg) | 1,510 lbs. (686 kg) | 2,100 lbs. (953 kg) | 4,000 lbs. (1,816 kg) | 8,100 lbs. (3,677 kg) | 10,900 lbs. (4,949 kg) |
| LOADED WEIGHT | 205 lbs. (93 kg) | 350 lbs. (159 kg) | 470 lbs. (213 kg) | 130 lbs. (59 kg) | 320 lbs. (145 kg) | 1,775 lbs. (806 kg) | 2,300 lbs. (1,044 kg) | 3,010 lbs. (1,367 kg) | 4,600 lbs. (2,088 kg) | 9,000 lbs. (4,086 kg) | 18,100 lbs. (8,217 kg) | 30,000 lbs. (13,620 kg) |
| OPERATING WEIGHT | 423 lbs. (192 kg) | 725 lbs. (329 kg) | 970 lbs. (440 kg) | 290 lbs. (132 kg) | 775 lbs. (352 kg) | 2,830 lbs. (1285 kg) | 3,730 lbs. (1,693 kg) | 5,750 lbs. (2,610 kg) | 9,476 lbs. (4,302 kg) | 24,000 lbs. (10,896 kg) | 36,500 lbs. (16,571 kg) | 67,900 lbs. (30,827 kg) |
| SPENT & DRAINED WEIGHT | 355 lbs. (161 kg) | 600 lbs. (272 kg) | 820 lbs. (372 kg) | 215 lbs. (98 kg) | 560 lbs. (254 kg) | 2,350 lbs. (1067 kg) | 3,200 lbs. (1,453 kg) | 4,510 lbs. (2,048 kg) | 7,100 lbs. (3,223 kg) | 14,000 lbs. (6,356 kg) | 28,100 lbs. (12,557 kg) | 50,900 lbs. (23,109 kg) |

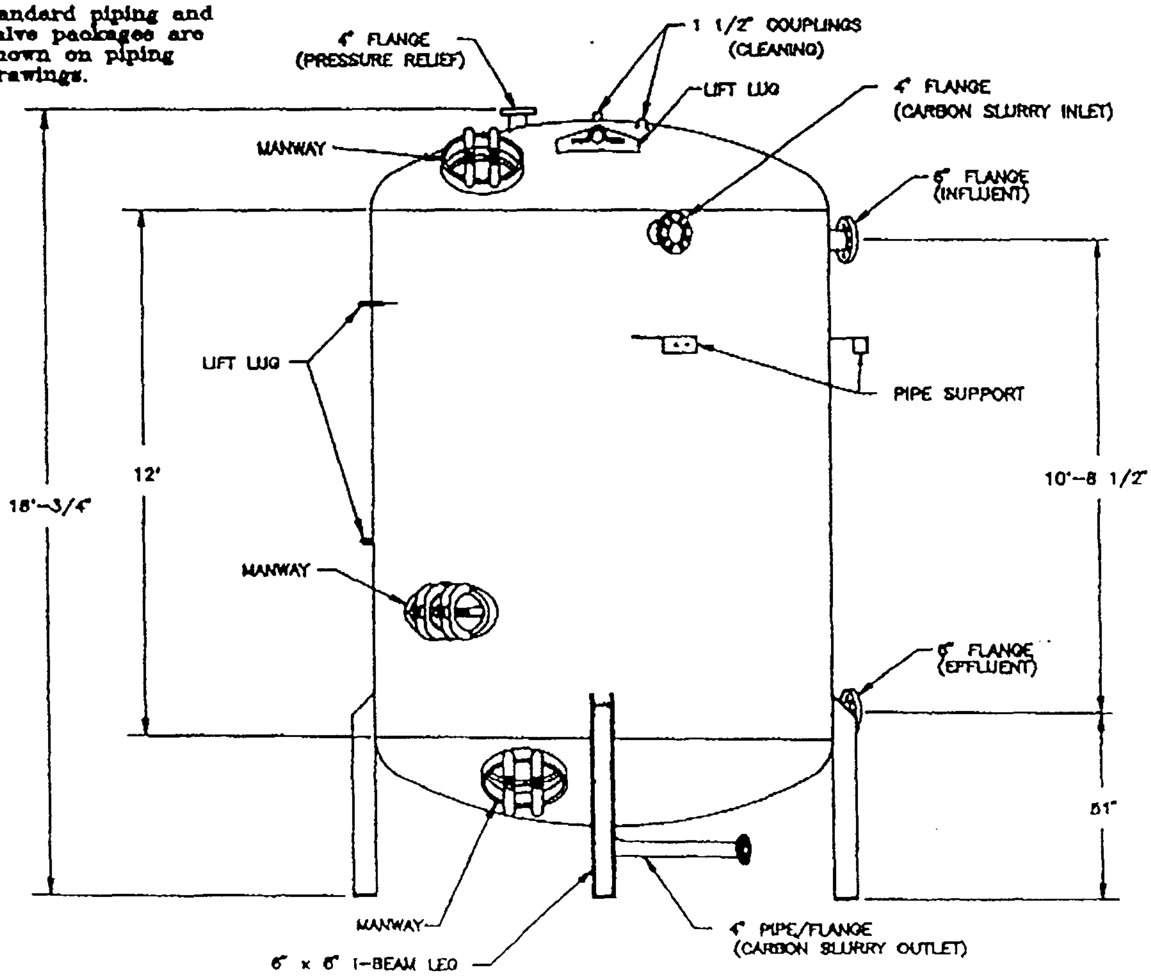
Carbon Adsorber–Liquid Phase
PC 78




TOP VIEW

Notes:

1. Pressure vessel manufactured to ASME standards with a pressure rating of 60 PSIG working pressure. Code stamp not included unless required.
2. Standard piping and valve packages are shown on piping drawings.




FRONT VIEW

Sales Drawing #111467
92.12.30

B07NE003702-09477

Delta Cooling Towers, Inc.
134 Clinton Road
P.O. Box 952
Fairfield, New Jersey 07004
Telephone 201/227-0300
Fax 201/227-0458

**Delta Cooling Towers**

December 15, 1994

Curt Elmore, Ph.D., P.E.
Woodward Clyde Consultants
10975 El Monte, Suite 100
Overland Park, Kansas 66211

Ph: (913) 344-1154
Fx: (913) 344-1012

Re: Omaha Nebraska Plant

Dear Dr. Elmore,

Delta is pleased to quote the following equipment and provide the following information per your request. The quotations are based on TCE removal. We do not have enough information to enable us to quote and guarantee for RDX removal. I understand that Douglas Fiscus has experience with carbon and RDX. Can this be combined with air stripping on a pilot scale basis?

The equipment has the ability to remove TCE to the degree requested.

Initially pretreatment is not required, but may be considered at a later date if the conditions change of the combination of elements in the water. Structured packing will aid in the reduction of fouling.

Process operation restriction are the water flow rate. Liquid loading is on the high end initially to reduce diameter and cost.

The tower diameters are shown, the approximate height is shown, estimated hp is given.

We can discuss pilot scale testing at your convenience.

Please call with any questions.

Thank You

Keith Kay
Sales Engineer

Delta Cooling Towers, Inc.
134 Clinton Road
P.O. Box 952
Fairfield, New Jersey 07004
Telephone 201/227-0300
Fax 201/227-0458

**Delta Cooling Towers**

Woodward Clyde Consultants

December 15, 1994

| GPM | % Rem. | Qty | Model number | Dia. (ft) | Pack-ing Height (ft) | HP | Est. Overall Height (FT) | Price |
|---|---|---|---|---|---|---|---|---|
| 970 | 77 | 1 | ΔS7-100 | 7 | 10 | 10 | 20 | $65,000 |
| 2100 | 65 | 1 | ΔS10-100 | 10 | 10 | 25 | 20 | $100,000 |
| 2330 | 62 | 2 | (2)ΔS8-100 | 8 | 10 | 15 | 20 | $140,000 |
| 1980 | 98.6 | 1 | ΔS10-200 | 10 | 20 | 25 | 30 | $12,000 |
| 3300 | 98 | 2 | (2) ΔS9-150 | 9 | 15 | 20 | 25 | $170,000 |
| 3530 | 98 | 2 | (2) ΔS10-150 | 10 | 15 | 25 | 25 | $220,000 |
| 1450 | 90.2 | 1 | ΔS9-150 | 9 | 15 | 20 | 25 | $170,000 |
| 2770 | 84 | 2 | (2)ΔS9-100 | 9 | 10 | 20 | 20 | $160,000 |
| 3000 | 79 | 2 | (2)ΔS9-100 | 9 | 10 | 20 | 20 | $160,000 |
| 2490 | 98.6 | 2 | (2)ΔS8-200 | 8 | 20 | 15 | 30 | $170,000 |
| 4200 | 98 | 3 | (3)ΔS9-150 | 9 | 15 | 20 | 25 | $255,000 |
| 4910 | 98 | 3 | (3)ΔS9-150 | 9 | 15 | 20 | 25 | $255,000 |

**BRANCH**
ENVIRONMENTAL CORP.

P.O. Box 5265, 3461 Route 22 East, Somerville, NJ 08876
Phone (908) 526-1114 Fax (908) 526-2881

December 14, 1994

Woodward-Clyde Consultant
10975 El Monte
Suite 100
Overland Park, Kansas 66211

Attention: Mr. Curt Elmore, Ph.D., P.E.
Project Engineer

Subject: Your Letter To Rauschert Industries Dated December 2
WCC Project 92KWO30R

Dear Mr. Elmore:

Vernon Christensen forwarded your inquiry for budget price information on the air stripping application. Rauschert Industries is one of the top suppliers for packing and internals for towers, but they do not manufacturer the complete unit.

Branch Environmental manufacturers the complete air stripper unit. We also provide steam stripping systems, and other mass transfer units including wet scrubbers and special design packages. We custom build the equipment for each application. We can provide just the stripper, stripper/fan with inlet and outlet transitions, silencers, downstream thermal oxidizers, or related equipment.

We hope the enclosed will be of help to you.

Regards,

Bill Gilbert

Bill Gilbert
Enc.

## FEASIBILITY

TCE is well known and documented. The attached table of sizes shows a unit based on the inlet and effluent concentrations of TCE required to be achieved.

After checking with all of the packing suppliers as well as our own references, no one has solid documented data on RDX. The properties of RDX would indicate that stripping may or may not work.

A feasibility study would consist of several steps:

1. Take a sample of the water with known quantity of RDX and determine the approximate Henry's Coefficient.

2. Assuming the results of step 1 are positive, run a pilot unit on the actual test waters.

3. Based on a results of the pilot, a full scale system can be designed.

Alternately, if the results of the RDX stripping are not positive, a secondary treatment system using activated carbon or alternate steam stripping technologies may prove necessary. Given the large quantity of water and the modest amount of RDX present, only carbon may be a suitable alternative.

Note: The presence of various other trace contaminants may influence the stripper results to some extent. Even if a decision is made not to remediate RDX with the stripper, a test unit is recommended.

**TABLE**

| Case | Flow GPM | Model | Budget Price | Fan CFM/ SP | Motor HP |
|---|---|---|---|---|---|
| 1 | 970 | 72Tx10H | $24,000. | 4000/1 | 1-1/2 |
| 2 | 2100 | 108Tx7H | $33,000. | 8400/1 | 3 |
| 3 | 2330 | 108Tx7H | $33,000. | 9400/1 | 5 |
| 4 | 1980 | 108Tx23H | $60.000. | 10600/2-1/2 | 10 |
| 5 | 3300 | 132Tx25H | $80,000. | 17600/2-1/2 | 15 |
| 6 | 3530 | 132Tx25H | $80,000. | 18800/2-1/2 | 20 |
| 7 | 1450 | 84Tx15H | $30,000. | 6000/1-1/2 | 3 |
| 8. | 2770 | 120Tx10H | $40,000. | 15000/1 | 5 |
| 9. | 3000 | 132Tx10H | $55,000. | 12000/1 | 5 |
| 10. | 2490 | 120Tx25H | $70,000. | 1300/2-1/2 | 15 |
| 11. | 4200 | 144Tx25H | $110,000. | 23000/2-1/2 | 20 |
| 12. | 4910 | 144Tx25H | $110,000. | 26000/3 | 30 |

Add for fan plus inlet screen/filter plus transition to tower inlet $.50/cfm

Model number represents diameter in inches - example 72T is a 6' diameter tower.

Packing height is second number - example 10H is 10' of packing.

To achieve overall height of packing, add 15' to packing height for preliminary purposes.

Design temperature 50°F.

## TREATABILITY STUDIES

Step 1 Feasibility

During step 1, samples of the water can be taken and, for example, put into containers 50% full of water and 50% air. After thorough agitation, the containers can be evaluated to determine the Henry Coefficient of the contaminants.

The evaluation would be done by first checking the concentration of the water, next agitation to disperse the contaminant between the water and air phases. Then, if facilities are available the air samples should be taken and an approximate concentration calculated. The water sample should be evaluated again to determine the residual amount of RDX.

From the change in the water concentration, and cross checking this against the amount in the air, the volatility of the compound can be determined. Once this is known, the feasibility of a pilot test can be determined.

Stripping studies at the site can be achieved using our rental pilot stripper. The rental stripper would be capable of liquid rates of 175 gpm. Fill heights of up t 20' can be used in the pilot.

The test unit includes the necessary fan, column, and interconnecting components. It requires a feed source for the water and a place to drain.

A pilot unit is provided at $4,500./month, with a minimum 2 month guarantee. Tests beyond 3 months are not normally required. If the unit is used for more than 6 months, the cost of rental is reduced to $3,000./month for up to 12 months.

Alternately, most of the test data can be achieved with a unit as small as a 24" diameter and with a 10' bed of packing. This smaller version would only need a liquid rate of 100 gpm. It can be built and rented for a fixed price of $10,500. At the end of the rental, you may either determine to keep it and use it at other sites for treatability studies or return it for partial credit against purchase of a full scale unit.

Again, should this alternative be attractive, a full proposal can be sent.


**BRANCH**
ENVIRONMENTAL CORP.

B07NE003702-09486

Branch Environmental Corporation supplies custom built scrubbers and systems for air pollution control.

From small units on a rush basis to large custom fabricated systems, you receive competitive pricing with the highest reliability and assurance that the equipment will work right the first time.

If you want a single source of responsibility, we can use our extensive experience and design of turnkey systems to provide all of the interconnecting components and controls necessary to give a trouble free installation.

The most common types of scrubbers we supply include:

- ☐ Packed Towers and Components
- ☐ HE Venturi Scrubbers (fixed & variable throat)
- ☐ Jet Venturi Scrubbers
- ☐ Fiberbed Mist Eliminator Systems
- ☐ Impingement Tray Scrubbers
- ☐ Special Units for applications such as $NO_x$

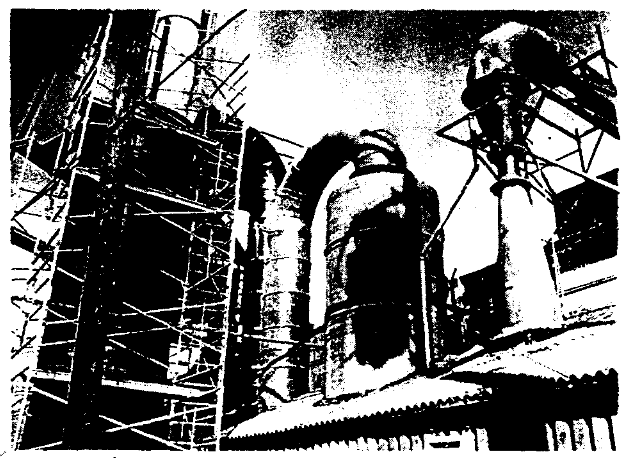
# Packed Towers

Packed towers are primarily designed for gas absorption. In a typical tower, the gas enters at the bottom and exits at the top. A scrubbing solution is sprayed over a bed of packing an drains out of the tower by gravity, to be further circulated. The packing is typically an injection piece of plastic which creates a tremendous surface and a mixing action between the gas and liquid. The higher the depth of packing, the longer the contact time between the gas and liquid, resulting in higher efficiencies.

We offer designs using any of the available packing suppliers, depending upon the specific application. We also can supply the unit in either crossflow or counterflow designs depending on the direction of gas and liquid. Counterflow designs offer the greatest efficiency and normally the lowest cost. If space limitations dictate crossflow designs, Branch Environmental Corporation can supply crossflow scrubbers.

Important points:

- ☐ All performance levels are guaranteed.
- ☐ Complete engineered systems can be provided including all related equipment as required.
- ☐ Any construction material is available including:
  ...Carbon or Stainless Steel
  ...PVC
  ...Fiberglass
  ...Or others as required.
- ☐ Shop fabricated units have capacities of up to about 50,000 cfm. Larger sizes are available using field erected columns.



# HE Venturi Scrubbers

HE Venturi Scrubbers are designed to remove very fine dust, fumes or mist. They can remove some gas, but contact time is limited and other designs are better for strictly gas absorption.

The air enters the venturi where the velocity is increased tremendously. The liquid is injected just in front of this venturi throat which results in extremely fine mist and contact with the small particles. Typically, the pressure drops vary from as low as 6" WG to as high at 60" WG depending on the quantity of liquid and the velocity in the throat.

Capacities of up to 80,000 cfm can be handled in shop fabricated units. Larger sizes are generally handled using multiple units because of the loss of performance if the venturi separator gets too large.

Because the velocity of the gas is critical, different designs are available to manually or automatically adjust the area of the throat for changing gas rates. **Branch Environmental** can provide several alternate designs which are custom built for various applications.

Important points:

- ☐ All performance levels are guaranteed.
- ☐ Complete engineered systems can be provided including all related equipment as required.
- ☐ Any contruction material is available.

# Jet Venturi Scubbers

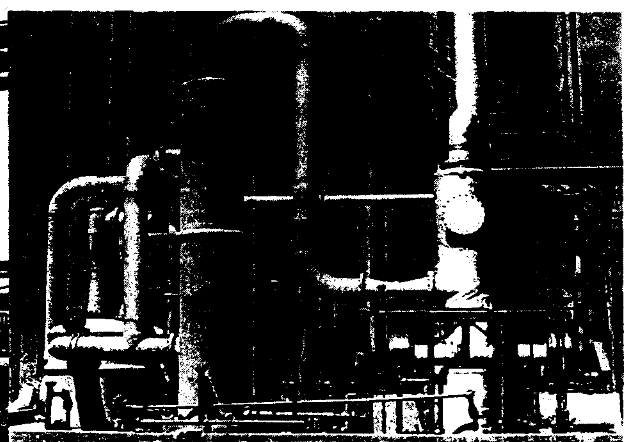
Jet Venturi Scrubbers use the energy from the liquid sprayed under pressure to entrain the air, scrub gases and remove dust without a fan (in any cases).

Jet Venturi Scrubbers allow the use of high liquid rates which are necessary for some applications, particularly emergency systems. The high liquid rate allows variable gas rates without loss of performance. These units can handle any gas rate up to design without any adjustments.

A separator is required with the venturi. Several different designs are available to provide an open and easily maintained separator.

Important points:

- ☐ All performance levels are guaranteed.
- ☐ Complete engineering service including design for creating draft (eliminating a fan), efficiency of scrubbing on both dust and gas and mist eliminator sizing.
- ☐ Construction materials, selected to minimize cost, include:
  ...Carbon or Stainless Steel
  ...Fiberglass
  ..Special alloys or
  ...Any other material required
- ☐ Complete systems are provided, including skid mounting if necessary and:
  ...Scrubber system
  ...Fan if necessary
  ...Recycle pump, piping
  ...Stack optional
  ...Liquid storage capacity



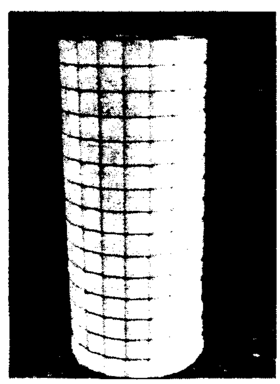
# Fiberbed Mist Eliminators

When extremely small particles are present, the energy required for scrubbing may increase tremendously. If the particles are oil, liquid aerosol such as an acid mist, a soluble salt, or low concentrations, a fiberbed may be the answer.

The principle of operation involves an extremely compressed medium of fiberglass with very low gas velocity. The result is removal of particles below 1 micron. The lower the velocity, the better the performance. Gas normally enters at the bottom of the vessel and passes upward through the special filters. The captured mist, plasticizer or other liquid drains from the filter surface at the low velocities used.

Important points:

- ☐ All performance levels are guaranteed.
- ☐ Complete engineering service is available including sizing of fiberbed mist eliminator units as well as coordinated packages with scrubbers.
- ☐ Construction materials, selected to minimize cost, include:
  ...Carbon or Stainless Steel
  ...PVC
  ...Fiberglass or
  ...Others as required
- ☐ Complete turnkey systems include:
  ...Prescrubber
  ...Fiberbed mist eliminator vessels
  ...All interconnecting ducts
  ...Fan if required
  ...All controls
  ...Preconditioners or liners as necessary



# Typical Installations

Following are some recently completed projects:

- ☐ Emergency Chlorine Scrubbing Systems
- ☐ Chemical Absorption Systems For Organics
- ☐ Chemical Absorption Systems For Acid Fumes
- ☐ Rotary Kiln Incinerator Scrubber
- ☐ $NO_x$ Removal Systems
- ☐ Carbon Furnace Regeneration Scrubber
- ☐ Fiberbed Mist Eliminator For Submicron Aerosols
- ☐ Sulfur Dioxide Scrubber For Boiler
- ☐ Metallurgical Fume From Furnace
- ☐ Gas Coolers
- ☐ Acid Mist Removal System For Phosphoric Acid
- ☐ Packaged Scrubber Systems For Hazardous Waste Incinerator
- ☐ Reactor Scrubbers
- ☐ Oil Aerosol Removal For Dryer Ovens
- ☐ Salt Aerosol Removal Scrubber
- ☐ Hospital Waste Incinerator Scrubber
- ☐ Design of Ductwork Systems
- ☐ Design of Complete Packaged Scrubber Systems
- ☐ Modification of Competitor's Scrubbers
- ☐ Hydrochloric Acid Storage Tank Scrubbers
- ☐ Odor Control Systems For Municipal Water Treatment
- ☐ Caustic Mist Removal Scrubbers

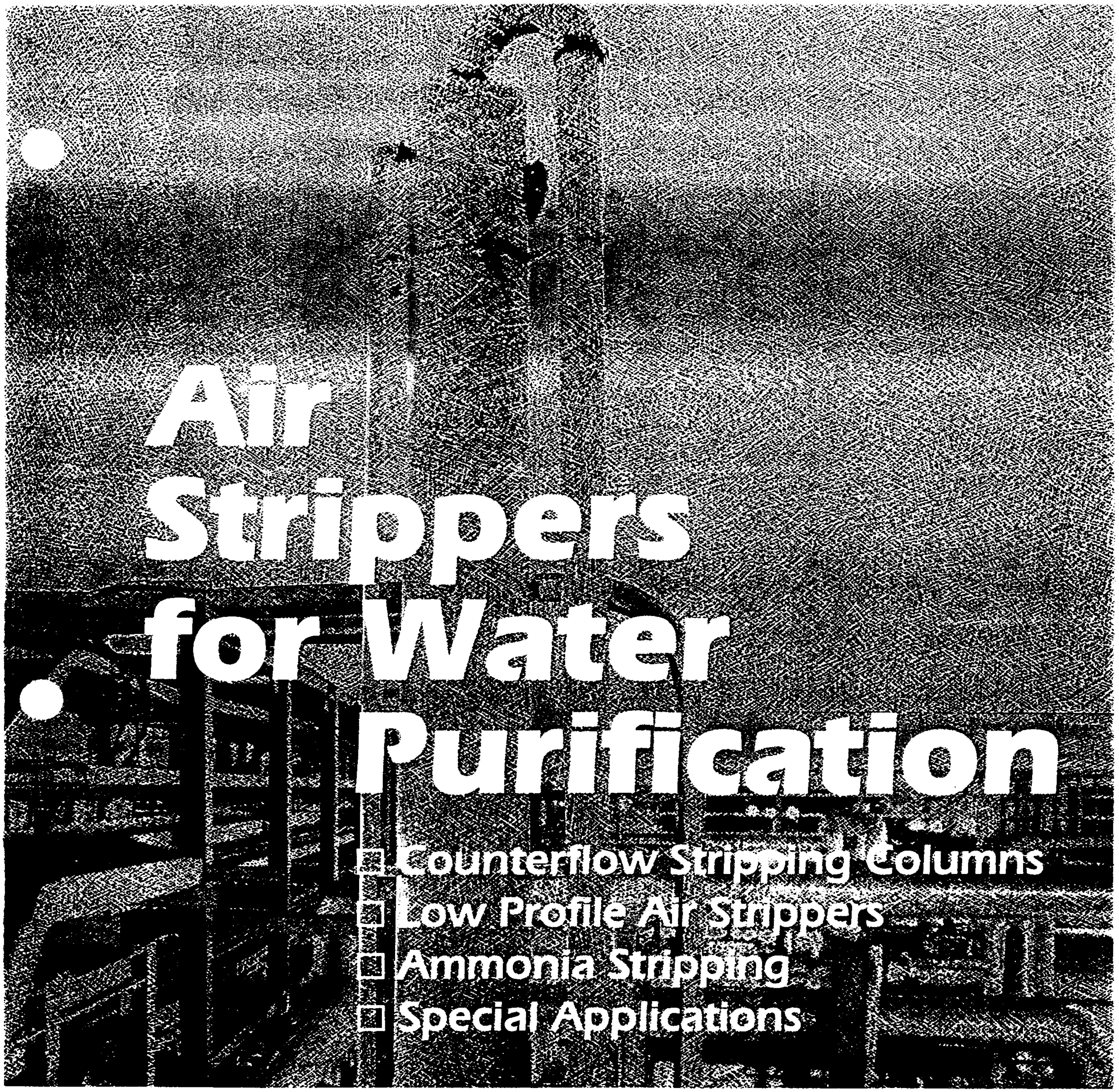
## Other systems available include:

- ☐ Dry Flue Gas Systems
- ☐ PCT System-Thermal Oxidation For Volatile Organic Compounds
- ☐ Fabric Filters Northeast For Dry Dust Collectors

If you have a pollution control problem, and a scrubber is not the answer, our other affiliated companies including dust collectors, thermal oxidizers, and solvent recovery systems may be able to help. For further information contact our office:

**BRANCH**
ENVIRONMENTAL CORP.

P.O. Box 5265, 3461 Route 22 East, Somerville, NJ 08876
Phone 908-526-1114, Fax 908-526-2881



# Air Strippers for Water Purification

- Counterflow Stripping Columns
- Low Profile Air Strippers
- Ammonia Stripping
- Special Applications

**BRANCH**
ENVIRONMENTAL CORP.

B07NE003702-09490

**Branch Environmental Corporation** supplies custom built air stripper units for removal of VOCs, ammonia, $H_2S$ and other volatile components from water.

From small units on a rush basis to large custom fabricated systems, you receive competitive pricing with the highest reliability and assurance that the equipment will work right the first time. If you want a single source of responsibility, we can use our extensive experience in design of turnkey systems to provide all of the related components and controls necessary to give a trouble free installation.

The most common types of air strippers we supply include:

- ☒ Counterflow air stripping units
- ☐ Low profile air stripping units
- ☐ Single pass ammonia stripping units
- ☐ Continuous closed loop ammonia removal systems
- ☐ Vacuum $CO_2$ and special applications

# Counterflow VOC Stripping Columns

Counterflow stripping columns are the most common design because of the high efficiencies that can be achieved, combined with the relatively low air volume required.

Air volume is important, because in many cases the air will require further treatment before it can be discharged. The smaller the volume, the lower the supplemental equipment cost.

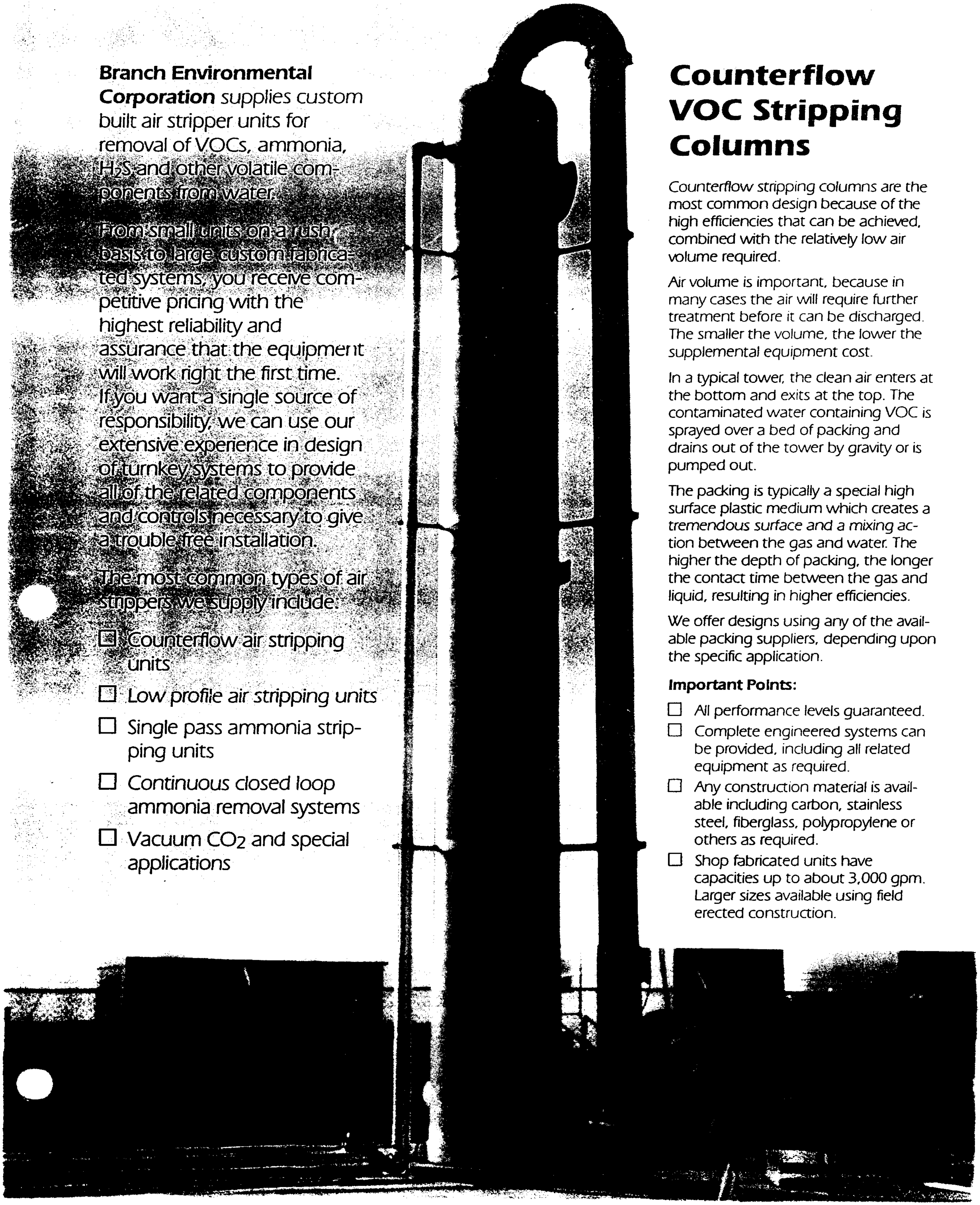
In a typical tower, the clean air enters at the bottom and exits at the top. The contaminated water containing VOC is sprayed over a bed of packing and drains out of the tower by gravity or is pumped out.

The packing is typically a special high surface plastic medium which creates a tremendous surface and a mixing action between the gas and water. The higher the depth of packing, the longer the contact time between the gas and liquid, resulting in higher efficiencies.

We offer designs using any of the available packing suppliers, depending upon the specific application.

**Important Points:**

- ☐ All performance levels guaranteed.
- ☐ Complete engineered systems can be provided, including all related equipment as required.
- ☐ Any construction material is available including carbon, stainless steel, fiberglass, polypropylene or others as required.
- ☐ Shop fabricated units have capacities up to about 3,000 gpm. Larger sizes available using field erected construction.



# Low Profile Air Strippers

Low profile air strippers use the same technology of air/water contact. The water flows in horizontal paths rather than vertically downward, reducing the overall height.

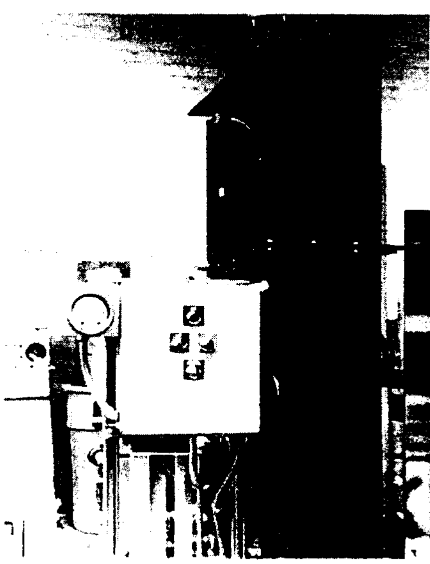
In the contact section, water flows across a support plate designed to hold our special mesh contact section. As air blows up through the support plate holes, it enters a mesh medium and encounters the water flowing horizontally. The result is a tremendous frothing action. The resulting air/water contact carries the VOCs into the air.

The low profile tray units offer the advantage of low height. They can be put inside of a room, located in an inconspicuous location, or easily moved.

Low profile strippers require much larger air flows. It takes several times as much air to properly operate. This is an important consideration where further air side treatment is required. Low profile units are also limited in capacity. Typically 200 gpm is the maximum single practical module available.

**Important Points:**

- ☐ All performance levels guaranteed.
- ☐ Complete engineered systems can be provided, including all related equipment as required.
- ☐ Typical construction materials available include stainless steel housing or polypropylene housing.
- ☐ Complete systems provided, including skid mounting, fans, and all controls and components as required.



# Ammonia Stripping

Where ammonia is present in waste water systems, it can be removed using air stripping technology.

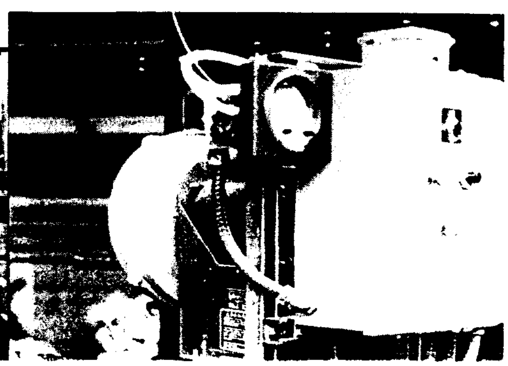
Unlike volatile organic compounds, ammonia is very soluble. To overcome the high solubility of ammonia, the pH is adjusted resulting in dissolved ammonia gas rather than ionized ammonium hydroxide. Following the pH shift, the gas can be effectively stripped with modest air flow rates.

The primary design for ammonia strippers is the counterflow packed tower. Just as in our standard counterflow VOC strippers, the stripping air enters the bottom of the column and exits at the top. A scrubbing solution is sprayed over the bed of packing and drains out of the tower by gravity. The same type of plastic packing is used to provide high surface and good contact.

We will provide a complete package including pH adjustment systems, chemical feed systems, counterflow strippers, air tempering systems, and other related components for a complete system.

**Important Points:**

- ☐ All performance levels are guaranteed.
- ☐ Complete engineering systems can be provided, including all related equipment as required.
- ☐ Construction material selected to minimize cost includes carbon steel for most cases, although fiberglass or special materials can be provided depending on the application.
- ☐ Complete systems are provided including skid mounting if necessary.
- ☐ Shop fabricated units have capacities of up to about 1,000 gpm. Larger sizes are available using field erected or multiple columns.



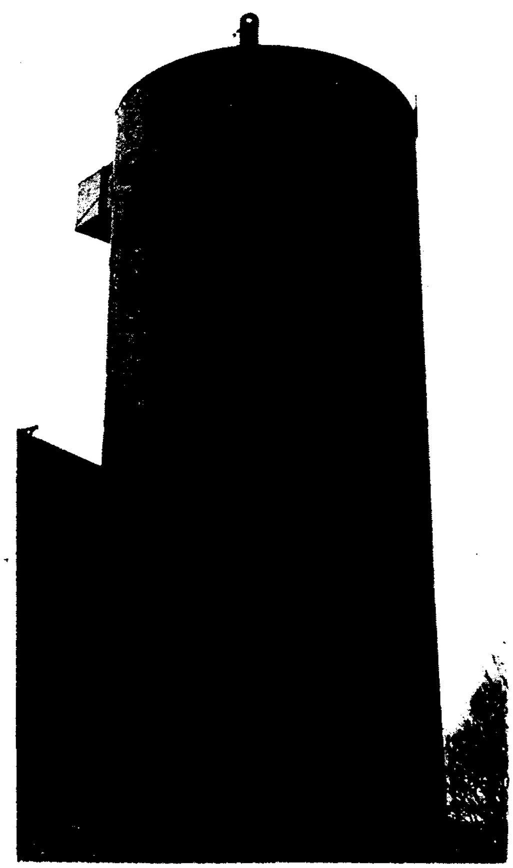
# Special Applications

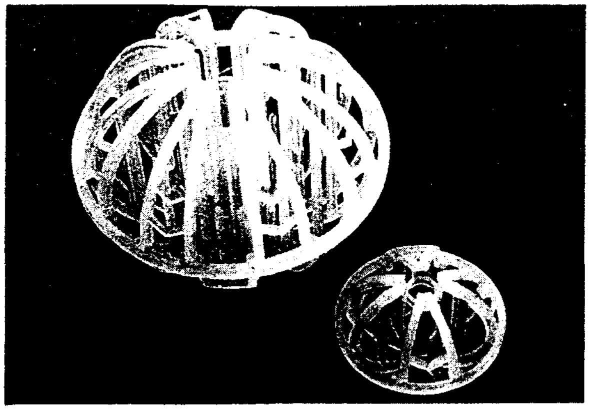
Carbon dioxide, hydrogen sulfide, and other soluble gases can often be removed using our air stripping technology.

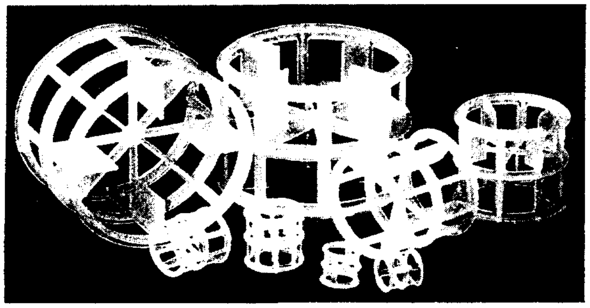
We have previously built units for many unusual applications and a combination of systems where recovery of the stripped gas was important. Since most of these applications are special, our engineering staff will work closely with you in selecting the best combination of components and operating conditions for your unique situation. This keeps your cost low and assures you of an overall package capable of meeting your needs without high cost.

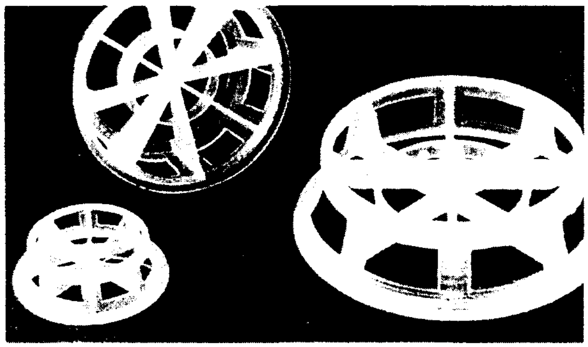
**Important Points:**

- ☐ Performance levels guaranteed.
- ☐ All engineering, pilot plant work, and engineering assistance provided.
- ☐ Viirtually any construction material available.
- ☐ Complete systems skid mounted or turnkey available including all related components.









# Tower Packing

The selection of tower packing is critical in designing the lowest initial and operating cost air stripper package. While there are many manufacturers of tower packing, some examples of the most commonly used types would be:

**1. Jaeger Tri-Pack**—The photo shows the range of sizes of Jaeger Tri-Pack. This high surface/low pressure drop packing has been used on virtually all applications involving air stripping.

**2. Rauschert Hiflow**—The photo shows the variety of sizes of Rauschert Hiflow. This high surface/low pressure drop packing has been used on virtually all applications involving air stripping.

**3. Other types of fill including Cascade Mini-Rings, Film Fill**, and more conventional packing may be selected depending on the specific operating conditions.

# Typical Installations

**The following are some recently completed projects:**

- ☐ Lakehurst Naval Air Station
- ☐ Fairchild Air Force Base
- ☐ Castle Air Force Base
- ☐ Rockaway Township
- ☐ City of Corning

**Other available systems include:**

- ☐ Wet scrubber systems
- ☐ Dry flue gas systems
- ☐ PCT system thermal oxidation for volatile organic compounds
- ☐ Fabric Filters Northeast for dry dust collectors
- ☐ Vapor phase carbon systems as an integrated package with air strippers

---

Tri-Packs is a registered trademark of Jaeger Products, Inc., 1611 Peach Leaf, Houston, TX 77039.
Hiflow is a registered trademark of Rauschert Industries, Inc., Route 5, Industrial Park, Madisonville, TN 37354.
Cascade Mini-Rings is a registered trademark of Glitsch International, 4900 Singleton Blvd., Dallas, TX 75266.

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## APPENDIX K
## GAC CONSUMPTION RATE AND INFLUENT CONCENTRATION ESTIMATES

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ATTACHMENT K3 REFERENCE: RDX ISOTHERMS FROM DATA BY MRI (1987)
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# 1.0
# INTRODUCTION

Remedial alternatives for the Site include extraction and treatment of groundwater. Several alternatives propose extraction wells to remove groundwater. The number and extraction flow rate for each groundwater extraction well varies with alternative and Target Groundwater Cleanup Goal. Summary information listing total number of wells and total flow rate is listed in **Table K-1**. Information for each individual extraction well is contained in **Table K-2**. Depending on which alternative and Target Groundwater Cleanup Goal is selected, the number of wells vary from five to 17 and the flow rate of extracted groundwater to be treated varies from 970 gallons per minute (gpm) to 4910 gpm. Extracted groundwater from each well is collected by a common piping and transfer pumping network which delivers the extracted groundwater to a central groundwater treatment facility. For the purpose of flow control to the treatment system, one receiver tank is used at the treatment facility to receive groundwater to be treated. The net result is that all extracted groundwaters are co-mingled before treatment and the influent concentration is the concentration of these co-mingled waters.

For estimating the treatment plant influent concentrations, there are two categories of chemicals which must be considered. The first category is the Chemicals of Concern (COC) for the Site (see **Section 2.0** of FS Report). Groundwater will be extracted from groundwater plumes where any of the COCs exceed Target Groundwater Cleanup Goals. The second category is the Groundwater Discharge Standards which are the EPA Drinking Water Standards of Maximum Contaminant Level (MCL) and Health Advisory (HA) (EPA, 1994). Influent concentrations that exceed the Groundwater Discharge Standards must be treated to these levels.

Both categories must be considered when estimating influent concentrations for any groundwater treatment system. For cost estimating purposes for this FS Report, granulated activated carbon (GAC) is chosen to provide a common basis for comparison of alternatives. Two other technologies of advanced oxidation for all COCs and air stripping for volatile Chemicals are retained as potentially applicable groundwater treatment technologies. GAC is selected as the technology used in developing estimated remedial alternative costs because GAC is commercially available and will remove all of the COCs.

The following sections discuss each chemical category, present calculation of weighted average influent concentrations, where appropriate, and summarize the calculation of estimated GAC consumption rates. These GAC consumption rates are then used in the detailed cost estimates for alternatives presented in **Appendix L - Cost Estimates for Remedial Alternatives**.

## 2.0
## CHEMICALS OF CONCERN

Chemicals of Potential Concern and Target Groundwater Cleanup Goals for these chemicals have been developed from drinking water MCLs and health-based goals. These Chemicals of Potential Concern, the associated cleanup goal for each chemical, and the definition of each individual cleanup goal concentration is listed in **Table K-3**. For all the Chemicals of Potential Concern, a comparison was made of the maximum concentration detected in the groundwater to the Target Groundwater Cleanup Goals. Maximum groundwater concentrations detected are listed in **Volume I, Table 1-3** of this FS Report. This **Table 1-3** lists Site groundwater monitoring results from the following five groundwater sampling events:

- August 1992 RI groundwater sampling
- November 1992 RI groundwater sampling
- February 1993 RI groundwater sampling
- May 1993 RI groundwater sampling
- May 1993 Additional Field Investigation (AFI) groundwater sampling

Comparisons were made for Target Cleanup Goals I, II and III and are listed in **Tables K-4, K-5** and **K-6** respectively. Only those chemicals whose maximum concentrations exceed the Target Groundwater Cleanup Goals are retained as a COC. Results of this screening process, which are listed in Tables **K-4, K-5** and **K-6**, are that the following seven chemicals are retained as COCs.

- TCE
- RDX
- 1,2-Dichloropropane
- Methylene Chloride
- TNB
- TNT
- 2,4-DNT

One exception is total lead which, as footnoted in **Tables K-4** through **K-6**, was detected in one well in November 1992 at levels above Target Cleanup Goals, but subsequent sampling did not find concentrations above Target Groundwater Cleanup Goals. Therefore lead was not retained as a COC.

The groundwater location distribution of the seven COCs is listed in **Tables K-7, K-8** and **K-9** for Target Groundwater Cleanup Goals I, II and III respectively. TCE concentrations were detected above Target Groundwater Cleanup Goals at 16 groundwater monitoring well locations and RDX concentrations were detected above Target Groundwater Cleanup Goals at 10 to 25 groundwater monitoring locations, depending on cleanup goal. Influent concentrations were then calculated using the concentrations from each groundwater monitoring well to establish estimated concentrations in each groundwater extraction well. A weighted average concentration was then calculated for the total co-mingled groundwater to be treated, using the design flow rates for each groundwater extraction well. A detailed discussion of the method and results is contained in the subsequent Sections 5 and 6 of this Appendix.

1,2-Dichloropropane and 2,4-DNT concentrations were detected in one groundwater monitoring well location, and TNB and TNT in two to three monitoring well locations at concentrations above Target Groundwater Cleanup Goals. Multiple groundwater monitoring wells are used to estimate groundwater concentrations in each extraction well. At a minimum, five groundwater extraction wells will be in operation at one time. Because of the co-mingling of contaminant concentrations (represented by multiple groundwater monitoring wells), it is therefore unlikely that these four compounds will be detected in the groundwater treatment system influent at concentrations above Target Groundwater Cleanup Goals. This does not mean that Target Groundwater Cleanup Goals will not be met, but only that influent concentrations at the groundwater treatment system are not a concern for operation of the treatment system on the basis of COCs. Therefore 1,2-Dichloropropane, 2,4-DNT, TNB and TNT do not warrant a detailed calculation of expected influent concentration, as was done for TCE and RDX.

Methylene chloride concentrations were reported above Target Groundwater Cleanup Goals in 11 groundwater monitoring wells. Unfortunately many of the concentrations reported were reported as an estimated value (i.e. "J" coded data) by the analytical laboratory and

Methylene chloride was also found in many of the groundwater sample blanks. Because Methylene chloride is a common laboratory contaminate, presence in sample blanks is not uncommon. The conclusion is that the number of groundwater monitoring locations at which Methylene Chloride concentrations are above Target Groundwater Cleanup Goals is uncertain. Because of this uncertainty, a detailed calculation of influent concentrations for Methylene chloride is not warranted at this time.

In summary, on the basis of COCs, TCE and RDX are used to estimate influent GAC usage rates, **only** for the purpose of developing Feasibility Study level cost estimates for the remedial alternatives because TCE and RDX are estimated to be the major chemical influent concentrations which must be treated in the groundwater treatment system.

## 3.0
## DRINKING WATER STANDARDS

The discharge of treated groundwater is not specified at this time. Several options exist which include discharge to a nearby stream and/or beneficial reuse options. Effluent standards for the treated groundwater are selected to allow the greatest versatility in disposition of treated groundwater. Effluent standards are EPA Drinking Water Regulations MCL and HA for those chemicals without MCLs listed. Maximum Contaminant Level Goals (MCLG) and Secondary Maximum Contaminant Levels (SMCL) are not used as effluent standards because SMCLs are not enforceable standards (See 40 CFR Parts 141,142,143). Groundwater has been sampled at the Site on the five different sampling events listed in Section 2 - Chemicals of Concern and a summary of groundwater sampling results is contained in **Table 1-3** in **Volume I** of this FS Report. The list of chemicals detected in groundwater samples for which MCL or HA exist and the maximum detected groundwater concentrations is contained in **Table K-10**.

The chemicals whose maximum detected concentrations exceed Drinking Water MCL or HA Standards are:

- RDX
- Trichloroethene (TCE)
- Lead
- Selenium
- Thallium
- 2,4,6-Trinitrotoluene (TNT)
- 1,2-Dichloropropane
- Methylene chloride

As shown in **Table K-10** all other chemicals detected for which drinking water standard currently exist were below MCL and HA standards.

**Table K-11** is a listing of the eight chemicals detected in the groundwater during the five sampling events for which concentrations exceed MCL and HA standards along with the number of groundwater monitoring well locations where these chemicals were detected.

TCE and RDX were detected above drinking water standards at 16 groundwater monitoring well locations. The same procedure discussed in the previous Section 2-Chemicals of Concern applies; where influent concentrations of RDX and TCE are calculated using concentrations from each groundwater monitoring well to established estimated concentrations in groundwater extraction wells and then a weighted average concentration calculated for the total flow from all extraction wells for each alternative and Target Groundwater Cleanup Goal.

Total Lead, Selenium, Thallium and 1,2-Dichloropropane were detected in one groundwater monitoring well location and TNT in three groundwater monitoring locations at concentrations above drinking water standards. The same rationale used for COCs detected in one to three groundwater monitoring wells discussed in Section 2 - Chemicals of Concern applies here to Lead, Selenium, Thallium and 1,2-Dichloropropane (also a COC) as well. Where groundwater is co-mingled from multiple groundwater extraction wells it is unlikely that these four chemicals will be detected in the co-mingled groundwater to be treated at concentrations above MCLs or HAs. Therefore Lead, Selenium, Thallium and 1,2-Dichloropropane do not warrant a detailed calculation of expected influent concentration, as was done for TCE and RDX.

As was the case in the previous Section 2 - Chemicals of Concern, Methylene chloride was detected in 11 monitoring well locations at concentrations above drinking water standards but many of these concentrations were estimated values and Methylene chloride, a known common laboratory contaminant, was found in sample blanks. Therefore, at what monitoring well locations Methylene Chloride exceed effluent standards is uncertain and a detailed influent concentration calculation, as was done for RDX and TCE, is not warranted.

## 4.0
## CHEMICALS USED FOR ESTIMATING INFLUENT CONCENTRATIONS TO THE GROUNDWATER TREATMENT SYSTEM

RDX and TCE are the two chemicals used for detailed calculations of estimated influent concentrations because:

- They are the only chemicals whose verified concentrations exceed Target Groundwater Cleanup Goals and treated groundwater effluent discharge standards at more than three groundwater monitoring locations.

- With the exception of Methylene chloride, all other chemicals are expected to be below Target Groundwater Cleanup Goals and treated groundwater effluent standards in the co-mingled extracted groundwater to be treated at the groundwater treatment system.

- Because of the uncertainty in the groundwater monitoring data, conclusions cannot be reached concerning Methylene chloride.

The estimated influent concentrations for RDX and TCE are presented next in Section 5 followed by estimated GAC usage rates in Section 6.

# 5.0
# INFLUENT CONCENTRATION ESTIMATION

This section contains the estimations of the influent concentrations of Trichloroethene (TCE) and Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) in the groundwater entering the Granular Activated Carbon (GAC) treatment system. The estimation of the influent concentrations is based on chemical data collected during the four quarterly groundwater sampling events at the Mead NOP site (August and November 1992, February and May 1993).

The following steps were followed in estimating the influent concentrations of TCE and RDX.

- Monitoring wells located upgradient and within the zone of influence of an extraction well were identified as contributors of RDX and TCE concentrations to that particular extraction well **(see Table K-12)**.

- Each of the identified monitoring wells were allocated a weight factor **(Wi)** calculated as the fraction of pumpage contributed by each extraction well with respect to the total pumpage of that alternative **(see Table K-13)**.

- A summary of the concentrations of RDX and TCE for each monitoring well, sampling event and screen interval was compiled.Average concentrations of RDX and TCE were calculated for each monitoring well, sampling event, and alternative. A weighted average concentration **(Wi*Ci)** was calculated as a product of the average concentration **(Ci)** and the weight factor (Wi) **(see Table K-14)**.

- The sum of the weighted average concentrations of each chemical by alternative and quarter was calculated **(see Table K-15)**.

- The maximum of the sums of the weighted average concentrations are summarized in **Table K-16** for TCE and RDX. These values are the influent concentrations used to estimate the GAC usage rate (see Section 3.0).

## 6.0
## GAC USAGE RATES ESTIMATION

---

### 6.1 ISOTHERM ESTIMATE

GAC usage rates for the treatment of groundwater containing TCE and RDX were estimated using a Freundlich adsorption isotherm model (Wujcik et. al., 1992) The isotherm equation and a sample calculation are provided below. The numerical value of the parameters used in the isotherm equation for RDX and TCE were provided by a literature review. Representative isotherms are included in Attachments 1, 2, and 3. Superposition was used to determine the GAC usage rate of the treatment system.

**Tables K-17** through **K-29** present the estimation of the GAC usage rates for each alternative based on the isotherms from the literature review, the influent concentrations of TCE and RDX (see **Table K-16**), the pumping rate (see **Table K-1**), and the target effluent concentrations of TCE and RDX. The target effluent concentrations are equivalent to the Drinking Water Regulations and Health Advisories issued by the U.S Environmental Protection Agency (EPA, 1994).

**Table K-30** presents a summary of the GAC Usage Rate Estimations for each alternative and Target Groundwater Cleanup Goal based on these two references. These references are from RDX removal from groundwater and TCE removal from deionized water (information on groundwater not available). Because of uncertainties in applying these references to Mead OU2, a scale-up factor of 2 is used. For example, the carbon usage estimated for RDX, Target Groundwater Cleanup Goal I, Alternative 2 through Wujcik et. al., 1992 is 129 lb/d (see **Table K-18**). Likewise, the carbon usage estimated for TCE, Target Cleanup Goal I, Alternative 2, through EPA, 1980, is 146 Lb/d (see **Table K-17**). The combined carbon usage for TCE and RDX for Target Cleanup Goal I, Alternative 2 is 275 lb/d which converts to 101,000 lb/yr (rounded up to next highest 1,000 lb/yr, see **Table K-30**).

Following is the Freundlich isotherm equation and an example calculation demonstrating the use of the equation.

Freundlich Isotherm Equation

$$q_e = KC^{1/n}$$

where

$$q_e = \frac{Co - C}{M}$$

| | | |
|---|---|---|
| $q_e$ | = | Weight of Contaminant adsorbed per unit weight of carbon, mg/g |
| Co | = | Initial (influent) contaminant concentration, mg/L |
| C | = | Equilibrium soluble-phase (effluent) contaminant concentration, mg/L |
| M | = | Carbon dosage = weight of carbon per unit volume, g/L |
| K | = | Empirical constant; same as $q_e$ when C = 1 mg/L |
| 1/n | = | Unitless empirical constant = slope of straight line isotherm when plotted in logarithmic form. |

Example Calculation

From Table F-18

- Isotherm constants from the selected references mentioned above are:

| | K mg/g | 1/n |
|---|---|---|
| RDX | 31 | 0.413 |
| TCE | 28 | 0.62 |

- Based on the RDX Isotherm:

$$q_e = \frac{(0.053 - 0.002)\ mg/L}{M(g/L)} = 31\ mg/g\ (0.053\ mg/L)^{0.413}$$

- $M = 5.53 \times 10^{-3}\ g/L$

In the above equation, a Co of 0.053 mg/L is used which is the influent concentration. Influent concentration is used here, because it represents the ultimate loading for a single component that can be attained during GAC column treatment, if the column is operated until the contaminant concentration in the effluent is equal to the influent. This condition can be achieved by operating columns in series.

- Carbon usage rate =

$$5.53 \ x \ 10^{-3} \ \frac{g}{L} \ x \ \frac{lb}{453.6g} \ x \ \frac{3.78L}{gal} \ x \ \frac{970 \ gal}{\min} \ x \ \frac{1{,}440 \ \min}{d} \ x \ 2 scale\text{-}up \ factor$$

= *129 lb/d*

- Similarly, carbon usage rate for TCE is 146 lb/d
- The total carbon usage rate using a scale-up factor of 2.0 is:

$$(129 \ lb/d \ + \ 146 \ lb/d) \ = \ 275 lb/d$$

$$(275 \ lb/d) \ (365 \ d/yr) \ = \ 100{,}375 \ lb/yr$$

= 101,000 lb/yr rounded up to next 1,000 lb/yr

## 6.2 SCALE-UP FACTOR

A scale-up factor of two is used in the GAC usage rate estimates. This value is conservative. Scale-up factors 1.2 to 1.5 are typically used for GAC treatment of groundwater. As a result, there exists the possibility that actual GAC usage rates may be lower than calculated in this appendix. A scale-up factor greater than the typical range was used because of several uncertainties, some of which are listed below.

**Uncertainties**

- Absence of treatability data specific to the Mead Site
- RDX isotherm used for GAC usage estimate is from groundwater (Table F-17 Reference A) which is not Mead Groundwater. How

water chemistry differences between the reference groundwater and Mead groundwater may effect GAC usage is unknown.

- TCE isotherm used for GAC usage estimate is from deionized water (Table F-17 Reference D). How water chemistry differences between deionized water and Mead groundwater may effect GAC usage is unknown.

- Methylene chloride may be present in the groundwater. During Site groundwater monitoring well sampling, Methylene chloride, a common laboratory contaminant, was detected in sample blanks and some of the sample data results were "J" coded as estimated concentrations. Although Methylene chloride may be present, because of the data uncertainty, an accurate estimate of influent concentrations cannot be made. Therefore potential GAC usage for methylene chloride adsorption is not included in the GAC usage rate calculations.

Plans are underway which will help address the scale-up factor question. A groundwater containment action (WCC, 1994) is planned for the year 1995, where approximately 600 gpm of groundwater will be extracted from the leading edge of the contaminant plume at the Mead Site. This extracted groundwater will be treated using GAC. Performance data from this containment action (actual Mead Site groundwater treatment by GAC) will assist in determining an appropriate scale-up factor.

In conclusion, until uncertainties are reduced, and a better estimate of actual GAC usage is available from the Mead containment action and/or treatability tests, the conservative scale-up factor of two is used for cost estimating purposes.

# 7.0 REFERENCES

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Midwest-Research Institute. 1987. Granular Activated Carbon (GAC) System Performance Capabilities and Optimization. MRI Project No. 8182-S. Prepared for U.S. Army Toxic and Hazardous Material Agency.

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Woodward-Clyde Consultants (WCC). 1994. Intermediate Design Analysis, Groundwater Containment Removal Action, Operable Unit No. 2 (Groundwater), Former Nebraska Ordnance Plant, Mead, Nebraska. DACAA41-92-C-0023. Prepared for the U.S. Army Corps of Engineers, Kansas City District. October.

**Table K-1**
**Summary of Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Remedial Alternative Description | Target Groundwater Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | Combined Flowrate (gpm) | Wells | Combined Flowrate (gpm) | Wells | Combined Flowrate (gpm) | Wells | Combined Flowrate (gpm) |
| **1** | No Action | **I** | | | | | | | **0** | **0** |
| | | **II** | | | | | | | **0** | **0** |
| | | **III** | | | | | | | **0** | **0** |
| **2** | Hydraulic Containment | **I** | 1 | 110 | 3 | 620 | 1 | 240 | **5** | **970** |
| | | **II** | 1 | 160 | 7 | 1580 | 1 | 360 | **9** | **2100** |
| | | **III** | 1 | 160 | 7 | 1810 | 1 | 360 | **9** | **2330** |
| **3** | Focused Extraction | **I** | 6 | 1120 | 3 | 620 | 1 | 240 | **10** | **1980** |
| | | **II** | 6 | 1170 | 8 | 1770 | 1 | 360 | **15** | **3300** |
| | | **III** | 6 | 1170 | 8 | 2000 | 1 | 360 | **15** | **3530** |
| **4** | Focused Extraction and Soil Excavation | **I** | 6 | 1120 | 3 | 620 | 1 | 240 | **10** | **1980** |
| | | **II** | 6 | 1170 | 8 | 1770 | 1 | 360 | **15** | **3300** |
| | | **III** | 6 | 1170 | 8 | 2000 | 1 | 360 | **15** | **3530** |
| **5** | Focused Extraction and Air Sparging | **I** | 4 | 590 | 3 | 620 | 1 | 240 | **8** | **1450** |
| | | **II** | 4 | 640 | 8 | 1770 | 1 | 360 | **13** | **2770** |
| | | **III** | 4 | 640 | 8 | 2000 | 1 | 360 | **13** | **3000** |
| **6** | Focused Extraction with Air Sparging and Soil Excavation | **I** | 4 | 590 | 3 | 620 | 1 | 240 | **8** | **1450** |
| | | **II** | 4 | 640 | 8 | 1770 | 1 | 360 | **13** | **2770** |
| | | **III** | 4 | 640 | 8 | 2000 | 1 | 360 | **13** | **3000** |
| **7** | Groundwater Extraction | **I** | 5 | 1630 | 3 | 620 | 1 | 240 | **9** | **2490** |
| | | **II** | 5 | 1680 | 9 | 2160 | 1 | 360 | **15** | **4200** |
| | | **III** | 5 | 1680 | 11 | 2870 | 1 | 360 | **17** | **4910** |
| **8** | Groundwater Extraction and Soil Excavation | **I** | 5 | 1630 | 3 | 620 | 1 | 240 | **9** | **2490** |
| | | **II** | 5 | 1680 | 9 | 2160 | 1 | 360 | **15** | **4200** |
| | | **III** | 5 | 1680 | 11 | 2870 | 1 | 360 | **17** | **4910** |

Table K-2
Specific Groundwater Containment and Extraction Wells Required for Each Alternative

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 2 | Hydraulic Containment | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | | | EW-3 | 260 | | | | |
| | | | | | EW-4 | 170 | | | | |
| Total | | | 1 | 110 | 3 | 620 | 1 | 240 | 5 | 970 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | | | EW-3 | 190 | | | | |
| | | | | | EW-4 | 250 | | | | |
| | | | | | EW-5 | 230 | | | | |
| | | | | | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| Total | | | 1 | 160 | 7 | 1580 | 1 | 360 | 9 | 2100 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | | | EW-3 | 160 | | | | |
| | | | | | EW-4 | 190 | | | | |
| | | | | | EW-5 | 250 | | | | |
| | | | | | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| Total | | | 1 | 160 | 7 | 1810 | 1 | 360 | 9 | 2330 |

**Table K-2**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 3 | Focused Extraction | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| | | | EW-D | 250 | | | | | | |
| | | | EW-E | 280 | | | | | | |
| **Total** | | | 6 | 1120 | 3 | 620 | 1 | 240 | **10** | **1980** |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | EW-D | 250 | EW-6 | 230 | | | | |
| | | | EW-E | 280 | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-F | 190 | | | | |
| **Total** | | | 6 | 1170 | 8 | 1770 | 1 | 360 | **15** | **3300** |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | 200 | EW-5 | 250 | | | | |
| | | | EW-D | 250 | EW-6 | 350 | | | | |
| | | | EW-E | 280 | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-F | 190 | | | | |
| **Total** | | | 6 | 1170 | 8 | 2000 | 1 | 360 | **15** | **3530** |

**Table K-2**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| | Focused Extraction and | | | | | | | | | |
| 4 | Soil Excavation | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| | | | EW-D | 250 | | | | | | |
| | | | EW-E | 280 | | | | | | |
| Total | | | 6 | 1120 | 3 | 620 | 1 | 240 | 10 | 1980 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | EW-D | 250 | EW-6 | 230 | | | | |
| | | | EW-E | 280 | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-F | 190 | | | | |
| **Total** | | | **6** | **1170** | **8** | **1770** | **1** | **360** | **15** | **3300** |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | 200 | EW-5 | 250 | | | | |
| | | | EW-D | 250 | EW-6 | 350 | | | | |
| | | | EW-E | 280 | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-F | 190 | | | | |
| **Total** | | | **6** | **1170** | **8** | **2000** | **1** | **360** | **15** | **3530** |

**Table K-2**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 5 | Focused Extraction and Air Sparging | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| **Total** | | | 4 | 590 | 3 | 620 | 1 | 240 | 8 | 1450 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | | | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 1770 | 1 | 360 | 13 | 2770 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | 200 | EW-5 | 250 | | | | |
| | | | | | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 2000 | 1 | 360 | 13 | 3000 |

Table K-2
Specific Groundwater Containment and Extraction Wells Required for Each Alternative

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 6 | Focused Extraction With Air Sparging and Soil Excavation | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| **Total** | | | 4 | 590 | 3 | 620 | 1 | 240 | 8 | 1450 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | | | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 1770 | 1 | 360 | 13 | 2770 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | 200 | EW-5 | 250 | | | | |
| | | | | | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 2000 | 1 | 360 | 13 | 3000 |

**Table K-2**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 7 | Groundwater Extraction | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-6 | 160 | EW-3 | 260 | | | | |
| | | | EW-7 | 250 | EW-4 | 170 | | | | |
| | | | EW-8 | 500 | | | | | | |
| | | | EW-9 | 610 | | | | | | |
| **Total** | | | 5 | 1630 | 3 | 620 | 1 | 240 | **9** | **2490** |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 190 | | | | |
| | | | EW-11 | 250 | EW-4 | 250 | | | | |
| | | | EW-12 | 500 | EW-5 | 230 | | | | |
| | | | EW-13 | 610 | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-14 | 290 | | | | |
| | | | | | EW-15 | 290 | | | | |
| **Total** | | | 5 | 1680 | 9 | 2160 | 1 | 360 | **15** | **4200** |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 160 | | | | |
| | | | EW-11 | 250 | EW-4 | 190 | | | | |
| | | | EW-12 | 500 | EW-5 | 250 | | | | |
| | | | EW-13 | 610 | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-14 | 230 | | | | |
| | | | | | EW-15 | 290 | | | | |
| | | | | | EW-16 | 250 | | | | |
| | | | | | EW-17 | 290 | | | | |
| **Total** | | | 5 | 1680 | 11 | 2870 | 1 | 360 | **17** | **4910** |

**Table K-2**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 8 | Groundwater Extraction and Soil Excavation | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-6 | 160 | EW-3 | 260 | | | | |
| | | | EW-7 | 250 | EW-4 | 170 | | | | |
| | | | EW-8 | 500 | | | | | | |
| | | | EW-9 | 610 | | | | | | |
| **Total** | | | 5 | 1630 | 3 | 620 | 1 | 240 | 9 | 2490 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 190 | | | | |
| | | | EW-11 | 250 | EW-4 | 250 | | | | |
| | | | EW-12 | 500 | EW-5 | 230 | | | | |
| | | | EW-13 | 610 | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-14 | 290 | | | | |
| | | | | | EW-15 | 290 | | | | |
| **Total** | | | 5 | 1680 | 9 | 2160 | 1 | 360 | 15 | 4200 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 160 | | | | |
| | | | EW-11 | 250 | EW-4 | 190 | | | | |
| | | | EW-12 | 500 | EW-5 | 250 | | | | |
| | | | EW-13 | 610 | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-14 | 230 | | | | |
| | | | | | EW-15 | 290 | | | | |
| | | | | | EW-16 | 250 | | | | |
| | | | | | EW-17 | 290 | | | | |
| **Total** | | | 5 | 1680 | 11 | 2870 | 1 | 360 | 17 | 4910 |

# TABLE K-3
# CHEMICALS OF POTENTIAL CONCERN

| Chemical | Target Groundwater Cleanup Goals (μg/L) | | |
|---|---|---|---|
| | I | II | III |
| Trichlorethene | 5[a] | 5[a] | 5[a] |
| RDX | 7.74[c] | 2[e] | 0.774[b] |
| 1,1,1-Trichlorethene | 200[a] | 200[a] | 200[a] |
| 1,2-Dichlorethene (total) | 70[a] | 70[a] | 70[a] |
| 1,2-Dichloropropane | 5[a] | 5[a] | 5[a] |
| Acetone | 1,560[d] | 1,560[d] | 1,560[d] |
| Chloroform | 100[a] | 100[a] | 100[a] |
| Methylene chloride | 5[a] | 5[a] | 5[a] |
| Tetrachloroethene | 5[a] | 5[a] | 5[a] |
| Diethyl phthalate | 12,400[d] | 5,000[e] | 12,400[d] |
| Di-n-butyl phthalate | 1,050[d] | 1,050[d] | 1,050[d] |
| N-Nitrosodiphenylamine | 162[c] | 162[c] | 16.2[b] |
| Phenol | 9,320[d] | 4,000[e] | 9,320[d] |
| TNB | 0.778[d] | 0.778[d] | 0.778[d] |
| TNT | 7.78[d] | 2[e] | 2.82[b] |
| 2,4-DNT | 1.24[c] | 1.24[c] | 0.124[b] |
| HMX | 782[d] | 400[e] | 782[d] |
| Lead | 15[f] | 15[f] | 15[f] |
| Nickel | 100[a] | 100[a] | 100[a] |
| Vanadium | 109[d] | 109[d] | 109[d] |
| Aluminum | None | None | None |
| Tetryl | 370[g] | 370[g] | 370[g] |

Notes:

[a] Drinking Water MCL
[b] Carcinogenic risk of one in one million ($10^{-6}$)
[c] Carcinogenic risk of one in one hundred thousand ($10^{-5}$)
[d] Non-carcinogenic risk
[e] Health advisory
[f] Drinking Water Action Level
[g] Tetryl was not identified in the OU2 BRA as a potential contaminant of concern, thus a site specific health based PRG was not calculated. The value presented is a generic health based value from the EPA Region 9 PRG tables, based on residential exposure to groundwater.

**TABLE K-4**

**SCREENING OF CHEMICALS OF POTENTIAL CONCERN FOR TARGET GROUNDWATER CLEANUP GOAL I**

| Chemical of Potential Concern | Target Groundwater Cleanup Goal I µg/L | Maximum[a] Concentration Detected µg/L | Maximum Concentration Below Target Cleanup Goal I | Retain as Chemical of Concern |
|---|---|---|---|---|
| Trichloroethene (TCE) | 5[a] | 4800 | | Trichloroethene (TCE) |
| RDX | 7.74[b] | 535 | | RDX |
| 1,1,1-Trichloroethane | 200[a] | 2 | below | |
| 1,2-Dichloroethane (total) | 70[a] | 10 | below | |
| 1,2-Dichloropropane | 5[a] | 25 | | 1,2-Dichloropropane |
| Acetone | 1,560[c] | 28 | below | |
| Chloroform | 100[a] | 26 | below | |
| Methylene chloride | 5[a] | 610 | | Methylene chloride |
| Tetrachloroethene | 5[a] | 3 | below | |
| Diethyl phthalate | 12,400[c] | 3 | below | |
| Di-n-butyl phthalate | 1,050[c] | 1 | below | |
| N-Nitrosodiphenylamine | 162[b] | 1 | below | |
| Phenol | 9,320[c] | 9 | below | |
| TNB | 0.778[c] | 2.8 | | TNB |
| TNT | 7.78[c] | 39 | | TNT |
| 2,4-DNT | 1.24[b] | 1.9 | | 2,4-DNT |
| HMX | 782[c] | 57 | below | |

# TABLE K-4

## SCREENING OF CHEMICALS OF POTENTIAL CONCERN FOR TARGET GROUNDWATER CLEANUP GOAL I (CONTINUED)

| Chemical of Potential Concern | Target Groundwater Cleanup Goal I µg/L | Maximum[e] Concentration Detected µg/L | Maximum Concentration Below Target Cleanup Goal I | Retain as Chemical of Concern |
|---|---|---|---|---|
| Lead (total) | 15[d] | 33.2 | | [f] |
| Nickel (total) | 100[a] | 30.1 | below | |
| Vanadium (total) | 109[c] | 53.7 | below | |
| Aluminum (total) | None | 19,700 | not applicable | |
| Tetryl | 370[g] | 5.1 | below | |

Notes:

[a]Drinking Water MCL
[b]Carcinogenic risk of one in one hundred thousand ($10^{-5}$)
[c]Non-carcinogenic risk
[d]Drinking Water Action Level
[e]Refer to Table 1-3 in Volume I, Summary of OU2 Groundwater Monitoring Well Sampling which lists additional details of results
[f]Lead not retained as chemical of concern because concentration exceeding Target Clean Goal I was only detected in one well in November 1992. Subsequent Sampling (Refer Table 1-3 in Volume I) did not find lead concentrations above the Target Cleanup Goal.
[g]Health based value

## TABLE K-5

## SCREENING OF CHEMICALS OF POTENTIAL CONCERN FOR TARGET GROUNDWATER CLEANUP GOAL II

| Chemical of Potential Concern | Target Groundwater Cleanup Goal II µg/L | Maximum[f] Concentration Detected µg/L | Maximum Concentration Below Target Cleanup Goal I | Retain as Chemical of Concern |
|---|---|---|---|---|
| Trichloroethene (TCE) | 5[a] | 4800 | | Trichloroethene (TCE) |
| RDX | 2[b] | 535 | | RDX |
| 1,1,1-Trichloroethane | 200[a] | 2 | below | |
| 1,2-Dichloroethane (total) | 70[a] | 10 | below | |
| 1,2-Dichloropropane | 5[a] | 25 | | 1,2-Dichloropropane |
| Acetone | 1,560[d] | 28 | below | |
| Chloroform | 100[a] | 26 | below | |
| Methylene chloride | 5[a] | 610 | | Methylene chloride |
| Tetrachloroethene | 5[a] | 3 | below | |
| Diethyl phthalate | 5,000[b] | 3 | below | |
| Di-n-butyl phthalate | 1,050[d] | 1 | below | |
| N-Nitrosodiphenylamine | 162[c] | 1 | below | |
| Phenol | 4,000[b] | 9 | below | |
| TNB | 0.778[d] | 2.8 | | TNB |
| TNT | 2[b] | 39 | | TNT |
| 2,4-DNT | 1.24[c] | 1.9 | | 2,4-DNT |
| HMX | 400[b] | 57 | below | |

# TABLE K-5

## SCREENING OF CHEMICALS OF POTENTIAL CONCERN FOR TARGET GROUNDWATER CLEANUP GOAL II (CONTINUED)

| Chemical of Potential Concern | Target Groundwater Cleanup Goal II μg/L | Maximum[f] Concentration Detected μg/L | Maximum Concentration Below Target Cleanup Goal I | Retain as Chemical of Concern |
|---|---|---|---|---|
| Lead (total) | 15[e] | 33.2 | | see not "g" below |
| Nickel (total) | 100[a] | 30.1 | below | |
| Vanadium (total) | 109[d] | 53.7 | below | |
| Aluminum (total) | None | 19,700 | not applicable | |
| Tetryl | 370[h] | 5.1 | below | |

Notes:

- [a] Drinking Water MCL
- [b] Health Advisory
- [c] Carcinogenic risk of one in one hundred thousand ($10^{-5}$)
- [d] Non-carcinogenic risk
- [e] Drinking Water Action Level
- [f] Refer to Table 1-3 in Volume I, Summary of OU2 Groundwater Monitoring Well Sampling which lists additional details of results
- [g] Lead not retained as chemical of concern because concentration exceeding Target Clean Goal I was only detected in one well in November 1992. Subsequent Sampling (Refer Table 1-3 in Volume I) did not find lead concentrations above the Target Cleanup Goal.
- [h] Health based value

## TABLE K-6

## SCREENING OF CHEMICALS OF POTENTIAL CONCERN FOR TARGET GROUNDWATER CLEANUP GOAL III

| Chemical of Potential Concern | Target Groundwater Cleanup Goal I µg/L | Maximum[a] Concentration Detected µg/L | Maximum Concentration Below Target Cleanup Goal I | Retain as Chemcial of Concern |
|---|---|---|---|---|
| Trichloroethene (TCE) | 5[a] | 4800 | | Trichloroethene (TCE) |
| RDX | 0.774[b] | 535 | | RDX |
| 1,1,1-Trichloroethane | 200[a] | 2 | below | |
| 1,2-Dichloroethane (total) | 70[a] | 10 | below | |
| 1,2-Dichloropropane | 5[a] | 25 | | 1,2-Dichloropropane |
| Acetone | 1,560[c] | 28 | below | |
| Chloroform | 100[a] | 26 | below | |
| Methylene chloride | 5[a] | 610 | | Methylene chloride |
| Tetrachloroethene | 5[a] | 3 | below | |
| Diethyl phthalate | 12,400[c] | 3 | below | |
| Di-n-butyl phthalate | 1,050[c] | 1 | below | |
| N-Nitrosodiphenylamine | 16.2[b] | 1 | below | |
| Phenol | 9,320[c] | 9 | below | |
| TNB | 0.778[c] | 2.8 | | TNB |
| TNT | 2.82[b] | 39 | | TNT |
| 2,4-DNT | 0.124[b] | 1.9 | | 2,4-DNT |
| HMX | 782[c] | 57 | below | |

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## TABLE K-6

## SCREENING OF CHEMICALS OF POTENTIAL CONCERN FOR TARGET GROUNDWATER CLEANUP GOAL III (CONTINUED)

| Chemical of Potential Concern | Target Groundwater Cleanup Goal I µg/L | Maximum[e] Concentration Detected µg/L | Maximum Concentration Below Target Cleanup Goal I | Retain as Chemcial of Concern |
|---|---|---|---|---|
| Lead (total) | 15[d] | 33.2 | | see note "f" below |
| Nickel (total) | 100[a] | 30.1 | below | |
| Vanadium (total) | 109[c] | 53.7 | below | |
| Aluminum (total) | None | 19,700 | not applicable | |
| Tetryl | 370[g] | 5.1 | below | |

Notes:

[a] Drinking Water MCL
[b] Carcinogenic risk of one in one million ($10^{-6}$)
[c] Non-carcinogenic risk
[d] Drinking Water Action Level
[e] Refer to Table 1-3 in Volume I, Summary of OU2 Groundwater Monitoring Well Sampling which lists additional details of results
[f] Lead not retained as chemical of concern because concentration exceeding Target Clean Goal I was only detected in one well in November 1992. Subsequent Sampling (Refer Table 1-3 in Volume I) did not find lead concentrations above the Target Cleanup Goal.
[g] Health based value

**TABLE K-7**

**CHEMICALS OF CONCERN**
**FOR TARGET GROUNDWATER CLEANUP GOAL I**

| Chemical | Target Groundwater Cleanup Goal I (μg/L) | Groundwater Monitoring Wells where Groundwater Concentration Exceeds Target Cleanup Goal I | |
|---|---|---|---|
| | | Number of Wells | Monitoring Well[d] Name (MW-__) |
| Trichloroethene (TCE) | 5[a] | 16 | 2, 5, 9, 12, 18, 21, 23, 36, 40, 43, 44, 45, 52, 53, 56, 58, |
| RDX | 7.74[b] | 10 | 2, 4, 5, 11, 21, 29, 33, 43, 52, 53 |
| 1,2-Dichloropropane | 5[a] | 1 | 14 |
| Methylene chloride | 5[a] | 11 | 5, 9, 20, 24, 30, 31, 32, 35, 40, 43, 54 |
| TNB | 0.778[c] | 3 | 2, 5, 29 |
| TNT | 7.78[c] | 2 | 2, 5 |
| 2,4-DNT | 1.24[b] | 1 | 5 |

__Notes:__

[a] MCL
[b] Carcinogenic risk of one in one hundred thousand ($10^{-5}$)
[c] Non-carcinogenic risk
[d] Groundwater monitoring well location name. Distinction not made between shallow, intermediate and deep groundwater extraction well depths because groundwater extraction wells will draw groundwater from multiple depths.

## TABLE K-8

## CHEMICALS OF CONCERN
## FOR TARGET GROUNDWATER CLEANUP GOAL II

| Chemical | Target Groundwater Cleanup Goal II (µg/L) | Groundwater Monitoring Wells where Groundwater Concentration Exceeds Target Cleanup Goal II | |
|---|---|---|---|
| | | Number of Wells | Monitoring Well[e] Name (MW__) |
| Trichloroethane (TCE) | 5[a] | 16 | 2, 5, 9, 12, 18, 21, 23, 36, 40, 43, 44, 45, 52, 53, 56, 58 |
| RDX | 2[b] | 17 | 2, 4, 5, 7, 8, 11, 16, 18, 21, 29, 31, 32, 33, 43, 45, 52, 53 |
| 1,2-Dichloropropane | 5[a] | 1 | 14 |
| Methylene chloride | 5[a] | 11 | 5, 9, 20, 24, 30, 31, 32, 35, 40, 43, 54 |
| TNB | 0.778[c] | 3 | 2, 5, 29 |
| TNT | 2[b] | 3 | 2, 5, 7 |
| 2,4-DNT | 1.24[d] | 1 | 5 |

<u>Notes:</u>

[a] MCL
[b] Health Advisory
[c] Non-carcinogenic risk
[d] Carcinogenic risk of one in one hundred thousand ($10^{-5}$)
[e] Groundwater monitoring well location name. Distinction not made between shallow, intermediate and deep groundwater monitoring well depths because groundwater extraction wells will draw groundwater from multiple depths.

## TABLE K-9

## CHEMICALS OF CONCERN
## FOR TARGET GROUNDWATER CLEANUP GOAL III

| Chemical | Target Groundwater Cleanup Goal III (µg/L) | Groundwater Monitoring Wells where Groundwater Concentration Exceeds Target Cleanup Goal III | |
|---|---|---|---|
| | | Number of Wells | Monitoring Well[d] Name (MW __) |
| Trichloroethane (TCE) | 5[a] | 16 | 2, 5, 9, 12, 18, 21, 23, 36, 40, 43, 44, 45, 52, 53, 56, 58 |
| RDX | 0.774[b] | 25 | 2, 3, 4, 5, 7, 8, 11, 16, 18, 21, 29, 31, 32, 33, 34, 35, 42, 43, 44, 45, 52, 53, 54, 55, 56 |
| 1,2-Dichloropropane | 5[a] | 1 | 14 |
| Methylene chloride | 5[a] | 11 | 5, 9, 20, 24, 30, 31, 32, 35, 40, 43, 54 |
| TNB | 0.778[c] | 3 | 2, 5, 29 |
| TNT | 2.82[b] | 3 | 2, 5, 7 |
| 2,4-DNT | 0.124[b] | 1 | 5 |

<u>Notes</u>:

[a] MCL
[b] Carcinogenic risk of one in one million ($10^{-6}$)
[c] Non-carcinogenic risk
[d] Groundwater monitoring well location name. Distinction not made between shallow, intermediate and deep groundwater monitoring well depths because groundwater extraction wells will draw groundwater from multiple depths.

**TABLE K-10**
**COMPARISON OF CHEMICALS DETECTED IN GROUNDWATER TO DRINKING WATER MAXIMUM CONTAMINANT LEVELS (MCL) AND HEALTH ADVISORIES**

| Chemical Detected | Maximum Concentration (μg/L) | MCL or Ha (μg/L) | Maximum Concentration Above MCL or Ha |
|---|---|---|---|
| Arsenic | 24.8 | 50 | |
| Barium | 691 | 2000 | |
| Beryllium | 1 | 4 | |
| Chromium | 25.2 | 100 | |
| Lead | 33.2 | 15[1] | Above |
| Mercury | 0.33 | 2 | |
| Nickel | 30.1 | 100 | |
| Selenium | 53 | 50 | Above |
| Thallium | 2.4 | 2 | Above |
| Zinc | 92.3 | 2000 | |
| 2,4,6-Trinitrotoluene (TNT) | 39 | 2 | Above |
| HMX | 57 | 400 | |
| RDX | 534 | 2 | Above |
| Buty benzyl phthalate | 1 | 100 | |
| Diethyl phthalate | 3 | 5000 | |
| Phenol | 9 | 4000 | |
| Aldrin | 0.0017 | 0.3 | |
| Alpha chlordane | 0.015 | 2 | |
| Gamma chlordane | 0.015 | 2 | |
| Dieldrin | 0.034 | 2 | |
| Endrin | 0.0038 | 2 | |
| Heptachlor | 0.0019 | 4 | |
| Heptachlor epoxide | 0.0018 | 2 | |
| p,p'-Methoxychlor | 0.12 | 40 | |

## TABLE K-10 (Continued)
## COMPARISON OF CHEMICALS DETECTED IN GROUNDWATER TO DRINKING WATER MAXIMUM CONTAMINANT LEVELS (MCL) AND HEALTH ADVISORIES (HA)

| Chemical Detected | Maximum Concentration ($\mu$g/L) | MCL or Ha ($\mu$g/L) | Maximum Concentration Above MCL or Ha |
|---|---|---|---|
| 1,1,1-Trichloroethane | 2 | 200 | |
| 1,2-Dichloroethane | 0.5 | 5 | |
| 1,2-Dichloroethene (Total) | 10 | 70 | |
| 1,2-Dichloropropane | 25 | 5 | Above |
| Carbon Tetrachloride | 1 | 5 | |
| Chloroform | 26 | 100 | |
| Cis-1,2-Dichloroethene | 23 | 70 | |
| Ethylbenzene | 1 | 700 | |
| Methylene chloride | 610 | 5 | Above |
| Tetrachlorethene | 3 | 5 | |
| Toluene | 30 | 1000 | |
| Trichloroethene (TCE) | 4800 | 5 | Above |
| Xylenes (Total) | 4 | 10,000 | |

Note:

[1] Action Level for Lead

**TABLE K-11**
**CHEMICALS WHOSE GROUNDWATER CONCENTRATIONS EXCEEDED EFFLUENT STANDARDS**

| Chemical | Effluent Standard Drinking Water MCL or HA (μg/L) | Number of Groundwater Monitoring Well Locations in Which MCL or HA Exceeded |
|---|---|---|
| TCE | 5 | 16 |
| RDX | 2 | 16 |
| Methylene Chloride | 5 | 11 |
| TNT | 2 | 3 |
| Total Lead | 15[1] | 1 |
| Selenium | 50 | 1 |
| Thallium | 2 | 1 |
| 1,2-Dichloropropane | 5 | 1 |

Note:

[1] Action Level for Lead

## Table K-12 Associated Monitoring Wells and Extraction Wells

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 2 | I | EW-1 | MW-36A | I |
| 2 | I | EW-1 | MW-36B | S |
| 2 | I | EW-1 | MW-45A | I |
| 2 | I | EW-1 | MW-45B | S |
| 2 | I | EW-2 | MW-33A | I |
| 2 | I | EW-2 | MW-33B | S |
| 2 | I | EW-3 | MW-29A | I |
| 2 | I | EW-3 | MW-29B | S |
| 2 | I | EW-4 | MW-04A | I |
| 2 | I | EW-4 | MW-04B | S |
| 2 | I | EW-4 | MW-05A | I |
| 2 | I | EW-4 | MW-05B | S |
| 2 | I | EW-5 | MW-21A | I |
| 2 | I | EW-5 | MW-21B | S |
| 2 | I | EW-5 | MW-25A | I |
| 2 | I | EW-5 | MW-25B | S |
| 2 | I | EW-5 | MW-03A | I |
| 2 | I | EW-5 | MW-03B | S |
| 2 | I | EW-5 | MW-02A | I |
| 2 | I | EW-5 | MW-02B | S |
| 2 | II | EW-1 | MW-36A | I |
| 2 | II | EW-1 | MW-36B | S |
| 2 | II | EW-1 | MW-45A | I |
| 2 | II | EW-1 | MW-45B | S |
| 2 | II | EW-2 | MW-35A | I |
| 2 | II | EW-2 | MW-35B | S |
| 2 | II | EW-3 | MW-35A | I |
| 2 | II | EW-3 | MW-35B | S |
| 2 | II | EW-4 | MW-34A | I |
| 2 | II | EW-4 | MW-34B | S |
| 2 | II | EW-5 | MW-32A | I |
| 2 | II | EW-5 | MW-32B | S |
| 2 | II | EW-6 | MW-32A | I |
| 2 | II | EW-6 | MW-32B | S |
| 2 | II | EW-7 | MW-29A | I |
| 2 | II | EW-7 | MW-29B | S |
| 2 | II | EW-8 | MW-29A | I |
| 2 | II | EW-8 | MW-29B | S |
| 2 | II | EW-9 | MW-21A | I |
| 2 | II | EW-9 | MW-21B | S |
| 2 | II | EW-9 | MW-25A | I |
| 2 | II | EW-9 | MW-25B | S |
| 2 | II | EW-9 | MW-02A | I |
| 2 | II | EW-9 | MW-02B | S |
| 2 | II | EW-9 | MW-03A | I |
| 2 | II | EW-9 | MW-03B | S |
| 2 | III | EW-1 | MW-36A | I |
| 2 | III | EW-1 | MW-36B | S |
| 2 | III | EW-1 | MW-45A | I |
| 2 | III | EW-1 | MW-45B | S |
| 2 | III | EW-2 | MW-35A | I |
| 2 | III | EW-2 | MW-35B | S |
| 2 | III | EW-3 | MW-35A | I |

## Table K-12 Associated Monitoring Wells and Extraction Wells

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 2 | III | EW-3 | MW-35B | S |
| 2 | III | EW-4 | MW-34A | I |
| 2 | III | EW-4 | MW-34B | S |
| 2 | III | EW-5 | MW-32A | I |
| 2 | III | EW-5 | MW-32B | S |
| 2 | III | EW-6 | MW-32A | I |
| 2 | III | EW-6 | MW-32B | S |
| 2 | III | EW-7 | MW-29A | I |
| 2 | III | EW-7 | MW-29B | S |
| 2 | III | EW-8 | MW-29A | I |
| 2 | III | EW-8 | MW-29B | S |
| 2 | III | EW-9 | MW-21A | I |
| 2 | III | EW-9 | MW-21B | S |
| 2 | III | EW-9 | MW-25A | I |
| 2 | III | EW-9 | MW-25B | S |
| 2 | III | EW-9 | MW-02A | I |
| 2 | III | EW-9 | MW-02B | S |
| 2 | III | EW-9 | MW-03A | I |
| 2 | III | EW-9 | MW-03B | S |
| 3 & 4 | I | EW-1 | MW-36A | I |
| 3 & 4 | I | EW-1 | MW-36B | S |
| 3 & 4 | I | EW-1 | MW-45A | I |
| 3 & 4 | I | EW-1 | MW-45B | S |
| 3 & 4 | I | EW-2 | MW-33A | I |
| 3 & 4 | I | EW-2 | MW-33B | S |
| 3 & 4 | I | EW-3 | MW-29A | I |
| 3 & 4 | I | EW-3 | MW-29B | S |
| 3 & 4 | I | EW-4 | MW-04A | I |
| 3 & 4 | I | EW-4 | MW-04B | S |
| 3 & 4 | I | EW-4 | MW-05A | I |
| 3 & 4 | I | EW-4 | MW-05B | S |
| 3 & 4 | I | EW-5 | MW-21A | I |
| 3 & 4 | I | EW-5 | MW-21B | S |
| 3 & 4 | I | EW-5 | MW-25A | I |
| 3 & 4 | I | EW-5 | MW-25B | S |
| 3 & 4 | I | EW-5 | MW-03A | I |
| 3 & 4 | I | EW-5 | MW-03B | S |
| 3 & 4 | I | EW-5 | MW-02A | I |
| 3 & 4 | I | EW-5 | MW-02B | S |
| 3 & 4 | I | EW-A | MW-44A | I |
| 3 & 4 | I | EW-A | MW-44B | S |
| 3 & 4 | I | EW-B | MW-11A | S |
| 3 & 4 | I | EW-B | MW-18B | I |
| 3 & 4 | I | EW-B | MW-18C | S |
| 3 & 4 | I | EW-B | MW-52A | I |
| 3 & 4 | I | EW-B | MW-52B | S |
| 3 & 4 | I | EW-B | MW-53A | I |
| 3 & 4 | I | EW-B | MW-53B | S |
| 3 & 4 | I | EW-B | MW-54A | I |
| 3 & 4 | I | EW-B | MW-54B | S |
| 3 & 4 | I | EW-B | MW-55A | I |
| 3 & 4 | I | EW-B | MW-55B | S |
| 3 & 4 | I | EW-B | MW-56A | I |

**Table K-12 Associated Monitoring Wells and Extraction Wells**

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 3 & 4 | I | EW-B | MW-56B | S |
| 3 & 4 | I | EW-C | MW-09A | I |
| 3 & 4 | I | EW-C | MW-09B | S |
| 3 & 4 | I | EW-D | MW-40A | I |
| 3 & 4 | I | EW-D | MW-40B | S |
| 3 & 4 | I | EW-E | MW-58A | I |
| 3 & 4 | I | EW-E | MW-58B | S |
| 3 & 4 | II | EW-1 | MW-36A | I |
| 3 & 4 | II | EW-1 | MW-36B | S |
| 3 & 4 | II | EW-1 | MW-45A | I |
| 3 & 4 | II | EW-1 | MW-45B | S |
| 3 & 4 | II | EW-2 | MW-35A | I |
| 3 & 4 | II | EW-2 | MW-35B | S |
| 3 & 4 | II | EW-3 | MW-35A | I |
| 3 & 4 | II | EW-3 | MW-35B | S |
| 3 & 4 | II | EW-4 | MW-34A | I |
| 3 & 4 | II | EW-4 | MW-34B | S |
| 3 & 4 | II | EW-5 | MW-32A | I |
| 3 & 4 | II | EW-5 | MW-32B | S |
| 3 & 4 | II | EW-6 | MW-32A | I |
| 3 & 4 | II | EW-6 | MW-32B | S |
| 3 & 4 | II | EW-7 | MW-29A | I |
| 3 & 4 | II | EW-7 | MW-29B | S |
| 3 & 4 | II | EW-8 | MW-29A | I |
| 3 & 4 | II | EW-8 | MW-29B | S |
| 3 & 4 | II | EW-9 | MW-24A | I |
| 3 & 4 | II | EW-9 | MW-24B | S |
| 3 & 4 | II | EW-9 | MW-25A | I |
| 3 & 4 | II | EW-9 | MW-25B | S |
| 3 & 4 | II | EW-9 | MW-02A | I |
| 3 & 4 | II | EW-9 | MW-02B | S |
| 3 & 4 | II | EW-9 | MW-03A | I |
| 3 & 4 | II | EW-9 | MW-03B | S |
| 3 & 4 | II | EW-A | MW-44A | I |
| 3 & 4 | II | EW-A | MW-44B | S |
| 3 & 4 | II | EW-B | MW-11A | S |
| 3 & 4 | II | EW-B | MW-18B | I |
| 3 & 4 | II | EW-B | MW-18C | S |
| 3 & 4 | II | EW-B | MW-52A | I |
| 3 & 4 | II | EW-B | MW-52B | S |
| 3 & 4 | II | EW-B | MW-53A | I |
| 3 & 4 | II | EW-B | MW-53B | S |
| 3 & 4 | II | EW-B | MW-54A | I |
| 3 & 4 | II | EW-B | MW-54B | S |
| 3 & 4 | II | EW-B | MW-55A | I |
| 3 & 4 | II | EW-B | MW-55B | S |
| 3 & 4 | II | EW-B | MW-56A | I |
| 3 & 4 | II | EW-B | MW-56B | S |
| 3 & 4 | II | EW-C | MW-09A | I |
| 3 & 4 | II | EW-C | MW-09B | S |
| 3 & 4 | II | EW-D | MW-40A | I |
| 3 & 4 | II | EW-D | MW-40B | S |
| 3 & 4 | II | EW-E | MW-58A | I |

## Table K-12 Associated Monitoring Wells and Extraction Wells

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 3 & 4 | II | EW-E | MW-58B | S |
| 3 & 4 | II | EW-F | MW-04A | I |
| 3 & 4 | II | EW-F | MW-04B | S |
| 3 & 4 | II | EW-F | MW-05A | I |
| 3 & 4 | II | EW-F | MW-05B | S |
| 3 & 4 | III | EW-1 | MW-36A | I |
| 3 & 4 | III | EW-1 | MW-36B | S |
| 3 & 4 | III | EW-1 | MW-45A | I |
| 3 & 4 | III | EW-1 | MW-45B | S |
| 3 & 4 | III | EW-2 | MW-35A | I |
| 3 & 4 | III | EW-2 | MW-35B | S |
| 3 & 4 | III | EW-3 | MW-35A | I |
| 3 & 4 | III | EW-3 | MW-35B | S |
| 3 & 4 | III | EW-4 | MW-34A | I |
| 3 & 4 | III | EW-4 | MW-34B | S |
| 3 & 4 | III | EW-5 | MW-32A | I |
| 3 & 4 | III | EW-5 | MW-32B | S |
| 3 & 4 | III | EW-6 | MW-32A | I |
| 3 & 4 | III | EW-6 | MW-32B | S |
| 3 & 4 | III | EW-7 | MW-29A | I |
| 3 & 4 | III | EW-7 | MW-29B | S |
| 3 & 4 | III | EW-8 | MW-29A | I |
| 3 & 4 | III | EW-8 | MW-29B | S |
| 3 & 4 | III | EW-9 | MW-24A | I |
| 3 & 4 | III | EW-9 | MW-24B | S |
| 3 & 4 | III | EW-9 | MW-25A | I |
| 3 & 4 | III | EW-9 | MW-25B | S |
| 3 & 4 | III | EW-9 | MW-02A | I |
| 3 & 4 | III | EW-9 | MW-02B | S |
| 3 & 4 | III | EW-9 | MW-03A | I |
| 3 & 4 | III | EW-9 | MW-03B | S |
| 3 & 4 | III | EW-A | MW-44A | I |
| 3 & 4 | III | EW-A | MW-44B | S |
| 3 & 4 | III | EW-B | MW-11A | S |
| 3 & 4 | III | EW-B | MW-18B | I |
| 3 & 4 | III | EW-B | MW-18C | S |
| 3 & 4 | III | EW-B | MW-52A | I |
| 3 & 4 | III | EW-B | MW-52B | S |
| 3 & 4 | III | EW-B | MW-53A | I |
| 3 & 4 | III | EW-B | MW-53B | S |
| 3 & 4 | III | EW-B | MW-54A | I |
| 3 & 4 | III | EW-B | MW-54B | S |
| 3 & 4 | III | EW-B | MW-55A | I |
| 3 & 4 | III | EW-B | MW-55B | S |
| 3 & 4 | III | EW-B | MW-56A | I |
| 3 & 4 | III | EW-B | MW=56B | S |
| 3 & 4 | III | EW-C | MW-09A | I |
| 3 & 4 | III | EW-C | MW-09B | S |
| 3 & 4 | III | EW-D | MW-40A | I |
| 3 & 4 | III | EW-D | MW-40B | S |
| 3 & 4 | III | EW-E | MW-58A | I |
| 3 & 4 | III | EW-E | MW-58B | S |
| 3 & 4 | III | EW-F | MW-04A | I |

## Table K-12 Associated Monitoring Wells and Extraction Wells

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 3 & 4 | III | EW-F | MW-04B | S |
| 3 & 4 | III | EW-F | MW-05A | I |
| 3 & 4 | III | EW-F | MW-05B | S |
| 5 & 6 | I | EW-1 | MW-36A | I |
| 5 & 6 | I | EW-1 | MW-36B | S |
| 5 & 6 | I | EW-1 | MW-45A | I |
| 5 & 6 | I | EW-1 | MW-45B | S |
| 5 & 6 | I | EW-2 | MW-33A | I |
| 5 & 6 | I | EW-2 | MW-33B | S |
| 5 & 6 | I | EW-3 | MW-29A | I |
| 5 & 6 | I | EW-3 | MW-29B | S |
| 5 & 6 | I | EW-4 | MW-04A | I |
| 5 & 6 | I | EW-4 | MW-04B | S |
| 5 & 6 | I | EW-4 | MW-05A | I |
| 5 & 6 | I | EW-4 | MW-05B | S |
| 5 & 6 | I | EW-5 | MW-21A | I |
| 5 & 6 | I | EW-5 | MW-21B | S |
| 5 & 6 | I | EW-5 | MW-25A | I |
| 5 & 6 | I | EW-5 | MW-25B | S |
| 5 & 6 | I | EW-5 | MW-03A | I |
| 5 & 6 | I | EW-5 | MW-03B | S |
| 5 & 6 | I | EW-5 | MW-02A | I |
| 5 & 6 | I | EW-5 | MW-02B | S |
| 5 & 6 | I | EW-A | MW-44A | I |
| 5 & 6 | I | EW-A | MW-44B | S |
| 5 & 6 | I | EW-B | MW-11A | S |
| 5 & 6 | I | EW-B | MW-18B | I |
| 5 & 6 | I | EW-B | MW-18C | S |
| 5 & 6 | I | EW-B | MW-52A | I |
| 5 & 6 | I | EW-B | MW-52B | S |
| 5 & 6 | I | EW-B | MW-53A | I |
| 5 & 6 | I | EW-B | MW-53B | S |
| 5 & 6 | I | EW-B | MW-54A | I |
| 5 & 6 | I | EW-B | MW-54B | S |
| 5 & 6 | I | EW-B | MW-55A | I |
| 5 & 6 | I | EW-B | MW-55B | S |
| 5 & 6 | I | EW-B | MW-56A | I |
| 5 & 6 | I | EW-B | MW-56B | S |
| 5 & 6 | I | EW-C | MW-09A | I |
| 5 & 6 | I | EW-C | MW-09B | S |
| 5 & 6 | II | EW-1 | MW-36A | I |
| 5 & 6 | II | EW-1 | MW-36B | S |
| 5 & 6 | II | EW-1 | MW-45A | I |
| 5 & 6 | II | EW-1 | MW-45B | S |
| 5 & 6 | II | EW-2 | MW-35A | I |
| 5 & 6 | II | EW-2 | MW-35B | S |
| 5 & 6 | II | EW-3 | MW-35A | I |
| 5 & 6 | II | EW-3 | MW-35B | S |
| 5 & 6 | II | EW-4 | MW-33A | I |
| 5 & 6 | II | EW-4 | MW-33B | S |
| 5 & 6 | II | EW-5 | MW-32A | I |
| 5 & 6 | II | EW-5 | MW-32B | S |
| 5 & 6 | II | EW-6 | MW-32A | I |

## Table K-12 Associated Monitoring Wells and Extraction Wells

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 5 & 6 | II | EW-6 | MW-32B | S |
| 5 & 6 | II | EW-7 | MW-29A | I |
| 5 & 6 | II | EW-7 | MW-29B | S |
| 5 & 6 | II | EW-8 | MW-29A | I |
| 5 & 6 | II | EW-8 | MW-29B | S |
| 5 & 6 | II | EW-9 | MW-21A | I |
| 5 & 6 | II | EW-9 | MW-21B | S |
| 5 & 6 | II | EW-9 | MW-25A | I |
| 5 & 6 | II | EW-9 | MW-25B | S |
| 5 & 6 | II | EW-9 | MW-02A | I |
| 5 & 6 | II | EW-9 | MW-02B | S |
| 5 & 6 | II | EW-9 | MW-03A | I |
| 5 & 6 | II | EW-9 | MW-03B | S |
| 5 & 6 | II | EW-A | MW-44A | I |
| 5 & 6 | II | EW-A | MW-44B | S |
| 5 & 6 | II | EW-B | MW-11A | S |
| 5 & 6 | II | EW-B | MW-18B | I |
| 5 & 6 | II | EW-B | MW-18C | S |
| 5 & 6 | II | EW-B | MW-52A | I |
| 5 & 6 | II | EW-B | MW-52B | S |
| 5 & 6 | II | EW-B | MW-53A | I |
| 5 & 6 | II | EW-B | MW-53B | S |
| 5 & 6 | II | EW-B | MW-54A | I |
| 5 & 6 | II | EW-B | MW-54B | S |
| 5 & 6 | II | EW-B | MW-55A | I |
| 5 & 6 | II | EW-B | MW-55B | S |
| 5 & 6 | II | EW-B | MW-56A | I |
| 5 & 6 | II | EW-B | MW-56B | S |
| 5 & 6 | II | EW-C | MW-09A | I |
| 5 & 6 | II | EW-C | MW-09B | S |
| 5 & 6 | II | EW-D | MW-04A | I |
| 5 & 6 | II | EW-D | MW-04B | S |
| 5 & 6 | II | EW-D | MW-05A | I |
| 5 & 6 | II | EW-D | MW-05B | S |
| 5 & 6 | III | EW-1 | MW-36A | I |
| 5 & 6 | III | EW-1 | MW-36B | S |
| 5 & 6 | III | EW-1 | MW-45A | I |
| 5 & 6 | III | EW-1 | MW-45B | S |
| 5 & 6 | III | EW-2 | MW-35A | I |
| 5 & 6 | III | EW-2 | MW-35B | S |
| 5 & 6 | III | EW-3 | MW-35A | I |
| 5 & 6 | III | EW-3 | MW-35B | S |
| 5 & 6 | III | EW-4 | MW-34A | I |
| 5 & 6 | III | EW-4 | MW-34B | S |
| 5 & 6 | III | EW-5 | MW-32A | I |
| 5 & 6 | III | EW-5 | MW-32B | S |
| 5 & 6 | III | EW-6 | MW-32A | I |
| 5 & 6 | III | EW-6 | MW-32B | S |
| 5 & 6 | III | EW-7 | MW-29A | I |
| 5 & 6 | III | EW-7 | MW-29B | S |
| 5 & 6 | III | EW-8 | MW-29A | I |
| 5 & 6 | III | EW-8 | MW-29B | S |
| 5 & 6 | III | EW-9 | MW-24A | I |

Table K-12 Associated Monitoring Wells and Extraction Wells

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 5 & 6 | III | EW-9 | MW-24B | S |
| 5 & 6 | III | EW-9 | MW-25A | I |
| 5 & 6 | III | EW-9 | MW-25B | S |
| 5 & 6 | III | EW-9 | MW-02A | I |
| 5 & 6 | III | EW-9 | MW-02B | S |
| 5 & 6 | III | EW-9 | MW-03A | I |
| 5 & 6 | III | EW-9 | MW-03B | S |
| 5 & 6 | III | EW-A | MW-44A | I |
| 5 & 6 | III | EW-A | MW-44B | S |
| 5 & 6 | III | EW-B | MW-11A | S |
| 5 & 6 | III | EW-B | MW-18B | I |
| 5 & 6 | III | EW-B | MW-18C | S |
| 5 & 6 | III | EW-B | MW-52A | I |
| 5 & 6 | III | EW-B | MW-52B | S |
| 5 & 6 | III | EW-B | MW-53A | I |
| 5 & 6 | III | EW-B | MW-53B | S |
| 5 & 6 | III | EW-B | MW-54A | I |
| 5 & 6 | III | EW-B | MW-54B | S |
| 5 & 6 | III | EW-B | MW-55A | I |
| 5 & 6 | III | EW-B | MW-55B | S |
| 5 & 6 | III | EW-B | MW-56A | I |
| 5 & 6 | III | EW-B | MW-56B | S |
| 5 & 6 | III | EW-C | MW-09A | I |
| 5 & 6 | III | EW-C | MW-09B | S |
| 5 & 6 | III | EW-D | MW-04A | I |
| 5 & 6 | III | EW-D | MW-04B | S |
| 5 & 6 | III | EW-D | MW-05A | I |
| 5 & 6 | III | EW-D | MW-05B | S |
| 7 & 8 | I | EW-1 | MW-36A | I |
| 7 & 8 | I | EW-1 | MW-36B | S |
| 7 & 8 | I | EW-1 | MW-45A | I |
| 7 & 8 | I | EW-1 | MW-45B | S |
| 7 & 8 | I | EW-2 | MW-33A | I |
| 7 & 8 | I | EW-2 | MW-33B | S |
| 7 & 8 | I | EW-3 | MW-29A | I |
| 7 & 8 | I | EW-3 | MW-29B | S |
| 7 & 8 | I | EW-4 | MW-04A | I |
| 7 & 8 | I | EW-4 | MW-04B | S |
| 7 & 8 | I | EW-4 | MW-05A | I |
| 7 & 8 | I | EW-4 | MW-05B | S |
| 7 & 8 | I | EW-4 | MW-31A | I |
| 7 & 8 | I | EW-4 | MW-31B | S |
| 7 & 8 | I | EW-5 | MW-21A | I |
| 7 & 8 | I | EW-5 | MW-21B | S |
| 7 & 8 | I | EW-5 | MW-25A | I |
| 7 & 8 | I | EW-5 | MW-25B | S |
| 7 & 8 | I | EW-5 | MW-03A | I |
| 7 & 8 | I | EW-5 | MW-03B | S |
| 7 & 8 | I | EW-5 | MW-02A | I |
| 7 & 8 | I | EW-5 | MW-02B | S |
| 7 & 8 | I | EW-6 | MW-44A | I |
| 7 & 8 | I | EW-6 | MW-44B | S |
| 7 & 8 | I | EW-7 | MW-43A | I |

## Table K-12 Associated Monitoring Wells and Extraction Wells

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 7 & 8 | I | EW-7 | MW-43B | S |
| 7 & 8 | I | EW-7 | MW-18B | I |
| 7 & 8 | I | EW-7 | MW-18C | S |
| 7 & 8 | I | EW-8 | MW-11A | S |
| 7 & 8 | I | EW-8 | MW-52A | I |
| 7 & 8 | I | EW-8 | MW-52B | S |
| 7 & 8 | I | EW-8 | MW-09A | I |
| 7 & 8 | I | EW-8 | MW-09B | S |
| 7 & 8 | I | EW-9 | MW-40A | I |
| 7 & 8 | I | EW-9 | MW-40B | S |
| 7 & 8 | I | EW-9 | MW-58A | I |
| 7 & 8 | I | EW-9 | MW-58B | S |
| 7 & 8 | II | EW-1 | MW-36A | I |
| 7 & 8 | II | EW-1 | MW-36B | S |
| 7 & 8 | II | EW-1 | MW-45A | I |
| 7 & 8 | II | EW-1 | MW-45B | S |
| 7 & 8 | II | EW-2 | MW-35A | I |
| 7 & 8 | II | EW-2 | MW-35B | S |
| 7 & 8 | II | EW-3 | MW-35A | I |
| 7 & 8 | II | EW-3 | MW-35B | S |
| 7 & 8 | II | EW-4 | MW-34A | I |
| 7 & 8 | II | EW-4 | MW-34B | S |
| 7 & 8 | II | EW-5 | MW-32A | I |
| 7 & 8 | II | EW-5 | MW-32B | S |
| 7 & 8 | II | EW-6 | MW-32A | I |
| 7 & 8 | II | EW-6 | MW-32B | S |
| 7 & 8 | II | EW-7 | MW-29A | I |
| 7 & 8 | II | EW-7 | MW-29B | S |
| 7 & 8 | II | EW-8 | MW-29A | I |
| 7 & 8 | II | EW-8 | MW-29B | S |
| 7 & 8 | II | EW-9 | MW-21A | I |
| 7 & 8 | II | EW-9 | MW-21B | S |
| 7 & 8 | II | EW-9 | MW-25A | I |
| 7 & 8 | II | EW-9 | MW-25B | S |
| 7 & 8 | II | EW-9 | MW-03A | I |
| 7 & 8 | II | EW-9 | MW-03B | S |
| 7 & 8 | II | EW-9 | MW-02A | I |
| 7 & 8 | II | EW-9 | MW-02B | S |
| 7 & 8 | II | EW-10 | MW-44A | I |
| 7 & 8 | II | EW-10 | MW-44B | S |
| 7 & 8 | II | EW-11 | MW-18B | I |
| 7 & 8 | II | EW-11 | MW-18C | S |
| 7 & 8 | II | EW-12 | MW-11A | S |
| 7 & 8 | II | EW-12 | MW-52A | I |
| 7 & 8 | II | EW-12 | MW-52B | S |
| 7 & 8 | II | EW-12 | MW-09A | I |
| 7 & 8 | II | EW-12 | MW-09B | S |
| 7 & 8 | II | EW-13 | MW-40A | I |
| 7 & 8 | II | EW-13 | MW-40B | S |
| 7 & 8 | II | EW-13 | MW-58A | I |
| 7 & 8 | II | EW-13 | MW-58B | S |
| 7 & 8 | II | EW-14 | MW-33A | I |
| 7 & 8 | II | EW-14 | MW-33B | S |

**Table K-12 Associated Monitoring Wells and Extraction Wells**

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 7 & 8 | II | EW-14 | MW-04A | I |
| 7 & 8 | II | EW-14 | MW-04B | S |
| 7 & 8 | II | EW-14 | MW-05A | I |
| 7 & 8 | II | EW-14 | MW-05B | S |
| 7 & 8 | III | EW-1 | MW-36A | I |
| 7 & 8 | III | EW-1 | MW-36B | S |
| 7 & 8 | III | EW-1 | MW-45A | I |
| 7 & 8 | III | EW-1 | MW-45B | S |
| 7 & 8 | III | EW-2 | MW-35A | I |
| 7 & 8 | III | EW-2 | MW-35B | S |
| 7 & 8 | III | EW-3 | MW-35A | I |
| 7 & 8 | III | EW-3 | MW-35B | S |
| 7 & 8 | III | EW-4 | MW-34A | I |
| 7 & 8 | III | EW-4 | MW-34B | S |
| 7 & 8 | III | EW-5 | MW-32A | I |
| 7 & 8 | III | EW-5 | MW-32B | S |
| 7 & 8 | III | EW-6 | MW-32A | I |
| 7 & 8 | III | EW-6 | MW-32B | S |
| 7 & 8 | III | EW-7 | MW-29A | I |
| 7 & 8 | III | EW-7 | MW-29B | S |
| 7 & 8 | III | EW-8 | MW-29A | I |
| 7 & 8 | III | EW-8 | MW-29B | S |
| 7 & 8 | III | EW-9 | MW-24A | I |
| 7 & 8 | III | EW-9 | MW-24B | S |
| 7 & 8 | III | EW-9 | MW-21A | I |
| 7 & 8 | III | EW-9 | MW-21B | S |
| 7 & 8 | III | EW-9 | MW-25A | I |
| 7 & 8 | III | EW-9 | MW-25B | S |
| 7 & 8 | III | EW-9 | MW-03A | I |
| 7 & 8 | III | EW-9 | MW-03B | S |
| 7 & 8 | III | EW-9 | MW-02A | I |
| 7 & 8 | III | EW-9 | MW-02B | S |
| 7 & 8 | III | EW-10 | MW-44A | I |
| 7 & 8 | III | EW-10 | MW-44B | S |
| 7 & 8 | III | EW-11 | MW-43A | I |
| 7 & 8 | III | EW-11 | MW-43B | S |
| 7 & 8 | III | EW-11 | MW-18B | I |
| 7 & 8 | III | EW-11 | MW-18C | S |
| 7 & 8 | III | EW-12 | MW-11A | S |
| 7 & 8 | III | EW-12 | MW-52A | I |
| 7 & 8 | III | EW-12 | MW-52B | S |
| 7 & 8 | III | EW-12 | MW-09A | I |
| 7 & 8 | III | EW-12 | MW-09B | S |
| 7 & 8 | III | EW-13 | MW-58A | I |
| 7 & 8 | III | EW-13 | MW-58B | S |
| 7 & 8 | III | EW-13 | MW-40A | I |
| 7 & 8 | III | EW-13 | MW-40B | S |
| 7 & 8 | III | EW-14 | MW-08A | I |
| 7 & 8 | III | EW-14 | MW-08B | S |
| 7 & 8 | III | EW-15 | MW-33A | I |
| 7 & 8 | III | EW-15 | MW-33B | S |
| 7 & 8 | III | EW-16 | MW-31A | I |
| 7 & 8 | III | EW-16 | MW-31B | S |

**Table K-12 Associated Monitoring Wells and Extraction Wells**

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Monitoring Well | Screen Interval (3) |
|---|---|---|---|---|
| 7 & 8 | III | EW-17 | MW-04A | I |
| 7 & 8 | III | EW-17 | MW-04B | S |
| 7 & 8 | III | EW-17 | MW-05A | I |
| 7 & 8 | III | EW-17 | MW-05B | S |

Notes:
(1) Detailed Descriptions of the Remedial Alternatives are included in Volume I.
(2) Detailed Target Clean Up Goals are included in Volume I.
(3) I = Intermediate Interval, S = Shallow Interval

Table K-13
Weight Factor Allocation for Monitoring Well Clusters

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Pumping Rate for the Extraction Well (GPM) | Total Pumpage for the Alternative (GPM) | Monitoring Well Cluster | Allocated Pumpage for Each Monitoring Well (GPM) | Weight Factor (Wi) (%) (3) |
|---|---|---|---|---|---|---|---|
| 2 | I | EW-1 | 110 | 970 | MW-36 | 55 | 6 |
| 2 | I | EW-1 | | | MW-45 | 55 | 6 |
| 2 | I | EW-2 | 190 | | MW-33 | 190 | 20 |
| 2 | I | EW-3 | 260 | | MW-29 | 260 | 27 |
| 2 | I | EW-4 | 170 | | MW-04 | 85 | 9 |
| 2 | I | EW-4 | | | MW-05 | 85 | 9 |
| 2 | I | EW-5 | 240 | | MW-21 | 60 | 6 |
| 2 | I | EW-5 | | | MW-25 | 60 | 6 |
| 2 | I | EW-5 | | | MW-03 | 60 | 6 |
| 2 | I | EW-5 | | | MW-02 | 60 | 6 |
| 2 | II | EW-1 | 160 | 2100 | MW-36 | 80 | 4 |
| 2 | II | EW-1 | | | MW-45 | 80 | 4 |
| 2 | II | EW-2 | 160 | | MW-35 | 160 | 8 |
| 2 | II | EW-3 | 190 | | MW-35 | 190 | 9 |
| 2 | II | EW-4 | 250 | | MW-34 | 250 | 12 |
| 2 | II | EW-5 | 230 | | MW-32 | 230 | 11 |
| 2 | II | EW-6 | 230 | | MW-32 | 230 | 11 |
| 2 | II | EW-7 | 230 | | MW-29 | 230 | 11 |
| 2 | II | EW-8 | 290 | | MW-29 | 290 | 14 |
| 2 | II | EW-9 | 360 | | MW-21 | 90 | 4 |
| 2 | II | EW-9 | | | MW-25 | 90 | 4 |
| 2 | II | EW-9 | | | MW-02 | 90 | 4 |
| 2 | II | EW-9 | | | MW-03 | 90 | 4 |
| 2 | III | EW-1 | 160 | 2330 | MW-36 | 80 | 3 |
| 2 | III | EW-1 | | | MW-45 | 80 | 3 |
| 2 | III | EW-2 | 160 | | MW-35 | 160 | 7 |
| 2 | III | EW-3 | 160 | | MW-35 | 160 | 7 |
| 2 | III | EW-4 | 190 | | MW-34 | 190 | 8 |
| 2 | III | EW-5 | 250 | | MW-32 | 250 | 11 |
| 2 | III | EW-6 | 350 | | MW-32 | 350 | 15 |
| 2 | III | EW-7 | 350 | | MW-29 | 350 | 15 |
| 2 | III | EW-8 | 350 | | MW-29 | 350 | 15 |
| 2 | III | EW-9 | 360 | | MW-21 | 90 | 4 |
| 2 | III | EW-9 | | | MW-25 | 90 | 4 |
| 2 | III | EW-9 | | | MW-02 | 90 | 4 |
| 2 | III | EW-9 | | | MW-03 | 90 | 4 |
| 3 & 4 | I | EW-1 | 110 | 1980 | MW-36 | 55 | 3 |
| 3 & 4 | I | EW-1 | | | MW-45 | 55 | 3 |
| 3 & 4 | I | EW-2 | 190 | | MW-33 | 190 | 10 |
| 3 & 4 | I | EW-3 | 260 | | MW-29 | 260 | 13 |
| 3 & 4 | I | EW-4 | 170 | | MW-04 | 85 | 4 |
| 3 & 4 | I | EW-4 | | | MW-05 | 85 | 4 |
| 3 & 4 | I | EW-5 | 240 | | MW-21 | 60 | 3 |
| 3 & 4 | I | EW-5 | | | MW-25 | 60 | 3 |
| 3 & 4 | I | EW-5 | | | MW-03 | 60 | 3 |
| 3 & 4 | I | EW-5 | | | MW-02 | 60 | 3 |
| 3 & 4 | I | EW-A | 110 | | MW-44 | 110 | 6 |
| 3 & 4 | I | EW-B | 170 | | MW-11 | 24 | 1 |
| 3 & 4 | I | EW-B | | | MW-18 | 24 | 1 |
| 3 & 4 | I | EW-B | | | MW-52 | 24 | 1 |
| 3 & 4 | I | EW-B | | | MW-53 | 24 | 1 |
| 3 & 4 | I | EW-B | | | MW-54 | 24 | 1 |
| 3 & 4 | I | EW-B | | | MW-55 | 24 | 1 |
| 3 & 4 | I | EW-B | | | MW-56 | 26 | 1 |
| 3 & 4 | I | EW-C | 200 | | MW-09 | 200 | 10 |
| 3 & 4 | I | EW-D | 250 | | MW-40 | 250 | 13 |
| 3 & 4 | I | EW-E | 280 | | MW-58 | 280 | 14 |
| 3 & 4 | II | EW-1 | 160 | 3300 | MW-36 | 80 | 2 |
| 3 & 4 | II | EW-1 | | | MW-45 | 80 | 2 |
| 3 & 4 | II | EW-2 | 160 | | MW-35 | 160 | 5 |
| 3 & 4 | II | EW-3 | 190 | | MW-35 | 190 | 6 |
| 3 & 4 | II | EW-4 | 250 | | MW-34 | 250 | 8 |
| 3 & 4 | II | EW-5 | 230 | | MW-32 | 230 | 7 |
| 3 & 4 | II | EW-6 | 230 | | MW-32 | 230 | 7 |
| 3 & 4 | II | EW-7 | 230 | | MW-29 | 230 | 7 |
| 3 & 4 | II | EW-8 | 290 | | MW-29 | 290 | 9 |
| 3 & 4 | II | EW-9 | 360 | | MW-24 | 90 | 3 |

Table K-13
Weight Factor Allocation for Monitoring Well Clusters

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Pumping Rate for the Extraction Well (GPM) | Total Pumpage for the Alternative (GPM) | Monitoring Well Cluster | Allocated Pumpage for Each Monitoring Well (GPM) | Weight Factor (Wi) (%) (3) |
|---|---|---|---|---|---|---|---|
| 3 & 4 | II | EW-9 | | | MW-25 | 90 | 3 |
| 3 & 4 | II | EW-9 | | | MW-02 | 90 | 3 |
| 3 & 4 | II | EW-9 | | | MW-03 | 90 | 3 |
| 3 & 4 | II | EW-A | 110 | | MW-44 | 110 | 3 |
| 3 & 4 | II | EW-B | 170 | | MW-11 | 24 | 1 |
| 3 & 4 | II | EW-B | | | MW-18 | 24 | 1 |
| 3 & 4 | II | EW-B | | | MW-52 | 24 | 1 |
| 3 & 4 | II | EW-B | | | MW-53 | 24 | 1 |
| 3 & 4 | II | EW-B | | | MW-54 | 24 | 1 |
| 3 & 4 | II | EW-B | | | MW-55 | 24 | 1 |
| 3 & 4 | II | EW-B | | | MW-56 | 26 | 1 |
| 3 & 4 | II | EW-C | 200 | | MW-09 | 200 | 6 |
| 3 & 4 | II | EW-D | 250 | | MW-40 | 250 | 8 |
| 3 & 4 | II | EW-E | 280 | | MW-58 | 280 | 8 |
| 3 & 4 | II | EW-F | 190 | | MW-04 | 95 | 3 |
| 3 & 4 | II | EW-F | | | MW-05 | 95 | 3 |
| 3 & 4 | III | EW-1 | 160 | 3530 | MW-36 | 80 | 2 |
| 3 & 4 | III | EW-1 | | | MW-45 | 80 | 2 |
| 3 & 4 | III | EW-2 | 160 | | MW-35 | 160 | 5 |
| 3 & 4 | III | EW-3 | 160 | | MW-35 | 160 | 5 |
| 3 & 4 | III | EW-4 | 190 | | MW-34 | 190 | 5 |
| 3 & 4 | III | EW-5 | 250 | | MW-32 | 250 | 7 |
| 3 & 4 | III | EW-6 | 350 | | MW-32 | 350 | 10 |
| 3 & 4 | III | EW-7 | 350 | | MW-29 | 350 | 10 |
| 3 & 4 | III | EW-8 | 350 | | MW-29 | 350 | 10 |
| 3 & 4 | III | EW-9 | 360 | | MW-24 | 90 | 3 |
| 3 & 4 | III | EW-9 | | | MW-25 | 90 | 3 |
| 3 & 4 | III | EW-9 | | | MW-02 | 90 | 3 |
| 3 & 4 | III | EW-9 | | | MW-03 | 90 | 3 |
| 3 & 4 | III | EW-A | 110 | | MW-44 | 110 | 3 |
| 3 & 4 | III | EW-B | 170 | | MW-11 | 24 | 1 |
| 3 & 4 | III | EW-B | | | MW-18 | 24 | 1 |
| 3 & 4 | III | EW-B | | | MW-52 | 24 | 1 |
| 3 & 4 | III | EW-B | | | MW-53 | 24 | 1 |
| 3 & 4 | III | EW-B | | | MW-54 | 24 | 1 |
| 3 & 4 | III | EW-B | | | MW-55 | 24 | 1 |
| 3 & 4 | III | EW-B | | | MW-56 | 26 | 1 |
| 3 & 4 | III | EW-C | 200 | | MW-09 | 200 | 6 |
| 3 & 4 | III | EW-D | 250 | | MW-40 | 250 | 7 |
| 3 & 4 | III | EW-E | 280 | | MW-58 | 280 | 8 |
| 3 & 4 | III | EW-F | 190 | | MW-04 | 95 | 3 |
| 3 & 4 | III | EW-F | | | MW-05 | 95 | 3 |
| 5 & 6 | I | EW-1 | 110 | 1450 | MW-36 | 55 | 4 |
| 5 & 6 | I | EW-1 | | | MW-45 | 55 | 4 |
| 5 & 6 | I | EW-2 | 190 | | MW-33 | 190 | 13 |
| 5 & 6 | I | EW-3 | 260 | | MW-29 | 260 | 18 |
| 5 & 6 | I | EW-4 | 170 | | MW-04 | 85 | 6 |
| 5 & 6 | I | EW-4 | | | MW-05 | 85 | 6 |
| 5 & 6 | I | EW-5 | 240 | | MW-21 | 60 | 4 |
| 5 & 6 | I | EW-5 | | | MW-25 | 60 | 4 |
| 5 & 6 | I | EW-5 | | | MW-03 | 60 | 4 |
| 5 & 6 | I | EW-5 | | | MW-02 | 60 | 4 |
| 5 & 6 | I | EW-A | 110 | | MW-44 | 110 | 8 |
| 5 & 6 | I | EW-B | 170 | | MW-11 | 24 | 2 |
| 5 & 6 | I | EW-B | | | MW-18 | 24 | 2 |
| 5 & 6 | I | EW-B | | | MW-52 | 24 | 2 |
| 5 & 6 | I | EW-B | | | MW-53 | 24 | 2 |
| 5 & 6 | I | EW-B | | | MW-54 | 24 | 2 |
| 5 & 6 | I | EW-B | | | MW-55 | 24 | 2 |
| 5 & 6 | I | EW-B | | | MW-56 | 26 | 2 |
| 5 & 6 | I | EW-C | 200 | | MW-09 | 200 | 14 |
| 5 & 6 | II | EW-1 | 160 | 2770 | MW-36 | 80 | 3 |
| 5 & 6 | II | EW-1 | | | MW-45 | 80 | 3 |
| 5 & 6 | II | EW-2 | 160 | | MW-35 | 160 | 6 |
| 5 & 6 | II | EW-3 | 190 | | MW-35 | 190 | 7 |
| 5 & 6 | II | EW-4 | 250 | | MW-33 | 250 | 9 |
| 5 & 6 | II | EW-5 | 230 | | MW-32 | 230 | 8 |
| 5 & 6 | II | EW-6 | 230 | | MW-32 | 230 | 8 |

Table K-13
Weight Factor Allocation for Monitoring Well Clusters

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Pumping Rate for the Extraction Well (GPM) | Total Pumpage for the Alternative (GPM) | Monitoring Well Cluster | Allocated Pumpage for Each Monitoring Well (GPM) | Weight Factor (Wi) (%) (3) |
|---|---|---|---|---|---|---|---|
| 5 & 6 | II | EW-7 | 230 | | MW-29 | 230 | 8 |
| 5 & 6 | II | EW-8 | 290 | | MW-29 | 290 | 10 |
| 5 & 6 | II | EW-9 | 360 | | MW-21 | 90 | 3 |
| 5 & 6 | II | EW-9 | | | MW-25 | 90 | 3 |
| 5 & 6 | II | EW-9 | | | MW-02 | 90 | 3 |
| 5 & 6 | II | EW-9 | | | MW-03 | 90 | 3 |
| 5 & 6 | II | EW-A | 110 | | MW-44 | 110 | 4 |
| 5 & 6 | II | EW-B | 170 | | MW-11 | 24 | 1 |
| 5 & 6 | II | EW-B | | | MW-18 | 24 | 1 |
| 5 & 6 | II | EW-B | | | MW-52 | 24 | 1 |
| 5 & 6 | II | EW-B | | | MW-53 | 24 | 1 |
| 5 & 6 | II | EW-B | | | MW-54 | 24 | 1 |
| 5 & 6 | II | EW-B | | | MW-55 | 24 | 1 |
| 5 & 6 | II | EW-B | | | MW-56 | 26 | 1 |
| 5 & 6 | II | EW-C | 200 | | MW-09 | 200 | 7 |
| 5 & 6 | II | EW-D | 190 | | MW-04 | 95 | 3 |
| 5 & 6 | II | EW-D | | | MW-05 | 95 | 3 |
| 5 & 6 | III | EW-1 | 160 | 3000 | MW-36 | 80 | 3 |
| 5 & 6 | III | EW-1 | | | MW-45 | 80 | 3 |
| 5 & 6 | III | EW-2 | 160 | | MW-35 | 160 | 5 |
| 5 & 6 | III | EW-3 | 160 | | MW-35 | 160 | 5 |
| 5 & 6 | III | EW-4 | 190 | | MW-34 | 190 | 6 |
| 5 & 6 | III | EW-5 | 250 | | MW-32 | 250 | 8 |
| 5 & 6 | III | EW-6 | 350 | | MW-32 | 350 | 12 |
| 5 & 6 | III | EW-7 | 350 | | MW-29 | 350 | 12 |
| 5 & 6 | III | EW-8 | 350 | | MW-29 | 350 | 12 |
| 5 & 6 | III | EW-9 | 360 | | MW-24 | 90 | 3 |
| 5 & 6 | III | EW-9 | | | MW-25 | 90 | 3 |
| 5 & 6 | III | EW-9 | | | MW-02 | 90 | 3 |
| 5 & 6 | III | EW-9 | | | MW-03 | 90 | 3 |
| 5 & 6 | III | EW-A | 110 | | MW-44 | 110 | 4 |
| 5 & 6 | III | EW-B | 170 | | MW-11 | 24 | 1 |
| 5 & 6 | III | EW-B | | | MW-18 | 24 | 1 |
| 5 & 6 | III | EW-B | | | MW-52 | 24 | 1 |
| 5 & 6 | III | EW-B | | | MW-53 | 24 | 1 |
| 5 & 6 | III | EW-B | | | MW-54 | 24 | 1 |
| 5 & 6 | III | EW-B | | | MW-55 | 24 | 1 |
| 5 & 6 | III | EW-B | | | MW-56 | 26 | 1 |
| 5 & 6 | III | EW-C | 200 | | MW-09 | 200 | 7 |
| 5 & 6 | III | EW-D | 190 | | MW-04 | 95 | 3 |
| 5 & 6 | III | EW-D | | | MW-05 | 95 | 3 |
| 7 & 8 | I | EW-1 | 110 | 2490 | MW-36 | 55 | 2 |
| 7 & 8 | I | EW-1 | | | MW-45 | 55 | 2 |
| 7 & 8 | I | EW-2 | 190 | | MW-33 | 190 | 8 |
| 7 & 8 | I | EW-3 | 260 | | MW-29 | 260 | 10 |
| 7 & 8 | I | EW-4 | 170 | | MW-04 | 57 | 2 |
| 7 & 8 | I | EW-4 | | | MW-05 | 57 | 2 |
| 7 & 8 | I | EW-4 | | | MW-31 | 56 | 2 |
| 7 & 8 | I | EW-5 | 240 | | MW-21 | 60 | 2 |
| 7 & 8 | I | EW-5 | | | MW-25 | 60 | 2 |
| 7 & 8 | I | EW-5 | | | MW-03 | 60 | 2 |
| 7 & 8 | I | EW-5 | | | MW-02 | 60 | 2 |
| 7 & 8 | I | EW-6 | 160 | | MW-44 | 160 | 6 |
| 7 & 8 | I | EW-7 | 250 | | MW-43 | 125 | 5 |
| 7 & 8 | I | EW-7 | | | MW-18 | 125 | 5 |
| 7 & 8 | I | EW-8 | 500 | | MW-11 | 166 | 7 |
| 7 & 8 | I | EW-8 | | | MW-52 | 167 | 7 |
| 7 & 8 | I | EW-8 | | | MW-09 | 167 | 7 |
| 7 & 8 | I | EW-9 | 610 | | MW-40 | 305 | 12 |
| 7 & 8 | I | EW-9 | | | MW-58 | 305 | 12 |
| 7 & 8 | II | EW-1 | 160 | 4200 | MW-36 | 80 | 2 |
| 7 & 8 | II | EW-1 | | | MW-45 | 80 | 2 |
| 7 & 8 | II | EW-2 | 160 | | MW-35 | 160 | 4 |
| 7 & 8 | II | EW-3 | 190 | | MW-35 | 190 | 5 |
| 7 & 8 | II | EW-4 | 250 | | MW-34 | 250 | 6 |
| 7 & 8 | II | EW-5 | 230 | | MW-32 | 230 | 5 |
| 7 & 8 | II | EW-6 | 230 | | MW-32 | 230 | 5 |
| 7 & 8 | II | EW-7 | 230 | | MW-29 | 230 | 5 |

Table K-13
Weight Factor Allocation for Monitoring Well Clusters

| Alternative No. (1) | Target Cleanup Goal (2) | Extraction Well | Pumping Rate for the Extraction Well (GPM) | Total Pumpage for the Alternative (GPM) | Monitoring Well Cluster | Allocated Pumpage for Each Monitoring Well (GPM) | Weight Factor (Wi) (%) (3) |
|---|---|---|---|---|---|---|---|
| 7 & 8 | II | EW-8 | 290 | | MW-29 | 290 | 7 |
| 7 & 8 | II | EW-9 | 360 | | MW-21 | 90 | 2 |
| 7 & 8 | II | EW-9 | | | MW-25 | 90 | 2 |
| 7 & 8 | II | EW-9 | | | MW-03 | 90 | 2 |
| 7 & 8 | II | EW-9 | | | MW-02 | 90 | 2 |
| 7 & 8 | II | EW-10 | 160 | | MW-44 | 160 | 4 |
| 7 & 8 | II | EW-11 | 250 | | MW-18 | 250 | 6 |
| 7 & 8 | II | EW-12 | 500 | | MW-11 | 166 | 4 |
| 7 & 8 | II | EW-12 | | | MW-52 | 167 | 4 |
| 7 & 8 | II | EW-12 | | | MW-09 | 167 | 4 |
| 7 & 8 | II | EW-13 | 610 | | MW-40 | 305 | 7 |
| 7 & 8 | II | EW-13 | | | MW-58 | 305 | 7 |
| 7 & 8 | II | EW-14 | 290 | | MW-33 | 290 | 7 |
| 7 & 8 | II | EW-15 | 290 | | MW-04 | 145 | 3 |
| 7 & 8 | II | EW-15 | | | MW-05 | 145 | 3 |
| 7 & 8 | III | EW-1 | 160 | 4910 | MW-36 | 80 | 2 |
| 7 & 8 | III | EW-1 | | | MW-45 | 80 | 2 |
| 7 & 8 | III | EW-2 | 160 | | MW-35 | 160 | 3 |
| 7 & 8 | III | EW-3 | 160 | | MW-35 | 160 | 3 |
| 7 & 8 | III | EW-4 | 190 | | MW-34 | 190 | 4 |
| 7 & 8 | III | EW-5 | 250 | | MW-32 | 250 | 5 |
| 7 & 8 | III | EW-6 | 350 | | MW-32 | 350 | 7 |
| 7 & 8 | III | EW-7 | 350 | | MW-29 | 350 | 7 |
| 7 & 8 | III | EW-8 | 350 | | MW-29 | 350 | 7 |
| 7 & 8 | III | EW-9 | 360 | | MW-24 | 72 | 1 |
| 7 & 8 | III | EW-9 | | | MW-21 | 72 | 1 |
| 7 & 8 | III | EW-9 | | | MW-25 | 72 | 1 |
| 7 & 8 | III | EW-9 | | | MW-03 | 72 | 1 |
| 7 & 8 | III | EW-9 | | | MW-02 | 72 | 1 |
| 7 & 8 | III | EW-10 | 160 | | MW-44 | 160 | 3 |
| 7 & 8 | III | EW-11 | 250 | | MW-43 | 125 | 3 |
| 7 & 8 | III | EW-11 | | | MW-18 | 125 | 3 |
| 7 & 8 | III | EW-12 | 500 | | MW-11 | 166 | 3 |
| 7 & 8 | III | EW-12 | | | MW-52 | 167 | 3 |
| 7 & 8 | III | EW-12 | | | MW-09 | 167 | 3 |
| 7 & 8 | III | EW-13 | 610 | | MW-58 | 305 | 6 |
| 7 & 8 | III | EW-13 | | | MW-40 | 305 | 6 |
| 7 & 8 | III | EW-14 | 230 | | MW-08 | 230 | 5 |
| 7 & 8 | III | EW-15 | 290 | | MW-33 | 290 | 6 |
| 7 & 8 | III | EW-16 | 250 | | MW-31 | 250 | 5 |
| 7 & 8 | III | EW-17 | 290 | | MW-04 | 145 | 3 |
| 7 & 8 | III | EW-17 | | | MW-05 | 145 | 3 |

Notes:
(1) Detailed Descriptions of the Remedial Alternatives are included in Volume I.
(2) Detailed Target Clean Up Goals are included in Volume I.
(3) Allocated Pumpage for Each Monitoring Well divided by the Total Pumpage for the Alternative.

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 2 | I | MW-02 | 6% | Aug 1992 | EXPL | RDX | 3.435 | 0.212 |
| 2 | I | MW-02 | 6% | Aug 1992 | VOC | TCE | 70.5 | 4.361 |
| 2 | I | MW-02 | 6% | Nov 1992 | EXPL | RDX | 6.105 | 0.378 |
| 2 | I | MW-02 | 6% | Nov 1992 | VOC | TCE | 69.5 | 4.299 |
| 2 | I | MW-02 | 6% | Feb 1993 | EXPL | RDX | 9.12 | 0.564 |
| 2 | I | MW-02 | 6% | Feb 1993 | VOC | TCE | 103.5 | 6.402 |
| 2 | I | MW-02 | 6% | May 1993 | EXPL | RDX | 8.6 | 0.532 |
| 2 | I | MW-02 | 6% | May 1993 | VOC | TCE | 80.5 | 4.979 |
| 2 | I | MW-03 | 6% | Aug 1992 | EXPL | RDX | 0.37 | 0.023 |
| 2 | I | MW-03 | 6% | Aug 1992 | VOC | TCE | | |
| 2 | I | MW-03 | 6% | Nov 1992 | EXPL | RDX | 0.765 | 0.047 |
| 2 | I | MW-03 | 6% | Nov 1992 | VOC | TCE | | |
| 2 | I | MW-03 | 6% | Feb 1993 | EXPL | RDX | 0.985 | 0.061 |
| 2 | I | MW-03 | 6% | Feb 1993 | VOC | TCE | | |
| 2 | I | MW-03 | 6% | May 1993 | EXPL | RDX | 1.185 | 0.073 |
| 2 | I | MW-03 | 6% | May 1993 | VOC | TCE | | |
| 2 | I | MW-04 | 9% | Aug 1992 | EXPL | RDX | 2.33 | 0.204 |
| 2 | I | MW-04 | 9% | Aug 1992 | VOC | TCE | | |
| 2 | I | MW-04 | 9% | Nov 1992 | EXPL | RDX | 7.4 | 0.648 |
| 2 | I | MW-04 | 9% | Nov 1992 | VOC | TCE | | |
| 2 | I | MW-04 | 9% | Feb 1993 | EXPL | RDX | 5.68 | 0.498 |
| 2 | I | MW-04 | 9% | Feb 1993 | VOC | TCE | | |
| 2 | I | MW-04 | 9% | May 1993 | EXPL | RDX | 8.565 | 0.751 |
| 2 | I | MW-04 | 9% | May 1993 | VOC | TCE | | |
| 2 | I | MW-05 | 9% | Aug 1992 | EXPL | RDX | 98 | 8.588 |
| 2 | I | MW-05 | 9% | Aug 1992 | VOC | TCE | 4 | 0.351 |
| 2 | I | MW-05 | 9% | Nov 1992 | EXPL | RDX | 160.38 | 14.054 |
| 2 | I | MW-05 | 9% | Nov 1992 | VOC | TCE | 7 | 0.613 |
| 2 | I | MW-05 | 9% | Feb 1993 | EXPL | RDX | 320 | 28.041 |
| 2 | I | MW-05 | 9% | Feb 1993 | VOC | TCE | 6 | 0.526 |
| 2 | I | MW-05 | 9% | May 1993 | EXPL | RDX | 534 | 46.794 |
| 2 | I | MW-05 | 9% | May 1993 | VOC | TCE | 6 | 0.526 |
| 2 | I | MW-21 | 6% | Aug 1992 | EXPL | RDX | 10 | 0.619 |
| 2 | I | MW-21 | 6% | Aug 1992 | VOC | TCE | 140 | 8.660 |
| 2 | I | MW-21 | 6% | Nov 1992 | EXPL | RDX | 11 | 0.680 |
| 2 | I | MW-21 | 6% | Nov 1992 | VOC | TCE | 140 | 8.660 |
| 2 | I | MW-21 | 6% | Feb 1993 | EXPL | RDX | 18 | 1.113 |
| 2 | I | MW-21 | 6% | Feb 1993 | VOC | TCE | 130 | 8.041 |
| 2 | I | MW-21 | 6% | May 1993 | EXPL | RDX | 16 | 0.990 |
| 2 | I | MW-21 | 6% | May 1993 | VOC | TCE | 110 | 6.804 |
| 2 | I | MW-25 | 6% | Aug 1992 | EXPL | RDX | | |
| 2 | I | MW-25 | 6% | Aug 1992 | VOC | TCE | | |
| 2 | I | MW-25 | 6% | Nov 1992 | EXPL | RDX | | |
| 2 | I | MW-25 | 6% | Nov 1992 | VOC | TCE | | |
| 2 | I | MW-25 | 6% | Feb 1993 | EXPL | RDX | | |
| 2 | I | MW-25 | 6% | Feb 1993 | VOC | TCE | | |
| 2 | I | MW-25 | 6% | May 1993 | EXPL | RDX | | |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 2 | I | MW-25 | 6% | May 1993 | VOC | TCE | | |
| 2 | I | MW-29 | 27% | Aug 1992 | EXPL | RDX | 4.4 | 1.179 |
| 2 | I | MW-29 | 27% | Aug 1992 | VOC | TCE | | |
| 2 | I | MW-29 | 27% | Nov 1992 | EXPL | RDX | 6.1 | 1.635 |
| 2 | I | MW-29 | 27% | Nov 1992 | VOC | TCE | | |
| 2 | I | MW-29 | 27% | Feb 1993 | EXPL | RDX | 6.4 | 1.715 |
| 2 | I | MW-29 | 27% | Feb 1993 | VOC | TCE | | |
| 2 | I | MW-29 | 27% | May 1993 | EXPL | RDX | 8.6 | 2.305 |
| 2 | I | MW-29 | 27% | May 1993 | VOC | TCE | | |
| 2 | I | MW-33 | 20% | Aug 1992 | EXPL | RDX | 5.5 | 1.077 |
| 2 | I | MW-33 | 20% | Aug 1992 | VOC | TCE | 1 | 0.196 |
| 2 | I | MW-33 | 20% | Nov 1992 | EXPL | RDX | 8.55 | 1.675 |
| 2 | I | MW-33 | 20% | Nov 1992 | VOC | TCE | 1 | 0.196 |
| 2 | I | MW-33 | 20% | Feb 1993 | EXPL | RDX | 10.8 | 2.115 |
| 2 | I | MW-33 | 20% | Feb 1993 | VOC | TCE | | |
| 2 | I | MW-33 | 20% | May 1993 | EXPL | RDX | 8.85 | 1.734 |
| 2 | I | MW-33 | 20% | May 1993 | VOC | TCE | 1 | 0.196 |
| 2 | I | MW-36 | 6% | Aug 1992 | EXPL | RDX | | |
| 2 | I | MW-36 | 6% | Aug 1992 | VOC | TCE | 25 | 1.418 |
| 2 | I | MW-36 | 6% | Nov 1992 | EXPL | RDX | | |
| 2 | I | MW-36 | 6% | Nov 1992 | VOC | TCE | 37.5 | 2.126 |
| 2 | I | MW-36 | 6% | Feb 1993 | EXPL | RDX | | |
| 2 | I | MW-36 | 6% | Feb 1993 | VOC | TCE | 55.5 | 3.147 |
| 2 | I | MW-36 | 6% | May 1993 | EXPL | RDX | | |
| 2 | I | MW-36 | 6% | May 1993 | VOC | TCE | 58.5 | 3.317 |
| 2 | I | MW-45 | 6% | Aug 1992 | EXPL | RDX | 0.73 | 0.041 |
| 2 | I | MW-45 | 6% | Aug 1992 | VOC | TCE | 62.5 | 3.544 |
| 2 | I | MW-45 | 6% | Nov 1992 | EXPL | RDX | 3.75 | 0.213 |
| 2 | I | MW-45 | 6% | Nov 1992 | VOC | TCE | 18 | 1.021 |
| 2 | I | MW-45 | 6% | Feb 1993 | EXPL | RDX | 3.1 | 0.176 |
| 2 | I | MW-45 | 6% | Feb 1993 | VOC | TCE | 48 | 2.722 |
| 2 | I | MW-45 | 6% | May 1993 | EXPL | RDX | 4.8 | 0.272 |
| 2 | I | MW-45 | 6% | May 1993 | VOC | TCE | 83.5 | 4.735 |
| 2 | II | MW-02 | 4% | Aug 1992 | EXPL | RDX | 3.435 | 0.147 |
| 2 | II | MW-02 | 4% | Aug 1992 | VOC | TCE | 70.5 | 3.021 |
| 2 | II | MW-02 | 4% | Nov 1992 | EXPL | RDX | 6.105 | 0.262 |
| 2 | II | MW-02 | 4% | Nov 1992 | VOC | TCE | 69.5 | 2.979 |
| 2 | II | MW-02 | 4% | Feb 1993 | EXPL | RDX | 9.12 | 0.391 |
| 2 | II | MW-02 | 4% | Feb 1993 | VOC | TCE | 103.5 | 4.436 |
| 2 | II | MW-02 | 4% | May 1993 | EXPL | RDX | 8.6 | 0.369 |
| 2 | II | MW-02 | 4% | May 1993 | VOC | TCE | 80.5 | 3.450 |
| 2 | II | MW-03 | 4% | Aug 1992 | EXPL | RDX | 0.37 | 0.016 |
| 2 | II | MW-03 | 4% | Aug 1992 | VOC | TCE | | |
| 2 | II | MW-03 | 4% | Nov 1992 | EXPL | RDX | 0.765 | 0.033 |
| 2 | II | MW-03 | 4% | Nov 1992 | VOC | TCE | | |
| 2 | II | MW-03 | 4% | Feb 1993 | EXPL | RDX | 0.985 | 0.042 |
| 2 | II | MW-03 | 4% | Feb 1993 | VOC | TCE | | |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 2 | II | MW-03 | 4% | May 1993 | EXPL | RDX | 1.185 | 0.051 |
| 2 | II | MW-03 | 4% | May 1993 | VOC | TCE | | |
| 2 | II | MW-21 | 4% | Aug 1992 | EXPL | RDX | 10 | 0.429 |
| 2 | II | MW-21 | 4% | Aug 1992 | VOC | TCE | 140 | 6.000 |
| 2 | II | MW-21 | 4% | Nov 1992 | EXPL | RDX | 11 | 0.471 |
| 2 | II | MW-21 | 4% | Nov 1992 | VOC | TCE | 140 | 6.000 |
| 2 | II | MW-21 | 4% | Feb 1993 | EXPL | RDX | 18 | 0.771 |
| 2 | II | MW-21 | 4% | Feb 1993 | VOC | TCE | 130 | 5.571 |
| 2 | II | MW-21 | 4% | May 1993 | EXPL | RDX | 16 | 0.686 |
| 2 | II | MW-21 | 4% | May 1993 | VOC | TCE | 110 | 4.714 |
| 2 | II | MW-25 | 4% | Aug 1992 | EXPL | RDX | | |
| 2 | II | MW-25 | 4% | Aug 1992 | VOC | TCE | | |
| 2 | II | MW-25 | 4% | Nov 1992 | EXPL | RDX | | |
| 2 | II | MW-25 | 4% | Nov 1992 | VOC | TCE | | |
| 2 | II | MW-25 | 4% | Feb 1993 | EXPL | RDX | | |
| 2 | II | MW-25 | 4% | Feb 1993 | VOC | TCE | | |
| 2 | II | MW-25 | 4% | May 1993 | EXPL | RDX | | |
| 2 | II | MW-25 | 4% | May 1993 | VOC | TCE | | |
| 2 | II | MW-29 | 25% | Aug 1992 | EXPL | RDX | 4.4 | 1.090 |
| 2 | II | MW-29 | 25% | Aug 1992 | VOC | TCE | | |
| 2 | II | MW-29 | 25% | Nov 1992 | EXPL | RDX | 6.1 | 1.510 |
| 2 | II | MW-29 | 25% | Nov 1992 | VOC | TCE | | |
| 2 | II | MW-29 | 25% | Feb 1993 | EXPL | RDX | 6.4 | 1.585 |
| 2 | II | MW-29 | 25% | Feb 1993 | VOC | TCE | | |
| 2 | II | MW-29 | 25% | May 1993 | EXPL | RDX | 8.6 | 2.130 |
| 2 | II | MW-29 | 25% | May 1993 | VOC | TCE | | |
| 2 | II | MW-32 | 22% | Aug 1992 | EXPL | RDX | 2.03 | 0.445 |
| 2 | II | MW-32 | 22% | Aug 1992 | VOC | TCE | | |
| 2 | II | MW-32 | 22% | Nov 1992 | EXPL | RDX | 2.365 | 0.518 |
| 2 | II | MW-32 | 22% | Nov 1992 | VOC | TCE | | |
| 2 | II | MW-32 | 22% | Feb 1993 | EXPL | RDX | 3.28 | 0.718 |
| 2 | II | MW-32 | 22% | Feb 1993 | VOC | TCE | | |
| 2 | II | MW-32 | 22% | May 1993 | EXPL | RDX | 3.725 | 0.816 |
| 2 | II | MW-32 | 22% | May 1993 | VOC | TCE | | |
| 2 | II | MW-34 | 12% | Aug 1992 | EXPL | RDX | 0.91 | 0.108 |
| 2 | II | MW-34 | 12% | Aug 1992 | VOC | TCE | | |
| 2 | II | MW-34 | 12% | Nov 1992 | EXPL | RDX | 0.95 | 0.113 |
| 2 | II | MW-34 | 12% | Nov 1992 | VOC | TCE | | |
| 2 | II | MW-34 | 12% | Feb 1993 | EXPL | RDX | 1.6 | 0.190 |
| 2 | II | MW-34 | 12% | Feb 1993 | VOC | TCE | | |
| 2 | II | MW-34 | 12% | May 1993 | EXPL | RDX | 1.6 | 0.190 |
| 2 | II | MW-34 | 12% | May 1993 | VOC | TCE | | |
| 2 | II | MW-35 | 17% | Aug 1992 | EXPL | RDX | 0.34 | 0.057 |
| 2 | II | MW-35 | 17% | Aug 1992 | VOC | TCE | | |
| 2 | II | MW-35 | 17% | Nov 1992 | EXPL | RDX | 0.63 | 0.105 |
| 2 | II | MW-35 | 17% | Nov 1992 | VOC | TCE | | |
| 2 | II | MW-35 | 17% | Feb 1993 | EXPL | RDX | 0.75 | 0.125 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 2 | II | MW-35 | 17% | Feb 1993 | VOC | TCE | | |
| 2 | II | MW-35 | 17% | May 1993 | EXPL | RDX | 0.86 | 0.143 |
| 2 | II | MW-35 | 17% | May 1993 | VOC | TCE | | |
| 2 | II | MW-36 | 4% | Aug 1992 | EXPL | RDX | | |
| 2 | II | MW-36 | 4% | Aug 1992 | VOC | TCE | 25 | 0.952 |
| 2 | II | MW-36 | 4% | Nov 1992 | EXPL | RDX | | |
| 2 | II | MW-36 | 4% | Nov 1992 | VOC | TCE | 37.5 | 1.429 |
| 2 | II | MW-36 | 4% | Feb 1993 | EXPL | RDX | | |
| 2 | II | MW-36 | 4% | Feb 1993 | VOC | TCE | 55.5 | 2.114 |
| 2 | II | MW-36 | 4% | May 1993 | EXPL | RDX | | |
| 2 | II | MW-36 | 4% | May 1993 | VOC | TCE | 58.5 | 2.229 |
| 2 | II | MW-45 | 4% | Aug 1992 | EXPL | RDX | 0.73 | 0.028 |
| 2 | II | MW-45 | 4% | Aug 1992 | VOC | TCE | 62.5 | 2.381 |
| 2 | II | MW-45 | 4% | Nov 1992 | EXPL | RDX | 3.75 | 0.143 |
| 2 | II | MW-45 | 4% | Nov 1992 | VOC | TCE | 18 | 0.686 |
| 2 | II | MW-45 | 4% | Feb 1993 | EXPL | RDX | 3.1 | 0.118 |
| 2 | II | MW-45 | 4% | Feb 1993 | VOC | TCE | 48 | 1.829 |
| 2 | II | MW-45 | 4% | May 1993 | EXPL | RDX | 4.8 | 0.183 |
| 2 | II | MW-45 | 4% | May 1993 | VOC | TCE | 83.5 | 3.181 |
| 2 | III | MW-02 | 4% | Aug 1992 | EXPL | RDX | 3.435 | 0.133 |
| 2 | III | MW-02 | 4% | Aug 1992 | VOC | TCE | 70.5 | 2.723 |
| 2 | III | MW-02 | 4% | Nov 1992 | EXPL | RDX | 6.105 | 0.236 |
| 2 | III | MW-02 | 4% | Nov 1992 | VOC | TCE | 69.5 | 2.685 |
| 2 | III | MW-02 | 4% | Feb 1993 | EXPL | RDX | 9.12 | 0.352 |
| 2 | III | MW-02 | 4% | Feb 1993 | VOC | TCE | 103.5 | 3.998 |
| 2 | III | MW-02 | 4% | May 1993 | EXPL | RDX | 8.6 | 0.332 |
| 2 | III | MW-02 | 4% | May 1993 | VOC | TCE | 80.5 | 3.109 |
| 2 | III | MW-03 | 4% | Aug 1992 | EXPL | RDX | 0.37 | 0.014 |
| 2 | III | MW-03 | 4% | Aug 1992 | VOC | TCE | | |
| 2 | III | MW-03 | 4% | Nov 1992 | EXPL | RDX | 0.765 | 0.030 |
| 2 | III | MW-03 | 4% | Nov 1992 | VOC | TCE | | |
| 2 | III | MW-03 | 4% | Feb 1993 | EXPL | RDX | 0.985 | 0.038 |
| 2 | III | MW-03 | 4% | Feb 1993 | VOC | TCE | | |
| 2 | III | MW-03 | 4% | May 1993 | EXPL | RDX | 1.185 | 0.046 |
| 2 | III | MW-03 | 4% | May 1993 | VOC | TCE | | |
| 2 | III | MW-21 | 4% | Aug 1992 | EXPL | RDX | 10 | 0.386 |
| 2 | III | MW-21 | 4% | Aug 1992 | VOC | TCE | 140 | 5.408 |
| 2 | III | MW-21 | 4% | Nov 1992 | EXPL | RDX | 11 | 0.425 |
| 2 | III | MW-21 | 4% | Nov 1992 | VOC | TCE | 140 | 5.408 |
| 2 | III | MW-21 | 4% | Feb 1993 | EXPL | RDX | 18 | 0.695 |
| 2 | III | MW-21 | 4% | Feb 1993 | VOC | TCE | 130 | 5.021 |
| 2 | III | MW-21 | 4% | May 1993 | EXPL | RDX | 16 | 0.618 |
| 2 | III | MW-21 | 4% | May 1993 | VOC | TCE | 110 | 4.249 |
| 2 | III | MW-25 | 4% | Aug 1992 | EXPL | RDX | | |
| 2 | III | MW-25 | 4% | Aug 1992 | VOC | TCE | | |
| 2 | III | MW-25 | 4% | Nov 1992 | EXPL | RDX | | |
| 2 | III | MW-25 | 4% | Nov 1992 | VOC | TCE | | |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 2 | III | MW-25 | 4% | Feb 1993 | EXPL | RDX | | |
| 2 | III | MW-25 | 4% | Feb 1993 | VOC | TCE | | |
| 2 | III | MW-25 | 4% | May 1993 | EXPL | RDX | | |
| 2 | III | MW-25 | 4% | May 1993 | VOC | TCE | | |
| 2 | III | MW-29 | 30% | Aug 1992 | EXPL | RDX | 4.4 | 1.322 |
| 2 | III | MW-29 | 30% | Aug 1992 | VOC | TCE | | |
| 2 | III | MW-29 | 30% | Nov 1992 | EXPL | RDX | 6.1 | 1.833 |
| 2 | III | MW-29 | 30% | Nov 1992 | VOC | TCE | | |
| 2 | III | MW-29 | 30% | Feb 1993 | EXPL | RDX | 6.4 | 1.923 |
| 2 | III | MW-29 | 30% | Feb 1993 | VOC | TCE | | |
| 2 | III | MW-29 | 30% | May 1993 | EXPL | RDX | 8.6 | 2.584 |
| 2 | III | MW-29 | 30% | May 1993 | VOC | TCE | | |
| 2 | III | MW-32 | 26% | Aug 1992 | EXPL | RDX | 2.03 | 0.523 |
| 2 | III | MW-32 | 26% | Aug 1992 | VOC | TCE | | |
| 2 | III | MW-32 | 26% | Nov 1992 | EXPL | RDX | 2.365 | 0.609 |
| 2 | III | MW-32 | 26% | Nov 1992 | VOC | TCE | | |
| 2 | III | MW-32 | 26% | Feb 1993 | EXPL | RDX | 3.28 | 0.845 |
| 2 | III | MW-32 | 26% | Feb 1993 | VOC | TCE | | |
| 2 | III | MW-32 | 26% | May 1993 | EXPL | RDX | 3.725 | 0.959 |
| 2 | III | MW-32 | 26% | May 1993 | VOC | TCE | | |
| 2 | III | MW-34 | 8% | Aug 1992 | EXPL | RDX | 0.91 | 0.074 |
| 2 | III | MW-34 | 8% | Aug 1992 | VOC | TCE | | |
| 2 | III | MW-34 | 8% | Nov 1992 | EXPL | RDX | 0.95 | 0.077 |
| 2 | III | MW-34 | 8% | Nov 1992 | VOC | TCE | | |
| 2 | III | MW-34 | 8% | Feb 1993 | EXPL | RDX | 1.6 | 0.130 |
| 2 | III | MW-34 | 8% | Feb 1993 | VOC | TCE | | |
| 2 | III | MW-34 | 8% | May 1993 | EXPL | RDX | 1.6 | 0.130 |
| 2 | III | MW-34 | 8% | May 1993 | VOC | TCE | | |
| 2 | III | MW-35 | 14% | Aug 1992 | EXPL | RDX | 0.34 | 0.047 |
| 2 | III | MW-35 | 14% | Aug 1992 | VOC | TCE | | |
| 2 | III | MW-35 | 14% | Nov 1992 | EXPL | RDX | 0.63 | 0.087 |
| 2 | III | MW-35 | 14% | Nov 1992 | VOC | TCE | | |
| 2 | III | MW-35 | 14% | Feb 1993 | EXPL | RDX | 0.75 | 0.103 |
| 2 | III | MW-35 | 14% | Feb 1993 | VOC | TCE | | |
| 2 | III | MW-35 | 14% | May 1993 | EXPL | RDX | 0.86 | 0.118 |
| 2 | III | MW-35 | 14% | May 1993 | VOC | TCE | | |
| 2 | III | MW-36 | 3% | Aug 1992 | EXPL | RDX | | |
| 2 | III | MW-36 | 3% | Aug 1992 | VOC | TCE | 25 | 0.858 |
| 2 | III | MW-36 | 3% | Nov 1992 | EXPL | RDX | | |
| 2 | III | MW-36 | 3% | Nov 1992 | VOC | TCE | 37.5 | 1.288 |
| 2 | III | MW-36 | 3% | Feb 1993 | EXPL | RDX | | |
| 2 | III | MW-36 | 3% | Feb 1993 | VOC | TCE | 55.5 | 1.906 |
| 2 | III | MW-36 | 3% | May 1993 | EXPL | RDX | | |
| 2 | III | MW-36 | 3% | May 1993 | VOC | TCE | 58.5 | 2.009 |
| 2 | III | MW-45 | 3% | Aug 1992 | EXPL | RDX | 0.73 | 0.025 |
| 2 | III | MW-45 | 3% | Aug 1992 | VOC | TCE | 62.5 | 2.146 |
| 2 | III | MW-45 | 3% | Nov 1992 | EXPL | RDX | 3.75 | 0.129 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 2 | III | MW-45 | 3% | Nov 1992 | VOC | TCE | 18 | 0.618 |
| 2 | III | MW-45 | 3% | Feb 1993 | EXPL | RDX | 3.1 | 0.106 |
| 2 | III | MW-45 | 3% | Feb 1993 | VOC | TCE | 48 | 1.648 |
| 2 | III | MW-45 | 3% | May 1993 | EXPL | RDX | 4.8 | 0.165 |
| 2 | III | MW-45 | 3% | May 1993 | VOC | TCE | 83.5 | 2.867 |
| 3 & 4 | I | MW-02 | 3% | Aug 1992 | EXPL | RDX | 3.435 | 0.104 |
| 3 & 4 | I | MW-02 | 3% | Aug 1992 | VOC | TCE | 70.5 | 2.136 |
| 3 & 4 | I | MW-02 | 3% | Nov 1992 | EXPL | RDX | 6.105 | 0.185 |
| 3 & 4 | I | MW-02 | 3% | Nov 1992 | VOC | TCE | 69.5 | 2.106 |
| 3 & 4 | I | MW-02 | 3% | Feb 1993 | EXPL | RDX | 9.12 | 0.276 |
| 3 & 4 | I | MW-02 | 3% | Feb 1993 | VOC | TCE | 103.5 | 3.136 |
| 3 & 4 | I | MW-02 | 3% | May 1993 | EXPL | RDX | 8.6 | 0.261 |
| 3 & 4 | I | MW-02 | 3% | May 1993 | VOC | TCE | 80.5 | 2.439 |
| 3 & 4 | I | MW-03 | 3% | Aug 1992 | EXPL | RDX | 0.37 | 0.011 |
| 3 & 4 | I | MW-03 | 3% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-03 | 3% | Nov 1992 | EXPL | RDX | 0.765 | 0.023 |
| 3 & 4 | I | MW-03 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-03 | 3% | Feb 1993 | EXPL | RDX | 0.985 | 0.030 |
| 3 & 4 | I | MW-03 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-03 | 3% | May 1993 | EXPL | RDX | 1.185 | 0.036 |
| 3 & 4 | I | MW-03 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-04 | 4% | Aug 1992 | EXPL | RDX | 2.33 | 0.100 |
| 3 & 4 | I | MW-04 | 4% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-04 | 4% | Nov 1992 | EXPL | RDX | 7.4 | 0.318 |
| 3 & 4 | I | MW-04 | 4% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-04 | 4% | Feb 1993 | EXPL | RDX | 5.68 | 0.244 |
| 3 & 4 | I | MW-04 | 4% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-04 | 4% | May 1993 | EXPL | RDX | 8.565 | 0.368 |
| 3 & 4 | I | MW-04 | 4% | May 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-05 | 4% | Aug 1992 | EXPL | RDX | 98 | 4.207 |
| 3 & 4 | I | MW-05 | 4% | Aug 1992 | VOC | TCE | 4 | 0.172 |
| 3 & 4 | I | MW-05 | 4% | Nov 1992 | EXPL | RDX | 160.38 | 6.885 |
| 3 & 4 | I | MW-05 | 4% | Nov 1992 | VOC | TCE | 7 | 0.301 |
| 3 & 4 | I | MW-05 | 4% | Feb 1993 | EXPL | RDX | 320 | 13.737 |
| 3 & 4 | I | MW-05 | 4% | Feb 1993 | VOC | TCE | 6 | 0.258 |
| 3 & 4 | I | MW-05 | 4% | May 1993 | EXPL | RDX | 534 | 22.924 |
| 3 & 4 | I | MW-05 | 4% | May 1993 | VOC | TCE | 6 | 0.258 |
| 3 & 4 | I | MW-09 | 10% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-09 | 10% | Aug 1992 | VOC | TCE | 165.5 | 16.717 |
| 3 & 4 | I | MW-09 | 10% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-09 | 10% | Nov 1992 | VOC | TCE | 102 | 10.303 |
| 3 & 4 | I | MW-09 | 10% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-09 | 10% | Feb 1993 | VOC | TCE | 117 | 11.818 |
| 3 & 4 | I | MW-09 | 10% | May 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-09 | 10% | May 1993 | VOC | TCE | 88.5 | 8.939 |
| 3 & 4 | I | MW-11 | 1% | Aug 1992 | EXPL | RDX | 33 | 0.400 |
| 3 & 4 | I | MW-11 | 1% | Aug 1992 | VOC | TCE | | |

Table K-14
Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | I | MW-11 | 1% | Nov 1992 | EXPL | RDX | 35 | 0.424 |
| 3 & 4 | I | MW-11 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-11 | 1% | Feb 1993 | EXPL | RDX | 32 | 0.388 |
| 3 & 4 | I | MW-11 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-11 | 1% | May 1993 | EXPL | RDX | 12 | 0.145 |
| 3 & 4 | I | MW-11 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-18 | 1% | Aug 1992 | EXPL | RDX | 1.9 | 0.023 |
| 3 & 4 | I | MW-18 | 1% | Aug 1992 | VOC | TCE | 76 | 0.921 |
| 3 & 4 | I | MW-18 | 1% | Nov 1992 | EXPL | RDX | 3.6 | 0.044 |
| 3 & 4 | I | MW-18 | 1% | Nov 1992 | VOC | TCE | 56 | 0.679 |
| 3 & 4 | I | MW-18 | 1% | Feb 1993 | EXPL | RDX | 4.1 | 0.050 |
| 3 & 4 | I | MW-18 | 1% | Feb 1993 | VOC | TCE | 92 | 1.115 |
| 3 & 4 | I | MW-18 | 1% | May 1993 | EXPL | RDX | 4.2 | 0.051 |
| 3 & 4 | I | MW-18 | 1% | May 1993 | VOC | TCE | 76 | 0.921 |
| 3 & 4 | I | MW-21 | 3% | Aug 1992 | EXPL | RDX | 10 | 0.303 |
| 3 & 4 | I | MW-21 | 3% | Aug 1992 | VOC | TCE | 140 | 4.242 |
| 3 & 4 | I | MW-21 | 3% | Nov 1992 | EXPL | RDX | 11 | 0.333 |
| 3 & 4 | I | MW-21 | 3% | Nov 1992 | VOC | TCE | 140 | 4.242 |
| 3 & 4 | I | MW-21 | 3% | Feb 1993 | EXPL | RDX | 18 | 0.545 |
| 3 & 4 | I | MW-21 | 3% | Feb 1993 | VOC | TCE | 130 | 3.939 |
| 3 & 4 | I | MW-21 | 3% | May 1993 | EXPL | RDX | 16 | 0.485 |
| 3 & 4 | I | MW-21 | 3% | May 1993 | VOC | TCE | 110 | 3.333 |
| 3 & 4 | I | MW-25 | 3% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-25 | 3% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-25 | 3% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-25 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-25 | 3% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-25 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-25 | 3% | May 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-25 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-29 | 13% | Aug 1992 | EXPL | RDX | 4.4 | 0.578 |
| 3 & 4 | I | MW-29 | 13% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-29 | 13% | Nov 1992 | EXPL | RDX | 6.1 | 0.801 |
| 3 & 4 | I | MW-29 | 13% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-29 | 13% | Feb 1993 | EXPL | RDX | 6.4 | 0.840 |
| 3 & 4 | I | MW-29 | 13% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-29 | 13% | May 1993 | EXPL | RDX | 8.6 | 1.129 |
| 3 & 4 | I | MW-29 | 13% | May 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-33 | 10% | Aug 1992 | EXPL | RDX | 5.5 | 0.528 |
| 3 & 4 | I | MW-33 | 10% | Aug 1992 | VOC | TCE | 1 | 0.096 |
| 3 & 4 | I | MW-33 | 10% | Nov 1992 | EXPL | RDX | 8.55 | 0.820 |
| 3 & 4 | I | MW-33 | 10% | Nov 1992 | VOC | TCE | 1 | 0.096 |
| 3 & 4 | I | MW-33 | 10% | Feb 1993 | EXPL | RDX | 10.8 | 1.036 |
| 3 & 4 | I | MW-33 | 10% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-33 | 10% | May 1993 | EXPL | RDX | 8.85 | 0.849 |
| 3 & 4 | I | MW-33 | 10% | May 1993 | VOC | TCE | 1 | 0.096 |
| 3 & 4 | I | MW-36 | 3% | Aug 1992 | EXPL | RDX | | |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | I | MW-36 | 3% | Aug 1992 | VOC | TCE | 25 | 0.694 |
| 3 & 4 | I | MW-36 | 3% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-36 | 3% | Nov 1992 | VOC | TCE | 37.5 | 1.042 |
| 3 & 4 | I | MW-36 | 3% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-36 | 3% | Feb 1993 | VOC | TCE | 55.5 | 1.542 |
| 3 & 4 | I | MW-36 | 3% | May 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-36 | 3% | May 1993 | VOC | TCE | 58.5 | 1.625 |
| 3 & 4 | I | MW-40 | 13% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-40 | 13% | Aug 1992 | VOC | TCE | 911 | 115.025 |
| 3 & 4 | I | MW-40 | 13% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-40 | 13% | Nov 1992 | VOC | TCE | 1560 | 196.970 |
| 3 & 4 | I | MW-40 | 13% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-40 | 13% | Feb 1993 | VOC | TCE | 2408.5 | 304.104 |
| 3 & 4 | I | MW-40 | 13% | May 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-40 | 13% | May 1993 | VOC | TCE | 1960.5 | 247.538 |
| 3 & 4 | I | MW-44 | 6% | Aug 1992 | EXPL | RDX | 1.165 | 0.065 |
| 3 & 4 | I | MW-44 | 6% | Aug 1992 | VOC | TCE | 180 | 10.000 |
| 3 & 4 | I | MW-44 | 6% | Nov 1992 | EXPL | RDX | 0.69 | 0.038 |
| 3 & 4 | I | MW-44 | 6% | Nov 1992 | VOC | TCE | 170 | 9.444 |
| 3 & 4 | I | MW-44 | 6% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-44 | 6% | Feb 1993 | VOC | TCE | 85.35 | 4.742 |
| 3 & 4 | I | MW-44 | 6% | May 1993 | EXPL | RDX | 1.1 | 0.061 |
| 3 & 4 | I | MW-44 | 6% | May 1993 | VOC | TCE | 160 | 8.889 |
| 3 & 4 | I | MW-45 | 3% | Aug 1992 | EXPL | RDX | 0.73 | 0.020 |
| 3 & 4 | I | MW-45 | 3% | Aug 1992 | VOC | TCE | 62.5 | 1.736 |
| 3 & 4 | I | MW-45 | 3% | Nov 1992 | EXPL | RDX | 3.75 | 0.104 |
| 3 & 4 | I | MW-45 | 3% | Nov 1992 | VOC | TCE | 18 | 0.500 |
| 3 & 4 | I | MW-45 | 3% | Feb 1993 | EXPL | RDX | 3.1 | 0.086 |
| 3 & 4 | I | MW-45 | 3% | Feb 1993 | VOC | TCE | 48 | 1.333 |
| 3 & 4 | I | MW-45 | 3% | May 1993 | EXPL | RDX | 4.8 | 0.133 |
| 3 & 4 | I | MW-45 | 3% | May 1993 | VOC | TCE | 83.5 | 2.319 |
| 3 & 4 | I | MW-52 | 1% | Aug 1992 | EXPL | RDX | 1.735 | 0.021 |
| 3 & 4 | I | MW-52 | 1% | Aug 1992 | VOC | TCE | 2 | 0.024 |
| 3 & 4 | I | MW-52 | 1% | Nov 1992 | EXPL | RDX | 10.7 | 0.130 |
| 3 & 4 | I | MW-52 | 1% | Nov 1992 | VOC | TCE | 3.5 | 0.042 |
| 3 & 4 | I | MW-52 | 1% | Feb 1993 | EXPL | RDX | 15.15 | 0.184 |
| 3 & 4 | I | MW-52 | 1% | Feb 1993 | VOC | TCE | 8 | 0.097 |
| 3 & 4 | I | MW-52 | 1% | May 1993 | EXPL | RDX | 6.05 | 0.073 |
| 3 & 4 | I | MW-52 | 1% | May 1993 | VOC | TCE | 4.5 | 0.055 |
| 3 & 4 | I | MW-53 | 1% | Aug 1992 | EXPL | RDX | 4.5 | 0.055 |
| 3 & 4 | I | MW-53 | 1% | Aug 1992 | VOC | TCE | 52.5 | 0.636 |
| 3 & 4 | I | MW-53 | 1% | Nov 1992 | EXPL | RDX | 8.35 | 0.101 |
| 3 & 4 | I | MW-53 | 1% | Nov 1992 | VOC | TCE | 37.5 | 0.455 |
| 3 & 4 | I | MW-53 | 1% | Feb 1993 | EXPL | RDX | 10.35 | 0.125 |
| 3 & 4 | I | MW-53 | 1% | Feb 1993 | VOC | TCE | 39 | 0.473 |
| 3 & 4 | I | MW-53 | 1% | May 1993 | EXPL | RDX | 8.3 | 0.101 |
| 3 & 4 | I | MW-53 | 1% | May 1993 | VOC | TCE | 43 | 0.521 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | I | MW-54 | 1% | Aug 1992 | EXPL | RDX | 0.91 | 0.011 |
| 3 & 4 | I | MW-54 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-54 | 1% | Nov 1992 | EXPL | RDX | 1.4 | 0.017 |
| 3 & 4 | I | MW-54 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-54 | 1% | Feb 1993 | EXPL | RDX | 2.3 | 0.028 |
| 3 & 4 | I | MW-54 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-54 | 1% | May 1993 | EXPL | RDX | 2.4 | 0.029 |
| 3 & 4 | I | MW-54 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-55 | 1% | Aug 1992 | EXPL | RDX | 0.38 | 0.005 |
| 3 & 4 | I | MW-55 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-55 | 1% | Nov 1992 | EXPL | RDX | 0.63 | 0.008 |
| 3 & 4 | I | MW-55 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | I | MW-55 | 1% | Feb 1993 | EXPL | RDX | 0.76 | 0.009 |
| 3 & 4 | I | MW-55 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-55 | 1% | May 1993 | EXPL | RDX | 0.76 | 0.009 |
| 3 & 4 | I | MW-55 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | I | MW-56 | 1% | Aug 1992 | EXPL | RDX | 0.79 | 0.010 |
| 3 & 4 | I | MW-56 | 1% | Aug 1992 | VOC | TCE | 11 | 0.144 |
| 3 & 4 | I | MW-56 | 1% | Nov 1992 | EXPL | RDX | 0.875 | 0.011 |
| 3 & 4 | I | MW-56 | 1% | Nov 1992 | VOC | TCE | 12 | 0.158 |
| 3 & 4 | I | MW-56 | 1% | Feb 1993 | EXPL | RDX | 1.21 | 0.016 |
| 3 & 4 | I | MW-56 | 1% | Feb 1993 | VOC | TCE | 6 | 0.079 |
| 3 & 4 | I | MW-56 | 1% | May 1993 | EXPL | RDX | 1.08 | 0.014 |
| 3 & 4 | I | MW-56 | 1% | May 1993 | VOC | TCE | 9 | 0.118 |
| 3 & 4 | I | MW-58 | 14% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-58 | 14% | Aug 1992 | VOC | TCE | 130 | 18.384 |
| 3 & 4 | I | MW-58 | 14% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | I | MW-58 | 14% | Nov 1992 | VOC | TCE | 70.5 | 9.970 |
| 3 & 4 | I | MW-58 | 14% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-58 | 14% | Feb 1993 | VOC | TCE | 120 | 16.970 |
| 3 & 4 | I | MW-58 | 14% | May 1993 | EXPL | RDX | | |
| 3 & 4 | I | MW-58 | 14% | May 1993 | VOC | TCE | 97 | 13.717 |
| 3 & 4 | II | MW-02 | 3% | Aug 1992 | EXPL | RDX | 3.435 | 0.094 |
| 3 & 4 | II | MW-02 | 3% | Aug 1992 | VOC | TCE | 70.5 | 1.923 |
| 3 & 4 | II | MW-02 | 3% | Nov 1992 | EXPL | RDX | 6.105 | 0.167 |
| 3 & 4 | II | MW-02 | 3% | Nov 1992 | VOC | TCE | 69.5 | 1.895 |
| 3 & 4 | II | MW-02 | 3% | Feb 1993 | EXPL | RDX | 9.12 | 0.249 |
| 3 & 4 | II | MW-02 | 3% | Feb 1993 | VOC | TCE | 103.5 | 2.823 |
| 3 & 4 | II | MW-02 | 3% | May 1993 | EXPL | RDX | 8.6 | 0.235 |
| 3 & 4 | II | MW-02 | 3% | May 1993 | VOC | TCE | 80.5 | 2.195 |
| 3 & 4 | II | MW-03 | 3% | Aug 1992 | EXPL | RDX | 0.37 | 0.010 |
| 3 & 4 | II | MW-03 | 3% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-03 | 3% | Nov 1992 | EXPL | RDX | 0.765 | 0.021 |
| 3 & 4 | II | MW-03 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-03 | 3% | Feb 1993 | EXPL | RDX | 0.985 | 0.027 |
| 3 & 4 | II | MW-03 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-03 | 3% | May 1993 | EXPL | RDX | 1.185 | 0.032 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | II | MW-03 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-04 | 3% | Aug 1992 | EXPL | RDX | 2.33 | 0.067 |
| 3 & 4 | II | MW-04 | 3% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-04 | 3% | Nov 1992 | EXPL | RDX | 7.4 | 0.213 |
| 3 & 4 | II | MW-04 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-04 | 3% | Feb 1993 | EXPL | RDX | 5.68 | 0.164 |
| 3 & 4 | II | MW-04 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-04 | 3% | May 1993 | EXPL | RDX | 8.565 | 0.247 |
| 3 & 4 | II | MW-04 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-05 | 3% | Aug 1992 | EXPL | RDX | 98 | 2.821 |
| 3 & 4 | II | MW-05 | 3% | Aug 1992 | VOC | TCE | 4 | 0.115 |
| 3 & 4 | II | MW-05 | 3% | Nov 1992 | EXPL | RDX | 160.38 | 4.617 |
| 3 & 4 | II | MW-05 | 3% | Nov 1992 | VOC | TCE | 7 | 0.202 |
| 3 & 4 | II | MW-05 | 3% | Feb 1993 | EXPL | RDX | 320 | 9.212 |
| 3 & 4 | II | MW-05 | 3% | Feb 1993 | VOC | TCE | 6 | 0.173 |
| 3 & 4 | II | MW-05 | 3% | May 1993 | EXPL | RDX | 534 | 15.373 |
| 3 & 4 | II | MW-05 | 3% | May 1993 | VOC | TCE | 6 | 0.173 |
| 3 & 4 | II | MW-09 | 6% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-09 | 6% | Aug 1992 | VOC | TCE | 165.5 | 10.030 |
| 3 & 4 | II | MW-09 | 6% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-09 | 6% | Nov 1992 | VOC | TCE | 102 | 6.182 |
| 3 & 4 | II | MW-09 | 6% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-09 | 6% | Feb 1993 | VOC | TCE | 117 | 7.091 |
| 3 & 4 | II | MW-09 | 6% | May 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-09 | 6% | May 1993 | VOC | TCE | 88.5 | 5.364 |
| 3 & 4 | II | MW-11 | 1% | Aug 1992 | EXPL | RDX | 33 | 0.240 |
| 3 & 4 | II | MW-11 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-11 | 1% | Nov 1992 | EXPL | RDX | 35 | 0.255 |
| 3 & 4 | II | MW-11 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-11 | 1% | Feb 1993 | EXPL | RDX | 32 | 0.233 |
| 3 & 4 | II | MW-11 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-11 | 1% | May 1993 | EXPL | RDX | 12 | 0.087 |
| 3 & 4 | II | MW-11 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-18 | 1% | Aug 1992 | EXPL | RDX | 1.9 | 0.014 |
| 3 & 4 | II | MW-18 | 1% | Aug 1992 | VOC | TCE | 76 | 0.553 |
| 3 & 4 | II | MW-18 | 1% | Nov 1992 | EXPL | RDX | 3.6 | 0.026 |
| 3 & 4 | II | MW-18 | 1% | Nov 1992 | VOC | TCE | 56 | 0.407 |
| 3 & 4 | II | MW-18 | 1% | Feb 1993 | EXPL | RDX | 4.1 | 0.030 |
| 3 & 4 | II | MW-18 | 1% | Feb 1993 | VOC | TCE | 92 | 0.669 |
| 3 & 4 | II | MW-18 | 1% | May 1993 | EXPL | RDX | 4.2 | 0.031 |
| 3 & 4 | II | MW-18 | 1% | May 1993 | VOC | TCE | 76 | 0.553 |
| 3 & 4 | II | MW-24 | 3% | Aug 1992 | EXPL | RDX | 0.46 | 0.013 |
| 3 & 4 | II | MW-24 | 3% | Aug 1992 | VOC | TCE | 0.9 | 0.025 |
| 3 & 4 | II | MW-24 | 3% | Nov 1992 | EXPL | RDX | 0.26 | 0.007 |
| 3 & 4 | II | MW-24 | 3% | Nov 1992 | VOC | TCE | 0.8 | 0.022 |
| 3 & 4 | II | MW-24 | 3% | Feb 1993 | EXPL | RDX | 0.41 | 0.011 |
| 3 & 4 | II | MW-24 | 3% | Feb 1993 | VOC | TCE | 1 | 0.027 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | II | MW-24 | 3% | May 1993 | EXPL | RDX | 0.3 | 0.008 |
| 3 & 4 | II | MW-24 | 3% | May 1993 | VOC | TCE | 1 | 0.027 |
| 3 & 4 | II | MW-25 | 3% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-25 | 3% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-25 | 3% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-25 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-25 | 3% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-25 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-25 | 3% | May 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-25 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-29 | 16% | Aug 1992 | EXPL | RDX | 4.4 | 0.693 |
| 3 & 4 | II | MW-29 | 16% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-29 | 16% | Nov 1992 | EXPL | RDX | 6.1 | 0.961 |
| 3 & 4 | II | MW-29 | 16% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-29 | 16% | Feb 1993 | EXPL | RDX | 6.4 | 1.008 |
| 3 & 4 | II | MW-29 | 16% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-29 | 16% | May 1993 | EXPL | RDX | 8.6 | 1.355 |
| 3 & 4 | II | MW-29 | 16% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-32 | 14% | Aug 1992 | EXPL | RDX | 2.03 | 0.283 |
| 3 & 4 | II | MW-32 | 14% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-32 | 14% | Nov 1992 | EXPL | RDX | 2.365 | 0.330 |
| 3 & 4 | II | MW-32 | 14% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-32 | 14% | Feb 1993 | EXPL | RDX | 3.28 | 0.457 |
| 3 & 4 | II | MW-32 | 14% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-32 | 14% | May 1993 | EXPL | RDX | 3.725 | 0.519 |
| 3 & 4 | II | MW-32 | 14% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-34 | 8% | Aug 1992 | EXPL | RDX | 0.91 | 0.069 |
| 3 & 4 | II | MW-34 | 8% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-34 | 8% | Nov 1992 | EXPL | RDX | 0.95 | 0.072 |
| 3 & 4 | II | MW-34 | 8% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-34 | 8% | Feb 1993 | EXPL | RDX | 1.6 | 0.121 |
| 3 & 4 | II | MW-34 | 8% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-34 | 8% | May 1993 | EXPL | RDX | 1.6 | 0.121 |
| 3 & 4 | II | MW-34 | 8% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-35 | 11% | Aug 1992 | EXPL | RDX | 0.34 | 0.036 |
| 3 & 4 | II | MW-35 | 11% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-35 | 11% | Nov 1992 | EXPL | RDX | 0.63 | 0.067 |
| 3 & 4 | II | MW-35 | 11% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-35 | 11% | Feb 1993 | EXPL | RDX | 0.75 | 0.080 |
| 3 & 4 | II | MW-35 | 11% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-35 | 11% | May 1993 | EXPL | RDX | 0.86 | 0.091 |
| 3 & 4 | II | MW-35 | 11% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-36 | 2% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-36 | 2% | Aug 1992 | VOC | TCE | 25 | 0.606 |
| 3 & 4 | II | MW-36 | 2% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-36 | 2% | Nov 1992 | VOC | TCE | 37.5 | 0.909 |
| 3 & 4 | II | MW-36 | 2% | Feb 1993 | EXPL | RDX | | |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | II | MW-36 | 2% | Feb 1993 | VOC | TCE | 55.5 | 1.345 |
| 3 & 4 | II | MW-36 | 2% | May 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-36 | 2% | May 1993 | VOC | TCE | 58.5 | 1.418 |
| 3 & 4 | II | MW-40 | 8% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-40 | 8% | Aug 1992 | VOC | TCE | 911 | 69.015 |
| 3 & 4 | II | MW-40 | 8% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-40 | 8% | Nov 1992 | VOC | TCE | 1560 | 118.182 |
| 3 & 4 | II | MW-40 | 8% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-40 | 8% | Feb 1993 | VOC | TCE | 2408.5 | 182.462 |
| 3 & 4 | II | MW-40 | 8% | May 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-40 | 8% | May 1993 | VOC | TCE | 1960.5 | 148.523 |
| 3 & 4 | II | MW-44 | 3% | Aug 1992 | EXPL | RDX | 1.165 | 0.039 |
| 3 & 4 | II | MW-44 | 3% | Aug 1992 | VOC | TCE | 180 | 6.000 |
| 3 & 4 | II | MW-44 | 3% | Nov 1992 | EXPL | RDX | 0.69 | 0.023 |
| 3 & 4 | II | MW-44 | 3% | Nov 1992 | VOC | TCE | 170 | 5.667 |
| 3 & 4 | II | MW-44 | 3% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-44 | 3% | Feb 1993 | VOC | TCE | 85.35 | 2.845 |
| 3 & 4 | II | MW-44 | 3% | May 1993 | EXPL | RDX | 1.1 | 0.037 |
| 3 & 4 | II | MW-44 | 3% | May 1993 | VOC | TCE | 160 | 5.333 |
| 3 & 4 | II | MW-45 | 2% | Aug 1992 | EXPL | RDX | 0.73 | 0.018 |
| 3 & 4 | II | MW-45 | 2% | Aug 1992 | VOC | TCE | 62.5 | 1.515 |
| 3 & 4 | II | MW-45 | 2% | Nov 1992 | EXPL | RDX | 3.75 | 0.091 |
| 3 & 4 | II | MW-45 | 2% | Nov 1992 | VOC | TCE | 18 | 0.436 |
| 3 & 4 | II | MW-45 | 2% | Feb 1993 | EXPL | RDX | 3.1 | 0.075 |
| 3 & 4 | II | MW-45 | 2% | Feb 1993 | VOC | TCE | 48 | 1.164 |
| 3 & 4 | II | MW-45 | 2% | May 1993 | EXPL | RDX | 4.8 | 0.116 |
| 3 & 4 | II | MW-45 | 2% | May 1993 | VOC | TCE | 83.5 | 2.024 |
| 3 & 4 | II | MW-52 | 1% | Aug 1992 | EXPL | RDX | 1.735 | 0.013 |
| 3 & 4 | II | MW-52 | 1% | Aug 1992 | VOC | TCE | 2 | 0.015 |
| 3 & 4 | II | MW-52 | 1% | Nov 1992 | EXPL | RDX | 10.7 | 0.078 |
| 3 & 4 | II | MW-52 | 1% | Nov 1992 | VOC | TCE | 3.5 | 0.025 |
| 3 & 4 | II | MW-52 | 1% | Feb 1993 | EXPL | RDX | 15.15 | 0.110 |
| 3 & 4 | II | MW-52 | 1% | Feb 1993 | VOC | TCE | 8 | 0.058 |
| 3 & 4 | II | MW-52 | 1% | May 1993 | EXPL | RDX | 6.05 | 0.044 |
| 3 & 4 | II | MW-52 | 1% | May 1993 | VOC | TCE | 4.5 | 0.033 |
| 3 & 4 | II | MW-53 | 1% | Aug 1992 | EXPL | RDX | 4.5 | 0.033 |
| 3 & 4 | II | MW-53 | 1% | Aug 1992 | VOC | TCE | 52.5 | 0.382 |
| 3 & 4 | II | MW-53 | 1% | Nov 1992 | EXPL | RDX | 8.35 | 0.061 |
| 3 & 4 | II | MW-53 | 1% | Nov 1992 | VOC | TCE | 37.5 | 0.273 |
| 3 & 4 | II | MW-53 | 1% | Feb 1993 | EXPL | RDX | 10.35 | 0.075 |
| 3 & 4 | II | MW-53 | 1% | Feb 1993 | VOC | TCE | 39 | 0.284 |
| 3 & 4 | II | MW-53 | 1% | May 1993 | EXPL | RDX | 8.3 | 0.060 |
| 3 & 4 | II | MW-53 | 1% | May 1993 | VOC | TCE | 43 | 0.313 |
| 3 & 4 | II | MW-54 | 1% | Aug 1992 | EXPL | RDX | 0.91 | 0.007 |
| 3 & 4 | II | MW-54 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-54 | 1% | Nov 1992 | EXPL | RDX | 1.4 | 0.010 |
| 3 & 4 | II | MW-54 | 1% | Nov 1992 | VOC | TCE | | |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | II | MW-54 | 1% | Feb 1993 | EXPL | RDX | 2.3 | 0.017 |
| 3 & 4 | II | MW-54 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-54 | 1% | May 1993 | EXPL | RDX | 2.4 | 0.017 |
| 3 & 4 | II | MW-54 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-55 | 1% | Aug 1992 | EXPL | RDX | 0.38 | 0.003 |
| 3 & 4 | II | MW-55 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-55 | 1% | Nov 1992 | EXPL | RDX | 0.63 | 0.005 |
| 3 & 4 | II | MW-55 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | II | MW-55 | 1% | Feb 1993 | EXPL | RDX | 0.76 | 0.006 |
| 3 & 4 | II | MW-55 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-55 | 1% | May 1993 | EXPL | RDX | 0.76 | 0.006 |
| 3 & 4 | II | MW-55 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | II | MW-56 | 1% | Aug 1992 | EXPL | RDX | 0.79 | 0.006 |
| 3 & 4 | II | MW-56 | 1% | Aug 1992 | VOC | TCE | 11 | 0.087 |
| 3 & 4 | II | MW-56 | 1% | Nov 1992 | EXPL | RDX | 0.875 | 0.007 |
| 3 & 4 | II | MW-56 | 1% | Nov 1992 | VOC | TCE | 12 | 0.095 |
| 3 & 4 | II | MW-56 | 1% | Feb 1993 | EXPL | RDX | 1.21 | 0.010 |
| 3 & 4 | II | MW-56 | 1% | Feb 1993 | VOC | TCE | 6 | 0.047 |
| 3 & 4 | II | MW-56 | 1% | May 1993 | EXPL | RDX | 1.08 | 0.009 |
| 3 & 4 | II | MW-56 | 1% | May 1993 | VOC | TCE | 9 | 0.071 |
| 3 & 4 | II | MW-58 | 8% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-58 | 8% | Aug 1992 | VOC | TCE | 130 | 11.030 |
| 3 & 4 | II | MW-58 | 8% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | II | MW-58 | 8% | Nov 1992 | VOC | TCE | 70.5 | 5.982 |
| 3 & 4 | II | MW-58 | 8% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-58 | 8% | Feb 1993 | VOC | TCE | 120 | 10.182 |
| 3 & 4 | II | MW-58 | 8% | May 1993 | EXPL | RDX | | |
| 3 & 4 | II | MW-58 | 8% | May 1993 | VOC | TCE | 97 | 8.230 |
| 3 & 4 | III | MW-02 | 3% | Aug 1992 | EXPL | RDX | 3.435 | 0.088 |
| 3 & 4 | III | MW-02 | 3% | Aug 1992 | VOC | TCE | 70.5 | 1.797 |
| 3 & 4 | III | MW-02 | 3% | Nov 1992 | EXPL | RDX | 6.105 | 0.156 |
| 3 & 4 | III | MW-02 | 3% | Nov 1992 | VOC | TCE | 69.5 | 1.772 |
| 3 & 4 | III | MW-02 | 3% | Feb 1993 | EXPL | RDX | 9.12 | 0.233 |
| 3 & 4 | III | MW-02 | 3% | Feb 1993 | VOC | TCE | 103.5 | 2.639 |
| 3 & 4 | III | MW-02 | 3% | May 1993 | EXPL | RDX | 8.6 | 0.219 |
| 3 & 4 | III | MW-02 | 3% | May 1993 | VOC | TCE | 80.5 | 2.052 |
| 3 & 4 | III | MW-03 | 3% | Aug 1992 | EXPL | RDX | 0.37 | 0.009 |
| 3 & 4 | III | MW-03 | 3% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-03 | 3% | Nov 1992 | EXPL | RDX | 0.765 | 0.020 |
| 3 & 4 | III | MW-03 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-03 | 3% | Feb 1993 | EXPL | RDX | 0.985 | 0.025 |
| 3 & 4 | III | MW-03 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-03 | 3% | May 1993 | EXPL | RDX | 1.185 | 0.030 |
| 3 & 4 | III | MW-03 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-04 | 3% | Aug 1992 | EXPL | RDX | 2.33 | 0.063 |
| 3 & 4 | III | MW-04 | 3% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-04 | 3% | Nov 1992 | EXPL | RDX | 7.4 | 0.199 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | III | MW-04 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-04 | 3% | Feb 1993 | EXPL | RDX | 5.68 | 0.153 |
| 3 & 4 | III | MW-04 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-04 | 3% | May 1993 | EXPL | RDX | 8.565 | 0.231 |
| 3 & 4 | III | MW-04 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-05 | 3% | Aug 1992 | EXPL | RDX | 98 | 2.637 |
| 3 & 4 | III | MW-05 | 3% | Aug 1992 | VOC | TCE | 4 | 0.108 |
| 3 & 4 | III | MW-05 | 3% | Nov 1992 | EXPL | RDX | 160.38 | 4.316 |
| 3 & 4 | III | MW-05 | 3% | Nov 1992 | VOC | TCE | 7 | 0.188 |
| 3 & 4 | III | MW-05 | 3% | Feb 1993 | EXPL | RDX | 320 | 8.612 |
| 3 & 4 | III | MW-05 | 3% | Feb 1993 | VOC | TCE | 6 | 0.161 |
| 3 & 4 | III | MW-05 | 3% | May 1993 | EXPL | RDX | 534 | 14.371 |
| 3 & 4 | III | MW-05 | 3% | May 1993 | VOC | TCE | 6 | 0.161 |
| 3 & 4 | III | MW-09 | 6% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-09 | 6% | Aug 1992 | VOC | TCE | 165.5 | 9.377 |
| 3 & 4 | III | MW-09 | 6% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-09 | 6% | Nov 1992 | VOC | TCE | 102 | 5.779 |
| 3 & 4 | III | MW-09 | 6% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-09 | 6% | Feb 1993 | VOC | TCE | 117 | 6.629 |
| 3 & 4 | III | MW-09 | 6% | May 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-09 | 6% | May 1993 | VOC | TCE | 88.5 | 5.014 |
| 3 & 4 | III | MW-11 | 1% | Aug 1992 | EXPL | RDX | 33 | 0.224 |
| 3 & 4 | III | MW-11 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-11 | 1% | Nov 1992 | EXPL | RDX | 35 | 0.238 |
| 3 & 4 | III | MW-11 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-11 | 1% | Feb 1993 | EXPL | RDX | 32 | 0.218 |
| 3 & 4 | III | MW-11 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-11 | 1% | May 1993 | EXPL | RDX | 12 | 0.082 |
| 3 & 4 | III | MW-11 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-18 | 1% | Aug 1992 | EXPL | RDX | 1.9 | 0.013 |
| 3 & 4 | III | MW-18 | 1% | Aug 1992 | VOC | TCE | 76 | 0.517 |
| 3 & 4 | III | MW-18 | 1% | Nov 1992 | EXPL | RDX | 3.6 | 0.024 |
| 3 & 4 | III | MW-18 | 1% | Nov 1992 | VOC | TCE | 56 | 0.381 |
| 3 & 4 | III | MW-18 | 1% | Feb 1993 | EXPL | RDX | 4.1 | 0.028 |
| 3 & 4 | III | MW-18 | 1% | Feb 1993 | VOC | TCE | 92 | 0.625 |
| 3 & 4 | III | MW-18 | 1% | May 1993 | EXPL | RDX | 4.2 | 0.029 |
| 3 & 4 | III | MW-18 | 1% | May 1993 | VOC | TCE | 76 | 0.517 |
| 3 & 4 | III | MW-24 | 3% | Aug 1992 | EXPL | RDX | 0.46 | 0.012 |
| 3 & 4 | III | MW-24 | 3% | Aug 1992 | VOC | TCE | 0.9 | 0.023 |
| 3 & 4 | III | MW-24 | 3% | Nov 1992 | EXPL | RDX | 0.26 | 0.007 |
| 3 & 4 | III | MW-24 | 3% | Nov 1992 | VOC | TCE | 0.8 | 0.020 |
| 3 & 4 | III | MW-24 | 3% | Feb 1993 | EXPL | RDX | 0.41 | 0.010 |
| 3 & 4 | III | MW-24 | 3% | Feb 1993 | VOC | TCE | 1 | 0.025 |
| 3 & 4 | III | MW-24 | 3% | May 1993 | EXPL | RDX | 0.3 | 0.008 |
| 3 & 4 | III | MW-24 | 3% | May 1993 | VOC | TCE | 1 | 0.025 |
| 3 & 4 | III | MW-25 | 3% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-25 | 3% | Aug 1992 | VOC | TCE | | |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | III | MW-25 | 3% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-25 | 3% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-25 | 3% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-25 | 3% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-25 | 3% | May 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-25 | 3% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-29 | 20% | Aug 1992 | EXPL | RDX | 4.4 | 0.873 |
| 3 & 4 | III | MW-29 | 20% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-29 | 20% | Nov 1992 | EXPL | RDX | 6.1 | 1.210 |
| 3 & 4 | III | MW-29 | 20% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-29 | 20% | Feb 1993 | EXPL | RDX | 6.4 | 1.269 |
| 3 & 4 | III | MW-29 | 20% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-29 | 20% | May 1993 | EXPL | RDX | 8.6 | 1.705 |
| 3 & 4 | III | MW-29 | 20% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-32 | 17% | Aug 1992 | EXPL | RDX | 2.03 | 0.345 |
| 3 & 4 | III | MW-32 | 17% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-32 | 17% | Nov 1992 | EXPL | RDX | 2.365 | 0.402 |
| 3 & 4 | III | MW-32 | 17% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-32 | 17% | Feb 1993 | EXPL | RDX | 3.28 | 0.558 |
| 3 & 4 | III | MW-32 | 17% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-32 | 17% | May 1993 | EXPL | RDX | 3.725 | 0.633 |
| 3 & 4 | III | MW-32 | 17% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-34 | 5% | Aug 1992 | EXPL | RDX | 0.91 | 0.049 |
| 3 & 4 | III | MW-34 | 5% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-34 | 5% | Nov 1992 | EXPL | RDX | 0.95 | 0.051 |
| 3 & 4 | III | MW-34 | 5% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-34 | 5% | Feb 1993 | EXPL | RDX | 1.6 | 0.086 |
| 3 & 4 | III | MW-34 | 5% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-34 | 5% | May 1993 | EXPL | RDX | 1.6 | 0.086 |
| 3 & 4 | III | MW-34 | 5% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-35 | 9% | Aug 1992 | EXPL | RDX | 0.34 | 0.031 |
| 3 & 4 | III | MW-35 | 9% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-35 | 9% | Nov 1992 | EXPL | RDX | 0.63 | 0.057 |
| 3 & 4 | III | MW-35 | 9% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-35 | 9% | Feb 1993 | EXPL | RDX | 0.75 | 0.068 |
| 3 & 4 | III | MW-35 | 9% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-35 | 9% | May 1993 | EXPL | RDX | 0.86 | 0.078 |
| 3 & 4 | III | MW-35 | 9% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-36 | 2% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-36 | 2% | Aug 1992 | VOC | TCE | 25 | 0.567 |
| 3 & 4 | III | MW-36 | 2% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-36 | 2% | Nov 1992 | VOC | TCE | 37.5 | 0.850 |
| 3 & 4 | III | MW-36 | 2% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-36 | 2% | Feb 1993 | VOC | TCE | 55.5 | 1.258 |
| 3 & 4 | III | MW-36 | 2% | May 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-36 | 2% | May 1993 | VOC | TCE | 58.5 | 1.326 |
| 3 & 4 | III | MW-40 | 7% | Aug 1992 | EXPL | RDX | | |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | III | MW-40 | 7% | Aug 1992 | VOC | TCE | 911 | 64.518 |
| 3 & 4 | III | MW-40 | 7% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-40 | 7% | Nov 1992 | VOC | TCE | 1560 | 110.482 |
| 3 & 4 | III | MW-40 | 7% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-40 | 7% | Feb 1993 | VOC | TCE | 2408.5 | 170.574 |
| 3 & 4 | III | MW-40 | 7% | May 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-40 | 7% | May 1993 | VOC | TCE | 1960.5 | 138.846 |
| 3 & 4 | III | MW-44 | 3% | Aug 1992 | EXPL | RDX | 1.165 | 0.036 |
| 3 & 4 | III | MW-44 | 3% | Aug 1992 | VOC | TCE | 180 | 5.609 |
| 3 & 4 | III | MW-44 | 3% | Nov 1992 | EXPL | RDX | 0.69 | 0.022 |
| 3 & 4 | III | MW-44 | 3% | Nov 1992 | VOC | TCE | 170 | 5.297 |
| 3 & 4 | III | MW-44 | 3% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-44 | 3% | Feb 1993 | VOC | TCE | 85.35 | 2.660 |
| 3 & 4 | III | MW-44 | 3% | May 1993 | EXPL | RDX | 1.1 | 0.034 |
| 3 & 4 | III | MW-44 | 3% | May 1993 | VOC | TCE | 160 | 4.986 |
| 3 & 4 | III | MW-45 | 2% | Aug 1992 | EXPL | RDX | 0.73 | 0.017 |
| 3 & 4 | III | MW-45 | 2% | Aug 1992 | VOC | TCE | 62.5 | 1.416 |
| 3 & 4 | III | MW-45 | 2% | Nov 1992 | EXPL | RDX | 3.75 | 0.085 |
| 3 & 4 | III | MW-45 | 2% | Nov 1992 | VOC | TCE | 18 | 0.408 |
| 3 & 4 | III | MW-45 | 2% | Feb 1993 | EXPL | RDX | 3.1 | 0.070 |
| 3 & 4 | III | MW-45 | 2% | Feb 1993 | VOC | TCE | 48 | 1.088 |
| 3 & 4 | III | MW-45 | 2% | May 1993 | EXPL | RDX | 4.8 | 0.109 |
| 3 & 4 | III | MW-45 | 2% | May 1993 | VOC | TCE | 83.5 | 1.892 |
| 3 & 4 | III | MW-52 | 1% | Aug 1992 | EXPL | RDX | 1.735 | 0.012 |
| 3 & 4 | III | MW-52 | 1% | Aug 1992 | VOC | TCE | 2 | 0.014 |
| 3 & 4 | III | MW-52 | 1% | Nov 1992 | EXPL | RDX | 10.7 | 0.073 |
| 3 & 4 | III | MW-52 | 1% | Nov 1992 | VOC | TCE | 3.5 | 0.024 |
| 3 & 4 | III | MW-52 | 1% | Feb 1993 | EXPL | RDX | 15.15 | 0.103 |
| 3 & 4 | III | MW-52 | 1% | Feb 1993 | VOC | TCE | 8 | 0.054 |
| 3 & 4 | III | MW-52 | 1% | May 1993 | EXPL | RDX | 6.05 | 0.041 |
| 3 & 4 | III | MW-52 | 1% | May 1993 | VOC | TCE | 4.5 | 0.031 |
| 3 & 4 | III | MW-53 | 1% | Aug 1992 | EXPL | RDX | 4.5 | 0.031 |
| 3 & 4 | III | MW-53 | 1% | Aug 1992 | VOC | TCE | 52.5 | 0.357 |
| 3 & 4 | III | MW-53 | 1% | Nov 1992 | EXPL | RDX | 8.35 | 0.057 |
| 3 & 4 | III | MW-53 | 1% | Nov 1992 | VOC | TCE | 37.5 | 0.255 |
| 3 & 4 | III | MW-53 | 1% | Feb 1993 | EXPL | RDX | 10.35 | 0.070 |
| 3 & 4 | III | MW-53 | 1% | Feb 1993 | VOC | TCE | 39 | 0.265 |
| 3 & 4 | III | MW-53 | 1% | May 1993 | EXPL | RDX | 8.3 | 0.056 |
| 3 & 4 | III | MW-53 | 1% | May 1993 | VOC | TCE | 43 | 0.292 |
| 3 & 4 | III | MW-54 | 1% | Aug 1992 | EXPL | RDX | 0.91 | 0.006 |
| 3 & 4 | III | MW-54 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-54 | 1% | Nov 1992 | EXPL | RDX | 1.4 | 0.010 |
| 3 & 4 | III | MW-54 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-54 | 1% | Feb 1993 | EXPL | RDX | 2.3 | 0.016 |
| 3 & 4 | III | MW-54 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-54 | 1% | May 1993 | EXPL | RDX | 2.4 | 0.016 |
| 3 & 4 | III | MW-54 | 1% | May 1993 | VOC | TCE | | |

Table K-14
Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 3 & 4 | III | MW-55 | 1% | Aug 1992 | EXPL | RDX | 0.38 | 0.003 |
| 3 & 4 | III | MW-55 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-55 | 1% | Nov 1992 | EXPL | RDX | 0.63 | 0.004 |
| 3 & 4 | III | MW-55 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-55 | 1% | Feb 1993 | EXPL | RDX | 0.76 | 0.005 |
| 3 & 4 | III | MW-55 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-55 | 1% | May 1993 | EXPL | RDX | 0.76 | 0.005 |
| 3 & 4 | III | MW-55 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-56 | 1% | Aug 1992 | EXPL | RDX | 0.91 | 0.007 |
| 3 & 4 | III | MW-56 | 1% | Aug 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-56 | 1% | Nov 1992 | EXPL | RDX | 1.1 | 0.008 |
| 3 & 4 | III | MW-56 | 1% | Nov 1992 | VOC | TCE | | |
| 3 & 4 | III | MW-56 | 1% | Feb 1993 | EXPL | RDX | 1.7 | 0.013 |
| 3 & 4 | III | MW-56 | 1% | Feb 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-56 | 1% | May 1993 | EXPL | RDX | 1.6 | 0.012 |
| 3 & 4 | III | MW-56 | 1% | May 1993 | VOC | TCE | | |
| 3 & 4 | III | MW-58 | 8% | Aug 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-58 | 8% | Aug 1992 | VOC | TCE | 130 | 10.312 |
| 3 & 4 | III | MW-58 | 8% | Nov 1992 | EXPL | RDX | | |
| 3 & 4 | III | MW-58 | 8% | Nov 1992 | VOC | TCE | 70.5 | 5.592 |
| 3 & 4 | III | MW-58 | 8% | Feb 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-58 | 8% | Feb 1993 | VOC | TCE | 120 | 9.518 |
| 3 & 4 | III | MW-58 | 8% | May 1993 | EXPL | RDX | | |
| 3 & 4 | III | MW-58 | 8% | May 1993 | VOC | TCE | 97 | 7.694 |
| 5 & 6 | I | MW-02 | 4% | Aug 1992 | EXPL | RDX | 3.435 | 0.142 |
| 5 & 6 | I | MW-02 | 4% | Aug 1992 | VOC | TCE | 70.5 | 2.917 |
| 5 & 6 | I | MW-02 | 4% | Nov 1992 | EXPL | RDX | 6.105 | 0.253 |
| 5 & 6 | I | MW-02 | 4% | Nov 1992 | VOC | TCE | 69.5 | 2.876 |
| 5 & 6 | I | MW-02 | 4% | Feb 1993 | EXPL | RDX | 9.12 | 0.377 |
| 5 & 6 | I | MW-02 | 4% | Feb 1993 | VOC | TCE | 103.5 | 4.283 |
| 5 & 6 | I | MW-02 | 4% | May 1993 | EXPL | RDX | 8.6 | 0.356 |
| 5 & 6 | I | MW-02 | 4% | May 1993 | VOC | TCE | 80.5 | 3.331 |
| 5 & 6 | I | MW-03 | 4% | Aug 1992 | EXPL | RDX | 0.37 | 0.015 |
| 5 & 6 | I | MW-03 | 4% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-03 | 4% | Nov 1992 | EXPL | RDX | 0.765 | 0.032 |
| 5 & 6 | I | MW-03 | 4% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-03 | 4% | Feb 1993 | EXPL | RDX | 0.985 | 0.041 |
| 5 & 6 | I | MW-03 | 4% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-03 | 4% | May 1993 | EXPL | RDX | 1.185 | 0.049 |
| 5 & 6 | I | MW-03 | 4% | May 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-04 | 6% | Aug 1992 | EXPL | RDX | 2.33 | 0.137 |
| 5 & 6 | I | MW-04 | 6% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-04 | 6% | Nov 1992 | EXPL | RDX | 7.4 | 0.434 |
| 5 & 6 | I | MW-04 | 6% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-04 | 6% | Feb 1993 | EXPL | RDX | 5.68 | 0.333 |
| 5 & 6 | I | MW-04 | 6% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-04 | 6% | May 1993 | EXPL | RDX | 8.565 | 0.502 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | I | MW-04 | 6% | May 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-05 | 6% | Aug 1992 | EXPL | RDX | 98 | 5.745 |
| 5 & 6 | I | MW-05 | 6% | Aug 1992 | VOC | TCE | 4 | 0.234 |
| 5 & 6 | I | MW-05 | 6% | Nov 1992 | EXPL | RDX | 160.38 | 9.402 |
| 5 & 6 | I | MW-05 | 6% | Nov 1992 | VOC | TCE | 7 | 0.410 |
| 5 & 6 | I | MW-05 | 6% | Feb 1993 | EXPL | RDX | 320 | 18.759 |
| 5 & 6 | I | MW-05 | 6% | Feb 1993 | VOC | TCE | 6 | 0.352 |
| 5 & 6 | I | MW-05 | 6% | May 1993 | EXPL | RDX | 534 | 31.303 |
| 5 & 6 | I | MW-05 | 6% | May 1993 | VOC | TCE | 6 | 0.352 |
| 5 & 6 | I | MW-09 | 14% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | I | MW-09 | 14% | Aug 1992 | VOC | TCE | 165.5 | 22.828 |
| 5 & 6 | I | MW-09 | 14% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | I | MW-09 | 14% | Nov 1992 | VOC | TCE | 102 | 14.069 |
| 5 & 6 | I | MW-09 | 14% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | I | MW-09 | 14% | Feb 1993 | VOC | TCE | 117 | 16.138 |
| 5 & 6 | I | MW-09 | 14% | May 1993 | EXPL | RDX | | |
| 5 & 6 | I | MW-09 | 14% | May 1993 | VOC | TCE | 88.5 | 12.207 |
| 5 & 6 | I | MW-11 | 2% | Aug 1992 | EXPL | RDX | 33 | 0.546 |
| 5 & 6 | I | MW-11 | 2% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-11 | 2% | Nov 1992 | EXPL | RDX | 35 | 0.579 |
| 5 & 6 | I | MW-11 | 2% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-11 | 2% | Feb 1993 | EXPL | RDX | 32 | 0.530 |
| 5 & 6 | I | MW-11 | 2% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-11 | 2% | May 1993 | EXPL | RDX | 12 | 0.199 |
| 5 & 6 | I | MW-11 | 2% | May 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-18 | 2% | Aug 1992 | EXPL | RDX | 1.9 | 0.031 |
| 5 & 6 | I | MW-18 | 2% | Aug 1992 | VOC | TCE | 76 | 1.258 |
| 5 & 6 | I | MW-18 | 2% | Nov 1992 | EXPL | RDX | 3.6 | 0.060 |
| 5 & 6 | I | MW-18 | 2% | Nov 1992 | VOC | TCE | 56 | 0.927 |
| 5 & 6 | I | MW-18 | 2% | Feb 1993 | EXPL | RDX | 4.1 | 0.068 |
| 5 & 6 | I | MW-18 | 2% | Feb 1993 | VOC | TCE | 92 | 1.523 |
| 5 & 6 | I | MW-18 | 2% | May 1993 | EXPL | RDX | 4.2 | 0.070 |
| 5 & 6 | I | MW-18 | 2% | May 1993 | VOC | TCE | 76 | 1.258 |
| 5 & 6 | I | MW-21 | 4% | Aug 1992 | EXPL | RDX | 10 | 0.414 |
| 5 & 6 | I | MW-21 | 4% | Aug 1992 | VOC | TCE | 140 | 5.793 |
| 5 & 6 | I | MW-21 | 4% | Nov 1992 | EXPL | RDX | 11 | 0.455 |
| 5 & 6 | I | MW-21 | 4% | Nov 1992 | VOC | TCE | 140 | 5.793 |
| 5 & 6 | I | MW-21 | 4% | Feb 1993 | EXPL | RDX | 18 | 0.745 |
| 5 & 6 | I | MW-21 | 4% | Feb 1993 | VOC | TCE | 130 | 5.379 |
| 5 & 6 | I | MW-21 | 4% | May 1993 | EXPL | RDX | 16 | 0.662 |
| 5 & 6 | I | MW-21 | 4% | May 1993 | VOC | TCE | 110 | 4.552 |
| 5 & 6 | I | MW-25 | 4% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | I | MW-25 | 4% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-25 | 4% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | I | MW-25 | 4% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-25 | 4% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | I | MW-25 | 4% | Feb 1993 | VOC | TCE | | |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | I | MW-25 | 4% | May 1993 | EXPL | RDX | | |
| 5 & 6 | I | MW-25 | 4% | May 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-29 | 18% | Aug 1992 | EXPL | RDX | 4.4 | 0.789 |
| 5 & 6 | I | MW-29 | 18% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-29 | 18% | Nov 1992 | EXPL | RDX | 6.1 | 1.094 |
| 5 & 6 | I | MW-29 | 18% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-29 | 18% | Feb 1993 | EXPL | RDX | 6.4 | 1.148 |
| 5 & 6 | I | MW-29 | 18% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-29 | 18% | May 1993 | EXPL | RDX | 8.6 | 1.542 |
| 5 & 6 | I | MW-29 | 18% | May 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-33 | 13% | Aug 1992 | EXPL | RDX | 5.5 | 0.721 |
| 5 & 6 | I | MW-33 | 13% | Aug 1992 | VOC | TCE | 1 | 0.131 |
| 5 & 6 | I | MW-33 | 13% | Nov 1992 | EXPL | RDX | 8.55 | 1.120 |
| 5 & 6 | I | MW-33 | 13% | Nov 1992 | VOC | TCE | 1 | 0.131 |
| 5 & 6 | I | MW-33 | 13% | Feb 1993 | EXPL | RDX | 10.8 | 1.415 |
| 5 & 6 | I | MW-33 | 13% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-33 | 13% | May 1993 | EXPL | RDX | 8.85 | 1.160 |
| 5 & 6 | I | MW-33 | 13% | May 1993 | VOC | TCE | 1 | 0.131 |
| 5 & 6 | I | MW-36 | 4% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | I | MW-36 | 4% | Aug 1992 | VOC | TCE | 25 | 0.948 |
| 5 & 6 | I | MW-36 | 4% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | I | MW-36 | 4% | Nov 1992 | VOC | TCE | 37.5 | 1.422 |
| 5 & 6 | I | MW-36 | 4% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | I | MW-36 | 4% | Feb 1993 | VOC | TCE | 55.5 | 2.105 |
| 5 & 6 | I | MW-36 | 4% | May 1993 | EXPL | RDX | | |
| 5 & 6 | I | MW-36 | 4% | May 1993 | VOC | TCE | 58.5 | 2.219 |
| 5 & 6 | I | MW-44 | 8% | Aug 1992 | EXPL | RDX | 1.165 | 0.088 |
| 5 & 6 | I | MW-44 | 8% | Aug 1992 | VOC | TCE | 180 | 13.655 |
| 5 & 6 | I | MW-44 | 8% | Nov 1992 | EXPL | RDX | 0.69 | 0.052 |
| 5 & 6 | I | MW-44 | 8% | Nov 1992 | VOC | TCE | 170 | 12.897 |
| 5 & 6 | I | MW-44 | 8% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | I | MW-44 | 8% | Feb 1993 | VOC | TCE | 85.35 | 6.475 |
| 5 & 6 | I | MW-44 | 8% | May 1993 | EXPL | RDX | 1.1 | 0.083 |
| 5 & 6 | I | MW-44 | 8% | May 1993 | VOC | TCE | 160 | 12.138 |
| 5 & 6 | I | MW-45 | 4% | Aug 1992 | EXPL | RDX | 0.73 | 0.028 |
| 5 & 6 | I | MW-45 | 4% | Aug 1992 | VOC | TCE | 62.5 | 2.371 |
| 5 & 6 | I | MW-45 | 4% | Nov 1992 | EXPL | RDX | 3.75 | 0.142 |
| 5 & 6 | I | MW-45 | 4% | Nov 1992 | VOC | TCE | 18 | 0.683 |
| 5 & 6 | I | MW-45 | 4% | Feb 1993 | EXPL | RDX | 3.1 | 0.118 |
| 5 & 6 | I | MW-45 | 4% | Feb 1993 | VOC | TCE | 48 | 1.821 |
| 5 & 6 | I | MW-45 | 4% | May 1993 | EXPL | RDX | 4.8 | 0.182 |
| 5 & 6 | I | MW-45 | 4% | May 1993 | VOC | TCE | 83.5 | 3.167 |
| 5 & 6 | I | MW-52 | 2% | Aug 1992 | EXPL | RDX | 1.735 | 0.029 |
| 5 & 6 | I | MW-52 | 2% | Aug 1992 | VOC | TCE | 2 | 0.033 |
| 5 & 6 | I | MW-52 | 2% | Nov 1992 | EXPL | RDX | 10.7 | 0.177 |
| 5 & 6 | I | MW-52 | 2% | Nov 1992 | VOC | TCE | 3.5 | 0.058 |
| 5 & 6 | I | MW-52 | 2% | Feb 1993 | EXPL | RDX | 15.15 | 0.251 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | I | MW-52 | 2% | Feb 1993 | VOC | TCE | 8 | 0.132 |
| 5 & 6 | I | MW-52 | 2% | May 1993 | EXPL | RDX | 6.05 | 0.100 |
| 5 & 6 | I | MW-52 | 2% | May 1993 | VOC | TCE | 4.5 | 0.074 |
| 5 & 6 | I | MW-53 | 2% | Aug 1992 | EXPL | RDX | 4.5 | 0.074 |
| 5 & 6 | I | MW-53 | 2% | Aug 1992 | VOC | TCE | 52.5 | 0.869 |
| 5 & 6 | I | MW-53 | 2% | Nov 1992 | EXPL | RDX | 8.35 | 0.138 |
| 5 & 6 | I | MW-53 | 2% | Nov 1992 | VOC | TCE | 37.5 | 0.621 |
| 5 & 6 | I | MW-53 | 2% | Feb 1993 | EXPL | RDX | 10.35 | 0.171 |
| 5 & 6 | I | MW-53 | 2% | Feb 1993 | VOC | TCE | 39 | 0.646 |
| 5 & 6 | I | MW-53 | 2% | May 1993 | EXPL | RDX | 8.3 | 0.137 |
| 5 & 6 | I | MW-53 | 2% | May 1993 | VOC | TCE | 43 | 0.712 |
| 5 & 6 | I | MW-54 | 2% | Aug 1992 | EXPL | RDX | 0.91 | 0.015 |
| 5 & 6 | I | MW-54 | 2% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-54 | 2% | Nov 1992 | EXPL | RDX | 1.4 | 0.023 |
| 5 & 6 | I | MW-54 | 2% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-54 | 2% | Feb 1993 | EXPL | RDX | 2.3 | 0.038 |
| 5 & 6 | I | MW-54 | 2% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-54 | 2% | May 1993 | EXPL | RDX | 2.4 | 0.040 |
| 5 & 6 | I | MW-54 | 2% | May 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-55 | 2% | Aug 1992 | EXPL | RDX | 0.38 | 0.006 |
| 5 & 6 | I | MW-55 | 2% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-55 | 2% | Nov 1992 | EXPL | RDX | 0.63 | 0.010 |
| 5 & 6 | I | MW-55 | 2% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | I | MW-55 | 2% | Feb 1993 | EXPL | RDX | 0.76 | 0.013 |
| 5 & 6 | I | MW-55 | 2% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-55 | 2% | May 1993 | EXPL | RDX | 0.76 | 0.013 |
| 5 & 6 | I | MW-55 | 2% | May 1993 | VOC | TCE | | |
| 5 & 6 | I | MW-56 | 2% | Aug 1992 | EXPL | RDX | 0.79 | 0.014 |
| 5 & 6 | I | MW-56 | 2% | Aug 1992 | VOC | TCE | 11 | 0.197 |
| 5 & 6 | I | MW-56 | 2% | Nov 1992 | EXPL | RDX | 0.875 | 0.016 |
| 5 & 6 | I | MW-56 | 2% | Nov 1992 | VOC | TCE | 12 | 0.215 |
| 5 & 6 | I | MW-56 | 2% | Feb 1993 | EXPL | RDX | 1.21 | 0.022 |
| 5 & 6 | I | MW-56 | 2% | Feb 1993 | VOC | TCE | 6 | 0.108 |
| 5 & 6 | I | MW-56 | 2% | May 1993 | EXPL | RDX | 1.08 | 0.019 |
| 5 & 6 | I | MW-56 | 2% | May 1993 | VOC | TCE | 9 | 0.161 |
| 5 & 6 | II | MW-02 | 3% | Aug 1992 | EXPL | RDX | 3.435 | 0.112 |
| 5 & 6 | II | MW-02 | 3% | Aug 1992 | VOC | TCE | 70.5 | 2.291 |
| 5 & 6 | II | MW-02 | 3% | Nov 1992 | EXPL | RDX | 6.105 | 0.198 |
| 5 & 6 | II | MW-02 | 3% | Nov 1992 | VOC | TCE | 69.5 | 2.258 |
| 5 & 6 | II | MW-02 | 3% | Feb 1993 | EXPL | RDX | 9.12 | 0.296 |
| 5 & 6 | II | MW-02 | 3% | Feb 1993 | VOC | TCE | 103.5 | 3.363 |
| 5 & 6 | II | MW-02 | 3% | May 1993 | EXPL | RDX | 8.6 | 0.279 |
| 5 & 6 | II | MW-02 | 3% | May 1993 | VOC | TCE | 80.5 | 2.616 |
| 5 & 6 | II | MW-03 | 3% | Aug 1992 | EXPL | RDX | 0.37 | 0.012 |
| 5 & 6 | II | MW-03 | 3% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-03 | 3% | Nov 1992 | EXPL | RDX | 0.765 | 0.025 |
| 5 & 6 | II | MW-03 | 3% | Nov 1992 | VOC | TCE | | |

Table K-14
Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | II | MW-03 | 3% | Feb 1993 | EXPL | RDX | 0.985 | 0.032 |
| 5 & 6 | II | MW-03 | 3% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-03 | 3% | May 1993 | EXPL | RDX | 1.185 | 0.039 |
| 5 & 6 | II | MW-03 | 3% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-04 | 3% | Aug 1992 | EXPL | RDX | 2.33 | 0.080 |
| 5 & 6 | II | MW-04 | 3% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-04 | 3% | Nov 1992 | EXPL | RDX | 7.4 | 0.254 |
| 5 & 6 | II | MW-04 | 3% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-04 | 3% | Feb 1993 | EXPL | RDX | 5.68 | 0.195 |
| 5 & 6 | II | MW-04 | 3% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-04 | 3% | May 1993 | EXPL | RDX | 8.565 | 0.294 |
| 5 & 6 | II | MW-04 | 3% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-05 | 3% | Aug 1992 | EXPL | RDX | 98 | 3.361 |
| 5 & 6 | II | MW-05 | 3% | Aug 1992 | VOC | TCE | 4 | 0.137 |
| 5 & 6 | II | MW-05 | 3% | Nov 1992 | EXPL | RDX | 160.38 | 5.500 |
| 5 & 6 | II | MW-05 | 3% | Nov 1992 | VOC | TCE | 7 | 0.240 |
| 5 & 6 | II | MW-05 | 3% | Feb 1993 | EXPL | RDX | 320 | 10.975 |
| 5 & 6 | II | MW-05 | 3% | Feb 1993 | VOC | TCE | 6 | 0.206 |
| 5 & 6 | II | MW-05 | 3% | May 1993 | EXPL | RDX | 534 | 18.314 |
| 5 & 6 | II | MW-05 | 3% | May 1993 | VOC | TCE | 6 | 0.206 |
| 5 & 6 | II | MW-09 | 7% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | II | MW-09 | 7% | Aug 1992 | VOC | TCE | 165.5 | 11.949 |
| 5 & 6 | II | MW-09 | 7% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | II | MW-09 | 7% | Nov 1992 | VOC | TCE | 102 | 7.365 |
| 5 & 6 | II | MW-09 | 7% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | II | MW-09 | 7% | Feb 1993 | VOC | TCE | 117 | 8.448 |
| 5 & 6 | II | MW-09 | 7% | May 1993 | EXPL | RDX | | |
| 5 & 6 | II | MW-09 | 7% | May 1993 | VOC | TCE | 88.5 | 6.390 |
| 5 & 6 | II | MW-11 | 1% | Aug 1992 | EXPL | RDX | 33 | 0.286 |
| 5 & 6 | II | MW-11 | 1% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-11 | 1% | Nov 1992 | EXPL | RDX | 35 | 0.303 |
| 5 & 6 | II | MW-11 | 1% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-11 | 1% | Feb 1993 | EXPL | RDX | 32 | 0.277 |
| 5 & 6 | II | MW-11 | 1% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-11 | 1% | May 1993 | EXPL | RDX | 12 | 0.104 |
| 5 & 6 | II | MW-11 | 1% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-18 | 1% | Aug 1992 | EXPL | RDX | 1.9 | 0.016 |
| 5 & 6 | II | MW-18 | 1% | Aug 1992 | VOC | TCE | 76 | 0.658 |
| 5 & 6 | II | MW-18 | 1% | Nov 1992 | EXPL | RDX | 3.6 | 0.031 |
| 5 & 6 | II | MW-18 | 1% | Nov 1992 | VOC | TCE | 56 | 0.485 |
| 5 & 6 | II | MW-18 | 1% | Feb 1993 | EXPL | RDX | 4.1 | 0.036 |
| 5 & 6 | II | MW-18 | 1% | Feb 1993 | VOC | TCE | 92 | 0.797 |
| 5 & 6 | II | MW-18 | 1% | May 1993 | EXPL | RDX | 4.2 | 0.036 |
| 5 & 6 | II | MW-18 | 1% | May 1993 | VOC | TCE | 76 | 0.658 |
| 5 & 6 | II | MW-21 | 3% | Aug 1992 | EXPL | RDX | 10 | 0.325 |
| 5 & 6 | II | MW-21 | 3% | Aug 1992 | VOC | TCE | 140 | 4.549 |
| 5 & 6 | II | MW-21 | 3% | Nov 1992 | EXPL | RDX | 11 | 0.357 |

Table K-14
Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | II | MW-21 | 3% | Nov 1992 | VOC | TCE | 140 | 4.549 |
| 5 & 6 | II | MW-21 | 3% | Feb 1993 | EXPL | RDX | 18 | 0.585 |
| 5 & 6 | II | MW-21 | 3% | Feb 1993 | VOC | TCE | 130 | 4.224 |
| 5 & 6 | II | MW-21 | 3% | May 1993 | EXPL | RDX | 16 | 0.520 |
| 5 & 6 | II | MW-21 | 3% | May 1993 | VOC | TCE | 110 | 3.574 |
| 5 & 6 | II | MW-25 | 3% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | II | MW-25 | 3% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-25 | 3% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | II | MW-25 | 3% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-25 | 3% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | II | MW-25 | 3% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-25 | 3% | May 1993 | EXPL | RDX | | |
| 5 & 6 | II | MW-25 | 3% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-29 | 19% | Aug 1992 | EXPL | RDX | 4.4 | 0.826 |
| 5 & 6 | II | MW-29 | 19% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-29 | 19% | Nov 1992 | EXPL | RDX | 6.1 | 1.145 |
| 5 & 6 | II | MW-29 | 19% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-29 | 19% | Feb 1993 | EXPL | RDX | 6.4 | 1.201 |
| 5 & 6 | II | MW-29 | 19% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-29 | 19% | May 1993 | EXPL | RDX | 8.6 | 1.614 |
| 5 & 6 | II | MW-29 | 19% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-32 | 17% | Aug 1992 | EXPL | RDX | 2.03 | 0.337 |
| 5 & 6 | II | MW-32 | 17% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-32 | 17% | Nov 1992 | EXPL | RDX | 2.365 | 0.393 |
| 5 & 6 | II | MW-32 | 17% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-32 | 17% | Feb 1993 | EXPL | RDX | 3.28 | 0.545 |
| 5 & 6 | II | MW-32 | 17% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-32 | 17% | May 1993 | EXPL | RDX | 3.725 | 0.619 |
| 5 & 6 | II | MW-32 | 17% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-33 | 9% | Aug 1992 | EXPL | RDX | 5.5 | 0.496 |
| 5 & 6 | II | MW-33 | 9% | Aug 1992 | VOC | TCE | 1 | 0.090 |
| 5 & 6 | II | MW-33 | 9% | Nov 1992 | EXPL | RDX | 8.55 | 0.772 |
| 5 & 6 | II | MW-33 | 9% | Nov 1992 | VOC | TCE | 1 | 0.090 |
| 5 & 6 | II | MW-33 | 9% | Feb 1993 | EXPL | RDX | 10.8 | 0.975 |
| 5 & 6 | II | MW-33 | 9% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-33 | 9% | May 1993 | EXPL | RDX | 8.85 | 0.799 |
| 5 & 6 | II | MW-33 | 9% | May 1993 | VOC | TCE | 1 | 0.090 |
| 5 & 6 | II | MW-35 | 13% | Aug 1992 | EXPL | RDX | 0.34 | 0.043 |
| 5 & 6 | II | MW-35 | 13% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-35 | 13% | Nov 1992 | EXPL | RDX | 0.63 | 0.080 |
| 5 & 6 | II | MW-35 | 13% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-35 | 13% | Feb 1993 | EXPL | RDX | 0.75 | 0.095 |
| 5 & 6 | II | MW-35 | 13% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-35 | 13% | May 1993 | EXPL | RDX | 0.86 | 0.109 |
| 5 & 6 | II | MW-35 | 13% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-36 | 3% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | II | MW-36 | 3% | Aug 1992 | VOC | TCE | 25 | 0.722 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | II | MW-36 | 3% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | II | MW-36 | 3% | Nov 1992 | VOC | TCE | 37.5 | 1.083 |
| 5 & 6 | II | MW-36 | 3% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | II | MW-36 | 3% | Feb 1993 | VOC | TCE | 55.5 | 1.603 |
| 5 & 6 | II | MW-36 | 3% | May 1993 | EXPL | RDX | | |
| 5 & 6 | II | MW-36 | 3% | May 1993 | VOC | TCE | 58.5 | 1.690 |
| 5 & 6 | II | MW-44 | 4% | Aug 1992 | EXPL | RDX | 1.165 | 0.046 |
| 5 & 6 | II | MW-44 | 4% | Aug 1992 | VOC | TCE | 180 | 7.148 |
| 5 & 6 | II | MW-44 | 4% | Nov 1992 | EXPL | RDX | 0.69 | 0.027 |
| 5 & 6 | II | MW-44 | 4% | Nov 1992 | VOC | TCE | 170 | 6.751 |
| 5 & 6 | II | MW-44 | 4% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | II | MW-44 | 4% | Feb 1993 | VOC | TCE | 85.35 | 3.389 |
| 5 & 6 | II | MW-44 | 4% | May 1993 | EXPL | RDX | 1.1 | 0.044 |
| 5 & 6 | II | MW-44 | 4% | May 1993 | VOC | TCE | 160 | 6.354 |
| 5 & 6 | II | MW-45 | 3% | Aug 1992 | EXPL | RDX | 0.73 | 0.021 |
| 5 & 6 | II | MW-45 | 3% | Aug 1992 | VOC | TCE | 62.5 | 1.805 |
| 5 & 6 | II | MW-45 | 3% | Nov 1992 | EXPL | RDX | 3.75 | 0.108 |
| 5 & 6 | II | MW-45 | 3% | Nov 1992 | VOC | TCE | 18 | 0.520 |
| 5 & 6 | II | MW-45 | 3% | Feb 1993 | EXPL | RDX | 3.1 | 0.090 |
| 5 & 6 | II | MW-45 | 3% | Feb 1993 | VOC | TCE | 48 | 1.386 |
| 5 & 6 | II | MW-45 | 3% | May 1993 | EXPL | RDX | 4.8 | 0.139 |
| 5 & 6 | II | MW-45 | 3% | May 1993 | VOC | TCE | 83.5 | 2.412 |
| 5 & 6 | II | MW-52 | 1% | Aug 1992 | EXPL | RDX | 1.735 | 0.015 |
| 5 & 6 | II | MW-52 | 1% | Aug 1992 | VOC | TCE | 2 | 0.017 |
| 5 & 6 | II | MW-52 | 1% | Nov 1992 | EXPL | RDX | 10.7 | 0.093 |
| 5 & 6 | II | MW-52 | 1% | Nov 1992 | VOC | TCE | 3.5 | 0.030 |
| 5 & 6 | II | MW-52 | 1% | Feb 1993 | EXPL | RDX | 15.15 | 0.131 |
| 5 & 6 | II | MW-52 | 1% | Feb 1993 | VOC | TCE | 8 | 0.069 |
| 5 & 6 | II | MW-52 | 1% | May 1993 | EXPL | RDX | 6.05 | 0.052 |
| 5 & 6 | II | MW-52 | 1% | May 1993 | VOC | TCE | 4.5 | 0.039 |
| 5 & 6 | II | MW-53 | 1% | Aug 1992 | EXPL | RDX | 4.5 | 0.039 |
| 5 & 6 | II | MW-53 | 1% | Aug 1992 | VOC | TCE | 52.5 | 0.455 |
| 5 & 6 | II | MW-53 | 1% | Nov 1992 | EXPL | RDX | 8.35 | 0.072 |
| 5 & 6 | II | MW-53 | 1% | Nov 1992 | VOC | TCE | 37.5 | 0.325 |
| 5 & 6 | II | MW-53 | 1% | Feb 1993 | EXPL | RDX | 10.35 | 0.090 |
| 5 & 6 | II | MW-53 | 1% | Feb 1993 | VOC | TCE | 39 | 0.338 |
| 5 & 6 | II | MW-53 | 1% | May 1993 | EXPL | RDX | 8.3 | 0.072 |
| 5 & 6 | II | MW-53 | 1% | May 1993 | VOC | TCE | 43 | 0.373 |
| 5 & 6 | II | MW-54 | 1% | Aug 1992 | EXPL | RDX | 0.91 | 0.008 |
| 5 & 6 | II | MW-54 | 1% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-54 | 1% | Nov 1992 | EXPL | RDX | 1.4 | 0.012 |
| 5 & 6 | II | MW-54 | 1% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-54 | 1% | Feb 1993 | EXPL | RDX | 2.3 | 0.020 |
| 5 & 6 | II | MW-54 | 1% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-54 | 1% | May 1993 | EXPL | RDX | 2.4 | 0.021 |
| 5 & 6 | II | MW-54 | 1% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-55 | 1% | Aug 1992 | EXPL | RDX | 0.38 | 0.003 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | II | MW-55 | 1% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-55 | 1% | Nov 1992 | EXPL | RDX | 0.63 | 0.005 |
| 5 & 6 | II | MW-55 | 1% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | II | MW-55 | 1% | Feb 1993 | EXPL | RDX | 0.76 | 0.007 |
| 5 & 6 | II | MW-55 | 1% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-55 | 1% | May 1993 | EXPL | RDX | 0.76 | 0.007 |
| 5 & 6 | II | MW-55 | 1% | May 1993 | VOC | TCE | | |
| 5 & 6 | II | MW-56 | 1% | Aug 1992 | EXPL | RDX | 0.79 | 0.007 |
| 5 & 6 | II | MW-56 | 1% | Aug 1992 | VOC | TCE | 11 | 0.103 |
| 5 & 6 | II | MW-56 | 1% | Nov 1992 | EXPL | RDX | 0.875 | 0.008 |
| 5 & 6 | II | MW-56 | 1% | Nov 1992 | VOC | TCE | 12 | 0.113 |
| 5 & 6 | II | MW-56 | 1% | Feb 1993 | EXPL | RDX | 1.21 | 0.011 |
| 5 & 6 | II | MW-56 | 1% | Feb 1993 | VOC | TCE | 6 | 0.056 |
| 5 & 6 | II | MW-56 | 1% | May 1993 | EXPL | RDX | 1.08 | 0.010 |
| 5 & 6 | II | MW-56 | 1% | May 1993 | VOC | TCE | 9 | 0.084 |
| 5 & 6 | III | MW-02 | 3% | Aug 1992 | EXPL | RDX | 3.435 | 0.103 |
| 5 & 6 | III | MW-02 | 3% | Aug 1992 | VOC | TCE | 70.5 | 2.115 |
| 5 & 6 | III | MW-02 | 3% | Nov 1992 | EXPL | RDX | 6.105 | 0.183 |
| 5 & 6 | III | MW-02 | 3% | Nov 1992 | VOC | TCE | 69.5 | 2.085 |
| 5 & 6 | III | MW-02 | 3% | Feb 1993 | EXPL | RDX | 9.12 | 0.274 |
| 5 & 6 | III | MW-02 | 3% | Feb 1993 | VOC | TCE | 103.5 | 3.105 |
| 5 & 6 | III | MW-02 | 3% | May 1993 | EXPL | RDX | 8.6 | 0.258 |
| 5 & 6 | III | MW-02 | 3% | May 1993 | VOC | TCE | 80.5 | 2.415 |
| 5 & 6 | III | MW-03 | 3% | Aug 1992 | EXPL | RDX | 0.37 | 0.011 |
| 5 & 6 | III | MW-03 | 3% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-03 | 3% | Nov 1992 | EXPL | RDX | 0.765 | 0.023 |
| 5 & 6 | III | MW-03 | 3% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-03 | 3% | Feb 1993 | EXPL | RDX | 0.985 | 0.030 |
| 5 & 6 | III | MW-03 | 3% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-03 | 3% | May 1993 | EXPL | RDX | 1.185 | 0.036 |
| 5 & 6 | III | MW-03 | 3% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-04 | 3% | Aug 1992 | EXPL | RDX | 2.33 | 0.074 |
| 5 & 6 | III | MW-04 | 3% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-04 | 3% | Nov 1992 | EXPL | RDX | 7.4 | 0.234 |
| 5 & 6 | III | MW-04 | 3% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-04 | 3% | Feb 1993 | EXPL | RDX | 5.68 | 0.180 |
| 5 & 6 | III | MW-04 | 3% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-04 | 3% | May 1993 | EXPL | RDX | 8.565 | 0.271 |
| 5 & 6 | III | MW-04 | 3% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-05 | 3% | Aug 1992 | EXPL | RDX | 98 | 3.103 |
| 5 & 6 | III | MW-05 | 3% | Aug 1992 | VOC | TCE | 4 | 0.127 |
| 5 & 6 | III | MW-05 | 3% | Nov 1992 | EXPL | RDX | 160.38 | 5.079 |
| 5 & 6 | III | MW-05 | 3% | Nov 1992 | VOC | TCE | 7 | 0.222 |
| 5 & 6 | III | MW-05 | 3% | Feb 1993 | EXPL | RDX | 320 | 10.133 |
| 5 & 6 | III | MW-05 | 3% | Feb 1993 | VOC | TCE | 6 | 0.190 |
| 5 & 6 | III | MW-05 | 3% | May 1993 | EXPL | RDX | 534 | 16.910 |
| 5 & 6 | III | MW-05 | 3% | May 1993 | VOC | TCE | 6 | 0.190 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | III | MW-09 | 7% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | III | MW-09 | 7% | Aug 1992 | VOC | TCE | 165.5 | 11.033 |
| 5 & 6 | III | MW-09 | 7% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | III | MW-09 | 7% | Nov 1992 | VOC | TCE | 102 | 6.800 |
| 5 & 6 | III | MW-09 | 7% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | III | MW-09 | 7% | Feb 1993 | VOC | TCE | 117 | 7.800 |
| 5 & 6 | III | MW-09 | 7% | May 1993 | EXPL | RDX | | |
| 5 & 6 | III | MW-09 | 7% | May 1993 | VOC | TCE | 88.5 | 5.900 |
| 5 & 6 | III | MW-11 | 1% | Aug 1992 | EXPL | RDX | 33 | 0.264 |
| 5 & 6 | III | MW-11 | 1% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-11 | 1% | Nov 1992 | EXPL | RDX | 35 | 0.280 |
| 5 & 6 | III | MW-11 | 1% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-11 | 1% | Feb 1993 | EXPL | RDX | 32 | 0.256 |
| 5 & 6 | III | MW-11 | 1% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-11 | 1% | May 1993 | EXPL | RDX | 12 | 0.096 |
| 5 & 6 | III | MW-11 | 1% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-18 | 1% | Aug 1992 | EXPL | RDX | 1.9 | 0.015 |
| 5 & 6 | III | MW-18 | 1% | Aug 1992 | VOC | TCE | 76 | 0.608 |
| 5 & 6 | III | MW-18 | 1% | Nov 1992 | EXPL | RDX | 3.6 | 0.029 |
| 5 & 6 | III | MW-18 | 1% | Nov 1992 | VOC | TCE | 56 | 0.448 |
| 5 & 6 | III | MW-18 | 1% | Feb 1993 | EXPL | RDX | 4.1 | 0.033 |
| 5 & 6 | III | MW-18 | 1% | Feb 1993 | VOC | TCE | 92 | 0.736 |
| 5 & 6 | III | MW-18 | 1% | May 1993 | EXPL | RDX | 4.2 | 0.034 |
| 5 & 6 | III | MW-18 | 1% | May 1993 | VOC | TCE | 76 | 0.608 |
| 5 & 6 | III | MW-24 | 3% | Aug 1992 | EXPL | RDX | 0.46 | 0.014 |
| 5 & 6 | III | MW-24 | 3% | Aug 1992 | VOC | TCE | 0.9 | 0.027 |
| 5 & 6 | III | MW-24 | 3% | Nov 1992 | EXPL | RDX | 0.26 | 0.008 |
| 5 & 6 | III | MW-24 | 3% | Nov 1992 | VOC | TCE | 0.8 | 0.024 |
| 5 & 6 | III | MW-24 | 3% | Feb 1993 | EXPL | RDX | 0.41 | 0.012 |
| 5 & 6 | III | MW-24 | 3% | Feb 1993 | VOC | TCE | 1 | 0.030 |
| 5 & 6 | III | MW-24 | 3% | May 1993 | EXPL | RDX | 0.3 | 0.009 |
| 5 & 6 | III | MW-24 | 3% | May 1993 | VOC | TCE | 1 | 0.030 |
| 5 & 6 | III | MW-25 | 3% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | III | MW-25 | 3% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-25 | 3% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | III | MW-25 | 3% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-25 | 3% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | III | MW-25 | 3% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-25 | 3% | May 1993 | EXPL | RDX | | |
| 5 & 6 | III | MW-25 | 3% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-29 | 23% | Aug 1992 | EXPL | RDX | 4.4 | 1.027 |
| 5 & 6 | III | MW-29 | 23% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-29 | 23% | Nov 1992 | EXPL | RDX | 6.1 | 1.423 |
| 5 & 6 | III | MW-29 | 23% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-29 | 23% | Feb 1993 | EXPL | RDX | 6.4 | 1.493 |
| 5 & 6 | III | MW-29 | 23% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-29 | 23% | May 1993 | EXPL | RDX | 8.6 | 2.007 |

Table K-14
Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | III | MW-29 | 23% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-32 | 20% | Aug 1992 | EXPL | RDX | 2.03 | 0.406 |
| 5 & 6 | III | MW-32 | 20% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-32 | 20% | Nov 1992 | EXPL | RDX | 2.365 | 0.473 |
| 5 & 6 | III | MW-32 | 20% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-32 | 20% | Feb 1993 | EXPL | RDX | 3.28 | 0.656 |
| 5 & 6 | III | MW-32 | 20% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-32 | 20% | May 1993 | EXPL | RDX | 3.725 | 0.745 |
| 5 & 6 | III | MW-32 | 20% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-34 | 6% | Aug 1992 | EXPL | RDX | 0.91 | 0.058 |
| 5 & 6 | III | MW-34 | 6% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-34 | 6% | Nov 1992 | EXPL | RDX | 0.95 | 0.060 |
| 5 & 6 | III | MW-34 | 6% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-34 | 6% | Feb 1993 | EXPL | RDX | 1.6 | 0.101 |
| 5 & 6 | III | MW-34 | 6% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-34 | 6% | May 1993 | EXPL | RDX | 1.6 | 0.101 |
| 5 & 6 | III | MW-34 | 6% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-35 | 11% | Aug 1992 | EXPL | RDX | 0.34 | 0.036 |
| 5 & 6 | III | MW-35 | 11% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-35 | 11% | Nov 1992 | EXPL | RDX | 0.63 | 0.067 |
| 5 & 6 | III | MW-35 | 11% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-35 | 11% | Feb 1993 | EXPL | RDX | 0.75 | 0.080 |
| 5 & 6 | III | MW-35 | 11% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-35 | 11% | May 1993 | EXPL | RDX | 0.86 | 0.092 |
| 5 & 6 | III | MW-35 | 11% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-36 | 3% | Aug 1992 | EXPL | RDX | | |
| 5 & 6 | III | MW-36 | 3% | Aug 1992 | VOC | TCE | 25 | 0.667 |
| 5 & 6 | III | MW-36 | 3% | Nov 1992 | EXPL | RDX | | |
| 5 & 6 | III | MW-36 | 3% | Nov 1992 | VOC | TCE | 37.5 | 1.000 |
| 5 & 6 | III | MW-36 | 3% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | III | MW-36 | 3% | Feb 1993 | VOC | TCE | 55.5 | 1.480 |
| 5 & 6 | III | MW-36 | 3% | May 1993 | EXPL | RDX | | |
| 5 & 6 | III | MW-36 | 3% | May 1993 | VOC | TCE | 58.5 | 1.560 |
| 5 & 6 | III | MW-44 | 4% | Aug 1992 | EXPL | RDX | 1.165 | 0.043 |
| 5 & 6 | III | MW-44 | 4% | Aug 1992 | VOC | TCE | 180 | 6.600 |
| 5 & 6 | III | MW-44 | 4% | Nov 1992 | EXPL | RDX | 0.69 | 0.025 |
| 5 & 6 | III | MW-44 | 4% | Nov 1992 | VOC | TCE | 170 | 6.233 |
| 5 & 6 | III | MW-44 | 4% | Feb 1993 | EXPL | RDX | | |
| 5 & 6 | III | MW-44 | 4% | Feb 1993 | VOC | TCE | 85.35 | 3.130 |
| 5 & 6 | III | MW-44 | 4% | May 1993 | EXPL | RDX | 1.1 | 0.040 |
| 5 & 6 | III | MW-44 | 4% | May 1993 | VOC | TCE | 160 | 5.867 |
| 5 & 6 | III | MW-45 | 3% | Aug 1992 | EXPL | RDX | 0.73 | 0.019 |
| 5 & 6 | III | MW-45 | 3% | Aug 1992 | VOC | TCE | 62.5 | 1.667 |
| 5 & 6 | III | MW-45 | 3% | Nov 1992 | EXPL | RDX | 3.75 | 0.100 |
| 5 & 6 | III | MW-45 | 3% | Nov 1992 | VOC | TCE | 18 | 0.480 |
| 5 & 6 | III | MW-45 | 3% | Feb 1993 | EXPL | RDX | 3.1 | 0.083 |
| 5 & 6 | III | MW-45 | 3% | Feb 1993 | VOC | TCE | 48 | 1.280 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 5 & 6 | III | MW-45 | 3% | May 1993 | EXPL | RDX | 4.8 | 0.128 |
| 5 & 6 | III | MW-45 | 3% | May 1993 | VOC | TCE | 83.5 | 2.227 |
| 5 & 6 | III | MW-52 | 1% | Aug 1992 | EXPL | RDX | 1.735 | 0.014 |
| 5 & 6 | III | MW-52 | 1% | Aug 1992 | VOC | TCE | 2 | 0.016 |
| 5 & 6 | III | MW-52 | 1% | Nov 1992 | EXPL | RDX | 10.7 | 0.086 |
| 5 & 6 | III | MW-52 | 1% | Nov 1992 | VOC | TCE | 3.5 | 0.028 |
| 5 & 6 | III | MW-52 | 1% | Feb 1993 | EXPL | RDX | 15.15 | 0.121 |
| 5 & 6 | III | MW-52 | 1% | Feb 1993 | VOC | TCE | 8 | 0.064 |
| 5 & 6 | III | MW-52 | 1% | May 1993 | EXPL | RDX | 6.05 | 0.048 |
| 5 & 6 | III | MW-52 | 1% | May 1993 | VOC | TCE | 4.5 | 0.036 |
| 5 & 6 | III | MW-53 | 1% | Aug 1992 | EXPL | RDX | 4.5 | 0.036 |
| 5 & 6 | III | MW-53 | 1% | Aug 1992 | VOC | TCE | 52.5 | 0.420 |
| 5 & 6 | III | MW-53 | 1% | Nov 1992 | EXPL | RDX | 8.35 | 0.067 |
| 5 & 6 | III | MW-53 | 1% | Nov 1992 | VOC | TCE | 37.5 | 0.300 |
| 5 & 6 | III | MW-53 | 1% | Feb 1993 | EXPL | RDX | 10.35 | 0.083 |
| 5 & 6 | III | MW-53 | 1% | Feb 1993 | VOC | TCE | 39 | 0.312 |
| 5 & 6 | III | MW-53 | 1% | May 1993 | EXPL | RDX | 8.3 | 0.066 |
| 5 & 6 | III | MW-53 | 1% | May 1993 | VOC | TCE | 43 | 0.344 |
| 5 & 6 | III | MW-54 | 1% | Aug 1992 | EXPL | RDX | 0.91 | 0.007 |
| 5 & 6 | III | MW-54 | 1% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-54 | 1% | Nov 1992 | EXPL | RDX | 1.4 | 0.011 |
| 5 & 6 | III | MW-54 | 1% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-54 | 1% | Feb 1993 | EXPL | RDX | 2.3 | 0.018 |
| 5 & 6 | III | MW-54 | 1% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-54 | 1% | May 1993 | EXPL | RDX | 2.4 | 0.019 |
| 5 & 6 | III | MW-54 | 1% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-55 | 1% | Aug 1992 | EXPL | RDX | 0.38 | 0.003 |
| 5 & 6 | III | MW-55 | 1% | Aug 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-55 | 1% | Nov 1992 | EXPL | RDX | 0.63 | 0.005 |
| 5 & 6 | III | MW-55 | 1% | Nov 1992 | VOC | TCE | | |
| 5 & 6 | III | MW-55 | 1% | Feb 1993 | EXPL | RDX | 0.76 | 0.006 |
| 5 & 6 | III | MW-55 | 1% | Feb 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-55 | 1% | May 1993 | EXPL | RDX | 0.76 | 0.006 |
| 5 & 6 | III | MW-55 | 1% | May 1993 | VOC | TCE | | |
| 5 & 6 | III | MW-56 | 1% | Aug 1992 | EXPL | RDX | 0.79 | 0.007 |
| 5 & 6 | III | MW-56 | 1% | Aug 1992 | VOC | TCE | 11 | 0.095 |
| 5 & 6 | III | MW-56 | 1% | Nov 1992 | EXPL | RDX | 0.875 | 0.008 |
| 5 & 6 | III | MW-56 | 1% | Nov 1992 | VOC | TCE | 12 | 0.104 |
| 5 & 6 | III | MW-56 | 1% | Feb 1993 | EXPL | RDX | 1.21 | 0.010 |
| 5 & 6 | III | MW-56 | 1% | Feb 1993 | VOC | TCE | 6 | 0.052 |
| 5 & 6 | III | MW-56 | 1% | May 1993 | EXPL | RDX | 1.08 | 0.009 |
| 5 & 6 | III | MW-56 | 1% | May 1993 | VOC | TCE | 9 | 0.078 |
| 7 & 8 | I | MW-02 | 2% | Aug 1992 | EXPL | RDX | 3.435 | 0.083 |
| 7 & 8 | I | MW-02 | 2% | Aug 1992 | VOC | TCE | 70.5 | 1.699 |
| 7 & 8 | I | MW-02 | 2% | Nov 1992 | EXPL | RDX | 6.105 | 0.147 |
| 7 & 8 | I | MW-02 | 2% | Nov 1992 | VOC | TCE | 69.5 | 1.675 |
| 7 & 8 | I | MW-02 | 2% | Feb 1993 | EXPL | RDX | 9.12 | 0.220 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | I | MW-02 | 2% | Feb 1993 | VOC | TCE | 103.5 | 2.494 |
| 7 & 8 | I | MW-02 | 2% | May 1993 | EXPL | RDX | 8.6 | 0.207 |
| 7 & 8 | I | MW-02 | 2% | May 1993 | VOC | TCE | 80.5 | 1.940 |
| 7 & 8 | I | MW-03 | 2% | Aug 1992 | EXPL | RDX | 0.37 | 0.009 |
| 7 & 8 | I | MW-03 | 2% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-03 | 2% | Nov 1992 | EXPL | RDX | 0.765 | 0.018 |
| 7 & 8 | I | MW-03 | 2% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-03 | 2% | Feb 1993 | EXPL | RDX | 0.985 | 0.024 |
| 7 & 8 | I | MW-03 | 2% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-03 | 2% | May 1993 | EXPL | RDX | 1.185 | 0.029 |
| 7 & 8 | I | MW-03 | 2% | May 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-04 | 2% | Aug 1992 | EXPL | RDX | 2.33 | 0.053 |
| 7 & 8 | I | MW-04 | 2% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-04 | 2% | Nov 1992 | EXPL | RDX | 7.4 | 0.169 |
| 7 & 8 | I | MW-04 | 2% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-04 | 2% | Feb 1993 | EXPL | RDX | 5.68 | 0.130 |
| 7 & 8 | I | MW-04 | 2% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-04 | 2% | May 1993 | EXPL | RDX | 8.565 | 0.196 |
| 7 & 8 | I | MW-04 | 2% | May 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-05 | 2% | Aug 1992 | EXPL | RDX | 98 | 2.243 |
| 7 & 8 | I | MW-05 | 2% | Aug 1992 | VOC | TCE | 4 | 0.092 |
| 7 & 8 | I | MW-05 | 2% | Nov 1992 | EXPL | RDX | 160.38 | 3.671 |
| 7 & 8 | I | MW-05 | 2% | Nov 1992 | VOC | TCE | 7 | 0.160 |
| 7 & 8 | I | MW-05 | 2% | Feb 1993 | EXPL | RDX | 320 | 7.325 |
| 7 & 8 | I | MW-05 | 2% | Feb 1993 | VOC | TCE | 6 | 0.137 |
| 7 & 8 | I | MW-05 | 2% | May 1993 | EXPL | RDX | 534 | 12.224 |
| 7 & 8 | I | MW-05 | 2% | May 1993 | VOC | TCE | 6 | 0.137 |
| 7 & 8 | I | MW-09 | 7% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-09 | 7% | Aug 1992 | VOC | TCE | 165.5 | 11.100 |
| 7 & 8 | I | MW-09 | 7% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-09 | 7% | Nov 1992 | VOC | TCE | 102 | 6.841 |
| 7 & 8 | I | MW-09 | 7% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-09 | 7% | Feb 1993 | VOC | TCE | 117 | 7.847 |
| 7 & 8 | I | MW-09 | 7% | May 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-09 | 7% | May 1993 | VOC | TCE | 88.5 | 5.936 |
| 7 & 8 | I | MW-11 | 7% | Aug 1992 | EXPL | RDX | 33 | 2.200 |
| 7 & 8 | I | MW-11 | 7% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-11 | 7% | Nov 1992 | EXPL | RDX | 35 | 2.333 |
| 7 & 8 | I | MW-11 | 7% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-11 | 7% | Feb 1993 | EXPL | RDX | 32 | 2.133 |
| 7 & 8 | I | MW-11 | 7% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-11 | 7% | May 1993 | EXPL | RDX | 12 | 0.800 |
| 7 & 8 | I | MW-11 | 7% | May 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-18 | 5% | Aug 1992 | EXPL | RDX | 1.9 | 0.095 |
| 7 & 8 | I | MW-18 | 5% | Aug 1992 | VOC | TCE | 76 | 3.815 |
| 7 & 8 | I | MW-18 | 5% | Nov 1992 | EXPL | RDX | 3.6 | 0.181 |
| 7 & 8 | I | MW-18 | 5% | Nov 1992 | VOC | TCE | 56 | 2.811 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | I | MW-18 | 5% | Feb 1993 | EXPL | RDX | 4.1 | 0.206 |
| 7 & 8 | I | MW-18 | 5% | Feb 1993 | VOC | TCE | 92 | 4.618 |
| 7 & 8 | I | MW-18 | 5% | May 1993 | EXPL | RDX | 4.2 | 0.211 |
| 7 & 8 | I | MW-18 | 5% | May 1993 | VOC | TCE | 76 | 3.815 |
| 7 & 8 | I | MW-21 | 2% | Aug 1992 | EXPL | RDX | 10 | 0.241 |
| 7 & 8 | I | MW-21 | 2% | Aug 1992 | VOC | TCE | 140 | 3.373 |
| 7 & 8 | I | MW-21 | 2% | Nov 1992 | EXPL | RDX | 11 | 0.265 |
| 7 & 8 | I | MW-21 | 2% | Nov 1992 | VOC | TCE | 140 | 3.373 |
| 7 & 8 | I | MW-21 | 2% | Feb 1993 | EXPL | RDX | 18 | 0.434 |
| 7 & 8 | I | MW-21 | 2% | Feb 1993 | VOC | TCE | 130 | 3.133 |
| 7 & 8 | I | MW-21 | 2% | May 1993 | EXPL | RDX | 16 | 0.386 |
| 7 & 8 | I | MW-21 | 2% | May 1993 | VOC | TCE | 110 | 2.651 |
| 7 & 8 | I | MW-25 | 2% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-25 | 2% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-25 | 2% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-25 | 2% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-25 | 2% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-25 | 2% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-25 | 2% | May 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-25 | 2% | May 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-29 | 10% | Aug 1992 | EXPL | RDX | 4.4 | 0.459 |
| 7 & 8 | I | MW-29 | 10% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-29 | 10% | Nov 1992 | EXPL | RDX | 6.1 | 0.637 |
| 7 & 8 | I | MW-29 | 10% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-29 | 10% | Feb 1993 | EXPL | RDX | 6.4 | 0.668 |
| 7 & 8 | I | MW-29 | 10% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-29 | 10% | May 1993 | EXPL | RDX | 8.6 | 0.898 |
| 7 & 8 | I | MW-29 | 10% | May 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-31 | 2% | Aug 1992 | EXPL | RDX | 4.7 | 0.106 |
| 7 & 8 | I | MW-31 | 2% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-31 | 2% | Nov 1992 | EXPL | RDX | 3.8 | 0.085 |
| 7 & 8 | I | MW-31 | 2% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | I | MW-31 | 2% | Feb 1993 | EXPL | RDX | 6.4 | 0.144 |
| 7 & 8 | I | MW-31 | 2% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-31 | 2% | May 1993 | EXPL | RDX | 5.3 | 0.119 |
| 7 & 8 | I | MW-31 | 2% | May 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-33 | 8% | Aug 1992 | EXPL | RDX | 5.5 | 0.420 |
| 7 & 8 | I | MW-33 | 8% | Aug 1992 | VOC | TCE | 1 | 0.076 |
| 7 & 8 | I | MW-33 | 8% | Nov 1992 | EXPL | RDX | 8.55 | 0.652 |
| 7 & 8 | I | MW-33 | 8% | Nov 1992 | VOC | TCE | 1 | 0.076 |
| 7 & 8 | I | MW-33 | 8% | Feb 1993 | EXPL | RDX | 10.8 | 0.824 |
| 7 & 8 | I | MW-33 | 8% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | I | MW-33 | 8% | May 1993 | EXPL | RDX | 8.85 | 0.675 |
| 7 & 8 | I | MW-33 | 8% | May 1993 | VOC | TCE | 1 | 0.076 |
| 7 & 8 | I | MW-36 | 2% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-36 | 2% | Aug 1992 | VOC | TCE | 25 | 0.552 |
| 7 & 8 | I | MW-36 | 2% | Nov 1992 | EXPL | RDX | | |

Table K-14
Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | I | MW-36 | 2% | Nov 1992 | VOC | TCE | 37.5 | 0.828 |
| 7 & 8 | I | MW-36 | 2% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-36 | 2% | Feb 1993 | VOC | TCE | 55.5 | 1.226 |
| 7 & 8 | I | MW-36 | 2% | May 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-36 | 2% | May 1993 | VOC | TCE | 58.5 | 1.292 |
| 7 & 8 | I | MW-40 | 12% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-40 | 12% | Aug 1992 | VOC | TCE | 911 | 111.588 |
| 7 & 8 | I | MW-40 | 12% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-40 | 12% | Nov 1992 | VOC | TCE | 1560 | 191.084 |
| 7 & 8 | I | MW-40 | 12% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-40 | 12% | Feb 1993 | VOC | TCE | 2408.5 | 295.017 |
| 7 & 8 | I | MW-40 | 12% | May 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-40 | 12% | May 1993 | VOC | TCE | 1960.5 | 240.142 |
| 7 & 8 | I | MW-43 | 5% | Aug 1992 | EXPL | RDX | 18 | 0.904 |
| 7 & 8 | I | MW-43 | 5% | Aug 1992 | VOC | TCE | 46 | 2.309 |
| 7 & 8 | I | MW-43 | 5% | Nov 1992 | EXPL | RDX | 20 | 1.004 |
| 7 & 8 | I | MW-43 | 5% | Nov 1992 | VOC | TCE | 38 | 1.908 |
| 7 & 8 | I | MW-43 | 5% | Feb 1993 | EXPL | RDX | 26 | 1.305 |
| 7 & 8 | I | MW-43 | 5% | Feb 1993 | VOC | TCE | 36 | 1.807 |
| 7 & 8 | I | MW-43 | 5% | May 1993 | EXPL | RDX | 32 | 1.606 |
| 7 & 8 | I | MW-43 | 5% | May 1993 | VOC | TCE | 38 | 1.908 |
| 7 & 8 | I | MW-44 | 6% | Aug 1992 | EXPL | RDX | 1.165 | 0.075 |
| 7 & 8 | I | MW-44 | 6% | Aug 1992 | VOC | TCE | 180 | 11.566 |
| 7 & 8 | I | MW-44 | 6% | Nov 1992 | EXPL | RDX | 0.69 | 0.044 |
| 7 & 8 | I | MW-44 | 6% | Nov 1992 | VOC | TCE | 170 | 10.924 |
| 7 & 8 | I | MW-44 | 6% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-44 | 6% | Feb 1993 | VOC | TCE | 85.35 | 5.484 |
| 7 & 8 | I | MW-44 | 6% | May 1993 | EXPL | RDX | 1.1 | 0.071 |
| 7 & 8 | I | MW-44 | 6% | May 1993 | VOC | TCE | 160 | 10.281 |
| 7 & 8 | I | MW-45 | 2% | Aug 1992 | EXPL | RDX | 0.73 | 0.016 |
| 7 & 8 | I | MW-45 | 2% | Aug 1992 | VOC | TCE | 62.5 | 1.381 |
| 7 & 8 | I | MW-45 | 2% | Nov 1992 | EXPL | RDX | 3.75 | 0.083 |
| 7 & 8 | I | MW-45 | 2% | Nov 1992 | VOC | TCE | 18 | 0.398 |
| 7 & 8 | I | MW-45 | 2% | Feb 1993 | EXPL | RDX | 3.1 | 0.068 |
| 7 & 8 | I | MW-45 | 2% | Feb 1993 | VOC | TCE | 48 | 1.060 |
| 7 & 8 | I | MW-45 | 2% | May 1993 | EXPL | RDX | 4.8 | 0.106 |
| 7 & 8 | I | MW-45 | 2% | May 1993 | VOC | TCE | 83.5 | 1.844 |
| 7 & 8 | I | MW-52 | 7% | Aug 1992 | EXPL | RDX | 1.735 | 0.116 |
| 7 & 8 | I | MW-52 | 7% | Aug 1992 | VOC | TCE | 2 | 0.134 |
| 7 & 8 | I | MW-52 | 7% | Nov 1992 | EXPL | RDX | 10.7 | 0.718 |
| 7 & 8 | I | MW-52 | 7% | Nov 1992 | VOC | TCE | 3.5 | 0.235 |
| 7 & 8 | I | MW-52 | 7% | Feb 1993 | EXPL | RDX | 15.15 | 1.016 |
| 7 & 8 | I | MW-52 | 7% | Feb 1993 | VOC | TCE | 8 | 0.537 |
| 7 & 8 | I | MW-52 | 7% | May 1993 | EXPL | RDX | 6.05 | 0.406 |
| 7 & 8 | I | MW-52 | 7% | May 1993 | VOC | TCE | 4.5 | 0.302 |
| 7 & 8 | I | MW-58 | 12% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-58 | 12% | Aug 1992 | VOC | TCE | 130 | 15.924 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | I | MW-58 | 12% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | I | MW-58 | 12% | Nov 1992 | VOC | TCE | 70.5 | 8.636 |
| 7 & 8 | I | MW-58 | 12% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-58 | 12% | Feb 1993 | VOC | TCE | 120 | 14.699 |
| 7 & 8 | I | MW-58 | 12% | May 1993 | EXPL | RDX | | |
| 7 & 8 | I | MW-58 | 12% | May 1993 | VOC | TCE | 97 | 11.882 |
| 7 & 8 | II | MW-02 | 2% | Aug 1992 | EXPL | RDX | 3.435 | 0.074 |
| 7 & 8 | II | MW-02 | 2% | Aug 1992 | VOC | TCE | 70.5 | 1.511 |
| 7 & 8 | II | MW-02 | 2% | Nov 1992 | EXPL | RDX | 6.105 | 0.131 |
| 7 & 8 | II | MW-02 | 2% | Nov 1992 | VOC | TCE | 69.5 | 1.489 |
| 7 & 8 | II | MW-02 | 2% | Feb 1993 | EXPL | RDX | 9.12 | 0.195 |
| 7 & 8 | II | MW-02 | 2% | Feb 1993 | VOC | TCE | 103.5 | 2.218 |
| 7 & 8 | II | MW-02 | 2% | May 1993 | EXPL | RDX | 8.6 | 0.184 |
| 7 & 8 | II | MW-02 | 2% | May 1993 | VOC | TCE | 80.5 | 1.725 |
| 7 & 8 | II | MW-03 | 2% | Aug 1992 | EXPL | RDX | 0.37 | 0.008 |
| 7 & 8 | II | MW-03 | 2% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-03 | 2% | Nov 1992 | EXPL | RDX | 0.765 | 0.016 |
| 7 & 8 | II | MW-03 | 2% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-03 | 2% | Feb 1993 | EXPL | RDX | 0.985 | 0.021 |
| 7 & 8 | II | MW-03 | 2% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-03 | 2% | May 1993 | EXPL | RDX | 1.185 | 0.025 |
| 7 & 8 | II | MW-03 | 2% | May 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-04 | 3% | Aug 1992 | EXPL | RDX | 2.33 | 0.080 |
| 7 & 8 | II | MW-04 | 3% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-04 | 3% | Nov 1992 | EXPL | RDX | 7.4 | 0.255 |
| 7 & 8 | II | MW-04 | 3% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-04 | 3% | Feb 1993 | EXPL | RDX | 5.68 | 0.196 |
| 7 & 8 | II | MW-04 | 3% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-04 | 3% | May 1993 | EXPL | RDX | 8.565 | 0.296 |
| 7 & 8 | II | MW-04 | 3% | May 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-05 | 3% | Aug 1992 | EXPL | RDX | 98 | 3.383 |
| 7 & 8 | II | MW-05 | 3% | Aug 1992 | VOC | TCE | 4 | 0.138 |
| 7 & 8 | II | MW-05 | 3% | Nov 1992 | EXPL | RDX | 160.38 | 5.537 |
| 7 & 8 | II | MW-05 | 3% | Nov 1992 | VOC | TCE | 7 | 0.242 |
| 7 & 8 | II | MW-05 | 3% | Feb 1993 | EXPL | RDX | 320 | 11.048 |
| 7 & 8 | II | MW-05 | 3% | Feb 1993 | VOC | TCE | 6 | 0.207 |
| 7 & 8 | II | MW-05 | 3% | May 1993 | EXPL | RDX | 534 | 18.436 |
| 7 & 8 | II | MW-05 | 3% | May 1993 | VOC | TCE | 6 | 0.207 |
| 7 & 8 | II | MW-09 | 4% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-09 | 4% | Aug 1992 | VOC | TCE | 165.5 | 6.581 |
| 7 & 8 | II | MW-09 | 4% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-09 | 4% | Nov 1992 | VOC | TCE | 102 | 4.056 |
| 7 & 8 | II | MW-09 | 4% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-09 | 4% | Feb 1993 | VOC | TCE | 117 | 4.652 |
| 7 & 8 | II | MW-09 | 4% | May 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-09 | 4% | May 1993 | VOC | TCE | 88.5 | 3.519 |
| 7 & 8 | II | MW-11 | 4% | Aug 1992 | EXPL | RDX | 33 | 1.304 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | II | MW-11 | 4% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-11 | 4% | Nov 1992 | EXPL | RDX | 35 | 1.383 |
| 7 & 8 | II | MW-11 | 4% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-11 | 4% | Feb 1993 | EXPL | RDX | 32 | 1.265 |
| 7 & 8 | II | MW-11 | 4% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-11 | 4% | May 1993 | EXPL | RDX | 12 | 0.474 |
| 7 & 8 | II | MW-11 | 4% | May 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-18 | 6% | Aug 1992 | EXPL | RDX | 1.9 | 0.113 |
| 7 & 8 | II | MW-18 | 6% | Aug 1992 | VOC | TCE | 76 | 4.524 |
| 7 & 8 | II | MW-18 | 6% | Nov 1992 | EXPL | RDX | 3.6 | 0.214 |
| 7 & 8 | II | MW-18 | 6% | Nov 1992 | VOC | TCE | 56 | 3.333 |
| 7 & 8 | II | MW-18 | 6% | Feb 1993 | EXPL | RDX | 4.1 | 0.244 |
| 7 & 8 | II | MW-18 | 6% | Feb 1993 | VOC | TCE | 92 | 5.476 |
| 7 & 8 | II | MW-18 | 6% | May 1993 | EXPL | RDX | 4.2 | 0.250 |
| 7 & 8 | II | MW-18 | 6% | May 1993 | VOC | TCE | 76 | 4.524 |
| 7 & 8 | II | MW-21 | 2% | Aug 1992 | EXPL | RDX | 10 | 0.214 |
| 7 & 8 | II | MW-21 | 2% | Aug 1992 | VOC | TCE | 140 | 3.000 |
| 7 & 8 | II | MW-21 | 2% | Nov 1992 | EXPL | RDX | 11 | 0.236 |
| 7 & 8 | II | MW-21 | 2% | Nov 1992 | VOC | TCE | 140 | 3.000 |
| 7 & 8 | II | MW-21 | 2% | Feb 1993 | EXPL | RDX | 18 | 0.386 |
| 7 & 8 | II | MW-21 | 2% | Feb 1993 | VOC | TCE | 130 | 2.786 |
| 7 & 8 | II | MW-21 | 2% | May 1993 | EXPL | RDX | 16 | 0.343 |
| 7 & 8 | II | MW-21 | 2% | May 1993 | VOC | TCE | 110 | 2.357 |
| 7 & 8 | II | MW-25 | 2% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-25 | 2% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-25 | 2% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-25 | 2% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-25 | 2% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-25 | 2% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-25 | 2% | May 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-25 | 2% | May 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-29 | 12% | Aug 1992 | EXPL | RDX | 4.4 | 0.545 |
| 7 & 8 | II | MW-29 | 12% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-29 | 12% | Nov 1992 | EXPL | RDX | 6.1 | 0.755 |
| 7 & 8 | II | MW-29 | 12% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-29 | 12% | Feb 1993 | EXPL | RDX | 6.4 | 0.792 |
| 7 & 8 | II | MW-29 | 12% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-29 | 12% | May 1993 | EXPL | RDX | 8.6 | 1.065 |
| 7 & 8 | II | MW-29 | 12% | May 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-32 | 11% | Aug 1992 | EXPL | RDX | 2.03 | 0.222 |
| 7 & 8 | II | MW-32 | 11% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-32 | 11% | Nov 1992 | EXPL | RDX | 2.365 | 0.259 |
| 7 & 8 | II | MW-32 | 11% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-32 | 11% | Feb 1993 | EXPL | RDX | 3.28 | 0.359 |
| 7 & 8 | II | MW-32 | 11% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-32 | 11% | May 1993 | EXPL | RDX | 3.725 | 0.408 |
| 7 & 8 | II | MW-32 | 11% | May 1993 | VOC | TCE | | |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | II | MW-33 | 7% | Aug 1992 | EXPL | RDX | 5.5 | 0.380 |
| 7 & 8 | II | MW-33 | 7% | Aug 1992 | VOC | TCE | 1 | 0.069 |
| 7 & 8 | II | MW-33 | 7% | Nov 1992 | EXPL | RDX | 8.55 | 0.590 |
| 7 & 8 | II | MW-33 | 7% | Nov 1992 | VOC | TCE | 1 | 0.069 |
| 7 & 8 | II | MW-33 | 7% | Feb 1993 | EXPL | RDX | 10.8 | 0.746 |
| 7 & 8 | II | MW-33 | 7% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-33 | 7% | May 1993 | EXPL | RDX | 8.85 | 0.611 |
| 7 & 8 | II | MW-33 | 7% | May 1993 | VOC | TCE | 1 | 0.069 |
| 7 & 8 | II | MW-34 | 6% | Aug 1992 | EXPL | RDX | 0.91 | 0.054 |
| 7 & 8 | II | MW-34 | 6% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-34 | 6% | Nov 1992 | EXPL | RDX | 0.95 | 0.057 |
| 7 & 8 | II | MW-34 | 6% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-34 | 6% | Feb 1993 | EXPL | RDX | 1.6 | 0.095 |
| 7 & 8 | II | MW-34 | 6% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-34 | 6% | May 1993 | EXPL | RDX | 1.6 | 0.095 |
| 7 & 8 | II | MW-34 | 6% | May 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-35 | 8% | Aug 1992 | EXPL | RDX | 0.34 | 0.028 |
| 7 & 8 | II | MW-35 | 8% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-35 | 8% | Nov 1992 | EXPL | RDX | 0.63 | 0.053 |
| 7 & 8 | II | MW-35 | 8% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | II | MW-35 | 8% | Feb 1993 | EXPL | RDX | 0.75 | 0.063 |
| 7 & 8 | II | MW-35 | 8% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-35 | 8% | May 1993 | EXPL | RDX | 0.86 | 0.072 |
| 7 & 8 | II | MW-35 | 8% | May 1993 | VOC | TCE | | |
| 7 & 8 | II | MW-36 | 2% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-36 | 2% | Aug 1992 | VOC | TCE | 25 | 0.476 |
| 7 & 8 | II | MW-36 | 2% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-36 | 2% | Nov 1992 | VOC | TCE | 37.5 | 0.714 |
| 7 & 8 | II | MW-36 | 2% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-36 | 2% | Feb 1993 | VOC | TCE | 55.5 | 1.057 |
| 7 & 8 | II | MW-36 | 2% | May 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-36 | 2% | May 1993 | VOC | TCE | 58.5 | 1.114 |
| 7 & 8 | II | MW-40 | 7% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-40 | 7% | Aug 1992 | VOC | TCE | 911 | 66.156 |
| 7 & 8 | II | MW-40 | 7% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-40 | 7% | Nov 1992 | VOC | TCE | 1560 | 113.286 |
| 7 & 8 | II | MW-40 | 7% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-40 | 7% | Feb 1993 | VOC | TCE | 2408.5 | 174.903 |
| 7 & 8 | II | MW-40 | 7% | May 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-40 | 7% | May 1993 | VOC | TCE | 1960.5 | 142.370 |
| 7 & 8 | II | MW-44 | 4% | Aug 1992 | EXPL | RDX | 1.165 | 0.044 |
| 7 & 8 | II | MW-44 | 4% | Aug 1992 | VOC | TCE | 180 | 6.857 |
| 7 & 8 | II | MW-44 | 4% | Nov 1992 | EXPL | RDX | 0.69 | 0.026 |
| 7 & 8 | II | MW-44 | 4% | Nov 1992 | VOC | TCE | 170 | 6.476 |
| 7 & 8 | II | MW-44 | 4% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-44 | 4% | Feb 1993 | VOC | TCE | 85.35 | 3.251 |
| 7 & 8 | II | MW-44 | 4% | May 1993 | EXPL | RDX | 1.1 | 0.042 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | II | MW-44 | 4% | May 1993 | VOC | TCE | 160 | 6.095 |
| 7 & 8 | II | MW-45 | 2% | Aug 1992 | EXPL | RDX | 0.73 | 0.014 |
| 7 & 8 | II | MW-45 | 2% | Aug 1992 | VOC | TCE | 62.5 | 1.190 |
| 7 & 8 | II | MW-45 | 2% | Nov 1992 | EXPL | RDX | 3.75 | 0.071 |
| 7 & 8 | II | MW-45 | 2% | Nov 1992 | VOC | TCE | 18 | 0.343 |
| 7 & 8 | II | MW-45 | 2% | Feb 1993 | EXPL | RDX | 3.1 | 0.059 |
| 7 & 8 | II | MW-45 | 2% | Feb 1993 | VOC | TCE | 48 | 0.914 |
| 7 & 8 | II | MW-45 | 2% | May 1993 | EXPL | RDX | 4.8 | 0.091 |
| 7 & 8 | II | MW-45 | 2% | May 1993 | VOC | TCE | 83.5 | 1.590 |
| 7 & 8 | II | MW-52 | 4% | Aug 1992 | EXPL | RDX | 1.735 | 0.069 |
| 7 & 8 | II | MW-52 | 4% | Aug 1992 | VOC | TCE | 2 | 0.080 |
| 7 & 8 | II | MW-52 | 4% | Nov 1992 | EXPL | RDX | 10.7 | 0.425 |
| 7 & 8 | II | MW-52 | 4% | Nov 1992 | VOC | TCE | 3.5 | 0.139 |
| 7 & 8 | II | MW-52 | 4% | Feb 1993 | EXPL | RDX | 15.15 | 0.602 |
| 7 & 8 | II | MW-52 | 4% | Feb 1993 | VOC | TCE | 8 | 0.318 |
| 7 & 8 | II | MW-52 | 4% | May 1993 | EXPL | RDX | 6.05 | 0.241 |
| 7 & 8 | II | MW-52 | 4% | May 1993 | VOC | TCE | 4.5 | 0.179 |
| 7 & 8 | II | MW-58 | 7% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-58 | 7% | Aug 1992 | VOC | TCE | 130 | 9.440 |
| 7 & 8 | II | MW-58 | 7% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | II | MW-58 | 7% | Nov 1992 | VOC | TCE | 70.5 | 5.120 |
| 7 & 8 | II | MW-58 | 7% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-58 | 7% | Feb 1993 | VOC | TCE | 120 | 8.714 |
| 7 & 8 | II | MW-58 | 7% | May 1993 | EXPL | RDX | | |
| 7 & 8 | II | MW-58 | 7% | May 1993 | VOC | TCE | 97 | 7.044 |
| 7 & 8 | III | MW-02 | 1% | Aug 1992 | EXPL | RDX | 3.435 | 0.050 |
| 7 & 8 | III | MW-02 | 1% | Aug 1992 | VOC | TCE | 70.5 | 1.034 |
| 7 & 8 | III | MW-02 | 1% | Nov 1992 | EXPL | RDX | 6.105 | 0.090 |
| 7 & 8 | III | MW-02 | 1% | Nov 1992 | VOC | TCE | 69.5 | 1.019 |
| 7 & 8 | III | MW-02 | 1% | Feb 1993 | EXPL | RDX | 9.12 | 0.134 |
| 7 & 8 | III | MW-02 | 1% | Feb 1993 | VOC | TCE | 103.5 | 1.518 |
| 7 & 8 | III | MW-02 | 1% | May 1993 | EXPL | RDX | 8.6 | 0.126 |
| 7 & 8 | III | MW-02 | 1% | May 1993 | VOC | TCE | 80.5 | 1.180 |
| 7 & 8 | III | MW-03 | 1% | Aug 1992 | EXPL | RDX | 0.37 | 0.005 |
| 7 & 8 | III | MW-03 | 1% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-03 | 1% | Nov 1992 | EXPL | RDX | 0.765 | 0.011 |
| 7 & 8 | III | MW-03 | 1% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-03 | 1% | Feb 1993 | EXPL | RDX | 0.985 | 0.014 |
| 7 & 8 | III | MW-03 | 1% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-03 | 1% | May 1993 | EXPL | RDX | 1.185 | 0.017 |
| 7 & 8 | III | MW-03 | 1% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-04 | 3% | Aug 1992 | EXPL | RDX | 2.33 | 0.069 |
| 7 & 8 | III | MW-04 | 3% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-04 | 3% | Nov 1992 | EXPL | RDX | 7.4 | 0.219 |
| 7 & 8 | III | MW-04 | 3% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-04 | 3% | Feb 1993 | EXPL | RDX | 5.68 | 0.168 |
| 7 & 8 | III | MW-04 | 3% | Feb 1993 | VOC | TCE | | |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | III | MW-04 | 3% | May 1993 | EXPL | RDX | 8.565 | 0.253 |
| 7 & 8 | III | MW-04 | 3% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-05 | 3% | Aug 1992 | EXPL | RDX | 98 | 2.894 |
| 7 & 8 | III | MW-05 | 3% | Aug 1992 | VOC | TCE | 4 | 0.118 |
| 7 & 8 | III | MW-05 | 3% | Nov 1992 | EXPL | RDX | 160.38 | 4.736 |
| 7 & 8 | III | MW-05 | 3% | Nov 1992 | VOC | TCE | 7 | 0.207 |
| 7 & 8 | III | MW-05 | 3% | Feb 1993 | EXPL | RDX | 320 | 9.450 |
| 7 & 8 | III | MW-05 | 3% | Feb 1993 | VOC | TCE | 6 | 0.177 |
| 7 & 8 | III | MW-05 | 3% | May 1993 | EXPL | RDX | 534 | 15.770 |
| 7 & 8 | III | MW-05 | 3% | May 1993 | VOC | TCE | 6 | 0.177 |
| 7 & 8 | III | MW-08 | 5% | Aug 1992 | EXPL | RDX | 4.7 | 0.220 |
| 7 & 8 | III | MW-08 | 5% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-08 | 5% | Nov 1992 | EXPL | RDX | 5.8 | 0.272 |
| 7 & 8 | III | MW-08 | 5% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-08 | 5% | Feb 1993 | EXPL | RDX | 5.5 | 0.258 |
| 7 & 8 | III | MW-08 | 5% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-08 | 5% | May 1993 | EXPL | RDX | 5.8 | 0.272 |
| 7 & 8 | III | MW-08 | 5% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-09 | 3% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-09 | 3% | Aug 1992 | VOC | TCE | 165.5 | 5.629 |
| 7 & 8 | III | MW-09 | 3% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-09 | 3% | Nov 1992 | VOC | TCE | 102 | 3.469 |
| 7 & 8 | III | MW-09 | 3% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-09 | 3% | Feb 1993 | VOC | TCE | 117 | 3.979 |
| 7 & 8 | III | MW-09 | 3% | May 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-09 | 3% | May 1993 | VOC | TCE | 88.5 | 3.010 |
| 7 & 8 | III | MW-11 | 3% | Aug 1992 | EXPL | RDX | 33 | 1.116 |
| 7 & 8 | III | MW-11 | 3% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-11 | 3% | Nov 1992 | EXPL | RDX | 35 | 1.183 |
| 7 & 8 | III | MW-11 | 3% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-11 | 3% | Feb 1993 | EXPL | RDX | 32 | 1.082 |
| 7 & 8 | III | MW-11 | 3% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-11 | 3% | May 1993 | EXPL | RDX | 12 | 0.406 |
| 7 & 8 | III | MW-11 | 3% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-18 | 3% | Aug 1992 | EXPL | RDX | 1.9 | 0.048 |
| 7 & 8 | III | MW-18 | 3% | Aug 1992 | VOC | TCE | 76 | 1.935 |
| 7 & 8 | III | MW-18 | 3% | Nov 1992 | EXPL | RDX | 3.6 | 0.092 |
| 7 & 8 | III | MW-18 | 3% | Nov 1992 | VOC | TCE | 56 | 1.426 |
| 7 & 8 | III | MW-18 | 3% | Feb 1993 | EXPL | RDX | 4.1 | 0.104 |
| 7 & 8 | III | MW-18 | 3% | Feb 1993 | VOC | TCE | 92 | 2.342 |
| 7 & 8 | III | MW-18 | 3% | May 1993 | EXPL | RDX | 4.2 | 0.107 |
| 7 & 8 | III | MW-18 | 3% | May 1993 | VOC | TCE | 76 | 1.935 |
| 7 & 8 | III | MW-21 | 1% | Aug 1992 | EXPL | RDX | 10 | 0.147 |
| 7 & 8 | III | MW-21 | 1% | Aug 1992 | VOC | TCE | 140 | 2.053 |
| 7 & 8 | III | MW-21 | 1% | Nov 1992 | EXPL | RDX | 11 | 0.161 |
| 7 & 8 | III | MW-21 | 1% | Nov 1992 | VOC | TCE | 140 | 2.053 |
| 7 & 8 | III | MW-21 | 1% | Feb 1993 | EXPL | RDX | 18 | 0.264 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | III | MW-21 | 1% | Feb 1993 | VOC | TCE | 130 | 1.906 |
| 7 & 8 | III | MW-21 | 1% | May 1993 | EXPL | RDX | 16 | 0.235 |
| 7 & 8 | III | MW-21 | 1% | May 1993 | VOC | TCE | 110 | 1.613 |
| 7 & 8 | III | MW-24 | 1% | Aug 1992 | EXPL | RDX | 0.46 | 0.007 |
| 7 & 8 | III | MW-24 | 1% | Aug 1992 | VOC | TCE | 0.9 | 0.013 |
| 7 & 8 | III | MW-24 | 1% | Nov 1992 | EXPL | RDX | 0.26 | 0.004 |
| 7 & 8 | III | MW-24 | 1% | Nov 1992 | VOC | TCE | 0.8 | 0.012 |
| 7 & 8 | III | MW-24 | 1% | Feb 1993 | EXPL | RDX | 0.41 | 0.006 |
| 7 & 8 | III | MW-24 | 1% | Feb 1993 | VOC | TCE | 1 | 0.015 |
| 7 & 8 | III | MW-24 | 1% | May 1993 | EXPL | RDX | 0.3 | 0.004 |
| 7 & 8 | III | MW-24 | 1% | May 1993 | VOC | TCE | 1 | 0.015 |
| 7 & 8 | III | MW-25 | 1% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-25 | 1% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-25 | 1% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-25 | 1% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-25 | 1% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-25 | 1% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-25 | 1% | May 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-25 | 1% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-29 | 14% | Aug 1992 | EXPL | RDX | 4.4 | 0.627 |
| 7 & 8 | III | MW-29 | 14% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-29 | 14% | Nov 1992 | EXPL | RDX | 6.1 | 0.870 |
| 7 & 8 | III | MW-29 | 14% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-29 | 14% | Feb 1993 | EXPL | RDX | 6.4 | 0.912 |
| 7 & 8 | III | MW-29 | 14% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-29 | 14% | May 1993 | EXPL | RDX | 8.6 | 1.226 |
| 7 & 8 | III | MW-29 | 14% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-31 | 5% | Aug 1992 | EXPL | RDX | 4.7 | 0.239 |
| 7 & 8 | III | MW-31 | 5% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-31 | 5% | Nov 1992 | EXPL | RDX | 3.8 | 0.193 |
| 7 & 8 | III | MW-31 | 5% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-31 | 5% | Feb 1993 | EXPL | RDX | 6.4 | 0.326 |
| 7 & 8 | III | MW-31 | 5% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-31 | 5% | May 1993 | EXPL | RDX | 5.3 | 0.270 |
| 7 & 8 | III | MW-31 | 5% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-32 | 12% | Aug 1992 | EXPL | RDX | 2.03 | 0.248 |
| 7 & 8 | III | MW-32 | 12% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-32 | 12% | Nov 1992 | EXPL | RDX | 2.365 | 0.289 |
| 7 & 8 | III | MW-32 | 12% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-32 | 12% | Feb 1993 | EXPL | RDX | 3.28 | 0.401 |
| 7 & 8 | III | MW-32 | 12% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-32 | 12% | May 1993 | EXPL | RDX | 3.725 | 0.455 |
| 7 & 8 | III | MW-32 | 12% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-33 | 6% | Aug 1992 | EXPL | RDX | 5.5 | 0.325 |
| 7 & 8 | III | MW-33 | 6% | Aug 1992 | VOC | TCE | 1 | 0.059 |
| 7 & 8 | III | MW-33 | 6% | Nov 1992 | EXPL | RDX | 8.55 | 0.505 |
| 7 & 8 | III | MW-33 | 6% | Nov 1992 | VOC | TCE | 1 | 0.059 |

**Table K-14**
**Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | III | MW-33 | 6% | Feb 1993 | EXPL | RDX | 10.8 | 0.638 |
| 7 & 8 | III | MW-33 | 6% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-33 | 6% | May 1993 | EXPL | RDX | 8.85 | 0.523 |
| 7 & 8 | III | MW-33 | 6% | May 1993 | VOC | TCE | 1 | 0.059 |
| 7 & 8 | III | MW-34 | 4% | Aug 1992 | EXPL | RDX | 0.91 | 0.035 |
| 7 & 8 | III | MW-34 | 4% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-34 | 4% | Nov 1992 | EXPL | RDX | 0.95 | 0.037 |
| 7 & 8 | III | MW-34 | 4% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-34 | 4% | Feb 1993 | EXPL | RDX | 1.6 | 0.062 |
| 7 & 8 | III | MW-34 | 4% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-34 | 4% | May 1993 | EXPL | RDX | 1.6 | 0.062 |
| 7 & 8 | III | MW-34 | 4% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-35 | 7% | Aug 1992 | EXPL | RDX | 0.34 | 0.022 |
| 7 & 8 | III | MW-35 | 7% | Aug 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-35 | 7% | Nov 1992 | EXPL | RDX | 0.63 | 0.041 |
| 7 & 8 | III | MW-35 | 7% | Nov 1992 | VOC | TCE | | |
| 7 & 8 | III | MW-35 | 7% | Feb 1993 | EXPL | RDX | 0.75 | 0.049 |
| 7 & 8 | III | MW-35 | 7% | Feb 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-35 | 7% | May 1993 | EXPL | RDX | 0.86 | 0.056 |
| 7 & 8 | III | MW-35 | 7% | May 1993 | VOC | TCE | | |
| 7 & 8 | III | MW-36 | 2% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-36 | 2% | Aug 1992 | VOC | TCE | 25 | 0.407 |
| 7 & 8 | III | MW-36 | 2% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-36 | 2% | Nov 1992 | VOC | TCE | 37.5 | 0.611 |
| 7 & 8 | III | MW-36 | 2% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-36 | 2% | Feb 1993 | VOC | TCE | 55.5 | 0.904 |
| 7 & 8 | III | MW-36 | 2% | May 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-36 | 2% | May 1993 | VOC | TCE | 58.5 | 0.953 |
| 7 & 8 | III | MW-40 | 6% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-40 | 6% | Aug 1992 | VOC | TCE | 911 | 56.590 |
| 7 & 8 | III | MW-40 | 6% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-40 | 6% | Nov 1992 | VOC | TCE | 1560 | 96.904 |
| 7 & 8 | III | MW-40 | 6% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-40 | 6% | Feb 1993 | VOC | TCE | 2408.5 | 149.612 |
| 7 & 8 | III | MW-40 | 6% | May 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-40 | 6% | May 1993 | VOC | TCE | 1960.5 | 121.783 |
| 7 & 8 | III | MW-43 | 3% | Aug 1992 | EXPL | RDX | 18 | 0.458 |
| 7 & 8 | III | MW-43 | 3% | Aug 1992 | VOC | TCE | 46 | 1.171 |
| 7 & 8 | III | MW-43 | 3% | Nov 1992 | EXPL | RDX | 20 | 0.509 |
| 7 & 8 | III | MW-43 | 3% | Nov 1992 | VOC | TCE | 38 | 0.967 |
| 7 & 8 | III | MW-43 | 3% | Feb 1993 | EXPL | RDX | 26 | 0.662 |
| 7 & 8 | III | MW-43 | 3% | Feb 1993 | VOC | TCE | 36 | 0.916 |
| 7 & 8 | III | MW-43 | 3% | May 1993 | EXPL | RDX | 32 | 0.815 |
| 7 & 8 | III | MW-43 | 3% | May 1993 | VOC | TCE | 38 | 0.967 |
| 7 & 8 | III | MW-44 | 3% | Aug 1992 | EXPL | RDX | 1.165 | 0.038 |
| 7 & 8 | III | MW-44 | 3% | Aug 1992 | VOC | TCE | 180 | 5.866 |
| 7 & 8 | III | MW-44 | 3% | Nov 1992 | EXPL | RDX | 0.69 | 0.022 |

## Table K-14
## Weighted Average Concentrations

| Alternative No. (1) | Target Clean Up Goal (2) | Monitoring Well Cluster | Weight Factor (Wi) (%) | Date of Sampling Event | Analysis | Parameter | Average Concentration (Ci) (1) (µg/L) | Weighted Average Concentration (Wi*Ci) (1) (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 7 & 8 | III | MW-44 | 3% | Nov 1992 | VOC | TCE | 170 | 5.540 |
| 7 & 8 | III | MW-44 | 3% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-44 | 3% | Feb 1993 | VOC | TCE | 85.35 | 2.781 |
| 7 & 8 | III | MW-44 | 3% | May 1993 | EXPL | RDX | 1.1 | 0.036 |
| 7 & 8 | III | MW-44 | 3% | May 1993 | VOC | TCE | 160 | 5.214 |
| 7 & 8 | III | MW-45 | 2% | Aug 1992 | EXPL | RDX | 0.73 | 0.012 |
| 7 & 8 | III | MW-45 | 2% | Aug 1992 | VOC | TCE | 62.5 | 1.018 |
| 7 & 8 | III | MW-45 | 2% | Nov 1992 | EXPL | RDX | 3.75 | 0.061 |
| 7 & 8 | III | MW-45 | 2% | Nov 1992 | VOC | TCE | 18 | 0.293 |
| 7 & 8 | III | MW-45 | 2% | Feb 1993 | EXPL | RDX | 3.1 | 0.051 |
| 7 & 8 | III | MW-45 | 2% | Feb 1993 | VOC | TCE | 48 | 0.782 |
| 7 & 8 | III | MW-45 | 2% | May 1993 | EXPL | RDX | 4.8 | 0.078 |
| 7 & 8 | III | MW-45 | 2% | May 1993 | VOC | TCE | 83.5 | 1.360 |
| 7 & 8 | III | MW-52 | 3% | Aug 1992 | EXPL | RDX | 1.735 | 0.059 |
| 7 & 8 | III | MW-52 | 3% | Aug 1992 | VOC | TCE | 2 | 0.068 |
| 7 & 8 | III | MW-52 | 3% | Nov 1992 | EXPL | RDX | 10.7 | 0.364 |
| 7 & 8 | III | MW-52 | 3% | Nov 1992 | VOC | TCE | 3.5 | 0.119 |
| 7 & 8 | III | MW-52 | 3% | Feb 1993 | EXPL | RDX | 15.15 | 0.515 |
| 7 & 8 | III | MW-52 | 3% | Feb 1993 | VOC | TCE | 8 | 0.272 |
| 7 & 8 | III | MW-52 | 3% | May 1993 | EXPL | RDX | 6.05 | 0.206 |
| 7 & 8 | III | MW-52 | 3% | May 1993 | VOC | TCE | 4.5 | 0.153 |
| 7 & 8 | III | MW-58 | 6% | Aug 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-58 | 6% | Aug 1992 | VOC | TCE | 130 | 8.075 |
| 7 & 8 | III | MW-58 | 6% | Nov 1992 | EXPL | RDX | | |
| 7 & 8 | III | MW-58 | 6% | Nov 1992 | VOC | TCE | 70.5 | 4.379 |
| 7 & 8 | III | MW-58 | 6% | Feb 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-58 | 6% | Feb 1993 | VOC | TCE | 120 | 7.454 |
| 7 & 8 | III | MW-58 | 6% | May 1993 | EXPL | RDX | | |
| 7 & 8 | III | MW-58 | 6% | May 1993 | VOC | TCE | 97 | 6.025 |

Notes:
(1) Where no value for concentration is present, no concentration was detected.
(2) Detailed Descriptions of the Remedial Alternatives are included in Volume I.
(3) Detailed Target Clean Up Goals are included in Volume I.

**Table K-15**
**Sum of Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Date of Sampling Event | Analysis | Parameter | Sum of Weighted Average Concentrations (µg/L) |
|---|---|---|---|---|---|
| 2 | I | Aug 1992 | EXPL | RDX | 12 |
| 2 | I | Aug 1992 | VOC | TCE | 19 |
| 2 | I | Nov 1992 | EXPL | RDX | 19 |
| 2 | I | Nov 1992 | VOC | TCE | 17 |
| 2 | I | Feb 1993 | EXPL | RDX | 34 |
| 2 | I | Feb 1993 | VOC | TCE | 21 |
| 2 | I | May 1993 | EXPL | RDX | 53 |
| 2 | I | May 1993 | VOC | TCE | 21 |
| 2 | II | Aug 1992 | EXPL | RDX | 2 |
| 2 | II | Aug 1992 | VOC | TCE | 12 |
| 2 | II | Nov 1992 | EXPL | RDX | 3 |
| 2 | II | Nov 1992 | VOC | TCE | 11 |
| 2 | II | Feb 1993 | EXPL | RDX | 4 |
| 2 | II | Feb 1993 | VOC | TCE | 14 |
| 2 | II | May 1993 | EXPL | RDX | 5 |
| 2 | II | May 1993 | VOC | TCE | 14 |
| 2 | III | Aug 1992 | EXPL | RDX | 3 |
| 2 | III | Aug 1992 | VOC | TCE | 11 |
| 2 | III | Nov 1992 | EXPL | RDX | 3 |
| 2 | III | Nov 1992 | VOC | TCE | 10 |
| 2 | III | Feb 1993 | EXPL | RDX | 4 |
| 2 | III | Feb 1993 | VOC | TCE | 13 |
| 2 | III | May 1993 | EXPL | RDX | 5 |
| 2 | III | May 1993 | VOC | TCE | 12 |
| 3 & 4 | I | Aug 1992 | EXPL | RDX | 6 |
| 3 & 4 | I | Aug 1992 | VOC | TCE | 171 |
| 3 & 4 | I | Nov 1992 | EXPL | RDX | 10 |
| 3 & 4 | I | Nov 1992 | VOC | TCE | 236 |
| 3 & 4 | I | Feb 1993 | EXPL | RDX | 18 |
| 3 & 4 | I | Feb 1993 | VOC | TCE | 350 |
| 3 & 4 | I | May 1993 | EXPL | RDX | 27 |
| 3 & 4 | I | May 1993 | VOC | TCE | 291 |
| 3 & 4 | II | Aug 1992 | EXPL | RDX | 4 |
| 3 & 4 | II | Aug 1992 | VOC | TCE | 101 |
| 3 & 4 | II | Nov 1992 | EXPL | RDX | 7 |
| 3 & 4 | II | Nov 1992 | VOC | TCE | 140 |
| 3 & 4 | II | Feb 1993 | EXPL | RDX | 12 |
| 3 & 4 | II | Feb 1993 | VOC | TCE | 209 |
| 3 & 4 | II | May 1993 | EXPL | RDX | 18 |
| 3 & 4 | II | May 1993 | VOC | TCE | 174 |
| 3 & 4 | III | Aug 1992 | EXPL | RDX | 4 |
| 3 & 4 | III | Aug 1992 | VOC | TCE | 95 |
| 3 & 4 | III | Nov 1992 | EXPL | RDX | 7 |
| 3 & 4 | III | Nov 1992 | VOC | TCE | 131 |
| 3 & 4 | III | Feb 1993 | EXPL | RDX | 12 |
| 3 & 4 | III | Feb 1993 | VOC | TCE | 195 |
| 3 & 4 | III | May 1993 | EXPL | RDX | 18 |
| 3 & 4 | III | May 1993 | VOC | TCE | 163 |
| 5 & 6 | I | Aug 1992 | EXPL | RDX | 9 |
| 5 & 6 | I | Aug 1992 | VOC | TCE | 51 |
| 5 & 6 | I | Nov 1992 | EXPL | RDX | 14 |
| 5 & 6 | I | Nov 1992 | VOC | TCE | 40 |
| 5 & 6 | I | Feb 1993 | EXPL | RDX | 24 |
| 5 & 6 | I | Feb 1993 | VOC | TCE | 39 |
| 5 & 6 | I | May 1993 | EXPL | RDX | 36 |
| 5 & 6 | I | May 1993 | VOC | TCE | 40 |

**Table K-15**
**Sum of Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Date of Sampling Event | Analysis | Parameter | Sum of Weighted Average Concentrations (µg/L) |
|---|---|---|---|---|---|
| 5 & 6 | II | Aug 1992 | EXPL | RDX | 6 |
| 5 & 6 | II | Aug 1992 | VOC | TCE | 30 |
| 5 & 6 | II | Nov 1992 | EXPL | RDX | 9 |
| 5 & 6 | II | Nov 1992 | VOC | TCE | 24 |
| 5 & 6 | II | Feb 1993 | EXPL | RDX | 16 |
| 5 & 6 | II | Feb 1993 | VOC | TCE | 24 |
| 5 & 6 | II | May 1993 | EXPL | RDX | 23 |
| 5 & 6 | II | May 1993 | VOC | TCE | 24 |
| 5 & 6 | III | Aug 1992 | EXPL | RDX | 5 |
| 5 & 6 | III | Aug 1992 | VOC | TCE | 23 |
| 5 & 6 | III | Nov 1992 | EXPL | RDX | 8 |
| 5 & 6 | III | Nov 1992 | VOC | TCE | 18 |
| 5 & 6 | III | Feb 1993 | EXPL | RDX | 14 |
| 5 & 6 | III | Feb 1993 | VOC | TCE | 18 |
| 5 & 6 | III | May 1993 | EXPL | RDX | 21 |
| 5 & 6 | III | May 1993 | VOC | TCE | 19 |
| 7 & 8 | I | Aug 1992 | EXPL | RDX | 7 |
| 7 & 8 | I | Aug 1992 | VOC | TCE | 164 |
| 7 & 8 | I | Nov 1992 | EXPL | RDX | 10 |
| 7 & 8 | I | Nov 1992 | VOC | TCE | 229 |
| 7 & 8 | I | Feb 1993 | EXPL | RDX | 14 |
| 7 & 8 | I | Feb 1993 | VOC | TCE | 338 |
| 7 & 8 | I | May 1993 | EXPL | RDX | 18 |
| 7 & 8 | I | May 1993 | VOC | TCE | 282 |
| 7 & 8 | II | Aug 1992 | EXPL | RDX | 7 |
| 7 & 8 | II | Aug 1992 | VOC | TCE | 100 |
| 7 & 8 | II | Nov 1992 | EXPL | RDX | 10 |
| 7 & 8 | II | Nov 1992 | VOC | TCE | 138 |
| 7 & 8 | II | Feb 1993 | EXPL | RDX | 16 |
| 7 & 8 | II | Feb 1993 | VOC | TCE | 204 |
| 7 & 8 | II | May 1993 | EXPL | RDX | 23 |
| 7 & 8 | II | May 1993 | VOC | TCE | 171 |
| 7 & 8 | III | Aug 1992 | EXPL | RDX | 7 |
| 7 & 8 | III | Aug 1992 | VOC | TCE | 84 |
| 7 & 8 | III | Nov 1992 | EXPL | RDX | 10 |
| 7 & 8 | III | Nov 1992 | VOC | TCE | 117 |
| 7 & 8 | III | Feb 1993 | EXPL | RDX | 15 |
| 7 & 8 | III | Feb 1993 | VOC | TCE | 173 |
| 7 & 8 | III | May 1993 | EXPL | RDX | 21 |
| 7 & 8 | III | May 1993 | VOC | TCE | 144 |

Notes:
(1) Detailed Descriptions of the Remedial Alternatives are included in Volume I.
(2) Detailed Target Clean Up Goals are included in Volume I .

**Table K-16**
**Maximum of Sum of Weighted Average Concentrations**

| Alternative No. (1) | Target Clean Up Goal (2) | Analysis | Parameter | Maximum of Sum of Weighted Average Concentrations (µg/L) |
|---|---|---|---|---|
| 2 | I | EXPL | RDX | 53 |
| 2 | I | VOC | TCE | 21 |
| 2 | II | EXPL | RDX | 5 |
| 2 | II | VOC | TCE | 14 |
| 2 | III | EXPL | RDX | 5 |
| 2 | III | VOC | TCE | 13 |
| 3 & 4 | I | EXPL | RDX | 27 |
| 3 & 4 | I | VOC | TCE | 350 |
| 3 & 4 | II | EXPL | RDX | 18 |
| 3 & 4 | II | VOC | TCE | 209 |
| 3 & 4 | III | EXPL | RDX | 18 |
| 3 & 4 | III | VOC | TCE | 195 |
| 5 & 6 | I | EXPL | RDX | 36 |
| 5 & 6 | I | VOC | TCE | 51 |
| 5 & 6 | II | EXPL | RDX | 23 |
| 5 & 6 | II | VOC | TCE | 30 |
| 5 & 6 | III | EXPL | RDX | 21 |
| 5 & 6 | III | VOC | TCE | 23 |
| 7 & 8 | I | EXPL | RDX | 18 |
| 7 & 8 | I | VOC | TCE | 338 |
| 7 & 8 | II | EXPL | RDX | 23 |
| 7 & 8 | II | VOC | TCE | 204 |
| 7 & 8 | III | EXPL | RDX | 21 |
| 7 & 8 | III | VOC | TCE | 173 |

Notes:
(1) Detailed Descriptions of the Remedial Alternatives are included in Volume I.
(2) Detailed Target Clean Up Goals are included in Volume I .

## Table K-17
## List of References and Notes Used for Tables K-18 through K-29

References :

A W. J. Wujcik, W. L. Lowe, P. J. Marks, and W.E. Sisk.1992. Granular Activated Carbon Pilot Treatment Studied for Explosives Removal From Contaminated Groundwater. Environmental Progress, Volume 11, No. 3, August 1992.

B W. D. Burrows. 1982. Tertiary Treatment of Effluent From Holston AAP Industrial Liquid Waste Treatment Facility, I. Batch Carbon Adsorption Studies: TNT, RDX, HMX, TAX, and SEX. Prepared for US Army Armament Research and Development Command, Dover, NJ.

C Midwest Research Institute. 1987. Granular Activated Carbon (GAC) System Performance Capabilities and Optimization, MRI Project No. 8182-S. Prepared for U.S. Army Toxic and Hazardous Material Agency.

D EPA. 1980. Carbon Adsorption Isotherms For Toxic Organics. EPA-600/8-80-023. April.

E A. L. Benedict. 1982. The Adsorption and Desorption of Trichloroethylene, Tetrachloroethylene, and Carbon Tetrachloride from Granular Activated Carbon. M.S. thesis, Department of Environmental Science, Rutgers University. New Brunswick, N.J. cited in "Adsorption Processes for Water Treatment" by S.D. Faust and O.M. Aly. Butterworths

* References selected as most conservative value for selecting carbon usage used for cost estimates.

Notes:

[1] Parameters explained in Appendix K text, section 6.0

| | |
|---|---|
| K | Isotherm constant (mg/g) |
| 1/n | Isotherm constant (unitless) |
| Co | Influent concentration (µg/L) |
| C | Effluent concentration (µg/L) |
| M | Carbon Dosage (g/L) (Includes scale-up factor) |

[2] Chemical Mass Loading = flowrate x influent concentration with appropriate conversions to lb/d = mass per unit time of influent chemical.

[3] Chemical Adsorbed = flow rate x (Co - C) with appropriate conversions to lb/d = mass per unit time of chemical adsorbed by carbon.

[4] Carbon usage calculated as 2 times (scale-up factor) amount calculated from isotherm data.

[5] Carbon Loading = lb chemical/100 lb of carbon. Used as a check for reasonableness. Values < approximately 5% considered acceptable.

## Table K-18
## GAC Estimates for RDX and TCE based on Literature Isotherms
## Groundwater Target Cleanup Goal I
## Alternative 2

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 53 | 2 | 970 | 0.6169 | 0.5936 | 2 | 0.0111 | 128.84 | 0.46074% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 53 | 2 | 970 | 0.6169 | 0.5936 | 2 | 0.0026 | 30.41 | 1.95231% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 53 | 2 | 970 | 0.6169 | 0.5936 | 2 | 0.0074 | 86.21 | 0.68861% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 53 | 2 | 970 | 0.6169 | 0.5936 | 2 | 0.0044 | 50.83 | 1.16790% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 53 | 2 | 970 | 0.6169 | 0.5936 | 2 | 0.0041 | 47.51 | 1.24959% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 21 | 5 | 970 | 0.2444 | 0.1862 | 2 | 0.0125 | 145.94 | 0.12762% |
| E | Unknown | Unknown | 42.7 | 0.57 | 21 | 5 | 970 | 0.2444 | 0.1862 | 2 | 0.0068 | 78.89 | 0.23608% |

# Table K-19
## GAC Estimates for RDX and TCE based on Literature Isotherms
## Groundwater Target Cleanup Goal II
## Alternative 2

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] K (mg/g) | Isotherm Data[1] 1/n | Concentration (ug/l)[1] Influent (Co) | Concentration (ug/l)[1] Effluent (C) | Groundwater Flowrate (gpm) | Chemical Mass[2] Loading (lb/d) | Chemical Adsorbed[3] Loading (lb/d) | Scale-up[4] Factor | M[1] Carbon Dosage (g/L) | Carbon[2] Usage (lb/d) | Carbon[5] Loading |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 5 | 2 | 2100 | 0.1260 | 0.0756 | 2 | 0.0017 | 43.50 | 0.17378% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 5 | 2 | 2100 | 0.1260 | 0.0756 | 2 | 0.0003 | 8.21 | 0.92130% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 5 | 2 | 2100 | 0.1260 | 0.0756 | 2 | 0.0008 | 19.97 | 0.37849% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 5 | 2 | 2100 | 0.1260 | 0.0756 | 2 | 0.0007 | 17.41 | 0.43421% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 5 | 2 | 2100 | 0.1260 | 0.0756 | 2 | 0.0006 | 15.26 | 0.49551% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 14 | 5 | 2100 | 0.3528 | 0.2268 | 2 | 0.0091 | 228.52 | 0.09925% |
| E | Unknown | Unknown | 42.7 | 0.57 | 14 | 5 | 2100 | 0.3528 | 0.2268 | 2 | 0.0048 | 121.05 | 0.18737% |

# Table K-20
# GAC Estimates for RDX and TCE based on Literature Isotherms
# Groundwater Target Cleanup Goal III
# Alternative 2

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 5 | 2 | 2330 | 0.1398 | 0.0839 | 2 | 0.0017 | 48.27 | 0.17378% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 5 | 2 | 2330 | 0.1398 | 0.0839 | 2 | 0.0003 | 9.10 | 0.92130% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 5 | 2 | 2330 | 0.1398 | 0.0839 | 2 | 0.0008 | 22.16 | 0.37849% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 5 | 2 | 2330 | 0.1398 | 0.0839 | 2 | 0.0007 | 19.32 | 0.43421% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 5 | 2 | 2330 | 0.1398 | 0.0839 | 2 | 0.0006 | 16.93 | 0.49551% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 13 | 5 | 2330 | 0.3635 | 0.2237 | 2 | 0.0084 | 235.97 | 0.09479% |
| E | Unknown | Unknown | 42.7 | 0.57 | 13 | 5 | 2330 | 0.3635 | 0.2237 | 2 | 0.0045 | 124.53 | 0.17962% |

**Table K-21**
**GAC Estimates for RDX and TCE based on Literature Isotherms**
**Groundwater Target Cleanup Goal I**
**Alternative 3 & 4**

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 27 | 2 | 1980 | 0.6415 | 0.5940 | 2 | 0.0072 | 170.33 | 0.34873% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 27 | 2 | 1980 | 0.6415 | 0.5940 | 2 | 0.0016 | 37.71 | 1.57534% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 27 | 2 | 1980 | 0.6415 | 0.5940 | 2 | 0.0043 | 102.35 | 0.58039% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 27 | 2 | 1980 | 0.6415 | 0.5940 | 2 | 0.0028 | 67.47 | 0.88033% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 27 | 2 | 1980 | 0.6415 | 0.5940 | 2 | 0.0026 | 61.91 | 0.95941% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 350 | 5 | 1980 | 8.3160 | 8.1972 | 2 | 0.0472 | 1122.57 | 0.73021% |
| E | Unknown | Unknown | 42.7 | 0.57 | 350 | 5 | 1980 | 8.3160 | 8.1972 | 2 | 0.0294 | 698.47 | 1.17359% |

# Table K-22
## GAC Estimates for RDX and TCE based on Literature Isotherms
## Groundwater Target Cleanup Goal II
## Alternative 3 & 4

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] Loading (lb/d) | Chemical Adsorbed[3] Loading (lb/d) | Scale-up[4] Factor | M[1] Carbon Dosage (g/L) | Carbon[2] Usage (lb/d) | Carbon[5] Loading |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | | | | | | |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 18 | 2 | 3300 | 0.7128 | 0.6336 | 2 | 0.0054 | 214.81 | 0.29496% |
| B | Deionized Water | Calgon F300 | '99.4 | 0.3181 | 18 | 2 | 3300 | 0.7128 | 0.6336 | 2 | 0.0012 | 45.76 | 1.38471% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 18 | 2 | 3300 | 0.7128 | 0.6336 | 2 | 0.0031 | 120.99 | 0.52370% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 18 | 2 | 3300 | 0.7128 | 0.6336 | 2 | 0.0022 | 85.30 | 0.74275% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 18 | 2 | 3300 | 0.7128 | 0.6336 | 2 | 0.0020 | 77.41 | 0.81849% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 209 | 5 | 3300 | 8.2764 | 8.0784 | 2 | 0.0385 | 1523.02 | 0.53042% |
| E | Unknown | Unknown | 42.7 | 0.57 | 209 | 5 | 3300 | 8.2764 | 8.0784 | 2 | 0.0233 | 923.52 | 0.87474% |

# Table K-23
# GAC Estimates for RDX and TCE based on Literature Isotherms
# Groundwater Target Cleanup Goal III
# Alternative 3 & 4

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 18 | 2 | 3530 | 0.7625 | 0.6778 | 2 | 0.0054 | 229.78 | 0.29496% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 18 | 2 | 3530 | 0.7625 | 0.6778 | 2 | 0.0012 | 48.95 | 1.38471% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 18 | 2 | 3530 | 0.7625 | 0.6778 | 2 | 0.0031 | 129.42 | 0.52370% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 18 | 2 | 3530 | 0.7625 | 0.6778 | 2 | 0.0022 | 91.25 | 0.74275% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 18 | 2 | 3530 | 0.7625 | 0.6778 | 2 | 0.0020 | 82.81 | 0.81849% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 195 | 5 | 3530 | 8.2602 | 8.0484 | 2 | 0.0374 | 1584.02 | 0.50810% |
| E | Unknown | Unknown | 42.7 | 0.57 | 195 | 5 | 3530 | 8.2602 | 8.0484 | 2 | 0.0226 | 957.18 | 0.84085% |

# Table K-24
## GAC Estimates for RDX and TCE based on Literature Isotherms
## Groundwater Target Cleanup Goal I
## Alternative 5 & 6

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 36 | 2 | 1450 | 0.6264 | 0.5916 | 2 | 0.0087 | 150.64 | 0.39272% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 36 | 2 | 1450 | 0.6264 | 0.5916 | 2 | 0.0020 | 34.27 | 1.72630% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 36 | 2 | 1450 | 0.6264 | 0.5916 | 2 | 0.0054 | 94.76 | 0.62430% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 36 | 2 | 1450 | 0.6264 | 0.5916 | 2 | 0.0034 | 59.57 | 0.99313% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 36 | 2 | 1450 | 0.6264 | 0.5916 | 2 | 0.0032 | 55.09 | 1.07388% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 51 | 5 | 1450 | 0.8874 | 0.8004 | 2 | 0.0208 | 361.81 | 0.22122% |
| E | Unknown | Unknown | 42.7 | 0.57 | 51 | 5 | 1450 | 0.8874 | 0.8004 | 2 | 0.0118 | 204.45 | 0.39148% |

# Table K-25
## GAC Estimates for RDX and TCE based on Literature Isotherms
## Groundwater Target Cleanup Goal II
## Alternative 5 & 6

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 23 | 2 | 2770 | 0.7645 | 0.6980 | 2 | 0.0064 | 213.87 | 0.32638% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 23 | 2 | 2770 | 0.7645 | 0.6980 | 2 | 0.0014 | 46.63 | 1.49700% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 23 | 2 | 2770 | 0.7645 | 0.6980 | 2 | 0.0038 | 125.26 | 0.55727% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 23 | 2 | 2770 | 0.7645 | 0.6980 | 2 | 0.0026 | 84.80 | 0.82311% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 23 | 2 | 2770 | 0.7645 | 0.6980 | 2 | 0.0023 | 77.47 | 0.90099% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 30 | 5 | 2770 | 0.9972 | 0.8310 | 2 | 0.0157 | 521.98 | 0.15920% |
| E | Unknown | Unknown | 42.7 | 0.57 | 30 | 5 | 2770 | 0.9972 | 0.8310 | 2 | 0.0086 | 287.24 | 0.28931% |

# Table K-26
## GAC Estimates for RDX and TCE based on Literature Isotherms
## Groundwater Target Cleanup Goal III
## Alternative 5 & 6

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 21 | 2 | 3000 | 0.7560 | 0.6840 | 2 | 0.0060 | 217.59 | 0.31435% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 21 | 2 | 3000 | 0.7560 | 0.6840 | 2 | 0.0013 | 47.03 | 1.45430% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 21 | 2 | 3000 | 0.7560 | 0.6840 | 2 | 0.0035 | 125.60 | 0.54457% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 21 | 2 | 3000 | 0.7560 | 0.6840 | 2 | 0.0024 | 86.33 | 0.79232% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 21 | 2 | 3000 | 0.7560 | 0.6840 | 2 | 0.0022 | 78.67 | 0.86945% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 23 | 5 | 3000 | 0.8280 | 0.6480 | 2 | 0.0133 | 479.93 | 0.13502% |
| E | Unknown | Unknown | 42.7 | 0.57 | 23 | 5 | 3000 | 0.8280 | 0.6480 | 2 | 0.0072 | 260.61 | 0.24865% |

# Table K-27
# GAC Estimates for RDX and TCE based on Literature Isotherms
# Groundwater Target Cleanup Goal I
# Alternative 7 & 8

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 18 | 2 | 2490 | 0.5378 | 0.4781 | 2 | 0.0054 | 162.08 | 0.29496% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 18 | 2 | 2490 | 0.5378 | 0.4781 | 2 | 0.0012 | 34.53 | 1.38471% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 18 | 2 | 2490 | 0.5378 | 0.4781 | 2 | 0.0031 | 91.29 | 0.52370% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 18 | 2 | 2490 | 0.5378 | 0.4781 | 2 | 0.0022 | 64.37 | 0.74275% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 18 | 2 | 2490 | 0.5378 | 0.4781 | 2 | 0.0020 | 58.41 | 0.81849% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 338 | 5 | 2490 | 10.0994 | 9.9500 | 2 | 0.0466 | 1392.41 | 0.71459% |
| E | Unknown | Unknown | 42.7 | 0.57 | 338 | 5 | 2490 | 10.0994 | 9.9500 | 2 | 0.0289 | 864.86 | 1.15048% |

# Table K-28
# GAC Estimates for RDX and TCE based on Literature Isotherms
# Groundwater Target Cleanup Goal II
# Alternative 7 & 8

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[1] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 23 | 2 | 4200 | 1.1592 | 1.0584 | 2 | 0.0064 | 324.28 | 0.32638% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 23 | 2 | 4200 | 1.1592 | 1.0584 | 2 | 0.0014 | 70.70 | 1.49700% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 23 | 2 | 4200 | 1.1592 | 1.0584 | 2 | 0.0038 | 189.93 | 0.55727% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 23 | 2 | 4200 | 1.1592 | 1.0584 | 2 | 0.0026 | 128.58 | 0.82311% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 23 | 2 | 4200 | 1.1592 | 1.0584 | 2 | 0.0023 | 117.47 | 0.90099% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 204 | 5 | 4200 | 10.2816 | 10.0296 | 2 | 0.0381 | 1919.49 | 0.52251% |
| E | Unknown | Unknown | 42.7 | 0.57 | 204 | 5 | 4200 | 10.2816 | 10.0296 | 2 | 0.0231 | 1162.51 | 0.86275% |

# Table K-29
## GAC Estimates for RDX and TCE based on Literature Isotherms
## Groundwater Target Cleanup Goal III
## Alternative 7 & 8

| Reference | Chemical Medium | Carbon Type | Isotherm Data[1] | | Concentration (ug/l)[1] | | Groundwater Flowrate | Chemical Mass[2] | Chemical Adsorbed[3] | Scale-up[4] | M[3] Carbon | Carbon[2] | Carbon[5] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K (mg/g) | 1/n | Influent (Co) | Effluent (C) | (gpm) | Loading (lb/d) | Loading (lb/d) | Factor | Dosage (g/L) | Usage (lb/d) | Loading |
| | **RDX** | | | | | | | | | | | | |
| A* | Groundwater | Filtrasorb 300 | 31 | 0.413 | 21 | 2 | 4910 | 1.2373 | 1.1195 | 2 | 0.0060 | 356.13 | 0.31435% |
| B | Deionized Water | Calgon F300 | 99.4 | 0.3181 | 21 | 2 | 4910 | 1.2373 | 1.1195 | 2 | 0.0013 | 76.98 | 1.45430% |
| C | 4-component Synthetic Pink Water | Filtrasorb 300 | 29 | 0.2535 | 21 | 2 | 4910 | 1.2373 | 1.1195 | 2 | 0.0035 | 205.57 | 0.54457% |
| C | Pink Water | Witcarb 950 | 80 | 0.4191 | 21 | 2 | 4910 | 1.2373 | 1.1195 | 2 | 0.0024 | 141.29 | 0.79232% |
| C | 4-component Synthetic Pink Water | Witcarb 950 | 79 | 0.3918 | 21 | 2 | 4910 | 1.2373 | 1.1195 | 2 | 0.0022 | 128.76 | 0.86945% |
| | **TCE** | | | | | | | | | | | | |
| D* | Deionized Water | Filtrasorb 300 | 28 | 0.62 | 173 | 5 | 4910 | 10.1932 | 9.8986 | 2 | 0.0356 | 2098.24 | 0.47176% |
| E | Unknown | Unknown | 42.7 | 0.57 | 173 | 5 | 4910 | 10.1932 | 9.8986 | 2 | 0.0214 | 1260.34 | 0.78539% |

**Table K-30**
**Summary of GAC Usage Rate Estimations for Each Alternative**

| | Total Flowrate (gpm) | | | GAC Usage Rate (lbs/yr) | | |
|---|---|---|---|---|---|---|
| Remedial Alternative (1) | Target Cleanup Goal I (2) | Target Cleanup Goal II (2) | Target Cleanup Goal III (2) | Target Cleanup Goal I (2) | Target Cleanup Goal II (2) | Target Cleanup Goal III (2) |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 970 | 2100 | 2330 | 101,000 | 100,000 | 104,000 |
| 3 & 4 | 1980 | 3300 | 3530 | 472,000 | 635,000 | 663,000 |
| 5 & 6 | 1450 | 2770 | 3000 | 188,000 | 269,000 | 255,000 |
| 7 & 8 | 2490 | 4200 | 4910 | 568,000 | 819,000 | 896,000 |

Notes:
(1) Detail Descriptions of the Alternatives are included in Volume I.
(2) Detailed Target Cleanup Goals are included in Volume I.

**ATTACHMENT K1**
**REFERENCE: TCE ISOTHERMS FROM DATA BY A.L. BENEDICT (1982)**

# Adsorption Processes for Water Treatment

Samuel D. Faust

Osman M. Aly

**Butterworths**
Boston London Durban Singapore Sydney Toronto Wellington

Table 6–3 Freundlich Isotherm Constants for Light Halogenated Hydrocarbons Used in this Study

| *Compound* | *K (mg/g)* | *l/n* |
|---|---|---|
| Single compounds | | |
| $CCl_4$ | 11.6 | .71 |
| PCE | 57.7 | .48 |
| TCE | 42.7 | .57 |
| Mixed compounds | | |
| PCE | 44.7 | .48 |
| TCE | 25.1 | .49 |

Source: Benedict [23].

Table 6–4 Freundlich Isotherm Constants for Light Halogenated Hydrocarbons on GAC

| *Compound* | *K[a] (mg/g)* | *l/n* | *PAC[b] Dosage (mg/l)* |
|---|---|---|---|
| $CHCl_3$ | .0165 | .60 | 1,900. |
| $CHClBr_2$ | .130 | .62 | 410. |
| $CHCl_2Br$ | .150 | .51 | 500. |
| $CHBr_3$ | .185 | .32 | 150. |

Source: Youssefi [37].
Note: Phosphate buffer, pH 7. Temperature = 24°C.
[a]Contact time = 360 min.
[b]To reduce initial content of 1 mg/l to 0.1 mg/l (from Table 6–1).

Table 6–5 GAC Performance for Removal of Light Halogenated Hydrocarbons on Columns

| *Compound* | *$C_o$ (mg/l)* | *Breakthrough Point* | *Amount Adsorbed from a Mixture* | *Amount Adsorbed as Single Compounds* |
|---|---|---|---|---|
| $CHCl_3$ | 1.20 | 0.10 | 0.593 | 0.829 |
| $CCl_4$ | 1.89 | 0.094 | 1.88 | — |
| $CHCl_2Br$ | 3.69 | 0.10 | 3.14 | 3.22 |
| $CHClBr_2$ | 2.99 | 0.10 | 3.64 | — |
| $CHBr_3$ | 11.14 | 0.05 | 11.12 | 20.45 |

Source: Youssefi [37].
Note: Phosphate buffer, pH 7. Temperature = 24°C.

Source: Reproduced from Weber and Pirbazari [36], courtesy of the American Chemical Society.
Note: All studies were conducted at pH 7 unless otherwise noted.
[a]Based on $C_e$ and $q_e$ expressed in μg and mg/g, respectively.
[b]r = Correlation coefficient for fit of the isotherm to the experimental data.
[c]Organic-free water.
[d]Filtrasorb 400.

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**ATTACHMENT K2**
**REFERENCE: BATCH CARBON ADSORPTION STUDIES**
**BY W.D. BURROWS (1982)**

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TECHNICAL REPORT 8207

# TERTIARY TREATMENT OF EFFLUENT FROM HOLSTON AAP INDUSTRIAL LIQUID WASTE TREATMENT FACILITY I. BATCH CARBON ADSORPTION STUDIES: TNT, RDX, HMX, TAX, AND SEX

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| | |
|---|---|
| Carbon | TAX |
| HMX | TNT |
| RDX | Wastewater |
| SEX | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)


Adsorption of TNT, RDX, HMX, TAX, and SEX from aqueous solution by granular activated carbon has been investigated in the batch mode. Adsorption from solutions of individual compounds is favorable for TNT and reasonably efficient for nitramines; adsorption from a mixture of the compounds, however, exhibits competition for adsorption sites and reduced overall efficiency. These results do not encourage the use of granular activated carbon for nitramine control in munitions wastewaters.


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## RESULTS AND DISCUSSION

Adsorption on granular activated carbon (Calgon F300, -200 mesh) was measured for each chemical over its maximum anticipated concentration, i.e., 20 to 25 mg/L or less (depending on its water solubility) down to the limit of detectability, which is 0.1 to 0.4 mg/L, depending on the compound and on the analytical procedure. Freundlich equations for each chemical, run individually, are listed below and presented graphically in Figure 1.

TNT: $q_e = 0.3370\ C^{1/5.429}$

RDX: $q_e = 0.1118\ C^{1/2.938}$

HMX: $q_e = 0.1682\ C^{1/2.169}$

TAX: $q_e = 0.1002\ C^{1/3.498}$

SEX: $q_e = 0.2190\ C^{1/2.853}$

Log-log plots are generally linear at carbon-to-substrate ratios of 1:1 and higher. At lower ratios there is evidence for saturation of adsorption sites, except for RDX (see data from Table 4). At this stage the chemicals fall into three categories in terms of slopes: TNT, for which removal is least sensitive to concentration, RDX, HMX, and SEX, which are more dependent on concentration but not statistically separable from each other at the 95 percent level; and TAX, which is not classifiable (i.e., not distinguishable from TNT or the others). Statistical comparisons of slopes and intercepts are presented in Tables 1 and 2. In the same category as RDX, HMX, and SEX is adsorption of a mixture of TNT, RDX, TAX, SEX, and HMX (in the approximate ratio of 25:24:20:6:5, respectively), arbitrarily reported in terms of mg/L "total nitrobodies."

Values derived for K and n are in satisfactory agreement with those (0.30 L/mg and 6.35, respectively) extrapolated from graphical data presented for TNT by Layne and Tash;[1] parameters extrapolated for RDX (0.066 L/mg and 1.90, respectively) indicate a somewhat greater concentration dependence for adsorption than was measured at USAMBRDL. However, both sets of results are in agreement in demonstrating the effectiveness of granular activated carbon in TNT removal; the flat slope of the Freundlich plot (Fig. 1) reflects a high level of adsorption efficiency, even at very low TNT concentrations. RDX, HMX, and SEX give significantly steeper slopes and are less efficiently removed, particularly at low concentrations (< 1 mg/L).

In terms of intercepts, the chemicals fall into three categories: TNT, which is most efficiently removed at all measured concentrations; HMX and SEX, which are less efficiently removed than TNT; and RDX and TAX, which are least efficiently removed. Apparently, substitution of a single acetyl group for a nitro group has no significant effect on adsorption for the nitramines. [Although relative adsorption efficiencies are commonly related inversely to water solubilities, it is not remarkable when such is not the case, as is evident here. Water solubilities are related to standard state (crystal lattice) energies, while adsorption efficiencies are related to Van der Waals forces, for which the dependence on molecular structure may be quite different.]

TABLE 1. COMPARISON OF REGRESSION EQUATION SLOPES[a]

| | TNT | TAX | RDX | SEX | Mixture |
|---|---|---|---|---|---|
| HMX | $p < 0.05$[b] | (NS)[c] | (NS) | (NS) | (NS) |
| Mixture | $p < 0.05$ | $p < 0.05$ | (NS) | (NS) | |
| SEX | $p < 0.05$ | (NS) | | | |
| RDX | $p < 0.05$ | $p < 0.05$ | | | |
| TAX | (NS) | | | | |

a. Data from Table 7.
b. Intercepts differ at confidence level >95%.
c. Intercept difference not significant ($p > 0.05$).

TABLE 2. COMPARISON OF REGRESSION EQUATION INTERCEPTS[a]

| | HMX | TAX | RDX | SEX | Mixture |
|---|---|---|---|---|---|
| TNT | ND[b] | $p < 0.05$[c] | ND | ND | ND |
| Mixture | (NS)[d] | ND | $p < 0.05$ | $p < 0.05$ | |
| SEX | (NS) | $p < 0.05$ | $p < 0.05$ | | |
| RDX | $p < 0.05$ | ND | | | |
| TAX | $p < 0.05$ | | | | |

a. Data from Table 7.
b. Comparison not done.
c. Intercepts differ at confidence level >95%.
d. Intercept difference not significant ($p > 0.05$).

Total nitrobody adsorption in the mixture is significantly less efficient than adsorption of TNT and no more efficient than adsorption of HMX and SEX taken individually, in contrast to the general rule for mixtures but in agreement with the findings of Layne and Tash[1] for TNT and RDX. Log-log plots of Freundlich isotherms for RDX and HMX in the mixture (Fig. 2) are statistically parallel (95 percent confidence limits) in the linear portion to the same components examined individually, but have lesser intercepts, an indication of competition for adsorption sites. (The same is probably true for TNT, but only two points could be analyzed for the mixture.) The same plots for TAX and SEX in the mixture are not parallel to the corresponding lines for the individual components, and may not be linear. (See data from Table 5. If linear, these plots would have negative slopes, which are theoretically meaningless.) Nonlinearity is reported by Layne and Tash for mixtures of RDX and TNT, and some mixtures exhibit maxima in the Freundlich plots for RDX.

## SUMMARY AND CONCLUSIONS

Although the results developed here show that each of the five constituents is readily removed from uncontaminated water by granular activated carbon when present alone, these results do not necessarily endorse the choice of GAC as appropriate tertiary treatment technology for nitramine-contaminated wastewaters. The decision to proceed with GAC treatment must depend on continuous tests using GAC columns and authentic or synthetic wastewaters containing nitramines and nitrobodies, so that both kinetic and equilibrium effects can be evaluated. With respect to the latter the USAMBRDL results are not encouraging, since they indicate that the nitramines will be adsorbed in a series of bands (as in chromatography) at the tail end of the column and will be progressively displaced by TNT well before TNT achieves breakthrough. Layne and Tash argue similarly from their data that the use of carbon columns for removal of RDX/TNT mixtures is questionable, because RDX will be strongly desorbed as the column approaches breakthrough for TNT, making it possible for the effluent RDX concentration to exceed temporarily the influent concentration. This will have to be established through further research.

## EXPERIMENTAL PROCEDURES

### MATERIALS

1,2,3,4,5,6-Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and 1,2,3,4,5,6,7,8-octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) were provided by HSAAP and were of washed, crude quality (Table 3). Both were air-dried to constant weight before use. 1-Acetyl-1,2,3,4,5,6-hexahydro-3,5-dinitro-1,3,5-triazine (TAX) and 1-acetyl-1,2,3,4,5,6,7,8-octahydro-3,5,7-trinitro-1,3,5,7-tetrazocine (SEX) were prepared by SRI International by methods described previously,[3,4] and were used as received (Table 3). 2,4,6-Trinitrotoluene (TNT) was synthesized at USAMBRDL and recrystallized from ethanol. Granular activated carbon (GAC; Calgon F300) was pulverized and screened to -200 mesh. A single batch was used for all experiments.

TABLE 4. ADSORPTION OF NITRAMINES/NITROBODIES ON CARBON (DIRECT UV ANALYSIS)

| Chemical | Test Run-Sample | Concentration mg/L | Carbon mg/L | $q_e$[a] |
|---|---|---|---|---|
| TNT | 4-0 | 25.3 | | |
| | 4-1 | 19.6 | 12.00 | 0.475[b] |
| | 4-2 | 12.3 | 25.78 | 0.504 |
| | 4-3 | 2.7 | 51.98 | 0.435 |
| | 4-4 | 0.4 | 77.86 | 0.320 |
| | 4-5 | 0.2 | 122.20 | 0.205 |
| | 4-6 | <0.1 | 250.78 | |
| | 5.0 | 50.8 | | |
| | 5-1 | 37.4 | 26.04 | 0.515[b] |
| | 5-2 | 22.8 | 50.40 | 0.556 |
| | 5-3 | 3.7 | 100.50 | 0.469 |
| | 5-4 | 0.7 | 150.14 | 0.334 |
| RDX | 4-0 | 21.0 | | |
| | 4-1 | 14.6 | 22.40 | 0.286 |
| | 4-2 | 10.5 | 43.38 | 0.242 |
| | 4-3 | 3.3 | 102.26 | 0.173 |
| | 4-4 | 0.8 | 196.88 | 0.103 |
| | 4-5 | 0.1 | 408.0 | 0.051 |
| | 4-6 | 7.8 | 60.06 | 0.220 |
| HMX | 6-0 | 5.20 | | |
| | 6-1 | 3.49 | 5.86 | 0.292 |
| | 6-2 | 2.86 | 11.64 | 0.201 |
| | 6-3 | 0.93 | 18.60 | 0.230 |
| | 6-4 | 0.30 | 33.22 | 0.148 |
| | 6-5 | 0.19 | 62.60 | 0.080 |
| | 6-6 | 0.07 | 125.20 | 0.041 |
| TAX | 2-0 | 21.7 | | |
| | 2-1 | 18.8 | 20.94 | 0.138[b] |
| | 2-2 | 10.6 | 60.42 | 0.185 |
| | 2-3 | 1.5 | 198.76 | 0.102 |
| | 3-0 | 17.2 | | |
| | 3-1 | 13.4 | 21.40 | 0.180[b] |
| | 3-2 | 9.2 | 41.00 | 0.194 |
| | 3-3 | 6.3 | 61.08 | 0.178 |
| | 3-4 | 2.8 | 100.60 | 0.143 |
| | 3-5 | 0.45 | 203.60 | 0.082 |
| | 3-6 | <0.1 | 398.24 | |
| SEX | 1-0 | 5.16 | | |
| | 1-1 | 3.60 | 5.14 | 0.304 |
| | 1-2 | 1.25 | 16.02 | 0.244 |
| | 1-3 | 0.10 | 51.54 | 0.098 |
| | 2-0 | 6.00 | | |
| | 2-1 | 4.17 | 6.64 | 0.276 |
| | 2-2 | 2.20 | 13.20 | 0.288 |
| | 2-3 | 1.25 | 19.44 | 0.258 |
| | 2-4 | 0.35 | 31.22 | 0.191 |
| | 2-5 | 0.15 | 61.46 | 0.095 |
| Mixture | 1-0 | 71.0 | | |
| | 1-1 | 48.8 | 40.9 | 0.547[b] |
| | 1-2 | 27.3 | 79.4 | 0.550 |
| | 1-3 | 10.4 | 161.4 | 0.375 |
| | 1-4 | 3.8 | 225.5 | 0.298 |
| | 1-5 | 1.1 | 404.0 | 0.173 |
| | 1-6 | 0.2 | 798.0 | 0.089 |

a. $q_e$ = Chemical removed (mg/L) ÷ carbon applied (mg/L).
b. Point not used in calculation of regression line.

ANALYSIS BY HPLC

The major portion of each sample was filtered through Whatman 2V fluted paper. The filtered sample was collected on a Sep-Pak[R] $C_{18}$ cartridge as follows: the Sep-Pak was preconditioned by passing through, in sequence, 5 mL of methanol, 5 to 10 mL of deionized water, and 10 mL of air; then a 50 mL sample was passed through the Sep-Pak at a rate of 5 to 10 mL/min, followed by 5 mL of air, using a 50 mL syringe. The analytical procedure was adapted from Stidham (1979)[5]. Material to be analyzed was eluted from the Sep-Pak by passing through 4 mL of a 1:1 acetonitrile:water solution, followed by 10 mL of air. The eluent was centrifuged at 2000 rpm for 15 min before analysis. The Water HPLC with Model 720 systems controller, Model 730 data module, M450 detector, Model U6K injector, and Model M600A pumps was used according to the following operating parameters:

| | |
|---|---|
| Column: | RAD-PAK-A $C_{18}$ |
| Mobile Phase: | Pump A, 25% methanol in water<br>Pump B, 80% methanol in water |
| Gradient: | 5-50% B in 25 min |
| Flow Rate: | 1.7 mL/min |
| Detector Wavelength: | 240 nm |
| Injection Volume: | 20 µL |

Peak areas were compared with a standard curve prepared from solutions of 0.2, 0.4, 1.0, and 2.0 mg/L for each chemical, matched against 1,3-dinitrobenzene as internal standard. (Eluent samples were further diluted as required.)

Treatment of Data - Calculated values of $q_e$ for each adsorption experiment are listed in Tables 4 and 5. These data were treated by linear regression; regression equations are presented in Tables 7 and 8 for the individual compounds and for the individual compounds in mixture, respectively. [By inspection, it was apparent that saturation of adsorption sites occurred for some compounds at low carbon-substrate ratios (generally less than 1:1), i.e., $q_e$ was no greater than for higher ratios. These data points were omitted from the regression analysis.] Regression lines were compared by analysis of co-variance according to the method of Brownlee (1965)[6], with 95% confidence limits. Each compound, tested alone, was compared with every other compound and with the collective mixture with respect to slope (Table 1) and intercept (Table 2); and each compound, tested alone, was compared with the same compound in the mixture.

Sep-Pak is a registered trademark of Waters Associates, Inc., Milford, MA.

TABLE 8. REGRESSION EQUATIONS FOR GAC ADSORPTION DATA FROM MIXTURE (HPLC ANALYSIS)

$$\text{Log } q_e = \text{Log } K' + 1/n\ (\text{Log } C - \overline{\text{Log } C})^{a}$$

| Chemical | Log K'±S.E. | 1/n±S.E. | $\overline{\text{Log } C}$ |
|---|---|---|---|
| TNT[b] | −0.523 | 0.1338 | 0.654 |
| RDX | −1.0024±0.0362 | 0.3181±0.0444 | 0.655 |
| HMX | −1.384±0.0047 | 0.3899±0.0133 | −0.014 |
| TAX | −1.177±0.118 | −0.0538±0.1258 | 0.812 |
| SEX | −1.590±0.065 | −0.1931±0.1189 | 0.329 |

a. $\overline{\text{Log } C}$, the average value of Log C, is introduced into the regression equation so that the regression lines in Figure 2 are centered about the average. For the Freundlich equations,

$$\text{Log } K = \text{Log } K' - 1/n\ \overline{\text{Log } C}$$

(The listed S.E. for Log K' is actually the S.E. for Log K).

b. Two points only.

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## ATTACHMENT K3
## REFERENCE: RDX ISOTHERMS FROM DATA BY MRI (1987)

RDX Isotherm for Filtrasorb 300 (MRI), Synthetic 4-component

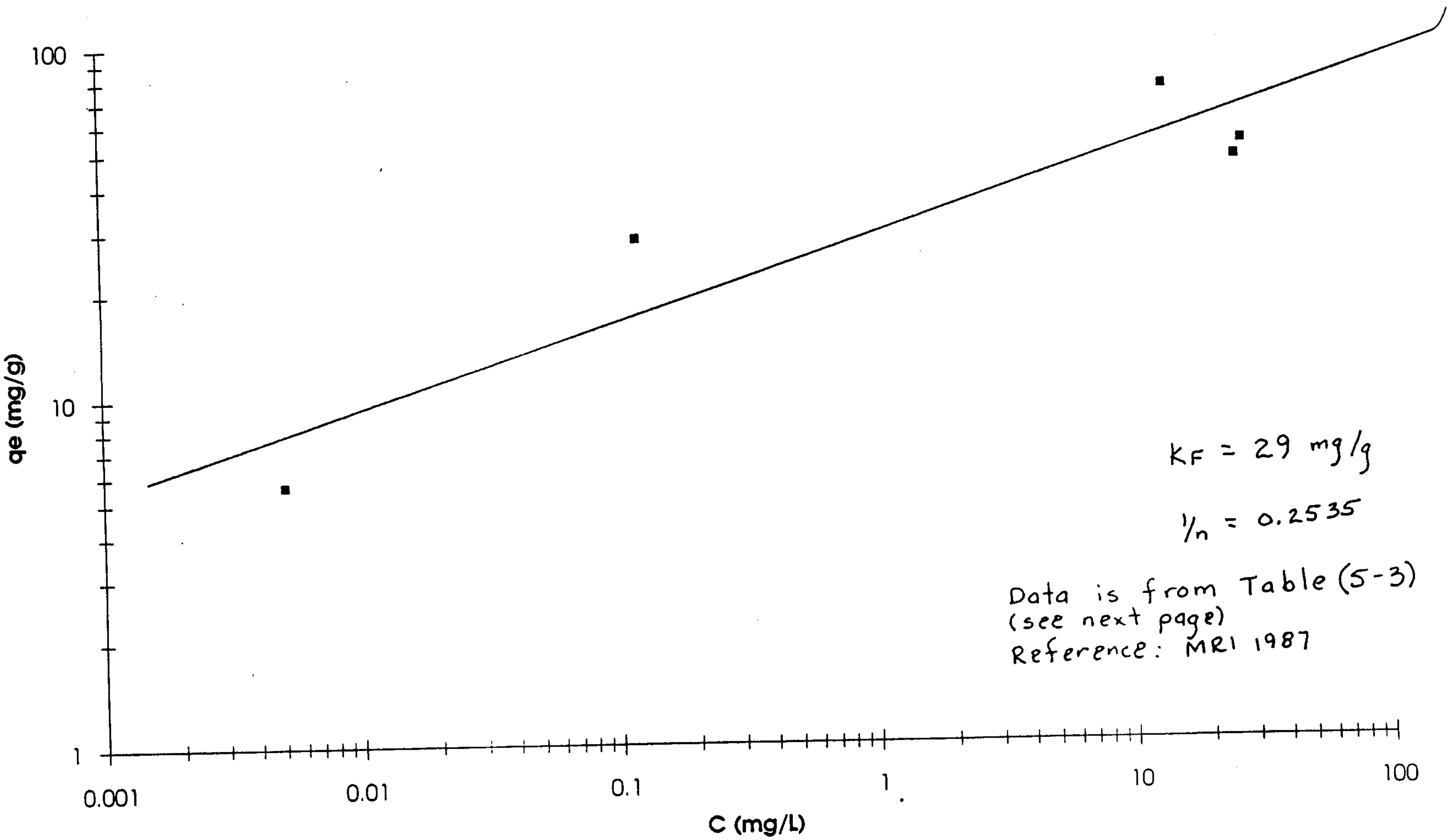


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TABLE 5-3. Isotherm Test Results for Calgon Filtrasorb 300.

| Carbon dosage (M), mg/L | RDX Equil. conc. ($C_e$), mg/L | RDX $q_e$ | HMX Equil. conc. ($C_e$), mg/L | HMX $q_e$ | 2,4-DNT Equil. conc. ($C_e$), mg/L | 2,4-DNT $q_e$ | TNT Equil. conc. ($C_e$), mg/L | TNT $q_e$ |
|---|---|---|---|---|---|---|---|---|
| Blank (0) | 28.0 | N/A | 5.61 | N/A | 0.915 | N/A | 73.7 | N/A |
| 12.0 | 27.4 | 0.0500 | 5.45 | 0.0133 | 0.802 | 0.0094 | 68.3 | 0.450 |
| 50.9 | 25.7 | 0.0452 | 4.98 | 0.0124 | 0.484 | 0.0085 | 51.3 | 0.440 |
| 201 | 13.5 | 0.0720 | 1.07 | 0.0226 | 0.0166 | 0.0045 | 2.74 | 0.353 |
| 1,000 | 0.120 | 0.0279 | 0.00248 | 0.0056 | < MDL[a] | > 0.0009 | < 0.0185 | > 0.0737 |
| 5,001 | 0.00508[a] | 0.0056 | 0.000216[a,b] | 0.0011 | ND[a] | N/A | < MDL[a] | N/A |

N/A = Not applicable
ND = Not detected
MDL = Minimum detection level (concentration at lowest level standard) using trace enrichment analysis
MDL = 0.000370 mg/L for RDX
MDL = 0.000416 mg/L for HMX
MDL = 0.000440 mg/L for 2,4-DNT
MDL = 0.000370 mg/L for TNT

[a] Indicates analysis by trace enrichment method.
[b] < MDL, but quantitated.

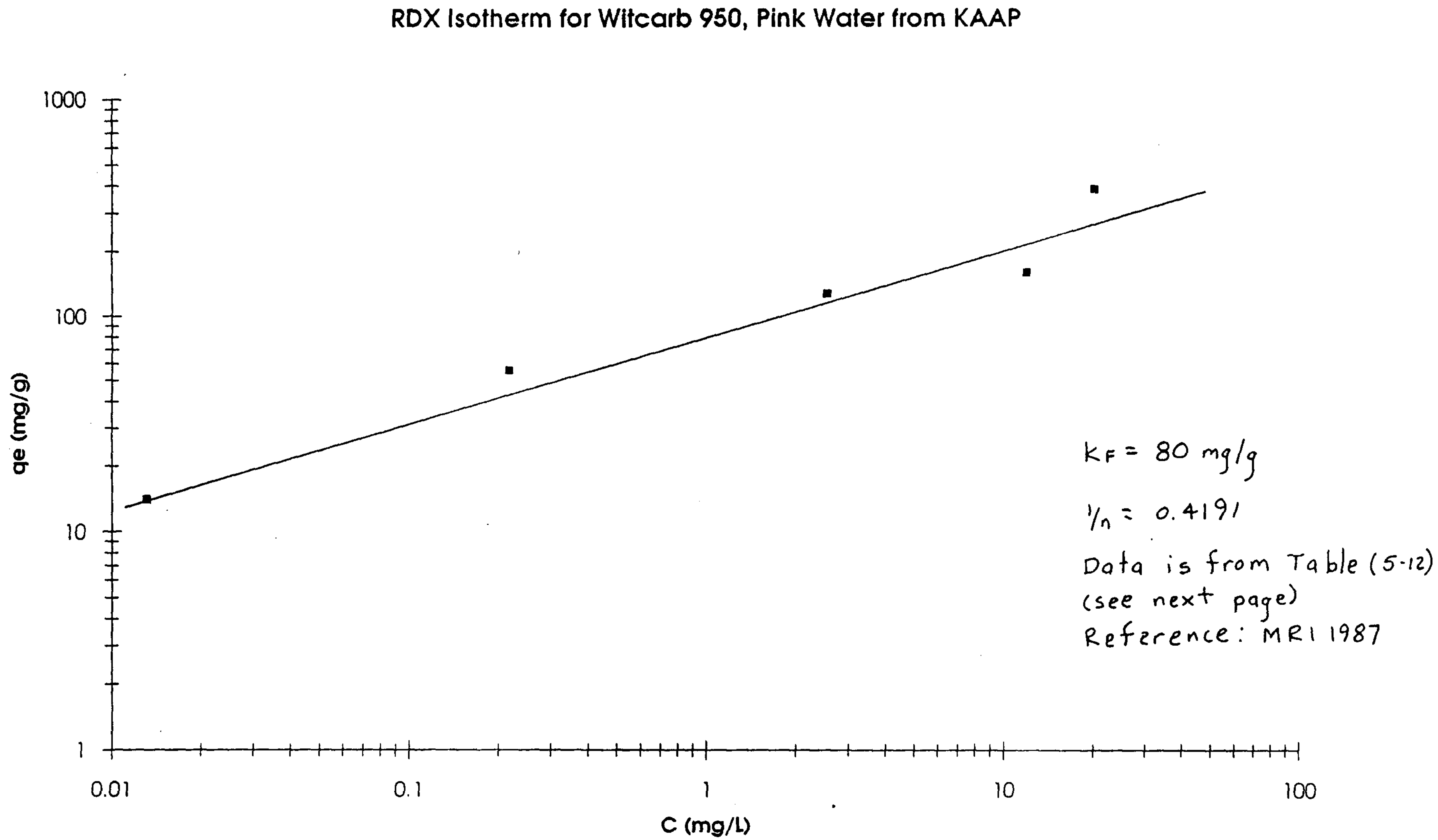


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TABLE 5-12. Isotherm Test Results for Pink Water from KAAP Using Witcarb 950.

| Carbon dosage (M), mg/L | RDX Equil. conc. ($C_e$), mg/L | RDX $q_e$ | HMX Equil. conc. ($C_e$), mg/L | HMX $q_e$ | 2,4-DNT Equil. conc. ($C_e$), mg/L | 2,4-DNT $q_e$ | TNT Equil. conc. ($C_e$), mg/L | TNT $q_e$ |
|---|---|---|---|---|---|---|---|---|
| Blank (0) | 22.0 | N/A | 4.02 | N/A | 0.0663 | N/A | 49.4 | N/A |
| 20.0 | 20.3 | 0.0848 | 3.57 | 0.0225 | 0.0430 | 0.0012 | 37.9 | 0.574 |
| 101 | 12.0 | 0.0989 | 1.54 | 0.0245 | 0.00264[a] | 0.0006 | 5.40 | 0.435 |
| 201 | 2.56 | 0.0966 | 0.0910 | 0.0195 | 0.0000893[a,b] | 0.0003 | 0.137 | 0.245 |
| 500 | 0.218 | 0.0436 | 0.00591[a] | 0.0080 | ND[a] | N/A | 0.0120[a] | 0.0989 |
| 1,998 | 0.0132[a] | 0.0110 | 0.000491[a] | 0.0020 | ND[a] | N/A | < MDL[a] | N/A |

N/A = Not applicable
ND = Not detected
MDL = Minimum detection level (concentration at lowest level standard) using trace enrichment analysis
MDL = 0.000370 mg/L for RDX
MDL = 0.000416 mg/L for HMX
MDL = 0.000440 mg/L for 2,4-DNT
MDL = 0.000370 mg/L for TNT

[a] Indicates analysis by trace enrichment method.
[b] < MDL, but quantitated.

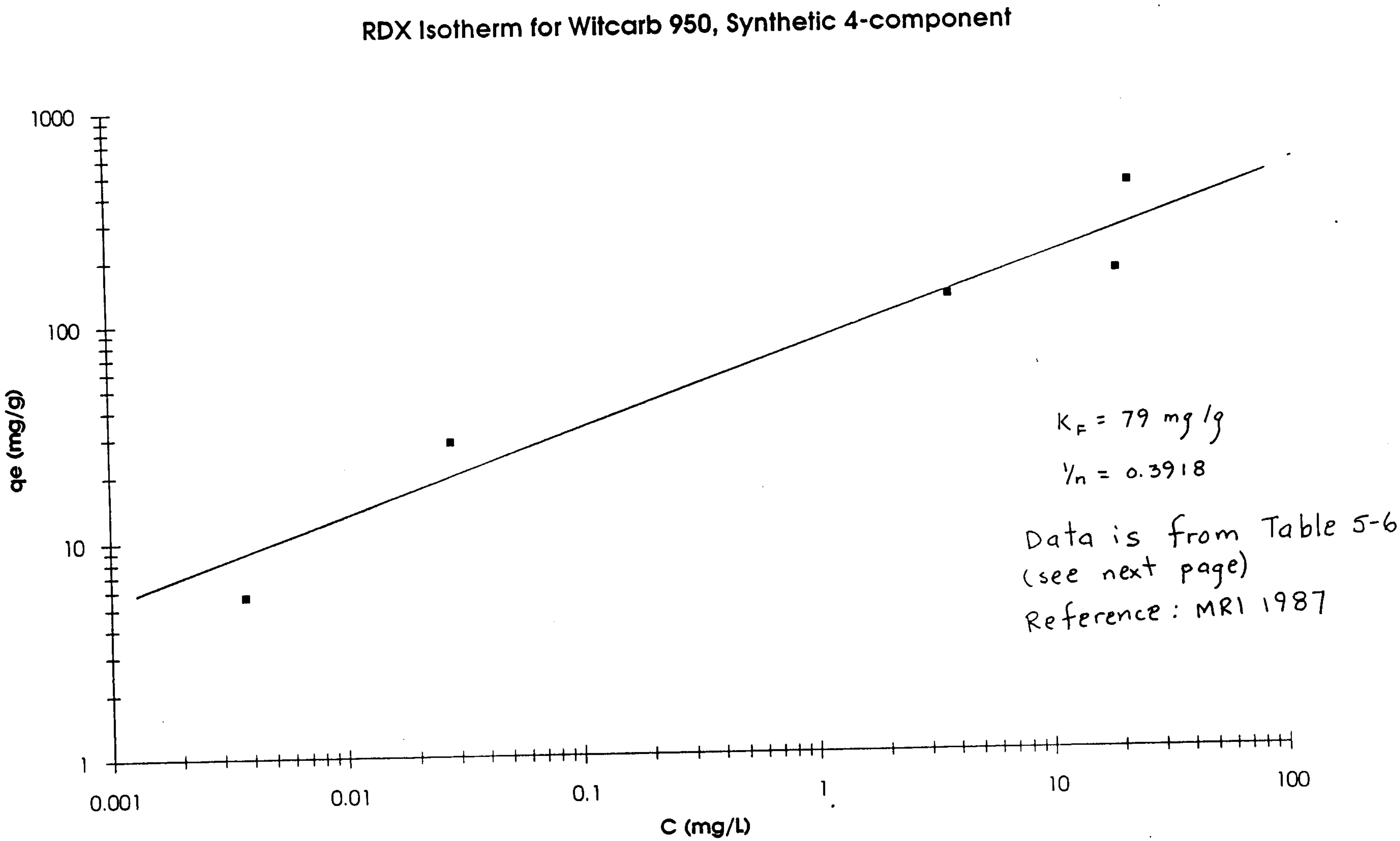


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TABLE 5-6. Isotherm Test Results for Witco Witcarb 950.

| Carbon dosage (M), mg/L | RDX Equil. conc. ($C_e$), mg/L | RDX $q_e$ | HMX Equil. conc. ($C_e$), mg/L | HMX $q_e$ | 2,4-DNT Equil. conc. ($C_e$), mg/L | 2,4-DNT $q_e$ | TNT Equil. conc. ($C_e$), mg/L | TNT $q_e$ |
|---|---|---|---|---|---|---|---|---|
| Blank (0) | 23.3 | N/A | 4.58 | N/A | 0.779 | N/A | 61.8 | N/A |
| 13.6 | 22.4 | 0.0662 | 4.26 | 0.0235 | 0.621 | 0.0116 | 54.2 | 0.559 |
| 52.6 | 19.6 | 0.0703 | 3.64 | 0.0179 | 0.261 | 0.0098 | 31.7 | 0.572 |
| 194 | 3.79 | 0.1006 | 0.144 | 0.0229 | 0.00113[a] | 0.0040 | 0.399 | 0.317 |
| 1,004 | 0.0284 | 0.0232 | 0.00142[a] | 0.0046 | < MDL[a] | > 0.0008 | 0.000687[a] | 0.0615 |
| 5,008 | 0.00375[a] | 0.0047 | ND[a] | N/A | ND[a] | N/A | ND[a] | 0.0123 |

N/A = Not applicable
ND = Not detected
MDL = Minimum detection level (concentration at lowest level standard) using trace enrichment analysis
MDL = 0.000370 mg/L for RDX
MDL = 0.000416 mg/L for HMX
MDL = 0.000440 mg/L for 2,4-DNT
MDL = 0.000370 mg/L for TNT

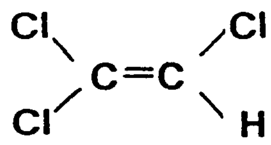
[a] Indicates analysis by trace enrichment method.

## ATTACHMENT K4
## REFERENCE: TCE ISOTHERMS FROM DATA BY EPA (1980)

TCE ADSORPTION ISOTHERM DATA

**COMPOUND:** Trichloroethene (Trichloroethylene)

**STRUCTURE:**



**FORMULA:** $C_2HCl_3$ **MOL. WT.** 131.39

| FREUNDLICH PARAMETERS | pH | | |
|---|---|---|---|
| | 5.3 | | |
| K | 28.0 | | |
| 1/n | 0.62 | | |
| Corr. Coef. r | 0.99 | | |
| INITIAL CONC. mg/l | ADSORPTION CAPACITY, mg/gm | | |
| 1.0 | 28 | | |
| 0.1 | 6.7 | | |
| 0.01 | 1.6 | | |
| 0.001 | 0.38 | | |

**CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)**

SINGLE STAGE POWDERED CARBON

$C_f$, mg/l

| $C_o$, mg/l | 0.1 | 0.01 | 0.001 |
|---|---|---|---|
| 1.0 | 130 | 620 | 2,600 |
| 0.1 | | 56 | 260 |
| 0.01 | | | 23 |
| | | | |

GRANULAR CARBON COLUMN

| $C_o$, mg/l | |
|---|---|
| 1.0 | 36 |
| 0.1 | 15 |
| 0.01 | 6.3 |
| | |

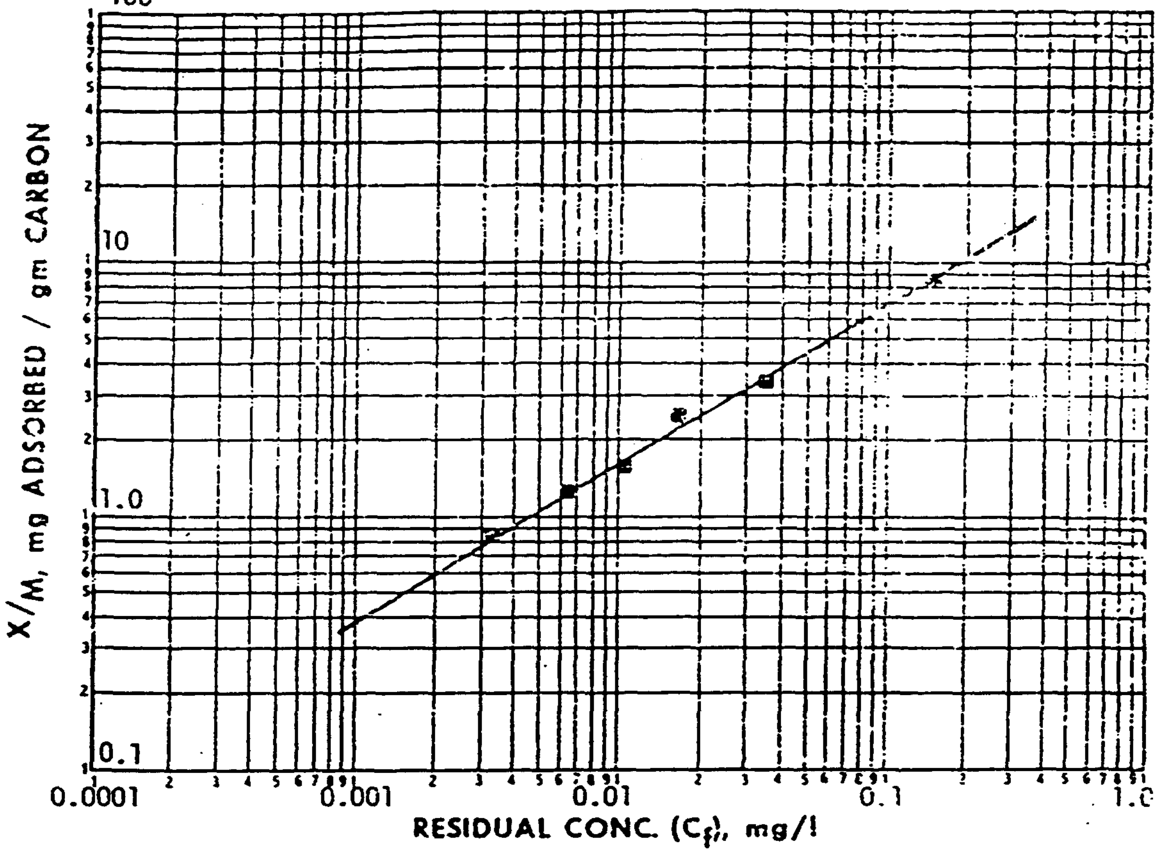
(a) Carbon doses in mg/l at neutral pH.

**ANALYTICAL METHOD:** G. C. Purge and Trap

**REMARKS:**

TCE ADSORPTION ISOTHERM DATA

COMPOUND: Trichloroethene (Trichloroethylene)




| CARBON DOSE mg/l | ■ pH= 5.3 $C_f$ | $C_o-C_f=X$ | X/M | pH= $C_f$ | $C_o-C_f=X$ | X/M | pH= $C_f$ | $C_o-C_f=X$ | X/M |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.000 | | | | | | | | |
| 96 | 0.164 | 0.836 | 8.70 | | | | | | |
| 289 | 0.035 | 0.965 | 3.35 | | | | | | |
| 385 | 0.018 | 0.982 | 2.55 | | | | | | |
| 577 | 0.0104 | 0.990 | 1.71 | | | | | | |
| 769 | 0.0061 | 0.994 | 1.29 | | | | | | |
| 1154 | 0.0052 | 0.995 | 0.862 | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**ATTACHMENT K5**
**REFERENCE: ISOTHERM MODEL FROM DATA**
**BY W.J. WUJCIK et al. (1992)**

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# Granular Activated Carbon Pilot Treatment Studies for Explosives Removal From Contaminated Groundwater

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*Manufacturing activities at Army Ammunition Plants (AAPs) result in the production of organic wastewaters that contain both explosive residues and other organic chemicals. As a result of past waste practices at such plants, explosive residues may leach through the soil and contaminate groundwater. Two pilot studies were performed to evaluate the use of granular activated carbon (GAC) to treat groundwater contaminated with explosives at Badger AAP and Milan AAP. An additional goal of the Badger AAP study was to examine the potential discharge of explosives 2,4-DNT and 2,6-DNT from a packed column air stripper used to remove volatile organic compounds from groundwater. A laboratory method was developed for the BAAP study to permit lower detection levels for 2,4-DNT and 2,6-DNT (0.46μg/L and 0.017μg/L, respectively). The studies concluded that removal of explosives from groundwater using continuous flow GAC is feasible.*

## INTRODUCTION

The United States Army operates explosives plants that load, assemble, and pack (LAP) explosives into military ordnance. Activities at such plants produce process wastewaters that contain both explosives residues and other organic chemicals. Several treatment technologies have been developed and are currently in use to treat these wastewaters for final discharge.

Past waste handling practices at explosives LAP plants often utilized unlined lagoons or pits to contain process wastewaters. As a result of this practice, some explosives residues have leached through the soil to contaminate groundwater. Therefore, groundwater treatment may be required. Based upon process wastewater treatment experience, potentially applicable treatment technologies are available. However, the similarities and differences between process wastewaters and explosives-contaminated groundwater should be considered before transferring technologies from one application to another.

Process wastewaters at explosives LAP plants are often treated by activated carbon adsorption. This treatment has been documented in the literature [*1, 2, 3, 4*]. Therefore, based upon process wastewater treatment experience, activated carbon adsorption would likely work for the treatment of explosives-contaminated groundwater. However, because of the similarities and differences between process wastewaters and explosives-contaminated groundwater, the feasibility of using activated carbon adsorption for treatment of groundwater should be determined.

Hinshaw et al. [*5*] present a multiphase study providing quantitative data on the ability of activated carbon to remove the nitrobodies 2,4,6-trinitrotoluene (TNT), 2,4-dinitrotoluene (2,4-DNT), cyclotrimethylenetrinitramine (RDX), and cyclotetramethylenetetranitramine (HMX) from pink water. The study included preliminary activated carbon screening, isotherm tests of activated carbon, preliminary column tests of selected activated carbons, four-in-series column tests, and an economic analysis of activated carbon. Isotherm tests on five different carbons were conducted to select the best performing carbon for further testing using continuous-flow columns. Pilot-scale column tests were subsequently performed with four columns in-series using one of the five carbons for the treatment of actual ammunition plant pink water. Effluent criteria (40 μg/L TNT, 30 μg/L RDX, 30 μg/L HMX, and 0.7 μg/L

2,4 DNT) were generally met for RDX, HMX, and 2,4-DNT, but not for TNT. The TNT performance limitation was determined to be a physicochemical phenomenon. This phenomenon did not appear during the isotherm tests and points to the importance of performing actual column tests with the wastewaters to be treated.

Groundwater in the area of the Propellant Burning Grounds at Badger Army Ammunition Plan (BAAP) in Baraboo, Wisconsin, has been found to be contaminated with explosives compounds, including dinitrotoluene isomers, volatile organic compounds (VOCs), and related degradation products [6]. A barrier well network to intercept the advancing contaminant plume with associated treatment using air stripping and/or granular activated carbon (GAC) has been proposed.

Explosives-contaminated water has percolated from the O-line ponds at the Milan Army Ammunition Plant (MAAP) in Milan, Tennessee, into the upper and middle part of the Clairborne aquifer underlying the facility. Migration of these wastes is expected to continue in the groundwater flow system and thereby contaminate additional groundwater and possibly surface water in the area. The chemical wastes that are of major concern at MAAP are 2,4,6-trinitrotoluene (TNT), cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), 2,4,6-trinitrophenylmethylnitramine (Tetryl), 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT), 1,3-dinitrobenzene (1,3-DNB), 1,3,5-trinitrobenzene (1,3,5-TNB), and nitro-benzene (NB).

The primary objective of these pilot studies was to determine the feasibility of using GAC to treat explosives-contaminated groundwater. The explosive contaminants studies were TNT, RDX, HMX, Tetryl, 2,4-DNT, 2,6-DNT, 1,3-DNB, 1,3,5-TNB, and NB. The studies included preliminary batch (isotherm) testing followed by column testing using a continuous-flow pilot plant. Since groundwater contamination at BAAP includes VOCs, an air stripper was used in conjunction with GAC treatment. The secondary objective of the pilot study at BAAP was to examine the potential for discharge of explosive components from the air stripper.

## ISOTHERM TEST PROGRAM

Laboratory GAC isotherm studies were conducted to evaluate the ability of activated carbon to remove 2,4-DNT and 2,6-DNT from groundwater at BAAP and TNT, RDX, HMX, Tetryl, 2,4-DNT, 2,6-DNT, 1,3,5-TNB, and NB from the explosives-contaminated groundwater at MAAP. Five different types of granular activated carbon were evaluated in both studies in terms of: (1) relative adsorbability of explosives; (2) adsorption capacities and associated exhaustion rates for explosives; (3) degrees of removal based on desired effluent objectives; and (4) preferential adsorption of component groups. The isotherm studies also evaluated the effect of an acidic pH (4.0) on adsorption capacities.

Isotherm testing consisted of a series of batch adsorption experiments in which multiple aliquots of groundwater from BAAP and MAAP were treated with varying dosages of GAC. The test containers were agitated to achieve equilibrium between the liquid phase and the solid phase. The GAC was then filtered out of the solution and the filtrate was analyzed to determine the equilibrium concentration of the parameters (or adsorbate) of interest. The data obtained from the analysis were interpreted by plotting the amount of adsorbate absorbed per unit weight of activated carbon versus the equilibrium concentration of adsorbate remaining in solution.

Groundwater samples from BAAP received additional treatment prior to isotherm testing. They were aerated for 1 hour and 15 minutes (to simulate air stripping) to strip off volatiles present in the groundwater. The pHs of the groundwater samples before aeration were in the range of 7.0 to 7.5. After aeration, the pH of the groundwater samples had increased to range from 8.3 to 8.7. Sulfuric acid ($H_2SO_4$) was added to the aerated groundwater samples to lower the pH to required levels prior to contacting the groundwater with carbon.

## ISOTHERM TEST RESULTS

The Freundlich adsorption equation was used in presenting the carbon isotherm test results. Isotherms were developed for BAAP for 2,4-DNT and 2,6-DNT by plotting the adsorption data on logarithmic coordinates as carbon loading ($q_e$) versus the equilibrium concentration ($C_e$) of compound remaining in the groundwater sample. The empirical constants of the Freundlich equation for the five test carbon isotherms are presented in Table 1.

On the basis of adsorption capacities for 2,4-DNT and 2,6-DNT, Filtrasorb 300 and Hydrodarco 4000 were judged to be the best performing GACs for removing both contaminants from groundwater at BAAP. The maximum saturation capacities (theoretical maximum loading) for Filtrasorb 300 and Hydrodarco 4000 were estimated by extrapolating the isotherms to $(q_e)C_0$. The carbon loading thus obtained corresponds by definition to a condition when all the carbon is in equilibrium with the influent concentration ($C_0$). In a carbon column treatment system, this equates to operating a GAC system until the concentration of a particular compound at the column effluent equals the influent concentration. The equilibrium $q_e$ values at different influent concentrations of 2,4-DNT and 2,6-DNT for the five GACs are presented in Table 2.

Therefore, as a result of this isotherm testing program, Filtrasorb 300 and Hydrodarco 4000 were selected for further testing, using continuous-flow GAC columns at BAAP.

The empirical constants of the Freundlich adsorption equation for the five test carbon isotherms for MAAP are presented in Table 3 for TNT and RDX. These constants for the three Filtrasorb carbons could not be determined for TNT because it was present at concentrations below its detection limit in all of the filtrates. For this same reason, the empirical constants of the Freundlich adsorption equation for all five carbons for the other seven explosives could not be determined.

The maximum saturation capacities (theoretical maximum loading) for all five carbons for RDX were estimated by ex-

**Table 1 Empirical Constants of Freundlich Adsorption Equation[a] for Five GACs Using Groundwater from Monitoring Well PBN82-02C at the Badger Army Ammunition Plant**

| Activated Carbon Type | 2,4-DNT Isotherms $K^b$ | 2,4-DNT Isotherms $1/n^c$ (slope) | 2,6-DNT Isotherms $K^b$ | 2,6-DNT Isotherms $1/n^c$ (slope) |
|---|---|---|---|---|
| Filtrasorb 200 | 0.085 | 0.077 | 0.03 | 0.022 |
| Filtrasorb 300 | 0.075 | 0.067 | 0.09 | 0.086 |
| Filtrasorb 400 | (0.9)[d] | (2.72) | 0.09 | 0.086 |
| Hydrodarco 3000 | 0.02 | 0.014 | 0.03 | 0.029 |
| Hydrodarco 4000 | 0.2 | 0.263 | 0.035 | 0.024 |

[a] $q_e = X/M = KC_e^{1/n}$.
where,

$q_e$ = Carbon loading, mg compound/mg carbon, dimensionless.
$X = C_0 - C_e$, the amount of compound adsorbed for a given volume of solution, mg/L.
$M$ = Carbon dosage, mg/L.
$C_0$ = Initial concentration of compound, mg/L.
$C_e$ = Concentration of compound remaining in solution, mg/L.
$K$ = Freundlich constant $(mg/L)^{-1/n}$.
$n$ = Empirical constant, dimensionless

[b] Intercept at $C_e = 1.0$ mg/L on the isotherm line. This intercept was determined by extrapolation.
[c] Slope of the line within the concentration range of 0.01–1.0 mg/L.
[d] By extrapolation from the maximum equilibrium concentration of 0.06 mg/L (obtained at the lowest carbon dosage of 10 mg/L) to a concentration of 1.0 mg/L.

**Table 2 Maximum Saturation Capacities ($q_s$) for Five GACs Tested for at the Badger Army Ammunition Plant**

| Carbon Type | Nitrobody | Influent Concentration $C_0$ (mg/L)[a] | Saturation Capacity ($q_s$) (mg/mg) |
|---|---|---|---|
| Filtrasorb 300 | 2,4-DNT | 2 | 0.1 |
| | | 10 | 0.21 |
| | 2,6-DNT | 1 | 0.09 |
| | | 4 | 0.21 |
| Hydrodarco 4000 | 2,4-DNT | 2 | 0.28 |
| | | 10 | 0.62 |
| | 2,6-DNT | 1 | 0.03 |
| | | 4 | 0.07 |
| Filtrasorb 200 | 2,4-DNT | 2 | 0.10 |
| | | 10 | 0.22 |
| | 2,6-DNT | 1 | 0.03 |
| | | 4 | 0.06 |
| Filtrasorb 400 | 2,4-DNT | 2 | —[b] |
| | | 10 | —[b] |
| | 2,6-DNT | 1 | 0.09 |
| | | 4 | 0.21 |
| Hydrodarco 3000 | 2,4-DNT | 2 | 0.02 |
| | | 10 | 0.03 |
| | 2,6-DNT | 1 | 0.03 |
| | | 4 | 0.12 |

[a]Influent concentrations correspond to those anticipated from previous work (10 mg/L for 2,4-DNT and 4 mg/L for 2,6-DNT) and to those actually found in the groundwater sample used for isotherm tests reported here (2 mg/L for 2,4-DNT and 1 mg/L for 2,6-DNT).
[b]Due to an elevated detection limit caused by sample interference, the exact value for the data point corresponding to this carbon dosage could not be determined.

trapolating their isotherms to $C_0$. This gives a $q_s$ that corresponds to a condition in which all the carbon is in equilibrium with the initial concentration of RDX. In a continuous-flow GAC column, this condition occurs when the RDX concentration in the effluent is the same as that in the influent. However, this does not occur in practice, because normally the column service is terminated when the effluent concentration reaches a predetermined effluent limit. In addition, maximum saturation capacities for Hydrodarco 4000 and Atochem, Inc. GAC 830 for TNT were estimated by extrapolating their isotherms to $C_0$.

**Table 3 Empirical Constants for Freundlich Adsorption Equation[a] for Five Test Carbons Using Groundwater from Monitoring Well MI051 at the Milan Army Ammunition Plant**

| Activated Carbon Type | TNT Isotherms $K$[b] | TNT Isotherms $1/n$[c] | RDX Isotherms $K$[b] | RDX Isotherms $1/n$[c] |
|---|---|---|---|---|
| Filtrasorb 200 | ND[d] | ND[d] | 0.052 | 0.535 |
| Filtrasorb 300 | ND[d] | ND[d] | 0.031 | 0.413 |
| Filtrasorb 400 | ND[d] | ND[d] | 0.049 | 0.555 |
| Hydrodarco 4000 | 0.128 | 0.828 | 0.0012 | 0.100 |
| Atochem, Inc. GAC 830 | 0.136 | 0.642 | 0.045 | 0.630 |

[a]$q_e = X/M = KC_e^{1/n}$.
where,

$q_e$ = Carbon loading, mg compound/mg carbon, dimensionless.
$X = C_0 - C_e$, the amount of compound adsorbed for a given volume of solution, mg/L.
$M$ = Carbon dosage, mg/L.
$C_0$ = Initial concentration of compound, mg/L.
$C_e$ = Concentration of compound remaining in solution, mg/L.
$K$ = Freundlich constant $(mg/L)^{-1/n}$.
$n$ = Empirical constant, dimensionless

[b]Intercept at $C_e$ = 1.0 mg/L on the isotherm line. This intercept was determined by extrapolation.
[c]Slope of the line within the concentration range of 0.01–1.0 mg/L.
[d]ND = Not determinable.

Because of inconclusive results on the effect of pH on the activated carbon adsorption of the groundwater from monitoring well M1051 at MAAP, the continuous-flow GAC columns at MAAP were run at pH 7.0. This decision was supported by the results on the effect of pH described in the previous pilot study at Badger Army Ammunition Plant (BAAP) [7]. In that study, the results of the isotherm tests for Filtrasorb 400, using explosives-contaminated groundwater from monitoring well PBN82-02C at BAAP, showed that relatively higher adsorption capacities were obtained at neutral pH (7.0) than at acidic pH (4.0). Even though previous results in the literature [3] showed the opposite to be true for TNT and other nitroaromatics, greater weight was given to the BAAP report because it represented the most recent experience with explosives-contaminated groundwater.

## PILOT STUDIES

### Activated Carbon Pilot-Scale Test at BAAP

The continuous-flow column testing was conducted at BAAP using the two types of carbons selected from the batch (isotherm) testing. A schematic of the pilot plant, including the air stripper, is shown in Figure 1. Two continuous-flow column tests were performed, each using two carbon columns.

For each test, the total groundwater flow was split between the two test trains (A and B) at different proportions depending on the desired hydraulic loading rates. The two columns in Train A and Train B contained carbon types designated as A and B, respectively.

All of the tests were conducted inside the test building located at BAAP. The test area was maintained at a minimum temperature of 50°F. The hydraulic surface loading rates that were employed during the pilot tests were 3, 5, and 7 gpm/ft². These values are within the range of hydraulic surface loading rates that are normally used in full-scale operation of GAC systems.

Adsorption and breakthrough characteristics were studied in the first column of each parallel pair. The function of the second column was to maintain effluent (discharge) quality within acceptable limits while allowing contaminant leakage up to influent levels (total exhaustion of capacity) of the first column. Influent and effluent (first column as well as second column) were monitored for pH and temperature at regular time intervals.

An air stripper was used to remove volatile solvents from the groundwater prior to its entering the GAC pilot plant. The primary function of the air stripper in this project was to minimize any effects of these solvents on the evaluation of activated carbon adsorption of explosives. The potential for discharge of explosives into the air stream was examined by emissions testing of the exhaust stack. Sampling points were located approximately 6 feet above (downstream from) the

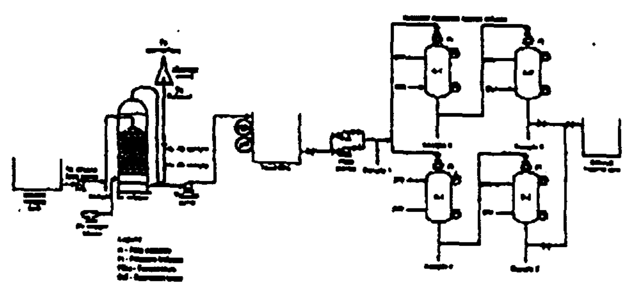

**FIGURE 1. BAAP Pilot Treatment Plant Configuration**

**Table 4 Summary of Granular Activated Carbon (GAC) Columns Operating and Performance Data for Pilot Tests at the Milan Army Ammunition Plant**

| | Test One<br>Starting Date: 7 September 1989<br>Ending Date: 15 September 1989<br>Column Inner Diameter: 4.25 in.<br>0.354 ft)<br>Column Area: 0.0985 $ft^2$<br>Bed Volume: 0.394 $ft^3$ (2.94 gal. | | Test Two<br>Starting Date: 19 September 1989<br>Ending Date: 6 October 1989<br>Column Inner Diameter: 4.25 in.<br>0.354 ft)<br>Column Area: 0.0985 $ft^2$<br>Bed Volume: 0.394 $ft^3$ (2.94 gal.) | | Test Three<br>Starting Date: 16 October 1989<br>Ending Date: 15 December 1989<br>Column Inner Diameter: 4.25 in.<br>0.354 ft)<br>Column Area: 0.0985 $ft^2$<br>Bed Volume: 0.197 $ft^3$ (1.47 gal.) | |
|---|---|---|---|---|---|---|
| | Column A1 | Column B1 | Column A1 | Column B1 | Column A1 | Column B1 |
| GAC Used | Atochem, Inc.<br>GAC 830 | Atochem, Inc.<br>GAC 830 | Atochem, Inc.<br>GAC 830 | Calgon<br>Filtrasorb 300 | Atochem, Inc.<br>GAC 830 | Calgon<br>Filtrasorb 300 |
| Flow Rate | 1.0 gpm | 0.2 gpm | 0.7 gpm | 0.7 gpm | 0.75 gpm | 0.75 gpm |
| Hydraulic Loading | 10.15 gpm/$ft^2$ | 2.03 gpm/$ft^2$ | 7.11 gpm/$ft^2$ | 7.11 gpm/$ft^2$ | 7.6 gpm/$ft^2$ | 7.6 gpm/$ft^2$ |
| Bed Depth | 4 ft | 4 ft | 4 ft | 4 ft | 2 ft | 2 ft |
| Empty-Bed Contact Time | 3.0 min. | 14.7 min. | 4.2 min. | 4.2 min. | 2.0 min. | 2.0 min. |
| Final Effluent Levels (µg/L) | | | | | | |
| TNT (Influent 433 µg/L) | ND | ND | ND | ND | 88.6 µg/L | 192 µg/L |
| RDX (Influent 487 µg/L) | 7.05 µg/L | ND | ND | ND | 315 µg/L | 344 µg/L |
| HMX (Influent 3.4 µg/L) | ND | ND | ND | ND | ND | ND |
| Tetryl (Influent ND) | ND | ND | ND | ND | ND | ND |
| 2,4-DNT (Influent 10.8 µg/L) | ND | ND | ND | ND | 3.6 µg/L | ND |
| 2,6-DNT (Influent ND) | ND | ND | ND | ND | ND | ND |
| 1,3-DNB (Influent 3.2 µg/L) | ND | ND | ND | ND | ND | ND |
| 1,3,5-TNB (Influent 21.4 µg/L) | ND | ND | ND | ND | 9.91 µg/L | 14.9 µg/L |
| NB (Influent ND) | ND | ND | ND | ND | ND | ND |
| Run Time | 7.6 days | 7.6 days | 16.5 days | 16.5 days | 54.5 days | 54.5 days |

Notes: ND = Not detected.
Concentrations in parentheses are average influent concentrations.

expansion point in order to eliminate any effects of flow disturbances caused by the expansion. Samples from the exhaust stack were analyzed for explosives components (2,4-DNT and 2,6-DNT). The adequacy with which the air stripper removed volatiles was verified by comparing GAC pilot-plant influent levels to those in the untreated groundwater.

Samples for explosives analysis were collected from the air stripper exhaust duct using an EPA Modified Method 5 (MM5) sampling train. The train was further modified by the inclusion of an additional XAD-2 resin trap (a total of two) to ensure complete collection of target explosives. Sampling was conducted along the horizontal axis of the 8-inch inner diameter duct. The number of sample points and the sampling duration were determined on-site, with a 4-hour sample time used at four traverse points. Sampling was isokinetic (90 to 110%). Volumetric flow rate was determined by EPA Methods 1 and 2 as part of the MM5 train. Moisture content was determined using the EPA MM5 sample train used for collection of explosives. Triplicate test repetitions were performed for each emission parameter.

A mobile field laboratory was used to provide rapid turnaround of the large number of samples generated during pilot testing. Samples were analyzed in the field laboratory for dinitrotoluenes by liquid/liquid extraction and electron capture gas chromatography (GC), utilizing USATHAMA Method UW01. The following modifications to Method UW01 were made for field use:

1. Use injection volume of 5 mL.
2. Calibration curves of 1×, 5×, 10×, 50×, and 100×.
3. Daily QC of blank and 10× spike.
4. Final 10× calibration standard.

Detection limits were determined by instrument sensitivity.

In order to verify treatability at very low contaminant influent and effluent concentrations, WESTON's Analytics Division obtained certification from USATHAMA for a low-level DNT analytical method employing liquid/liquid extraction and electron capture detector QC analysis. The detection limits established in this certification effort were 0.46 μg/L for 2,4-DNT and 0.017 μg/L for 2,6-DNT. Following certification, this method was used for explosives analyses at the WESTON Analytics Division laboratory. The WESTON Analytics Division laboratory data were used to verify the field data.

Samples were analyzed by U.S. EPA Method 8010 for carbon tetrachloride, chloroform, trichloroethylene, and 1,1,1-trichloroethane. Detection levels of 1 ppb were obtained with Method 8010.

## Activated Carbon Pilot-Scale Test at MAAP

The continuous-flow column testing at MAAP was conducted using the two types of carbon selected from the batch (isotherm) testing. A schematic of the pilot plant is shown in Figure 2. The air stripper was not used at MAAP because volatiles were not detected in the groundwater used for the pilot test. During the field test program at MAAP, three continuous-flow column tests were performed, each using two carbon column trains. The operating and performance data for Tests One, Two, and Three are presented in Table 4.

Test One was run for a total of 7.6 days, at which time it was decided by WESTON and USATHAMA that breakthrough would not be reached in a reasonable amount of time for study purposes using the operating parameters in Table 4. Except for RDX, none of the contaminants of concern in this table were detected in the effluent samples during Test One. RDX was detected in column A1's effluent sample, but at a concentration that was approximately 1% of its influent concentration.

Test Two was run for a total of 16.5 days, at which time it

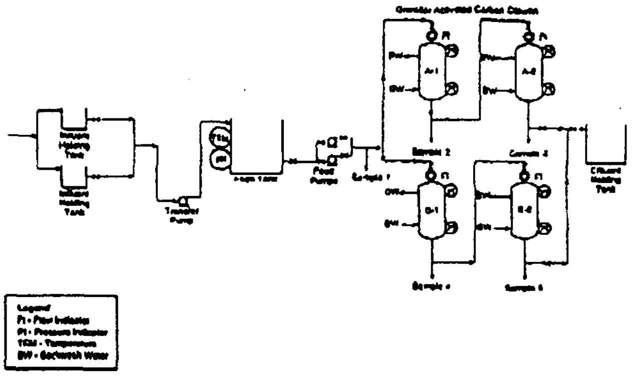

FIGURE 2. MAAP GAC Pilot Plant Configuration

was decided by WESTON and USATHAMA that breakthrough would not be reached in a reasonable amount of time for study purposes using the operating parameters in Table 4. None of the contaminants of concern in this table were detected in the effluent samples during Test Two.

Test Three was run for a total of 54.5 days, at which time, because of cold weather, it was decided by WESTON and USATHAMA that the unit should be shut down so that no damage would occur to the system. Of the contaminants of concern in Table 4, only TNT, RDX, 2,4-DNT, and 1,3,5-TNB were detected in the effluent samples during Test Three.

The analytical parameters for all tests were TNT, RDX, HMX, Tetryl, 2,4-DNT, 2,6-DNT, 1,3-DNB, 1,3,5-TNB, and NB. A total of 750 samples was analyzed by high-performance liquid chromatography (HPLC) for these parameters at the field laboratory at MAAP, utilizing USATHAMA Method UW01, Explosives in Waters. The samples included influent samples to the GAC unit and effluent samples from columns A1, A2, B1, and B2. The field laboratory was critical in providing rapid turnaround, facilitating operating decisions, and protecting effluent quality. In addition, 42 samples were sent to WESTON's Analytics Division for similar analysis. These samples represented 6% of the field laboratory samples analyzed and verified field laboratory performance.

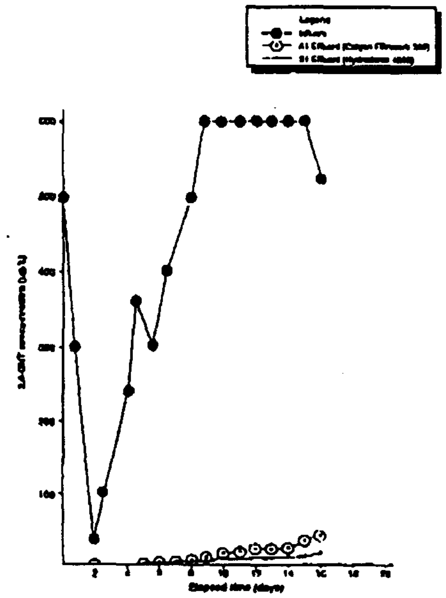

FIGURE 3. 2,4-DNT Concentration Using Early Morning Data (0600-0800) from Field Laboratory Results for Run One (Starting 15 February 1989) at BAAP

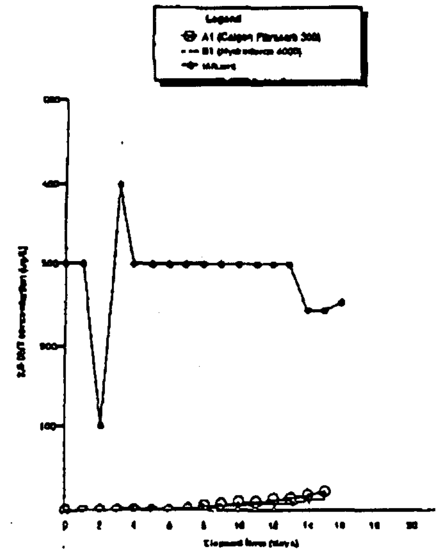

**FIGURE 4. 2,6-DNT Concentration Using Early Morning Data (0600–0800) from Field Laboratory Results for Run One (Starting 15 February 1989) at BAAP**

## DISCUSSION OF RESULTS

At the influent concentrations of groundwater from monitoring well PBN-82-02C at BAAP, influent surface loading rates of 3.0 to 7.0 gpm/ft$^2$ and an influent hydraulic loading rate of 1.5 to 3.5 gpm/ft$^3$, GAC columns employing either Filtrasorb 300 or Hydrodarco 4000 can provide run lengths of at least 16,130 gallons (10,970 bed volumes) while providing 2,4-DNT and 2,6-DNT removals of greater than 90%. Under conditions employed in this study, explosives concentrations could be reduced below detection limits (in this study, approximately 0.46 μg/L for 2,4-DNT and 0.017 μg/L for 2,6-DNT) for approximately 4,120 gallons (2,800 bed volumes) at the highest loading rate for 2,4-DNT and for approximately 180 gallons (123 bed volumes) at an intermediate loading rate for 2,6-DNT. Figures 3 through 6 summarize experimental results.

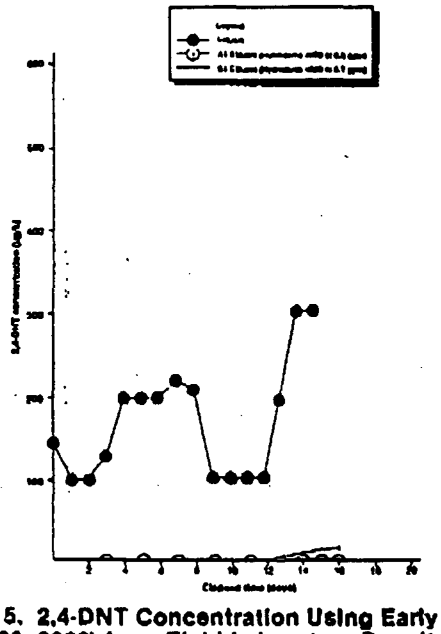

**FIGURE 5. 2,4-DNT Concentration Using Early Morning Data (0600–0800) from Field Laboratory Results for Run Two (Starting 8 March 1989) at BAAP**

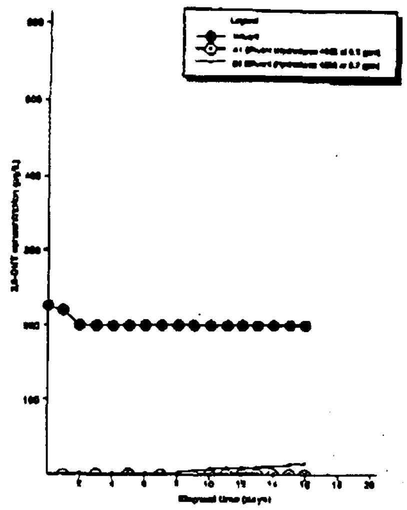

**FIGURE 6. 2,6-DNT Concentration Using Early Morning Data (0600–0800) from Field Laboratory Results for Run Two (Starting 8 March 1989) at BAAP**

Table 5 shows that generally good agreement was obtained between the mobile (field) laboratory analyses and those performed by WESTON's Analytics Division, particularly considering the difference in detection limits between the analytical methods.

Tables 6 and 7 summarize operating characteristics for runs one and two. Based upon the flow rate, observed (average) influent concentrations, and total operating time, the total mass loading of each explosive to each column was calculated. Based upon the total amount of carbon in each column and the specific adsorption capacity of the carbon for the explosive (as determined from the isotherm tests), the total column capacity for each explosive was calculated. Finally, from the mass of explosive applied and the capacity of the column, the percent utilization of column capacity was calculated. As noted previously, the effluent (that is, not adsorbed) fraction of the explosives did not exceed 10%, and most of the time was substantially lower. Therefore, for this calculation the difference between the total mass of explosive applied and that adsorbed (as would be estimated by integration under the respective concentration curves in Figures 3 through 6) was considered minor.

Table 6 shows that after 16 days of operation at the indicated loading, a relatively small fraction of each carbon's capacity for each explosive was utilized. Table 7 suggests the same conclusions for all three loading rates using Hydrodarco 4000. It should be noted that, even though the maximum hydraulic loading in run two was higher than in run one, the explosives concentrations in the groundwater had fallen as compared to run one, resulting in a lower mass loading rate of explosives to the column. Longer activated carbon column contact times (which in this study did not exceed 5 minutes) may provide even longer column lives for a given influent concentration.

These data clearly show that the use of new granular activated carbon in continuous-flow columns produced very low effluent explosives concentrations, generally in the low parts-per-billion (ppb) range during the early portions of each run. In most test runs effluent explosives levels rose gradually through the duration of the experiment. However, in no run did the effluent concentration of either 2,4-DNT, or 2,6-DNT exceed 10% of the respective (average) influent concentration before it became necessary to terminate the run. In the first run, which examined both selected carbons at an identical influent rate of 0.5 gpm, effluent levels of 2,4-DNT reached 40 μg/L (Filtrasorb 300) and 14 μg/L (Hydrodarco 4000) at the end of 16 days of operation (11,520 gallons—7,835 bed

**Table 5 WESTON's Analytics Division Results Versus WESTON Field Laboratory Results for Run Two at the Badger Army Ammunition Plant**

| Sample ID | Hours into Test | WESTON Analytics Laboratory Results Concentration (μg/L) 2,4-DNT | 2,6-DNT | Field Laboratory Results Concentration (μg/L) 2,4-DNT[a] | 2,6-DNT |
|---|---|---|---|---|---|
| Column A1 (Hydrodarco 4000 at 0.3 gpm) | | | | | |
| 8 March 1989, 16:00 | 2 | 18.10 | 9.80 | 0.7[b] | 0.6[b] |
| 9 March 1989, 16:00 | 26 | <0.46 | 0.30 | 0.4 | 0.4 |
| 10 March 1989, 16:00 | 50 | <0.46 | 0.27 | — | — |
| 11 March 1989, 16:00 | 74 | <0.46 | 0.26 | 0.3 | 0.3 |
| 12 March 1989, 16:00 | 98 | <0.46 | 0.20 | 0.25 | 0.25 |
| Column B1 (Hydrodarco 4000 at 0.7 gpm) | | | | | |
| 8 March 1989, 16:00 | 2 | 0.50 | 0.19 | 0.2[b] | 0.2[b] |
| 9 March 1989, 4:00 | 14 | <0.46 | 0.14 | ND[c] | 0.1[c] |
| 9 March 1989, 16:00 | 26 | <0.46 | 0.08 | ND | 0.1 |
| 10 March 1989, 4:00 | 38 | <0.46 | 0.07 | ND[c] | 0.1[c] |
| 10 March 1989, 16:00 | 50 | <0.46 | 0.06 | — | — |
| 11 March 1989, 4:00 | 62 | <0.46 | 0.05 | ND[d] | 0.1[d] |
| 11 March 1989, 16:00 | 74 | <0.46 | 0.05 | ND | 0.1 |
| 12 March 1989, 4:00 | 86 | <0.46 | 0.05 | ND[d] | 0.1[d] |
| 12 March 1989, 16:00 | 98 | <0.46 | 0.04 | | |

[a]ND = Below detection limit.
[b]Sample taken at 14:00 hours on 8 March 1989.
[c]Samples taken at 6:00 hours.
[d]Samples taken at 8:00 hours.

volumes). Effluent levels for 2,6-DNT at this point were 24 μg/L (Filtrasorb 300) and 15 μg/L (Hydrodarco 4000).

The second run employed a higher flow rate through one carbon train (0.7 gpm). Since the output of the monitoring well was limited to approximately 1.0 gpm, the other column train operated at 0.3 gpm. In this run, both column trains employed Hydrodarco 4000 carbon, which had provided the lower final effluent concentrations for both contaminants in run one. After a throughput volume of 16,130 gallons (10,970 bed volumes) for the higher (0.7 gpm) flow rate train, effluent 2,4-DNT was 10 μg/L and effluent 2,6-DNT was 1.6 μg/L. Effluent levels were 0.48 μg/L for 2,4-DNT and 0.12 μg/L for 2,6-DNT for the lower (0.3 gpm) flow rate train. As with run one, complete breakthrough was not observed, and with the concurrence of USATHAMA, run two was terminated at this point.

It should be noted that a major contributing factor to the inability to obtain breakthrough within available time periods was the low influent concentration of the contaminants of concern, at approximately two orders of magnitude lower than anticipated. The average influent 2,4-DNT concentration for the second run was 50% lower than the first run. Similarly, the average influent 2,6-DNT concentration for the second run was 33% lower than the first run.

**Table 6 Activated Carbon Column Operating and Performance Data for Run One at the Badger Army Ammunition Plant Hydrodarco 4000 Versus Calgon Filtrasorb 300**

Column Outer Diameter = 5 inches (0.42 ft)
Column Inner Diameter = 4.25 inches (0.354 ft)
Column Area = 0.0985 $ft^2$
Bed Volume (at 2-ft depth) = 0.197 $ft^3$ (1.47 gallons)

| | Hydrodarco 4000 | Filtrasorb 300 |
|---|---|---|
| Flow Rate | 0.5 gpm | 0.5 gpm |
| Surface Loading Rate | 5.0 $gpm/ft^2$ | 5.0 $gpm/ft^2$ |
| Contact Time | 3.0 min. | 3.0 min. |
| Hydraulic Loading | 2.50 $gpm/ft^3$ | 2.50 $gpm/ft^3$ |
| 2,4-DNT Influent Concentration (avg.) | 0.42 mg/L | 0.42 mg/L |
| 2,6-DNT Influent Concentration (avg.) | 0.3 mg/L | 0.3 mg/L |
| 2,4-DNT Capacity (rate)[a] | 0.12 lb/lb | 0.05 lb/lb |
| 2,6-DNT Capacity (rate)[a] | 0.016 lb/lb | 0.044 lb/lb |
| Weight of Carbon in Column | 4.8 lb | 5.8 lb |
| Column 2,4-DNT Capacity (wt) | 0.576 lb | 0.290 lb |
| Column 2,6-DNT Capacity (wt) | 0.077 lb | 0.255 lb |
| Total 2,4-DNT Loading to Column (lb) | 0.045 | 0.045 |
| Total 2,6-DNT Loading to Column (lb) | 0.029 | 0.029 |
| 2,4-DNT Capacity Utilized | 7.8% | 15.5% |
| 2,6-DNT Capacity Utilized | 37.7% | 11.4% |
| Run Time (days) | 16 | 16 |

[a]From isotherm data.

**Table 7 Activated Carbon Column Operating and Performance Data for Hydrodarco 4000 from Runs One and Two at the Badger Army Ammunition Plant**

| | |
|---|---|
| Column Outer Diameter | = 5 inches (0.42 ft) |
| Column Inner Diameter | = 4.25 inches (0.354 ft) |
| Column Area | = 0.0985 $ft^2$ |
| Bed Volume (at 2-ft depth) | = 0.197 $ft^3$ (1.47 gallons) |

| Flow Rate | 0.3 gpm (Run Two) | 0.5 gpm (Run One) | 0.7 gpm (Run Two) |
|---|---|---|---|
| Surface Loading Rate | 3.0 gpm/$ft^2$ | 5.0 gpm/$ft^2$ | 7.0 gpm/$ft^2$ |
| Contact Time | 5.0 min. | 3.0 min. | 2.2 min. |
| Hydraulic Loading | 1.50 gpm/$ft^3$ | 2.50 gpm/$ft^3$ | 3.50 gpm/$ft^3$ |
| 2,4-DNT Influent Concentration (avg.) | 0.17 mg/L | 0.42 mg/L | 0.17 mg/L |
| 2,6-DNT Influent Concentration (avg.) | 0.2 mg/L | 0.3 mg/L | 0.2 mg/L |
| 2,4-DNT Capacity (rate)* | 0.06 lb/lb | 0.12 lb/lb | 0.06 lb/lb |
| 2,6-DNT Capacity (rate)* | 0.013 lb/lb | 0.016 lb/lb | 0.013 lb/lb |
| Weight of Carbon in Column | 4.8 lb | 4.8 lb | 4.8 lb |
| Column 2,4-DNT Capacity (wt) | 0.288 lb | 0.576 lb | 0.288 lb |
| Column 2,6-DNT Capacity (wt) | 0.062 lb | 0.077 lb | 0.062 lb |
| Total 2,4-DNT Loading to Column (lb) | 0.0098 | 0.045 | 0.023 |
| Total 2,6-DNT Loading to Column (lb) | 0.012 | 0.029 | 0.027 |
| 2,4-DNT Capacity Utilized (lb) | 3.4% | 7.8% | 8.0% |
| 2,6-DNT Capacity Utilized | 19.4% | 37.7% | 43.5% |
| Run Time (days) | 16 | 16 | 16 |

*From isotherm data.

The explosives emissions evaluation during this study consisted of three separate tests during which exhaust gases from the stripper were sampled and analyzed. All three air stripper tests were conducted during the second GAC test run. Stack gases were near saturation at approximately 72% relative humidity for all three runs. Explosives emission data from all three test runs are presented in Table 8.

Table 8 indicates that explosives were detected in the exhaust of the stripper. The feed rate to the stripper was approximately 4 gpm of explosives-contaminated water for each time period for each test; therefore, over a 4-hour period approximately 960 gallons of water were processed through the stripper. The contaminated groundwater influent contained 0.18 mg/L of both 2,4-DNT and 2,6-DNT for emissions tests one and two, and 0.34 mg/L of 2,4-DNT and 0.19 mg/L of 2,6-DNT for test three. These concentrations equate to $3.62\times10^{-4}$ lb/hr for 2,4-DNT and 2,6-DNT for tests one and two, $6.84\times10^{-4}$ lb/hr for 2,4-DNT test three, and $3.82\times10^{-4}$ lb/hr for 2,6-DNT test three. When comparing input concentrations to output air emissions, on the average 99.8% of 2,4-DNT and 99.5% of 2,6-DNT remained in the liquid phase and did not exit through the stripper air exhaust.

It was found that the "U" connector at the base of the stack did accumulate contaminated condensate through the course of each test. This water was analyzed and found to contain almost identical levels of explosives as the feed water. Therefore, it can be assumed that this condesnate is a result of mist carryover through the air stripper mist eliminator and that this water should be returned to the feed tank for reprocessing.

Samples from the GAC influent tank indicated that the GAC influent contained very low concentrations of volatiles, as compared to the raw groundwater. Therefore, the air stripper was effective for its intended purpose of removing volatiles and minimizing their potential impact on the GAC test program.

Based upon the data obtained in this study, the preferred carbon for removing 2,4-DNT and 2,6-DNT from pretreated

**Table 8 Summary of Explosives Test Data and Test Results from Air Stripper Stack Testing at the Badger Army Ammunition Plant**

| Test Data | Air Stripper Stack | | | |
|---|---|---|---|---|
| Test Location | 1 | 2 | 3 | |
| Test Date | 3/13/89 | 3/13/89 | 3/14/89 | Series Average |
| Test Time Period | 0902-1310 | 1352-1758 | 0807-1342 | |
| Air Stripper Feed Rate (gpm) | 4 | 4 | 4 | |
| EXPLOSIVES EMISSIONS | | | | |
| 2,4-Dinitrotoluene | | | | |
| Concentration, lbs/dscf | 7.26E-11 | 9.61E-11 | 1.26E-10 | 9.23E-11 |
| Concentration, $\mu g/m^3$ | 1.16 | 1.54 | 2.02 | 1.57 |
| Concentration, ppm/v | 1.23E-04 | 1.63E-04 | 2.14E-04 | 1.67E-04 |
| Mass Rate, lb/hr | 5.47E-07 | 7.36E-07 | 9.59E-07 | 7.48E-07 |
| 2,6-Dinitrotoluene | | | | |
| Concentration, lb/dscf | 1.97E-10 | 2.90E-10 | 2.11E-10 | 2.32E-10 |
| Concentration, $\mu g/m^3$ | 3.15 | 4.64 | 3.38 | 3.72 |
| Concentration, ppm/v | 3.34E-04 | 4.92E-04 | 3.58E-04 | 3.95E-04 |
| Mass Rate, lb/hr | 1.48E-06 | 2.22E-06 | 1.60E-06 | 1.77E-06 |

Note: Standard Conditions = 68°F (20°C) and 29.2 inches Mg (760 mm Hg).

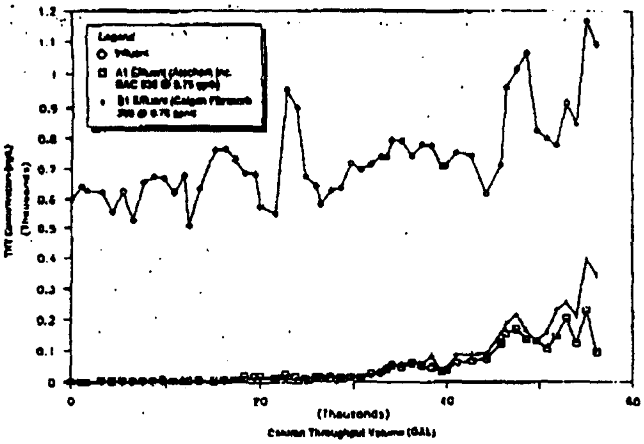


FIGURE 7. TNT Concentration vs. Column Throughput Volume for Test Three at MAAP

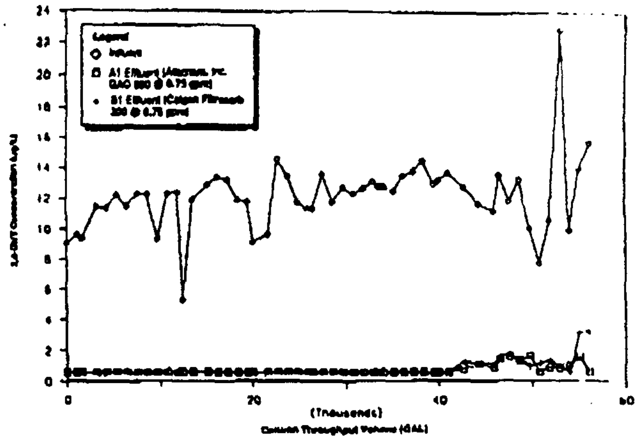


FIGURE 9. 2,4-DNT Concentration vs. Column Throughput Volume for Test Three at MAAP

groundwater at BAAP is Hydrodarco 4000.

Influent and effluent concentrations for Tests One, Two, and Three at MAAP showed that granular activated carbon in continuous-flow columns produced very low effluent concentrations for all nine explosives, generally in the low parts-per-billion (ppb) range during the early portions of each test. These concentrations for RDX, TNT, 2,4-DNT, and 1,3,5-TNB are presented graphically in Figures 7 through 10.

In Test One, columns A1 and B1 both contained Atochem, Inc. GAC 830 but were operated at different influent flow rates (see Table 4). Only RDX exceeded its detection limit of 0.63 μg/L in column A1's effluent during Test One. This occurred after approximately 8,000 gallons (2,715 bed volumes) of influent, containing an average RDX concentration of 487 μg/L, had passed through the column. When Test One was terminated at a column A1 throughput volume of 10,920 gallons (3,705 bed volumes), the RDX concentration in this column's effluent was 7.05 μg/L.

Test Two had Atochem, Inc. GAC 830 in column A1 and Calgon Filtrasorb 300 in column B1. Both columns were operated at the same influent flow rate (see Table 4). Even after 16,632 gallons (5,644 bed volumes) of influent had passed through both columns, the effluent concentrations of all nine explosives were below their detection limit, which were all approximately 1.0 ppb.

In Test Three, column A1 had Atochem, Inc. GAC 830, and column B1 had Calgon Filtrasorb 300. Both columns were operated at the same influent flow rate (see Table 4). Since the maximum pumping rate for the system was 1.5 gpm, the flow was split evenly between two sets of columns. Only TNT, RDX, 2,4-DNT, and 1,3,5-TNB exceeded their detection limits in columns A1 and B1 effluents. HMX, Tetryl, 2,6-DNB, 1,3-DNT, and NB were all below their detection limits, even after 56,160 gallons (38,112 bed volumes) of influent had passed through both primary columns (A1 and B1). However, Tetryl, 2,6-DNT, and NB were all below their detection limits in the influent, and HMX's and 1,3-DNB's influent concentrations were low, 3.8 and 4.2 μg/L, respectively.

In Test Three, the average TNT influent concentration was 734 μg/L, and final effluent levels in columns A1 and B1 were 88.6 and 192 μg/L, respectively (see Figure 7). Even though these levels indicate that Atochem, Inc. GAC 830 performed slightly better than Calgon Filtrasorb 300, both carbons performed about the same (see Figure 7) for most of the test. In particular, the apparent breakthroughs for both carbons occurred at approximately the same column throughput volume of 30,000 gallons (20,359 bed volumes). Apparent breakthrough is the point on the breakthrough curve where the concentration of the column effluent first begins to rise above its initial column leakage concentration. The average RDX influent concentration was 549.1 μg/L, and its final effluent levels in columns A1 and B1 were 315 and 344 μg/L, respectively (see Figure 8). As with TNT, the final effluent levels indicate that Atochem, Inc. GAC 830 performed slightly better than Calgon Filtrasorb 300. However, both carbons performed about the same for most of the test; the apparent breakthroughs for both carbons occurred at approximately the same column throughput volume of 12,000 gallons (8,144 bed volumes).

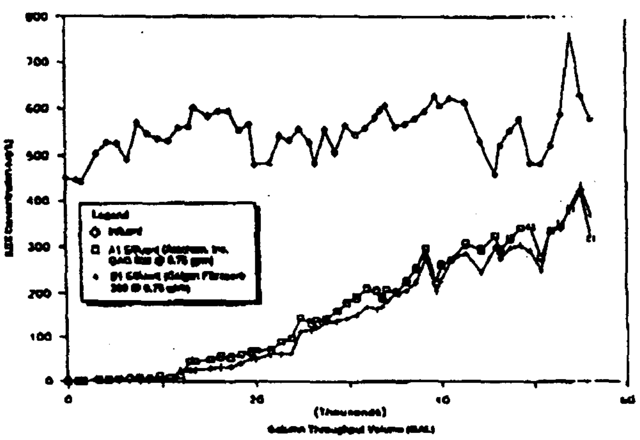


FIGURE 8. RDX Concentration vs. Column Throughput Volume for Test Three at MAAP

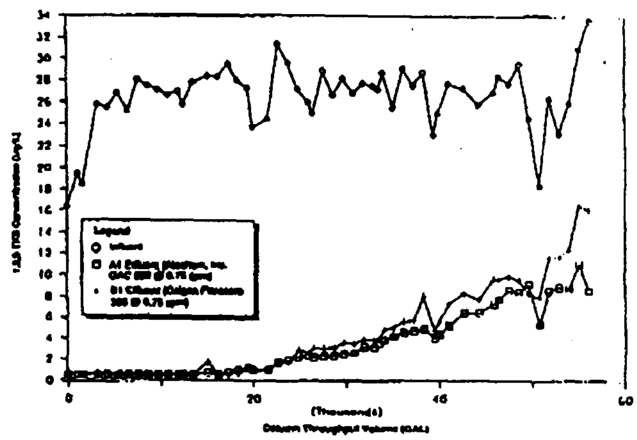


FIGURE 10. 1,3,5-TNB Concentration vs. Column Throughput Volume for Test Three at MAAP

**Table 9 Activated Carbon Column Operating and Performance Data for Test Three at the Milan Army Ammunition Plant Atochem, Inc. GAC 830 Versus Calgon Filtrasorb 300**

Starting Date: 16 October 1989
Ending Date: 15 December 1989
Column Inner Diameter: 4.25 in. (0.354 ft)
Column Area: 0.0985 $ft^2$
Bed Volume: 0.197 $ft^3$ (1.47 gal.)

| | Atochem, Inc. GAC 830 | Calgon Filtrasorb 300 |
|---|---|---|
| Flow Rate | 0.75 gpm | 0.75 gpm |
| Hydraulic Loading | 7.6 gpm/$ft^2$ | 7.6 gpm/$ft^2$ |
| Bed Depth | 2.0 ft | 2.0 ft |
| Empty-Bed Contact Time | 2.0 min. | 2.0 min. |
| TNT Influent Concentration (avg.) | 734 μg/L | 734 μg/L |
| RDX Influent Concentration (avg.) | 549.1 μg/L | 549.1 μg/L |
| TNT Capacity (rate)* | 0.112 lb/lb | 0.124 lb/lb |
| RDX Capacity (rate)* | 0.031 lb/lb | 0.024 lb/lb |
| Weight in Carbon in Column | 5.1 lb | 5.1 lb |
| Column TNT Capacity (wt) | 0.571 lb | 0.632 lb |
| Column RDX Capacity (wt) | 0.158 lb | 0.122 lb |
| Total TNT Loading to Column | 0.338 lb | 0.330 lb |
| Total RDX Loading to Column | 0.191 lb | 0.199 lb |
| TNT Capacity Utilized | 59.2% | 52.2% |
| RDX Capacity Utilized | 121% | 163% |
| Run Time | 54.5 days | 54.5 days |

*Calculated using isotherm data and average influent concentration.

Figures 9 and 10 present the results for 2,4-DNT and 1,3,5-TNB.

Good agreement was found between the analyses performed by WESTON's Analytic Division and those performed by the WESTON field laboratory for all three tests. Except for TNT and RDX, the analytical results from both WESTON's Analytics Division and the WESTON field laboratory show all explosive concentrations in columns A1 and B1 below their detection limits in all three tests. WESTON's Analytics Division's analytical results for TNT and RDX in columns A1 and B1 were for the most part slightly higher than the WESTON field laboratory's in all three tests. However, the WESTON field laboratory's analytical results for TNT and RDX in the influent were slightly higher than WESTON's Analytics Division's in Tests Two and Three.

Table 9 summarizes the operating characteristics for Test Three, and Table 10 summarizes the operating characteristics for Atochem, Inc. GAC 830 for Tests One and Two by flow rate. Table 9 shows 59.2% and 52.2% utilization for TNT in columns A1 and B1, respectively. Table 9 also shows 121% and 163% utilization for RDX in columns A1 and B1, respectively. These utilizations of greater than 100% may be attributable to microbiological activity on the carbon surfaces. This activity has been documented in the literature [8-13]. In addition, earlier studies [14] have shown that RDX can be biodegraded, even though it and most explosives are relatively

**Table 10 Activated Carbon Column Operating and Performance Data for Atochem, Inc. GAC 830 from Tests One and Two at the Milan Army Ammunition Plant**

Column Inner Diameter: 4.25 in. (0.354 ft)
Column Area: 0.0985 $ft^2$
Bed Volume: 0.394 $ft^3$ (2.94 gal.)

| Flow Rate | 0.2 gpm (Test One) | 0.7 gpm (Test Two) | 1.0 gpm (Test One) |
|---|---|---|---|
| Hydraulic Loading | 2.03 gpm/$ft^2$ | 7.11 gpm/$ft^2$ | 10.15 gpm/$ft^2$ |
| Bed Depth | 4.0 ft | 4.0 ft | 4.0 ft |
| Empty-Bed Contact Time | 14.7 min. | 4.2 min. | 2.9 min. |
| TNT Influent Concentration (avg.) | 433 μg/L | 508 μg/L | 433 μg/L |
| RDX Influent Concentration (avg.) | 487 μg/L | 536 μg/L | 487 μg/L |
| TNT Capacity (rate)* | 0.080 lb/lb | 0.088 lb/lb | 0.080 lb/lb |
| RDX Capacity (rate)* | 0.029 lb/lb | 0.030 lb/lb | 0.029 lb/lb |
| Weight of Carbon in Column | 10.2 lb | 10.2 lb | 10.2 lb |
| Column TNT Capacity (wt) | 0.816 lb | 0.898 lb | 0.816 lb |
| Column RDX Capacity (wt) | 0.296 lb | 0.306 lb | 0.296 lb |
| Total TNT Loading to Column | 0.0076 lb | 0.0722 lb | 0.0379 lb |
| Total RDX Loading to Column | 0.0086 lb | 0.0751 lb | 0.0431 lb |
| TNT Capacity Utilized | 0.9% | 8.0% | 4.6% |
| RDX Capacity Utilized | 2.9% | 24.5% | 14.6% |
| Run Time | 7.6 days | 16.5 days | 7.6 days |

*Calculated using isotherm data and average influent concentration.

**Table 11 Activated Carbon Bed Volumes to Reach TNT and RDX Effluent Levels of Approximately 1 μg/L, 10 μg/L, and 100 μg/L from Test Three at the Milan Army Ammunition Plant**

Columns A1 and A2: Atochem, Inc. GAC 830
Columns B1 and B2: Calgon Filtrasorb 300
Hydraulic Loading: 7.6 gpm/ft²
Bed Volume: 0.197 ft³ (1.47 gal.)

TNT

Average Influent Concentration to Columns A1 and B1: 734 μg/L
Range of Influent Concentration to Column A2: <0.78 to 232 μg/L
Range of Influent Concentration to Column B2: <0.78 to 397 μg/L

| Column A1: Effluent Level (μg/L) | Column A1: Bed Volumes | Column B1: Effluent Level (μg/L) | Column B1: Bed Volumes |
|---|---|---|---|
| 0.769 | 733 | 1.30 | 733 |
| 10.9 | 12,093 | 3.82 | 12,093 |
| 92.1 | 30,783 | 92.3 | 30,050 |

| Column A2: Effluent Level (μg/L) | Column A2: Bed Volumes | Column B2: Effluent Level (μg/L) | Column B2: Bed Volumes |
|---|---|---|---|
| <0.78[a] | 37,745[a] | <0.78[a] | 37,745[a] |

[a]Effluent level and bed volume at end of test.
[b]Effluent level and bed volume for first sample taken on 10 November 1989.
Notes: <0.78 = Detection limit of TNT.
<0.63 = Detection limit of RDX.

resistant to biodegradation. However, no attempt was made in the current study to assess this possibility.

Based on the percent utilizations in Table 9, Calgon Filtrasorb 300 appears to be slightly better for TNT removal. However, since the calculations of these utilizations are based on the extrapolation of limited isotherm test data, one cannot conclude that one carbon is definitely better than the other for removal of TNT and RDX.

Table 10 shows the percent utilizations of Atochem, Inc. GAC 830 at three different hydraulic loadings for TNT and RDX. Even after 7.6 days at the maximum hydraulic loading of 10.15 gpm/ft², percent utilizations for TNT and RDX were only 4.6% and 14.6%, respectively.

Table 11 shows the activated carbon bed volumes required to reach effluent RNT and RDX levels of approximately 1 μg/L, 10 μg/L, and 100 μg/L from Test Three. Based on these results, both Atochem, Inc. GAC 830 and Calgon Filtrasorb 300 appear to be equivalent in meeting the three effluent levels for both TNT and RDX. The results also show that if either columns A1 and A2 or columns B1 and B2 were used as two columns in-series instead of as single columns, a better effluent would be obtained over a longer period of time. The following conclusions were drawn from the two pilot studies:

- Granular activated carbon was capable of removing explosives from contaminated groundwater at two Army Ammunition Plants to 1 μg/L.
- The concurrent removal of 2,4-DNT and 2,6-DNT from groundwater at BAAP using continuous-flow granular activated carbon columns is feasible.
- Based on testing performed in the BAAP study, there is little potential for airborne emissions of 2,4-DNT or 2,6-DNT in the exhaust of an air stripper used to remove volatile compounds.
- The concurrent removal of TNT, RDX, HMX, Tetryl, 2,4-DNT, 2,6-DNT, 1,3-DNB, 1,3,5-TNB, and NB from groundwater at MAAP using continuous-flow granular activated carbon is feasible.

## ACKNOWLEDGEMENT

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# APPENDIX L
# COST ESTIMATES FOR REMEDIAL ALTERNATIVES

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## 1.0
## COST SUMMARY

**Table L-1** presents the estimated present worth of the groundwater remedial alternative costs. **Table L-2** presents a description of groundwater target cleanup goals. **Table L-3** presents a summary of remedial alternative costs by category.

# 2.0
# ASSUMPTIONS USED IN DEVELOPING COST ESTIMATES

## 2.1 PRESENT WORTH

Present worth costs are calculated using the following discount rate and time period.

**Discount Rate** - 6%

A discount rate of 6% is used to be typical of current financial rate conditions.

**Time Period** - 80 Years

An 80 year period was selected as a time period approaching the shortest restoration time estimates.

## 2.2 GROUNDWATER EXTRACTION AND TRANSFER SYSTEM

The groundwater extraction system is several groundwater extraction wells whose number and total gallon per minute (gpm) groundwater extraction flow rate varies with the Remedial Alternative and Target Groundwater Cleanup Goals. Each extraction well is fitted with a pump to deliver the extracted groundwater to a collection piping network. The extracted groundwater is transferred by the piping network which includes transfer pumps to a central collection and groundwater treatment location. At the treatment location a storage tank is used to receive extracted groundwater and to provide flow control to the treatment system. As a result, all extracted groundwaters are co-mingled before treatment.

The location of the groundwater treätment system is located in Section 33, Township 14N, Range 9E. This is the location of the treatment plant currently being designed for the estimates in the Groundwater Removal Action. Because a treatment facility will already be in existence, the FS Report is based on expanding the Removal Action treatment location to accommodate the potential increased groundwater flow rate for remediation as discussed in this FS Report. Therefore, the same groundwater treatment system location is in one location used for all alternatives. As a result, the piping network lengths vary with alternative and Target Groundwater Cleanup Goal because the central-most location per alternative and Target Groundwater Cleanup Goals is not used. The impact on the cost estimates is that alternatives/goals with smaller number of groundwater extraction wells do not have a proportionate decrease in transfer piping lengths.

For each alternative and Target Cleanup Goal, the number of extraction wells and their total flow rates are listed in **Table L-4**. For each alternative and Target Cleanup Goal, the number of extraction wells and their individual flow rates are listed in **Table L-5**. Collection piping lengths and number of transfer pumps are listed in **Table L-6**. Extraction well locations and the collection piping, transfer pumps and treatment system location are shown in **Drawings 4-1A** through **4-9C** contained this FS Report.

## 2.3 GROUNDWATER TREATMENT SYSTEM

### 2.3.1 Type of Treatment Technology

Granulated active carbon (GAC) was used as the treatment technology for all Alternatives to provide a common basis for comparison among all alternatives. GAC is selected as the technology used for the cost estimate because GAC is a commercially available technology that will remove all of the chemicals of concern (COCs). The two other technologies of advanced oxidation and air stripping are retained as potentially applicable groundwater treatment technologies. Cost estimates for these potential technologies are not included in this FS because the result would be a voluminous and unwieldy detailed cost estimate. At present there are eight alternatives including the No Action alternative. The result is seven alternatives for the three Target Cleanup Goals resulting in 21 detailed cost estimates where groundwater treatment is used. Expansion of the cost estimates using three groundwater treatment technologies each would result in ( 7 alternatives x 3 target cleanup goals x 3 treatment technologies = 63 estimates + 1 No Action = 64 estimates) 64 detailed cost estimates.

Information from advanced oxidation and air stripping vendors are included in Appendix I and J respectively. Cost information from these appendices for Alternative 4 - Focused

Extraction and Soil Excavation at Target Groundwater Cleanup Goal II are compared to GAC in **Table L-7.**

### 2.3.2 Treated Groundwater Discharge

Several options are available for discharge of the treated groundwater, including discharge to a nearby stream and/or beneficial reuse. To provide a common basis between alternatives, one mile of discharge piping is assumed for all cost estimates. No additional piping or pumping system is included in the cost estimates for the various discharge options.

### 2.3.3 Effluent Concentration

Because the final use of the treated groundwater is not specified at this time, effluent concentrations for treated groundwater used in the cost estimates are EPA Drinking Water Standards. These are Maximum Contaminant Level (MCL) or Health Advisory (HA) for those chemicals for which MCLs are not listed. Secondary Maximum Contaminant Levels (SMCLs) are not used as effluent standards because they are not EPA enforceable standards (Refer 40 CFR Parts 141, 142 and 143). Effluent concentrations are listed in Appendix K.

### 2.3.4 Influent Concentration

Influent concentrations are calculated for all alternative and Target Cleanup Goal groundwater extraction flow rates from a weighted average for RDX and TCE. Because they were detected sporadically in the groundwater monitoring wells sampled, the other chemicals of concern are expected to be below Target Groundwater Cleanup Goals and drinking water standards when the extracted groundwater is commingled from the network of groundwater extraction wells (Refer to Groundwater Extraction and Transfer System above). As a result, the groundwater presented to the groundwater treatment system is anticipated to contain only RDX and TCE at levels above Target Groundwater Cleanup Goals and EPA Drinking Water Standards. A discussion of groundwater chemicals to be treated and a listing of influent concentrations is contained in Appendix K.

### 2.3.5 Summary of Preliminary Design Assumptions for GAC Adsorption System

Following are the design assumptions used for the GAC treatment system in developing the detailed cost estimates for each alternative and Target Groundwater Cleanup Goal.

| | |
|---|---|
| **Design Flow Rate** | Groundwater design flow rate varies from 970 to 4,910 gpm as listed in **Table L-4**. |
| **Influent and Effluent** | Listed in Appendix K. Influent concentration remains relatively constant over the project life because the extraction rate is small compared to the overall plume volume. |
| **Estimate GAC Usage Rate** | Listed in Appendix K for each alternative and Target Groundwater Cleanup Goal. |
| **Equalization Tanks** | Equalization tanks with total capacity of 0.4 or 0.8 million gallons depending on groundwater flow rate are provided. |
| **Solids Filter** | A 10-micron filter is included upstream of the carbon columns to remove suspended solids. |
| **Hardness Pretreatment** | Maximum hardness reported as Calcium Carbonate is 730 mg/L with an average of approximately 247 mg/L (Volume I, Table 1-3). Carbonate hardness above typically 50 to 150 mg/L is objectionable[1] because it may result in the formation of scale on surfaces in contact with the water in heat exchangers such as boilers and water heaters. Because no heat is used in the GAC treatment process, potential scaling and fouling due to hardness is assumed not to be a problem that requires treatment. |
| **Discharge Piping** | One mile of treated groundwater discharge piping is provided. No additional piping and pumping system is included. |

[1]Hardenbergh, W.A. and E.B. Rode, Water Supply and Waste Disposal. 1970. International Textbook Co.

| | |
|---|---|
| **Spent Carbon** | Purchase, transportation and disposal of spent carbon will be handled by the carbon vendor for a flat fee of $1.00 per lb of GAC. On-site carbon regeneration is considered to be not cost effective when the carbon usage rate is less than approximately 1,000,000 lb/yr. For the alternatives evaluated for Mead OU2, estimated GAC usage rates (Refer to Table K-29, Appendix K) range for 101,000 to 896,000 lb/yr. |
| **Iron Pretreatment** | There is no need for pretreatment of iron. The maximum iron concentration observed in the groundwater samples 1.8 mg/L with an average of approximately 1.4 mg/L (Volume I, Table 1-3). At such low concentrations, iron is not expected to adversely affect the treatment process performance. Typically, pretreatment is necessary at iron concentrations exceeding 5 to 10 mg/L. This information is based on communication with Mark Zappi at USACE's Waterways Experiment Station in Vicksburg, Mississippi. |
| **Operator** | One operator is necessary for the operation and maintenance of the groundwater extraction and treatment system. |
| **Treatment Building** | Equalization tanks, GAC units, pumps and other appurtenances would be in a building; typical dimensions would be 130 ft. (length) x 100 ft. (width) x 26 ft. (height). |

## 2.4 SOIL EXCAVATION AND TREATMENT

### 2.4.1 Soil Volume - 2,600 Cubic Yards

Refer to Appendix E for a discussion of soil volume assumptions.

### 2.4.2 Soil Treatment

Excavated soil is assumed to be treated by using the OU1 on-site incinerator. The cost estimate includes costs for:

- Soil excavation and on-site hauling
- Operation of the OU1 incinerator
- Treated soil placement
- Soil sampling and laboratory analysis
- Ordnance management

Cost are **not included** for the following categories because these are included in the OU1 remedial action:

- treatment system equipment, structure and installation
- mobilization and demobilization of treatment system
- system startup
- trial burn operation and permitting

The OU1 FS includes cost estimates for soil treatment ranging from 8,400 to 42,000 cubic yards with unit costs varying with soil volume. The OU2 estimated soil volume is 2,600 cubic yards which is less than the smallest estimated volume included in the OU1 cost estimates. The assumption used for OU2 is that the unit cost for 2,600 cubic yards is the same as for the OU2 8,400 cubic yards.

Other unit costs for items such as excavation, hauling, sampling and analysis, soil placement, etc. are the same as used in the OU1 FS.

### 2.4.3 Soil Treatment Time

The unit rate (cubic yards per unit time) for treatment is assumed to be the same as estimated in the OU1 FS. Treatment is estimated to be accomplished in less than one year. Therefore a one time, one year O&M cost is assumed for soil excavation and treatment and there will not be re-occurring yearly O&M costs associated with soils.

### 2.4.4 Location of Soil Treatment and Placement of Treated Soil

It is assumed that all soil treatment and placement of treated soil will occur on-site and there will be no off-site transportation of either untreated or treated soil.

### 2.4.5 Treated Soil Controls

No costs are included for any control items such as a soil cap or precipitation run-on/runoff controls. It is assumed that contaminants are completely removed from the soil and that treated soil is replaced at the Site as uncontaminated soil.

## 3.0
## COST ESTIMATE FOR REMEDIAL ALTERNATIVES

The following spreadsheets present the cost estimates for the alternatives summarized below.

| Alternative | Description |
|---|---|
| 1 | No Action |
| 2 | Hydraulic Containment - Target Cleanup Goal I |
| 2 | Hydraulic Containment - Target Cleanup Goal II |
| 2 | Hydraulic Containment - Target Cleanup Goal III |
| 3 | Focused Extraction - Target Cleanup Goal I |
| 3 | Focused Extraction - Target Cleanup Goal II |
| 3 | Focused Extraction - Target Cleanup Goal III |
| 4 | Focused Extraction and Soil Excavation - Target Cleanup Goal I |
| 4 | Focused Extraction and Soil Excavation - Target Cleanup Goal II |
| 4 | Focused Extraction and Soil Excavation - Target Cleanup Goal III |
| 5 | Focused Extraction with Air Sparging - Target Cleanup Goal I |
| 5 | Focused Extraction with Air Sparging - Target Cleanup Goal II |
| 5 | Focused Extraction with Air Sparging - Target Cleanup Goal III |
| 6 | Focused Extraction with Air Sparging and Soil Excavation - Target Cleanup Goal I |
| 6 | Focused Extraction with Air Sparging and Soil Excavation - Target Cleanup Goal II |
| 6 | Focused Extraction with Air Sparging and Soil Excavation - Target Cleanup Goal III |
| 7 | Groundwater Extraction - Target Cleanup Goal I |
| 7 | Groundwater Extraction - Target Cleanup Goal II |
| 7 | Groundwater Extraction - Target Cleanup Goal III |
| 8 | Groundwater Extraction and Soil Excavation - Target Cleanup Goal I |
| 8 | Groundwater Extraction and Soil Excavation - Target Cleanup Goal II |
| 8 | Groundwater Extraction and Soil Excavation - Target Cleanup Goal III |

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**TABLES**

# TABLE L-1
# ESTIMATED PRESENT WORTH GROUNDWATER REMEDIAL ALTERNATIVE COSTS

| REMEDIAL ALTERNATIVE | REMEDIAL ALTERNATIVE DESCRIPTION | TOTAL PRESENT WORTH COST[a] ($ MILLION) AND APPROXIMATE GROUNDWATER RESTORATION TIME (YEARS) — TARGET GROUNDWATER CLEANUP GOAL[b] | | |
|---|---|---|---|---|
| | | I | II | III |
| 1 | NO ACTION<br>• Groundwater Monitoring | $11<br>Perpetuity | $11<br>Perpetuity | $11<br>Perpetuity |
| 2 | HYDRAULIC CONTAINMENT<br>• Hydraulic Containment of Groundwater<br>• Potable Water Supply<br>• Groundwater Monitoring | $30<br>Perpetuity | $35<br>Perpetuity | $35<br>Perpetuity |
| 3 | FOCUSED EXTRACTION<br>• Focused Extraction of Groundwater<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $47<br>Greater than 140 years | $57<br>Greater than 140 years | $57<br>Greater than 140 years |
| 4 | FOCUSED EXTRACTION AND SOIL EXCAVATION<br>• Soil Excavation and Treatment<br>• Focused Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $51<br>140 years | $61<br>140 years | $61<br>140 years |
| 5 | FOCUSED EXTRACTION WITH AIR SPARGING<br>• Air Sparging<br>• Focused Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $68<br>Greater than 110 years | $76<br>Greater than 110 years | $75<br>Greater than 110 years |
| 6 | FOCUSED EXTRACTION WITH AIR SPARGING AND SOIL EXCAVATION<br>• Soil Excavation and Treatment<br>• Air Sparging<br>• Focused Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $72<br>110 years | $81<br>110 years | $80<br>110 years |

## TABLE L-1
## ESTIMATED PRESENT WORTH GROUNDWATER REMEDIAL ALTERNATIVE COSTS
## (Continued)

| REMEDIAL ALTERNATIVE | REMEDIAL ALTERNATIVE DESCRIPTION | TOTAL PRESENT WORTH COST[a] ($ MILLION) AND APPROXIMATE GROUNDWATER RESTORATION TIME (YEARS) — TARGET GROUNDWATER CLEANUP GOAL[b] | | |
|---|---|---|---|---|
| | | I | II | III |
| 7 | **GROUNDWATER EXTRACTION**<br>• Groundwater Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $47<br><br>Greater than 90 years | $62<br><br>Greater than 90 years | $66<br><br>Greater than 90 years |
| 8 | **GROUNDWATER EXTRACTION AND SOIL EXCAVATION**<br>• Soil Excavation and Treatment<br>• Groundwater Extraction<br>• Hydraulic Containment<br>• Potable Water Supply<br>• Groundwater Monitoring | $51<br><br>90 years | $66<br><br>90 years | $71<br><br>90 years |

Notes: [a]6% discount rate for 80 years
[b]Refer to Table 5-2 - Description of Groundwater Target Cleanup Goals

## TABLE L-2

## TARGET GROUNDWATER CLEANUP GOALS

| Chemical | Target Groundwater Cleanup Goals ($\mu$g/L) | | |
|---|---|---|---|
| | I | II | III |
| TCE | 5[a] | 5[a] | 5[a] |
| RDX | 7.74[c] | 2[e] | 0.774[b] |
| 1,2-Dichloropropane | 5[a] | 5[a] | 5[a] |
| Methylene chloride | 5[a] | 5[a] | 5[a] |
| TNB | 0.778[d] | 0.778[d] | 0.778[d] |
| TNT | 7.78[d] | 2[e] | 2.82[b] |
| 2,4-DNT | 1.24[c] | 1.24[c] | 0.124[b] |

<u>Notes:</u>

[a] Drinking Water MCL
[b] Carcinogenic risk of one in one million ($10^{-6}$)
[c] Carcinogenic risk of one in one hundred thousand ($10^{-5}$)
[d] Non-carcinogenic risk
[e] Health advisory

**Table L-3**

*SUMMARY OF REMEDIAL ALTERNATIVE COSTS BY CATEGORY*

| | | | | O & M Cost Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alternative | Remedial Alternatives Description | Target Groundwater Cleanup Goal | Total Capital Cost (1) | A - Groundwater Monitoring, Years 1-5 (1) | B - Groundwater Monitoring, Years 6-80 (1) | C- Yearly O&M Cost (1) | D - O&M Pumps & Control Replacement, 5 year Intervals (1) | E - O&M GAC System Replacement, 20 year Intervals (1) | F- Air Sparging Yearly O&M Cost (1) | F or G - Soil Removal & Thermal Treatment, One Time O&M Cost (1) | Total O&M Present Worth Cost (1) (2) | Total Cost: Total Captial + Total Present Worh O&M (1) (2) |
| 1 | No Action | I | | 7.8 | 3.3 | | | | | | 11.1 | 11.1 |
| | | II | | 7.8 | 3.3 | | | | | | 11.1 | 11.1 |
| | | III | | 7.8 | 3.3 | | | | | | 11.1 | 11.1 |
| 2 | Hydraulic Containment | I | 6.4 | 7.8 | 3.3 | 11.6 | 0.2 | 0.3 | | | 23.2 | 29.6 |
| | | II | 8.2 | 7.8 | 3.3 | 15.4 | 0.4 | 0.3 | | | 27.1 | 35.3 |
| | | III | 7.9 | 7.8 | 3.3 | 15.5 | 0.4 | 0.3 | | | 27.2 | 35.2 |
| 3 | Focused Extraction | I | 11.0 | 7.8 | 3.3 | 23.9 | 0.5 | 0.4 | | | 35.8 | 46.8 |
| | | II | 12.8 | 7.8 | 3.3 | 32.0 | 0.7 | 0.4 | | | 44.2 | 57.0 |
| | | III | 12.8 | 7.8 | 3.3 | 32.1 | 0.7 | 0.4 | | | 44.3 | 57.1 |
| 4 | Focused Extraction and Soil Excavation | I | 15.2 | 7.8 | 3.3 | 23.9 | 0.5 | 0.4 | | 0.1 | 35.9 | 51.1 |
| | | II | 17.0 | 7.8 | 3.3 | 32.0 | 0.7 | 0.4 | | 0.1 | 44.3 | 61.3 |
| | | III | 17.0 | 7.8 | 3.3 | 32.1 | 0.7 | 0.4 | | 0.1 | 44.4 | 61.4 |
| 5 | Focused Extraction and Air Sparging | I | 29.6 | 7.8 | 3.3 | 16.6 | 0.4 | 0.4 | 9.4 | | 37.9 | 67.5 |
| | | II | 31.7 | 7.8 | 3.3 | 23.1 | 0.6 | 0.4 | 9.4 | | 44.6 | 76.3 |
| | | III | 31.4 | 7.8 | 3.3 | 22.3 | 0.6 | 0.4 | 9.4 | | 43.8 | 75.2 |
| 6 | Focused Extraction with Air Sparging and Soil Excavation | I | 33.9 | 7.8 | 3.3 | 16.6 | 0.4 | 0.4 | 9.4 | 0.1 | 38.0 | 71.8 |
| | | II | 36.0 | 7.8 | 3.3 | 23.1 | 0.6 | 0.4 | 9.4 | 0.1 | 44.7 | 80.6 |
| | | III | 35.7 | 7.8 | 3.3 | 22.3 | 0.6 | 0.4 | 9.4 | 0.1 | 43.9 | 79.5 |
| 7 | Groundwater Extraction | I | 10.3 | 7.8 | 3.3 | 25.0 | 0.4 | 0.4 | | | 36.8 | 47.2 |
| | | II | 14.8 | 7.8 | 3.3 | 34.9 | 0.7 | 0.8 | | | 47.4 | 62.2 |
| | | III | 15.2 | 7.8 | 3.3 | 38.4 | 0.8 | 0.8 | | | 51.0 | 66.2 |
| 8 | Groundwater Extraction and Soil Excavation | I | 14.6 | 7.8 | 3.3 | 25.0 | 0.4 | 0.4 | | 0.1 | 36.9 | 51.5 |
| | | II | 19.0 | 7.8 | 3.3 | 34.9 | 0.7 | 0.8 | | 0.1 | 47.5 | 66.5 |
| | | III | 19.4 | 7.8 | 3.3 | 38.4 | 0.8 | 0.8 | | 0.1 | 51.1 | 70.5 |

Note: (1) All costs in millions of dollars.
(2) Totals may be different by +/- $1 from Detailed Cost Estimate due to rounding.

**Table L-4**
**Total Number of Groundwater Extraction Wells and Total Flow Rates for Each Alternative**

| Alternative No. | Remedial Alternative Description | Target Groundwater Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 1 | No Action | I | | | | | | | **0** | **0** |
| | | II | | | | | | | **0** | **0** |
| | | III | | | | | | | **0** | **0** |
| 2 | Hydraulic Containment | I | 1 | 110 | 3 | 620 | 1 | 240 | **5** | **970** |
| | | II | 1 | 160 | 7 | 1580 | 1 | 360 | **9** | **2100** |
| | | III | 1 | 160 | 7 | 1810 | 1 | 360 | **9** | **2330** |
| 3 | Focused Extraction | I | 6 | 1120 | 3 | 620 | 1 | 240 | **10** | **1980** |
| | | II | 6 | 1170 | 8 | 1770 | 1 | 360 | **15** | **3300** |
| | | III | 6 | 1170 | 8 | 2000 | 1 | 360 | **15** | **3530** |
| 4 | Focused Extraction and Soil Excavation | I | 6 | 1120 | 3 | 620 | 1 | 240 | **10** | **1980** |
| | | II | 6 | 1170 | 8 | 1770 | 1 | 360 | **15** | **3300** |
| | | III | 6 | 1170 | 8 | 2000 | 1 | 360 | **15** | **3530** |
| 5 | Focused Extraction and Air Sparging | I | 4 | 590 | 3 | 620 | 1 | 240 | **8** | **1450** |
| | | II | 4 | 640 | 8 | 1770 | 1 | 360 | **13** | **2770** |
| | | III | 4 | 640 | 8 | 2000 | 1 | 360 | **13** | **3000** |
| 6 | Focused Extraction with Air Sparging and Soil Excavation | I | 4 | 590 | 3 | 620 | 1 | 240 | **8** | **1450** |
| | | II | 4 | 640 | 8 | 1770 | 1 | 360 | **13** | **2770** |
| | | III | 4 | 640 | 8 | 2000 | 1 | 360 | **13** | **3000** |
| 7 | Groundwater Extraction | I | 5 | 1630 | 3 | 620 | 1 | 240 | **9** | **2490** |
| | | II | 5 | 1680 | 9 | 2160 | 1 | 360 | **15** | **4200** |
| | | III | 5 | 1680 | 11 | 2870 | 1 | 360 | **17** | **4910** |
| 8 | Groundwater Extraction and Soil Excavation | I | 5 | 1630 | 3 | 620 | 1 | 240 | **9** | **2490** |
| | | II | 5 | 1680 | 9 | 2160 | 1 | 360 | **15** | **4200** |
| | | III | 5 | 1680 | 11 | 2870 | 1 | 360 | **17** | **4910** |

**Table L-5**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 2 | Hydraulic Containment | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | | | EW-3 | 260 | | | | |
| | | | | | EW-4 | 170 | | | | |
| **Total** | | | 1 | 110 | 3 | 620 | 1 | 240 | 5 | 970 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | | | EW-3 | 190 | | | | |
| | | | | | EW-4 | 250 | | | | |
| | | | | | EW-5 | 230 | | | | |
| | | | | | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| **Total** | | | 1 | 160 | 7 | 1580 | 1 | 360 | 9 | 2100 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | | | EW-3 | 160 | | | | |
| | | | | | EW-4 | 190 | | | | |
| | | | | | EW-5 | 250 | | | | |
| | | | | | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| **Total** | | | 1 | 160 | 7 | 1810 | 1 | 360 | 9 | 2330 |

**Table L-5**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 3 | Focused Extraction | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| | | | EW-D | 250 | | | | | | |
| | | | EW-E | 280 | | | | | | |
| Total | | | 6 | 1120 | 3 | 620 | 1 | 240 | 10 | 1980 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | EW-D | 250 | EW-6 | 230 | | | | |
| | | | EW-E | 280 | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-F | 190 | | | | |
| Total | | | 6 | 1170 | 8 | 1770 | 1 | 360 | 15 | 3300 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | 200 | EW-5 | 250 | | | | |
| | | | EW-D | 250 | EW-6 | 350 | | | | |
| | | | EW-E | 280 | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-F | 190 | | | | |
| Total | | | 6 | 1170 | 8 | 2000 | 1 | 360 | 15 | 3530 |

**Table L-5**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 4 | Focused Extraction and Soil Excavation | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| | | | EW-D | 250 | | | | | | |
| | | | EW-E | 280 | | | | | | |
| Total | | | 6 | 1120 | 3 | 620 | 1 | 240 | 10 | 1980 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | EW-D | 250 | EW-6 | 230 | | | | |
| | | | EW-E | 280 | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-F | 190 | | | | |
| Total | | | 6 | 1170 | 8 | 1770 | 1 | 360 | 15 | 3300 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | 200 | EW-5 | 250 | | | | |
| | | | EW-D | 250 | EW-6 | 350 | | | | |
| | | | EW-E | 280 | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-F | 190 | | | | |
| Total | | | 6 | 1170 | 8 | 2000 | 1 | 360 | 15 | 3530 |

**Table L-5**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 5 | Focused Extraction and Air Sparging | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| **Total** | | | 4 | 590 | 3 | 620 | 1 | 240 | **8** | **1450** |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | | | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 1770 | 1 | 360 | **13** | **2770** |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | 200 | EW-5 | 250 | | | | |
| | | | | | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 2000 | 1 | 360 | **13** | **3000** |

**Table L-5**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 6 | Focused Extraction With Air Sparging and Soil Excavation | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-A | 110 | EW-3 | 260 | | | | |
| | | | EW-B | 170 | EW-4 | 170 | | | | |
| | | | EW-C | 200 | | | | | | |
| **Total** | | | 4 | 590 | 3 | 620 | 1 | 240 | **8** | **1450** |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 190 | | | | |
| | | | EW-B | 170 | EW-4 | 250 | | | | |
| | | | EW-C | 200 | EW-5 | 230 | | | | |
| | | | | | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 1770 | 1 | 360 | **13** | **2770** |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-A | 110 | EW-3 | 160 | | | | |
| | | | EW-B | 170 | EW-4 | 190 | | | | |
| | | | EW-C | .200 | EW-5 | 250 | | | | |
| | | | | | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-D | 190 | | | | |
| **Total** | | | 4 | 640 | 8 | 2000 | 1 | 360 | **13** | **3000** |

**Table L-5**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 7 | Groundwater Extraction | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-6 | 160 | EW-3 | 260 | | | | |
| | | | EW-7 | 250 | EW-4 | 170 | | | | |
| | | | EW-8 | 500 | | | | | | |
| | | | EW-9 | 610 | | | | | | |
| Total | | | 5 | 1630 | 3 | 620 | 1 | 240 | 9 | 2490 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 190 | | | | |
| | | | EW-11 | 250 | EW-4 | 250 | | | | |
| | | | EW-12 | 500 | EW-5 | 230 | | | | |
| | | | EW-13 | 610 | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-14 | 290 | | | | |
| | | | | | EW-15 | 290 | | | | |
| Total | | | 5 | 1680 | 9 | 2160 | 1 | 360 | 15 | 4200 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 160 | | | | |
| | | | EW-11 | 250 | EW-4 | 190 | | | | |
| | | | EW-12 | 500 | EW-5 | 250 | | | | |
| | | | EW-13 | 610 | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-14 | 230 | | | | |
| | | | | | EW-15 | 290 | | | | |
| | | | | | EW-16 | 250 | | | | |
| | | | | | EW-17 | 290 | | | | |
| Total | | | 5 | 1680 | 11 | 2870 | 1 | 360 | 17 | 4910 |

**Table L-5**
**Specific Groundwater Containment and Extraction Wells Required for Each Alternative**

| Alternative No. | Description of Alternative | Target Cleanup Goal | Atlas Missile Area | | Load Lines 2 & 3 | | Load Line 1 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Wells | GPM | Wells | GPM | Wells | GPM | Wells | GPM |
| 8 | Groundwater Extraction and Soil Excavation | I | EW-1 | 110 | EW-2 | 190 | EW-5 | 240 | | |
| | | | EW-6 | 160 | EW-3 | 260 | | | | |
| | | | EW-7 | 250 | EW-4 | 170 | | | | |
| | | | EW-8 | 500 | | | | | | |
| | | | EW-9 | 610 | | | | | | |
| Total | | | 5 | 1630 | 3 | 620 | 1 | 240 | 9 | 2490 |
| | | II | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 190 | | | | |
| | | | EW-11 | 250 | EW-4 | 250 | | | | |
| | | | EW-12 | 500 | EW-5 | 230 | | | | |
| | | | EW-13 | 610 | EW-6 | 230 | | | | |
| | | | | | EW-7 | 230 | | | | |
| | | | | | EW-8 | 290 | | | | |
| | | | | | EW-14 | 290 | | | | |
| | | | | | EW-15 | 290 | | | | |
| Total | | | 5 | 1680 | 9 | 2160 | 1 | 360 | 15 | 4200 |
| | | III | EW-1 | 160 | EW-2 | 160 | EW-9 | 360 | | |
| | | | EW-10 | 160 | EW-3 | 160 | | | | |
| | | | EW-11 | 250 | EW-4 | 190 | | | | |
| | | | EW-12 | 500 | EW-5 | 250 | | | | |
| | | | EW-13 | 610 | EW-6 | 350 | | | | |
| | | | | | EW-7 | 350 | | | | |
| | | | | | EW-8 | 350 | | | | |
| | | | | | EW-14 | 230 | | | | |
| | | | | | EW-15 | 290 | | | | |
| | | | | | EW-16 | 250 | | | | |
| | | | | | EW-17 | 290 | | | | |
| Total | | | 5 | 1680 | 11 | 2870 | 1 | 360 | 17 | 4910 |

## TABLE L-6
## EXTRACTED GROUNDWATER TRANSFER SYSTEM PIPING LENGTHS AND NUMBER OF TRANSFER PUMPS

| Alternatives | Description | Cleanup Goal | Number of Groundwater Extraction Wells | Extraction Well Piping Length (mile) | Number of Groundwater Transfer Pumps |
|---|---|---|---|---|---|
| 1 | No Action | I | | | |
| | | II | | | |
| | | III | | | |
| 2 | Hydraulic Containment | I | 5 | 10 | 4 |
| | | II | 9 | 12 | 8 |
| | | III | 9 | 11 | 7 |
| 3 | Focused Extraction | I | 10 | 16 | 8 |
| | | II | 15 | 21 | 13 |
| | | III | 15 | 21 | 12 |
| 4 | Focused Extraction and Soil Excavation | I | 10 | 16 | 8 |
| | | II | 15 | 21 | 13 |
| | | III | 15 | 21 | 12 |
| 5 | Focused Extraction and Air Sparging | I | 8 | 14 | 7 |
| | | II | 13 | 20 | 12 |
| | | III | 13 | 19 | 11 |
| 6 | Focused Extraction with Air Sparging and Soil Excavation | I | 8 | 14 | 7 |
| | | II | 13 | 20 | 12 |
| | | III | 13 | 19 | 11 |
| 7 | Groundwater Extraction | I | 9 | 14 | 7 |
| | | II | 15 | 18 | 11 |
| | | III | 17 | 19 | 13 |
| 8 | Groundwater Extraction and Soil Excavation | I | 9 | 14 | 7 |
| | | II | 15 | 18 | 11 |
| | | III | 17 | 19 | 13 |

**TABLE L-7**
**COMPARISON OF COSTS FOR**
**EXTRACTED GROUNDWATER TREATMENT TECHNOLOGIES**

The following vendor costs data is taken from Appendices H, I, and J. Because vendors were not consistent in their responses, this cost comparison includes only capital costs for vendor's equipment only and yearly operating and maintenance (O&M) costs to provide as common a basis as possible between technologies. Costs for auxiliary equipment, controls, assembly and startup are not included. Comparisons are made for the following combination of alternative and Cleanup Goal:

Alternative 4 - Focused Extraction and Soil Excavation
Target Groundwater Cleanup Goal II
Influent Flow Rate - 3300 gpm

| | | Cost | Annual Cost |
|---|---|---|---|
| <u>GAC</u> | | | |
| **Vendor:** | Calgon Carbon Corporation | | |
| **Capital Cost - Equipment:** | 5 Model 10 Adsorption Systems at $165,000 each | $ 825,000 | |
| **Yearly O&M Cost:** | GAC Usage 635,000 lbs/yr at $1/lb (Engineering analysis estimated, not vendor estimated) | | $635,000 |
| <u>ADVANCED OXIDATION</u> | | | |
| **Vendor:** | Solarchem Environmental Systems, Inc. | | |
| **Capital Cost - Equipment:** | 18 UV Reactors | $ 503,000 | |
| **Yearly O&M Cost:** | 3300 gpm x 525,600 min/yr x $0.22/1000 gal. | | $382,000 |
| **Vendor:** | Ultrox (Vendor did not provide estimate for 3300 gpm. Following is their estimate for 4910 gpm system) | | |
| **Capital Cost - Equipment:** | | $ 450,000 | |
| **Yearly O&M Cost:** | 3300 gpm x 525,600 min/yr x $0.04/1000 gal. | | $ 70,000 |
| **Vendor:** | Vulcan Peroxidation Systems, Inc. | | |
| **Capital Cost - Equipment:** | | $1,500,000 | |
| **Yearly O&M Cost:** | Peroxide $290,000/yr + maintenance $120,000/yr | | $410,000 |
| <u>AIR STRIPPING</u> | | | |
| **Vendor:** | Carbonair Environmental Systems | | |
| **Capital Cost - Equipment:** | Air Stripper at $107,476 + Carbon filter system of 12 Model PC78 Carbon Units at $93,650/2 Units | $ 670,000 | |
| **Yearly O&M Cost:** | Not Available (NA) because not specified by vendor | | NA |
| **Vendor:** | Delta Cooling Towers, Inc. | | |
| **Capital Cost - Equipment:** | Air stripper tower only | $ 170,000 | |
| **Yearly O&M Cost:** | Not Available (NA) because not specified by vendor | | NA |
| **Vendor:** | Branch Environmental Corp. | | |
| **Capital Cost - Equipment** | Air Stripping tower only. $80,000 + 17,600 cfm at $0.50/cfm for air handling equipment | $ 89,000 | |
| **Yearly O&M Cost:** | Not Available (NA) because not specified by vendor | | NA |

# COST ESTIMATES FOR ALTERNATIVE 1
# NO ACTION

# Cost Estimate for Groundwater Alternative 1 : No Action

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| Direct Cost | | | | | |
| None | 0 | | 0 | 0 | |
| Subtotal, Direct Cost | | | | 0 | |
| Indirect Cost | | | | | |
| None | 0 | | 0 | 0 | |
| Subtotal, Indirect Cost | | | | 0 | |
| Contingency (50% Direct and Indirect) | | | | 0 | |
| **Total Capital Cost** | | | | **0** | |
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| ***C. O&M Cost : Years 1-80*** | | | | | |
| None | | | | 0 | |
| Subtotal, O&M Cost : Years 1-80 | | | | 0 | |
| Contingency (25%) | | | | 0 | |
| **Total O&M Cost : Years 1-30** | | | | **0** | |

## Cost Estimate for Groundwater Alternative 1 : No Action

**3. Present Worth**

| | |
|---|---|
| **A. PW Groundwater Monitoring : Years 1-5** | 7,796,296 |
| **B. PW Groundwater Monitoring : Years 6-80** | 3,279,163 |
| **C. PW O&M : Years 1-80** | 0 |
| **Total Present Worth Cost** | **11,075,459** |

| | |
|---|---|
| **4. TOTAL CAPITAL AND PRSENT WORTH COST** | **11,075,459** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 0 | 0 | 0 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 0 | 0 | 0 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 0 | 0 | 0 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 16,613,189 | 11,075,459 | 7,752,821 |

**COST ESTIMATES FOR ALTERNATIVE 2**
**HYDRAULIC CONTAINMENT**

# Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal I)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 5 | Well | 24,000 | 120,000 | 4 |
| Extraction Well Pumps (installed) | 5 | Pump | 7,500 | 37,500 | 4 |
| Extraction Well Controls | 5 | Well | 1,200 | 6,000 | 4 |
| Extraction Well Piping (installed) | 10 | mile | 140,000 | 1,400,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **1,568,500** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (970 gpm) | 1 | Lump Sum | 460,000 | 460,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.4M gal) | 2 | Tank | 135,000 | 270,000 | 4 |
| Transfer Pumps | 4 | Pump | 5,000 | 20,000 | 4 |
| **Subtotal, Treatment System** | | | | **1,030,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **2,727,980** | |
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Direct) | | | | 327,358 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 218,238 | 4 |
| Contractor Profit (7% Direct) | | | | 190,959 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | | | | 272,798 | 4 |
| **Subtotal, Indirect Cost** | | | | **1,534,353** | |
| Contingencies (50% Direct and Indirect) | | | | 2,131,166 | |
| **Total Capital Cost** | | | | **6,393,499** | |

## Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal I)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 7,500 | 7,500 | 2 |
| Extraction Well Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 3 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (5 well , 4 transfer pumps @ 50 hp each) | | | | | |
| 450 hp x 0.75 kw/hp x 8760 hr/yr | 2,956,500 | kwhr | 0.07 | 206,955 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |

## Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal I)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| Granular Activated Carbon (GAC) @ 970 GPM (Includes Reactivation, Transportation, and Carbon Replacement) | 101,000 | lbs. | 1.00 | 101,000 | 3 |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost : Years 1-80** | | | | **563,635** | |
| Contingency (25%) | | | | 140,909 | |
| **Total O&M Cost : Years 1-80** | | | | **704,544** | |
| **D. O&M Cost : Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Containment Well Pumps | 5 | Pump | 7,500 | 37,500 | 4 |
| Containment Well Controls | 5 | Well | 1,200 | 6,000 | 4 |
| Transfer Pumps | 4 | Pump | 5,000 | 20,000 | 4 |
| **Subtotal, O&M Each 5 Years** | | | | **63,500** | |
| Contingency (25%) | | | | 15,875 | |
| **Total O&M Cost : Each 5 Years** | | | | **79,375** | |
| **E. O&M Cost : GAC Treatment System Replacement : 20 Year Intervals** | | | | | |
| GAC Treatment System Life 20 Years | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 460,000 | 460,000 | 3 |
| **Subtotal, O&M Cost : Each 20 Years** | | | | **460,000** | |
| Contingency (25%) | | | | 115,000 | |
| **Total O&M Cost : Each 20 Years** | | | | **575,000** | |

# Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal I)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring : Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring : Years 6-80 | $3,279,163 |
| C. PW O&M : Years 1-80 | $11,631,405 |
| D. PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $232,462 |
| E. PW O&M : Years 20, 40, 60, 80 | $258,056 |
| **Total Present Worth Cost** | **$23,197,383** |

**4. TOTAL CAPITAL AND PRESENT WORTH COSTS** **$29,590,881**

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 9,590,248 | 6,393,499 | 4,475,449 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 1,056,816 | 704,544 | 493,181 |
| D. | Total O&M Cost : Each 5 Years | 119,063 | 79,375 | 55,563 |
| E. | Total O&M Cost : Year 20 | 862,500 | 575,000 | 402,500 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 17,447,107 | 11,631,405 | 8,141,983 |
| D. | PW O&M : Each 5 Years | 348,694 | 232,462 | 162,724 |
| E. | PW O&M : Each 20 Years | 387,084 | 258,056 | 180,639 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 44,386,322 | 29,590,881 | 20,713,617 |

## Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal II)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 9 | Well | 24,000 | 216,000 | 4 |
| Extraction Well Pumps (installed) | 9 | Pump | 7,500 | 67,500 | 4 |
| Extraction Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Extraction Well Piping (installed) | 12 | mile | 140,000 | 1,680,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **1,979,300** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (2100 gpm) | 1 | Lump Sum | 920,000 | 920,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.4M gal) | 2 | Tank | 135,000 | 270,000 | 4 |
| Transfer Pumps | 8 | Pump | 5,000 | 40,000 | 4 |
| **Subtotal, Treatment System** | | | | **1,510,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **3,618,780** | |
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Direct) | | | | 434,254 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 289,502 | 4 |
| Contractor Profit (7% Direct) | | | | 253,315 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | | | | 361,878 | 4 |
| **Subtotal, Indirect Cost** | | | | **1,863,949** | |
| Contingencies (50% Direct and Indirect) | | | | 2,741,364 | |
| **Total Capital Cost** | | | | **8,224,093** | |

# Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal II)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 7,500 | 7,500 | 2 |
| Extraction Well Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 3 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (9 wells, 8 transfer pumps @ 50 hp each) | | | | | |
| 850 hp x 0.75 kw/hp x 8760 hr/yr | 5,584,500 | kwhr | 0.07 | 390,915 | 4 |

## Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal II)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC) @ 2100 GPM (Includes Reactivation, Transportation, and Carbon Replacement) | 100,000 | lbs. | 1.00 | 100,000 | 3 |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost : Years 1-80** | | | | **746,595** | |
| Contingency (25%) | | | | 186,649 | |
| **Total O&M Cost : Years 1-80** | | | | **933,244** | |
| **D. O&M Cost : Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Containment Well Pumps | 9 | Pump | 7,500 | 67,500 | 4 |
| Containment Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Transfer Pumps | 4 | Pump | 5,000 | 20,000 | 4 |
| **Subtotal, O&M Each 5 Years** | | | | **98,300** | |
| Contingency (25%) | | | | 24,575 | |
| **Total O&M Cost : Each 5 Years** | | | | **122,875** | |
| **E. O&M Cost : GAC Treatment System Replacement : 20 Year Intervals** | | | | | |
| GAC Treatment System Life 20 Years | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 460,000 | 460,000 | 3 |
| **Subtotal, O&M Cost : Each 20 Years** | | | | **460,000** | |
| Contingency (25%) | | | | 115,000 | |
| **Total O&M Cost : Each 20 Years** | | | | **575,000** | |

# Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal II)

**3. Present Worth**

| | |
|---|---|
| A. PW Groundwater Monitoring : Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring : Years 6-80 | $3,279,163 |
| C. PW O&M : Years 1-80 | $15,407,043 |
| D. PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $359,859 |
| E. PW O&M : Years 20, 40, 60, 80 | $258,056 |
| **Total Present Worth Cost** | **$27,100,417** |

| | |
|---|---|
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$35,324,510** |

**Summary of Estimated Costs**

| | | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|---|
| 1. | | Total Capital Cost | 12,336,139 | 8,224,093 | 5,756,865 |
| 2. | A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| | B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| | C. | Total Annual O & M Cost (Years 1-80) | 1,399,866 | 933,244 | 653,271 |
| | D. | Total O&M Cost : Each 5 Years | 184,313 | 122,875 | 86,013 |
| | E. | Total O&M Cost : Year 20 | 862,500 | 575,000 | 402,500 |
| 3. | A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| | B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| | C. | PW O&M : Years 1-80 | 23,110,565 | 15,407,043 | 10,784,930 |
| | D. | PW O&M : Each 5 Years | 539,789 | 359,859 | 251,901 |
| | E. | PW O&M : Each 20 Years | 387,084 | 258,056 | 180,639 |
| 4. | | TOTAL CAPITAL AND PRESENT WORTH COSTS | 52,986,766 | 35,324,510 | 24,727,157 |

# Cost Estimate for Groundwater Alternative 2: Hydraulic Containment
## (Target Cleanup Goal III)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 9 | Well | 24,000 | 216,000 | 4 |
| Extraction Well Pumps (installed) | 9 | Pump | 7,500 | 67,500 | 4 |
| Extraction Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Extraction Well Piping (installed) | 11 | mile | 140,000 | 1,540,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | |
| **Subtotal, Containment Well System** | | | | **1,839,300** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (2330 gpm) | 1 | Lump Sum | 920,000 | 920,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.4M gal) | 2 | Tank | 135,000 | 270,000 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, Treatment System** | | | | **1,505,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **3,473,780** | |
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Direct) | | | | 416,854 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 277,902 | 4 |
| Contractor Profit (7% Direct) | | | | 243,165 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | | | | 347,378 | 4 |
| **Subtotal, Indirect Cost** | | | | **1,810,299** | |
| Contingencies (50% Direct and Indirect) | | | | 2,642,039 | |
| **Total Capital Cost** | | | | **7,926,118** | |

# Cost Estimate for Groundwater Alternative 2: Hydraulic Containment
## (Target Cleanup Goal III)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 7,500 | 7,500 | 2 |
| Extraction Well Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 3 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (9 wells, 7 transfer pumps @ 50 hp each) | | | | | |
| 850 hp x 0.75 kw/hp x 8760 hr/yr | 5,584,500 | kwhr | 0.07 | 390,915 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |

## Cost Estimate for Groundwater Alternative 2: Hydraulic Containment
## (Target Cleanup Goal III)

| Cost Items | Quantity | Unit | Unit Cost,$ | Total Base Cost,$ | Reference |
|---|---|---|---|---|---|
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC) @ 2330 GPM (Includes Reactivation, Transportation, and Carbon Replacement) | 104,000 | lbs. | 1.00 | 104,000 | 3 |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost : Years 1-80** | | | | **750,595** | |
| Contingency (25%) | | | | 187,649 | |
| **Total O&M Cost : Years 1-80** | | | | **938,244** | |
| **D. O&M Cost : Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Containment Well Pumps | 9 | Pump | 7,500 | 67,500 | 4 |
| Containment Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, O&M Each 5 Years** | | | | **113,300** | |
| Contingency (25%) | | | | 28,325 | |
| **Total O&M Cost : Each 5 Years** | | | | **141,625** | |
| **E. O&M Cost : GAC Treatment System Replacement : 20 Year Intervals** | | | | | |
| GAC Treatment System Life 20 Years | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 460,000 | 460,000 | 3 |
| **Subtotal, O&M Cost : Each 20 Years** | | | | **460,000** | |
| Contingency (25%) | | | | 115,000 | |
| **Total O&M Cost : Each 20 Years** | | | | **575,000** | |

## Cost Estimate for Groundwater Alternative 2: Hydraulic Containment (Target Cleanup Goal III)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring : Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring : Years 6-80 | $3,279,163 |
| C. PW O&M : Years 1-80 | $15,489,589 |
| D. PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $414,772 |
| E. PW O&M : Years 20, 40, 60, 80 | $258,056 |
| **Total Present Worth Cost** | **$27,237,876** |
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **35,163,993** |

### Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 11,889,177 | 7,926,118 | 5,548,283 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 1,407,366 | 938,244 | 656,771 |
| D. | Total O&M Cost : Each 5 Years | 212,438 | 141,625 | 99,138 |
| E. | Total O&M Cost : Year 20 | 862,500 | 575,000 | 402,500 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 23,234,383 | 15,489,589 | 10,842,712 |
| D. | PW O&M : Each 5 Years | 622,157 | 414,772 | 290,340 |
| E. | PW O&M : Each 20 Years | 387,084 | 258,056 | 180,639 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 52,745,990 | 35,163,993 | 24,614,795 |

## COST ESTIMATES FOR ALTERNATIVE 3
## FOCUSED EXTRACTION

# Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 10 | Well | 24,000 | 240,000 | 4 |
| Extraction Well Pumps (installed) | 10 | Pump | 7,500 | 75,000 | 4 |
| Extraction Well Controls | 10 | Well | 1,200 | 12,000 | 4 |
| Extraction Well Piping (installed) | 16 | mile | 140,000 | 2,240,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **2,572,000** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (1980 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 8 | Pump | 5,000 | 40,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,240,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **4,941,480** | |
| **Indirect Cost** | | | | | |
| Construction Services (12% Direct) | | | | 592,978 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 395,318 | 4 |
| Contractor Profit (7%Direct) | | | | 345,904 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 494,148 | 4 |
| **Subtotal, Indirect Cost** | | | | **2,383,348** | |
| Contingencies (50% Direct and Indirect) | | | | 3,662,414 | |
| **Total Capital Cost** | | | | **10,987,241** | |

# Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | 213,335 | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (10 wells, 8 transfer pumps @ 50 hp each) | | | | | |

# Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| 900 hp x 0.75 kw/hp x 8760 hr/yr | 5,913,000 | kwhr | 0.07 | 413,910 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@1980 GPM | 472,000 | lbs. | 1.00 | 472,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,159,090** | |
| Contingency (25%) | | | | 289,773 | |
| **Total O&M Cost: Years 1-80** | | | | **1,448,863** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 10 | Pump | 7,500 | 75,000 | 4 |
| Extraction Well Controls | 10 | Well | 1,200 | 12,000 | 4 |
| Transfer Pumps | 8 | Pump | 5,000 | 40,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **127,000** | |
| Contingency (25%) | | | | 31,750 | |
| **Total O&M Cost: Each 5 Years** | | | | **158,750** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |

## Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal I)

**3. Present Worth**

| | |
|---|---|
| **A. PW Groundwater Monitoring: Years 1-5** | **$7,796,296** |
| **B. PW Groundwater Monitoring: Years 6-80** | **$3,279,163** |
| **C. PW O&M: Years 1-80** | **$23,919,460** |
| **D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80** | **$464,925** |
| **E. PW O&M: Years 20, 40,60,80** | **$387,084** |
| **Total Present Worth Cost** | **$35,846,929** |

**4. TOTAL CAPITAL AND PRESENT WORTH COSTS** **$46,834,170**

### Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 16,480,862 | 10,987,241 | 7,691,069 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 2,173,294 | 1,448,863 | 1,014,204 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 238,125 | 158,750 | 111,125 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 35,879,191 | 23,919,460 | 16,743,622 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 697,387 | 464,925 | 325,447 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 70,251,255 | 46,834,170 | 32,783,919 |

## Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| ***Subtotal, Point of Entry Treatment*** | | | | **45,000** | |
| Hydraulic Containment/ Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 15 | Well | 24,000 | 360,000 | 4 |
| Extraction Well Pumps (installed) | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Extraction Well Piping (installed) | 21 | mile | 140,000 | 2,940,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,435,500** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (3300 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,265,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **5,829,980** | |
| **Indirect Cost** | | | | | |
| Construction Services (12% Direct) | | | | 699,598 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 466,398 | 4 |
| Contractor Profit (7%Direct) | | | | 408,099 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 582,998 | 4 |
| **Subtotal, Indirect Cost** | | | | **2,712,093** | |
| *Contingencies (50% Direct and Indirect)* | | | | 4,271,036 | |
| **Total Capital Cost** | | | | **12,813,109** | |



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# Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | 213,335 | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |

## Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Electrical (15 wells, 13 transfer pumps @ 50 hp each) | | | | | |
| 1400 hp x 0.75 kw/hp x 8760 hr/yr | 9,198,000 | kwhr | 0.07 | 643,860 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@3300 gpm (Includes Reactivation, Transportation, and Carbon Replacement) | 635,000 | lbs. | 1.00 | 635,000 | 3 |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,552,040** | |
| Contingency (25%) | | | | 388,010 | |
| **Total O&M Cost: Years 1-80** | | | | **1,940,050** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **195,500** | |
| Contingency (25%) | | | | 48,875 | |
| **Total O&M Cost: Each 5 Years** | | | | **244,375** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |

## Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal II)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $32,028,539 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $715,691 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| Total Present Worth Cost | $44,206,774 |
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $57,019,883 |

### Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 19,219,663 | 12,813,109 | 8,969,176 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 2,910,075 | 1,940,050 | 1,358,035 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 366,563 | 244,375 | 171,063 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 48,042,809 | 32,028,539 | 22,419,977 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,073,537 | 715,691 | 500,984 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 85,529,824 | 57,019,883 | 39,913,918 |

# Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 15 | Well | 24,000 | 360,000 | 4 |
| Extraction Well Pumps (installed) | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Extraction Well Piping (installed) | 21 | mile | 140,000 | 2,940,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,435,500** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (3530 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 12 | Pump | 5,000 | 60,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,260,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **5,824,980** | |
| **Indirect Cost** | | | | | |
| Construction Services (12% Direct) | | | | 698.998 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60.000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50.000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 465.998 | 4 |
| Contractor Profit (7%Direct) | | | | 407,749 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75.000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 582.498 | 4 |
| **Subtotal, Indirect Cost** | | | | **2,710,243** | |
| Contingencies (50% Direct and Indirect) | | | | 4,267,611 | |
| **Total Capital Cost** | | | | **12,802,834** | |

# Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | 213,335 | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 whoosh./wk.) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |

## Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Electrical (15 wells, 12 transfer pumps, @ 50 hp each) | | | | | |
| 1350 hp x 0.75 kw/hp x 8760 hr/yr | 8,869,500 | kwhr | 0.07 | 620,865 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@3530gpm | 663,000 | lbs. | 1.00 | 663,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,557,045** | |
| Contingency (25%) | | | | 389,261 | |
| **Total O&M Cost: Years 1-80** | | | | **1,946,306** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| *Equipment Replacement* | | | | | |
| Extraction Well Pumps | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Transfer Pumps | 12 | Pump | 5,000 | 60,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **190,500** | |
| **Contingency (25%)** | | | | 47,625 | |
| **Total O&M Cost: Each 5 Years** | | | | **238,125** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |

## Cost Estimate for Groundwater Alternative 3: Focused Extraction (Target Cleanup Goal III)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $32,131,824 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $697,387 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| Total Present Worth Cost | $44,291,755 |

| | |
|---|---|
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $57,094,589 |

### Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 19,204,251 | 12,802,834 | 8,961,984 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 2,919,459 | 1,946,306 | 1,362,414 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 357,188 | 238,125 | 166,688 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 48,197,737 | 32,131,824 | 22,492,277 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,046,081 | 697,387 | 488,171 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 85,641,883 | 57,094,589 | 39,966,212 |

**COST ESTIMATES FOR ALTERNATIVE 4**
**FOCUSED EXTRACTION AND SOIL EXCAVATION**

# Cost Estimate for Groundwater Alternative 4: Focused Extraction and Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 10 | Well | 24,000 | 240,000 | 4 |
| Extraction Well Pumps (installed) | 10 | Pump | 7,500 | 75,000 | 4 |
| Extraction Well Controls | 10 | Well | 1,200 | 12,000 | 4 |
| Extraction Well Piping (installed) | 16 | mile | 140,000 | 2,240,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **2,572,000** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (1980 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 8 | Pump | 5,000 | 40,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,240,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| ***Subtotal Groundwater Containment and Partial Extraction*** | | | | **4,941,480** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |

# Cost Estimate for Groundwater Alternative 4: Focused Extraction and Soil Excavation (Target Cleanup Goal I)

| | | | | | |
|---|---|---|---|---|---|
| Residuals Management | | | | | |
| Residuals Characterization | 6 | Each | $1,100 | $6,600 | 21 |
| (1 sample per 500 cy) | | | | | |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material | 260 | Cubic Yard | $45 | $11,700 | 21 |
| (1/10 Excavation Volume) | | | | | |
| **Subtotal, Residuals Management** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **7,073,256** | |
| **Indirect Cost** | | | | | |
| Groundwater Containment System | | | | | |
| Construction Services (12% GW Con. Direct) | | | | 592,978 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% GW Con. Direct) | | | | 395,318 | 4 |
| Contractor Profit (7% GW Con. Direct) | | | | 345,904 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Con. and Instru. (10% GW Con. Direct) | 1 | | | 494,148 | 4 |
| **Subtotal, Groundwater Containment/Par. Extr.** | | | | **2,383,348** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment | | | | | |
| (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Subtotal, Indirect Cost** | | | | **3,071,773** | |
| Contingencies (50% Direct and Indirect) | | | | 5,072,514 | |
| **Total Capital Cost** | | | | **15,217,543** | |

## Cost Estimate for Groundwater Alternative 4: Focused Extraction and Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (10 wells, 8 transfer pumps @ 50 hp each) | | | | | |

## Cost Estimate for Groundwater Alternative 4: Focused Extraction and Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| 900 hp x 0.75 kw/hp x 8760 hr/yr | 5,913,000 | kwhr | 0.07 | 413,910 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@1980 GPM | 472,000 | lbs. | 1.00 | 472,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,159,090** | |
| Contingency (25%) | | | | 289,773 | |
| **Total O&M Cost: Years 1-80** | | | | **1,448,863** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 10 | Pump | 7,500 | 75,000 | 4 |
| Extraction Well Controls | 10 | Well | 1,200 | 12,000 | 4 |
| Transfer Pumps | 8 | Pump | 5,000 | 40,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **127,000** | |
| Contingency (25%) | | | | 31,750 | |
| **Total O&M Cost: Each 5 Years** | | | | **158,750** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

## Cost Estimate for Groundwater Alternative 4: Focused Extraction and Soil Excavation (Target Cleanup Goal I)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $23,919,460 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $464,925 |
| E. PW O&M: Years 20, 40, 60, 80 | $387,084 |
| F. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| Total Present Worth Cost | $35,930,891 |
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $51,148,433 |

Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 22,826,314 | 15,217,543 | 10,652,280 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 2,173,294 | 1,448,863 | 1,014,204 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 238,125 | 158,750 | 111,125 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Annual O & M Cost : Soil Exc./Thermal Treat. : (Years 1-80) | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 35,879,191 | 23,919,460 | 16,743,622 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 697,387 | 464,925 | 325,447 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 76,722,650 | 51,148,433 | 35,803,903 |

# Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Extraction and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 15 | Well | 24,000 | 360,000 | 4 |
| Extraction Well Pumps (installed) | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Extraction Well Piping (installed) | 21 | mile | 140,000 | 2,940,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,435,500** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (3300 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,265,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Subtotal Groundwater Containment and Partial Extraction** | | | | **5,829,980** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |

## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Extraction and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Residuals Management | | | | | |
| Residuals Characterization (1 sample per 500 cy) | 6 | Each | $1,100 | $6,600 | 21 |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material (1/10 Excavation Volume) | 260 | Cubic Yard | $45 | $11,700 | 21 |
| **Subtotal, Residuals Management** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **7,961,756** | |
| **Indirect Cost** | | | | | |
| Groundwater Containment System | | | | | |
| Construction Services (12% GW Con. Direct) | | | | 699,598 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% GW Con. Direct) | | | | 466,398 | 4 |
| Contractor Profit (7% GW Con. Direct) | | | | 408,099 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Con. and Instru. (10% GW Con. Direct) | 1 | | | 582,998 | 4 |
| **Subtotal, Groundwater Containment/Par. Extr.** | | | | **2,712,093** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Subtotal, Indirect Cost** | | | | **3,400,518** | |
| Contingencies (50% Direct and Indirect) | | | | 5,681,137 | |
| **Total Capital Cost** | | | | **17,043,410** | |

## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Extraction and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (15 wells, 13 transfer pumps @ 50 hp each) | | | | | |
| 1400 hp x 0.75 kw/hp x 8760 hr/yr | 9,198,000 | kwhr | 0.07 | 643,860 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |

## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Extraction and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@3300 GPM | 635,000 | lbs. | 1.00 | 635,000 | 3 |
| (Includes Reactivation, Transportation, | | | | | |
| and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,552,040** | |
| Contingency (25%) | | | | 388,010 | |
| **Total O&M Cost: Years 1-80** | | | | **1,940,050** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **195,500** | |
| Contingency (25%) | | | | 48,875 | |
| **Total O&M Cost: Each 5 Years** | | | | **244,375** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |



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## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Extraction and Soil Excavation (Target Cleanup Goal II)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $32,028,539 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $715,691 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| **Total Present Worth Cost** | **$44,290,736** |

| | |
|---|---|
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$61,334,146** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 25,565,116 | 17,043,410 | 11,930,387 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 2,910,075 | 1,940,050 | 1,358,035 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 366,563 | 244,375 | 171,063 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Annual O & M Cost : Soil Exc./Thermal Treat. : (Years 1-80) | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 48,042,809 | 32,028,539 | 22,419,977 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,073,537 | 715,691 | 500,984 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 92,001,219 | 61,334,146 | 42,933,902 |

## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Groundwater Extraction and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 15 | Well | 24,000 | 360,000 | 4 |
| Extraction Well Pumps (installed) | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Extraction Well Piping (installed) | 21 | mile | 140,000 | 2,940,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,435,500** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (3530 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 12 | Pump | 5,000 | 60,000 | 4 |
| ***Subtotal, Treatment System*** | | | | **2,260,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Subtotal Groundwater Containment and Partial Extraction** | | | | **5,824,980** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |



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## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Groundwater Extraction and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Residuals Management | | | | | |
| Residuals Characterization | 6 | Each | $1,100 | $6,600 | 21 |
| (1 sample per 500 cy) | | | | | |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material | 260 | Cubic Yard | $45 | $11,700 | 21 |
| (1/10 Excavation Volume) | | | | | |
| **Subtotal, Residuals Management** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **7,956,756** | |
| **Indirect Cost** | | | | | |
| Groundwater Containment System | | | | | |
| Construction Services (12% GW Con. Direct) | | | | 698,998 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% GW Con. Direct) | | | | 465,998 | 4 |
| Contractor Profit (7% GW Con. Direct) | | | | 407,749 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Con. and Instru. (10% GW Con. Direct) | 1 | | | 582,498 | 4 |
| **Subtotal, Groundwater Containment/Par. Extr.** | | | | **2,710,243** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment | | | | | |
| (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Subtotal, Indirect Cost** | | | | **3,398,668** | |
| Contingencies (50% Direct and Indirect) | | | | 5,677,712 | |
| **Total Capital Cost** | | | | **17,033,135** | |

## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Groundwater Extraction and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (15 wells, 12 transfer pumps @ 50 hp each) | | | | | |
| 1350 hp x 0.75 kw/hp x 8760 hr/yr | 8,869,500 | kwhr | 0.07 | 620,865 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |

## Cost Estimate for Groundwater Alternative 4: Hydraulic Containment, Focused Groundwater Extraction and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@3530 GPM (Includes Reactivation, Transportation, and Carbon Replacement) | 663,000 | lbs. | 1.00 | 663,000 | 3 |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,557,045** | |
| Contingency (25%) | | | | 389,261 | |
| **Total O&M Cost: Years 1-80** | | | | **1,946,306** | |
| **D. O&M Cost: *Pumps and Control Replacement : 5 Year Intervals*** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Transfer Pumps | 12 | Pump | 5,000 | 60,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **190,500** | |
| Contingency (25%) | | | | 47,625 | |
| **Total O&M Cost: Each 5 Years** | | | | **238,125** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

## *Cost Estimate for Groundwater Alternative 4:* Hydraulic Containment, Focused Groundwater Extraction and Soil Excavation (Target Cleanup Goal III)

**3. Present Worth**

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $32,131,824 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $697,387 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| **Total Present Worth Cost** | **$44,375,717** |

| | |
|---|---|
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$61,408,852** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 25,549,703 | 17,033,135 | 11,923,195 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 2,919,459 | 1,946,306 | 1,362,414 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 357,188 | 238,125 | 166,688 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Annual O & M Cost : Soil Exc./Thermal Treat. : (Years 1-80) | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 48,197,737 | 32,131,824 | 22,492,277 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,046,081 | 697,387 | 488,171 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 92,113,278 | 61,408,852 | 42,986,197 |

## COST ESTIMATES FOR ALTERNATIVE 5
## FOCUSED EXTRACTION AND AIR SPARGING

# Cost Estimate for Groundwater Alternative 5: Focused Extraction and Air Sparging (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 8 | Well | 24,000 | 192,000 | 4 |
| Extraction Well Pumps (installed) | 8 | Pump | 7,500 | 60,000 | 4 |
| Extraction Well Controls | 8 | Well | 1,200 | 9,600 | 4 |
| Extraction Well Piping (installed) | 14 | mile | 140,000 | 1,960,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **2,226,600** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (1450 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,235,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total, Hydraulic Containment System Cost** | | | | **4,591,080** | |
| Air Sparging | | | | | |
| Horizontal Well Installation | | | | | |
| 15 Wells @ 300' Long x 60' Deep | 4500 | linear foot | 1,500 | 6,750,000 | 7,8 |
| Vapor Extraction Wells | | | | | |
| 90 Wells @ 30' Deep | 90 | each | 4,000 | 360,000 | 7,8 |
| Vapor/Air Separators | | | | | |
| 15 @ 600 cfm | 15 | each | 3,500 | 52,500 | 7,8 |
| Sparging Pumps | | | | | |
| 15 @ 500 cfm | 15 | each | 5,000 | 75,000 | 7,8 |
| Vacuum Pumps | | | | | |
| 90 @ 100 cfm | 90 | each | 3,000 | 270,000 | 7,8 |
| Carbon Adsorption Units | | | | | |
| 9 @ 1,100 cfm | 9 | each | 11,000 | 99,000 | 7,8 |
| Vacuum Gauges | 90 | each | 100 | 9,000 | 7,8 |
| Air flow meters | 90 | each | 300 | 27,000 | 7,8 |
| OVA Instruments | 2 | each | 10,000 | 20,000 | 7,8 |
| Building | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **7,712,500** | |
| **Total Direct Cost** | | | | **12,303,580** | |

## Cost Estimate for Groundwater Alternative 5: Focused Extraction and Air Sparging (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Hyd. Con. Direct) | | | | 550,930 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hyd. Con. Direct) | | | | 367,286 | 4 |
| Contractor Profit (7% Hyd. Con. Direct) | | | | 321,376 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 459,108 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **2,253,700** | |
| Air Sparging | | | | | |
| Mobilization/Set-up (8% Air Sp. Direct) | | | | 617,000 | 7,8 |
| Health & Safety (10% Air Sp.Direct) | | | | 771,250 | 7,8 |
| Piping and Insulation (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Electrical/Process Control (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Construction Services (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Engineering Design (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 7,8 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 7,8 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **5,196,750** | |
| **Total, Indirect Cost** | | | | **7,450,450** | |
| Contingencies (50% Direct and Indirect) | | | | 9,877,015 | |
| **Total Capital Cost** | | | | **29,631,044** | |

# Cost Estimate for Groundwater Alternative 5: Focused Extraction and Air Sparging (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Containment System : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |

# Cost Estimate for Groundwater Alternative 5: Focused Extraction and Air Sparging (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Electrical (8 wells, 7 transfer pumps @ 50 hp each) | | | | | |
| 750 hp x 0.75 kw/hp x 8760 hr/yr | 4,927,500 | kwhr | 0.07 | 344,925 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@1450gpm | 188,000 | lbs. | 1.00 | 188,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75.00 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **806,105** | |
| Contingency (25%) | | | | 201,526 | |
| **Total O&M Cost: Containment System : Years 1-80** | | | | **1,007,631** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 8 | Pump | 7,500.00 | 60,000 | 4 |
| Extraction Well Controls | 8 | Well | 1,200.00 | 9,600 | 4 |
| Transfer Pumps | 7 | Pump | 5,000.00 | 35,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **104,600** | |
| Contingency (25%) | | | | 26,150 | |
| **Total O&M Cost: Each 5 Years** | | | | **130,750** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000.00 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Air Sparging : Years 1-80** | | | | | |
| Carbon Purchase/Regeneration | 49,140 | lbs. | 2 | 98,280 | 3 |
| Energy | 2,700,000 | kwhr | 0.07 | 189,000 | 7,8 |
| System Maintenance | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Health & Safety | 183 | day | 50 | 9,150 | 7,8 |
| Maintenance Supplies | 1 | Lump Sum | 12,000 | 12,000 | 7,8 |
| Labor | | | | | |
| Technician | 1,040 | hour | 75 | 78,000 | 7,8 |
| Oversight Engineer | 200 | hour | 100 | 20,000 | 7,8 |
| **Subtotal, Air Sparging : Years 1-80** | | | | **456,430** | |
| Contingency (25%) | | | | 114,108 | |
| **Total Annual O&M Cost: Years 1-80** | | | | **570,538** | |

# Cost Estimate for Groundwater Alternative 5: Focused Extraction and Air Sparging (Target Cleanup Goal I)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW Containment System O&M: Years 1-80 | $16,635,116 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $382,922 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Air Sparging O&M: Years 1-80 | $9,419,078 |
| **Total Present Worth Cost** | **$37,899,660** |
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$67,530,704** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 44,446,567 | 29,631,044 | 20,741,731 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual Containment System O & M Cost : Years 1-80 | 1,511,447 | 1,007,631 | 705,342 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 196,125 | 130,750 | 91,525 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Air Sparging O&M Cost : Years 1-80 | 855,806 | 570,538 | 399,376 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW Containment System O&M : Years 1-80 | 24,952,674 | 16,635,116 | 11,644,581 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 574,384 | 382,922 | 268,046 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Air Sparging O&M : Years 1-80 | 14,128,617 | 9,419,078 | 6,593,355 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 101,296,057 | 67,530,704 | 47,271,493 |

# Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 13 | Well | 24,000 | 312,000 | 4 |
| Extraction Well Pumps (installed) | 13 | Pump | 7,500 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200 | 15,600 | 4 |
| Extraction Well Piping (installed) | 20 | mile | 140,000 | 2,800,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,230,100** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (2770 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 12 | Pump | 5,000 | 60,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,260,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total, Hydraulic Containment System Cost** | | | | **5,619,580** | |
| Air Sparging | | | | | |
| Horizontal Well Installation | | | | | |
| 15 Wells @ 300' Long x 60' Deep | 4500 | linear foot | 1,500 | 6,750,000 | 7,8 |
| Vapor Extraction Wells | | | | | |
| 90 Wells @ 30' Deep | 90 | each | 4,000 | 360,000 | 7,8 |
| Vapor/Air Separators | | | | | |
| 15 @ 600 cfm | 15 | each | 3,500 | 52,500 | 7,8 |
| Sparging Pumps | | | | | |
| 15 @ 500 cfm | 15 | each | 5,000 | 75,000 | 7,8 |
| Vacuum Pumps | | | | | |
| 90 @ 100 cfm | 90 | each | 3,000 | 270,000 | 7,8 |
| Carbon Adsorption Units | | | | | |
| 9 @ 1,100 cfm | 9 | each | 11,000 | 99,000 | 7,8 |
| Vacuum Gauges | 90 | each | 100 | 9,000 | 7,8 |
| Air flow meters | 90 | each | 300 | 27,000 | 7,8 |
| OVA Instruments | 2 | each | 10,000 | 20,000 | 7,8 |
| Building | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **7,712,500** | |
| **Total Direct Cost** | | | | **13,332,080** | |



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## Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Hyd. Con. Direct) | | | | 674,350 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hyd. Con. Direct) | | | | 449,566 | 4 |
| Contractor Profit (7% Hyd. Con. Direct) | | | | 393,371 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 561,958 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **2,634,245** | |
| Air Sparging | | | | | |
| Mobilization/Set-up (8% Air Sp. Direct) | | | | 617,000 | 7,8 |
| Health & Safety (10% Air Sp.Direct) | | | | 771,250 | 7,8 |
| Piping and Insulation (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Electrical/Process Control (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Construction Services (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Engineering Design (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 7,8 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 7,8 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **5,196,750** | |
| **Total, Indirect Cost** | | | | **7,830,995** | |
| Contingencies (50% Direct and Indirect) | | | | 10,581,537 | |
| **Total Capital Cost** | | | | **31,744,612** | |

## Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Containment System : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |

## Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Treatment System | | | | | |
| Electrical (13 wells, 12 transfer pumps @ 50 hp each) | | | | | |
| 1250 hp x 0.75 kw/hp x 8760 hr/yr | 8,212,500 | kwhr | 0.07 | 574,875 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@2770gpm | 269,000 | lbs. | 1.00 | 269,000 | 3 |
| (Includes Reactivation, Transportation, | | | | | |
| and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75.00 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,117,055** | |
| Contingency (25%) | | | | 279,264 | |
| **Total O&M Cost: Containment System : Years 1-80** | | | | **1,396,319** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 13 | Pump | 7,500.00 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200.00 | 15,600 | 4 |
| Transfer Pumps | 12 | Pump | 5,000.00 | 60,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **173,100** | |
| Contingency (25%) | | | | 43,275 | |
| **Total O&M Cost: Each 5 Years** | | | | **216,375** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000.00 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Air Sparging : Years 1-80** | | | | | |
| Carbon Purchase/Regeneration | 49,140 | lbs. | 2 | 98,280 | 3 |
| Energy | 2,700,000 | kwhr | 0.07 | 189,000 | 7,8 |
| System Maintenance | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Health & Safety | 183 | day | 50 | 9,150 | 7,8 |
| Maintenance Supplies | 1 | Lump Sum | 12,000 | 12,000 | 7,8 |
| Labor | | | | | |
| Technician | 1,040 | hour | 75 | 78,000 | 7,8 |
| Oversight Engineer | 200 | hour | 100 | 20,000 | 7,8 |
| **Subtotal, Air Sparging : Years 1-80** | | | | **456,430** | |
| Contingency (25%) | | | | 114,108 | |
| **Total Annual O&M Cost: Years 1-80** | | | | **570,538** | |



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## Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal II)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW Containment System O&M: Years 1-80 | $23,052,009 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $633,689 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Air Sparging O&M: Years 1-80 | $9,419,078 |
| Total Present Worth Cost | $44,567,319 |
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $76,311,931 |

### Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 47,616,918 | 31,744,612 | 22,221,228 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual Containment System O & M Cost : Years 1-80 | 2,094,478 | 1,396,319 | 977,423 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 324,563 | 216,375 | 151,463 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Air Sparging O&M Cost : Years 1-80 | 855,806 | 570,538 | 399,376 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW Containment System O&M : Years 1-80 | 34,578,013 | 23,052,009 | 16,136,406 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 950,533 | 633,689 | 443,582 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Air Sparging O&M : Years 1-80 | 14,128,617 | 9,419,078 | 6,593,355 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 114,467,897 | 76,311,931 | 53,418,352 |

# Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment/Focussed G.W. Extraction System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 13 | Well | 24,000 | 312,000 | 4 |
| Extraction Well Pumps (installed) | 13 | Pump | 7,500 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200 | 15,600 | 4 |
| Extraction Well Piping (installed) | 19 | mile | 140,000 | 2,660,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,090,100** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (3000 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 11 | Pump | 5,000 | 55,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,255,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total, Hydraulic Containment System Cost** | | | | **5,474,580** | |
| Air Sparging | | | | | |
| Horizontal Well Installation | | | | | |
| 15 Wells @ 300' Long x 60' Deep | 4500 | linear foot | 1,500 | 6,750,000 | 7,8 |
| Vapor Extraction Wells | | | | | |
| 90 Wells @ 30' Deep | 90 | each | 4,000 | 360,000 | 7,8 |
| Vapor/Air Separators | | | | | |
| 15 @ 600 cfm | 15 | each | 3,500 | 52,500 | 7,8 |
| Sparging Pumps | | | | | |
| 15 @ 500 cfm | 15 | each | 5,000 | 75,000 | 7,8 |
| Vacuum Pumps | | | | | |
| 90 @ 100 cfm | 90 | each | 3,000 | 270,000 | 7,8 |
| Carbon Adsorption Units | | | | | |
| 9 @ 1,100 cfm | 9 | each | 11,000 | 99,000 | 7,8 |
| Vacuum Gauges | 90 | each | 100 | 9,000 | 7,8 |
| Air flow meters | 90 | each | 300 | 27,000 | 7,8 |
| OVA Instruments | 2 | each | 10,000 | 20,000 | 7,8 |
| Building | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **7,712,500** | |
| **Total Direct Cost** | | | | **13,187,080** | |

# Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Hyd. Con. Direct) | | | | 656,950 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hyd. Con. Direct) | | | | 437,966 | 4 |
| Contractor Profit (7% Hyd. Con. Direct) | | | | 383,221 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 547,458 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **2,580,595** | |
| Air Sparging | | | | | |
| Mobilization/Set-up (8% Air Sp. Direct) | | | | 617,000 | 7,8 |
| Health & Safety (10% Air Sp.Direct) | | | | 771,250 | 7,8 |
| Piping and Insulation (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Electrical/Process Control (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Construction Services (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Engineering Design (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 7,8 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 7,8 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **5,196,750** | |
| **Total, Indirect Cost** | | | | **7,777,345** | |
| Contingencies (50% Direct and Indirect) | | | | 10,482,212 | |
| **Total Capital Cost** | | | | **31,446,637** | |

## Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Containment System : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |

# Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Treatment System | | | | | |
| Electrical (13 wells, 11 transfer pumps @ 50 hp each) | | | | | |
| 1200 hp x 0.75 kw/hp x 8760 hr/yr | 7,884,000 | kwhr | 0.07 | 551,880 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@3000gpm | 255,000 | lbs. | 1.00 | 255,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75.00 | 7,200 | 4 |
| ***Subtotal, O&M Cost: Years 1-80*** | | | | **1,080,060** | |
| Contingency (25%) | | | | 270,015 | |
| **Total O&M Cost: Containment System : Years 1-80** | | | | **1,350,075** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 13 | Pump | 7,500.00 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200.00 | 15,600 | 4 |
| Transfer Pumps | 11 | Pump | 5,000.00 | 55,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **168,100** | |
| Contingency (25%) | | | | 42,025 | |
| **Total O&M Cost: Each 5 Years** | | | | **210,125** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000.00 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Air Sparging : Years 1-80** | | | | | |
| Carbon Purchase/Regeneration | 49,140 | lbs. | 2 | 98,280 | 3 |
| Energy | 2,700,000 | kwhr | 0.07 | 189,000 | 7,8 |
| System Maintenance | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Health & Safety | 183 | day | 50 | 9,150 | 7,8 |
| Maintenance Supplies | 1 | Lump Sum | 12,000 | 12,000 | 7,8 |
| Labor | | | | | |
| Technician | 1,040 | hour | 75 | 78,000 | 7,8 |
| Oversight Engineer | 200 | hour | 100 | 20,000 | 7,8 |
| **Subtotal, Air Sparging : Years 1-80** | | | | **456,430** | |
| Contingency (25%) | | | | 114,108 | |
| **Total Annual O&M Cost: Years 1-80** | | | | **570,538** | |

## Cost Estimate for Groundwater Alternative 5: Hydraulic Containment, Focused Groundwater Extraction and Air Sparging (Target Cleanup Goal III)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW Containment System O&M: Years 1-80 | $22,288,565 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $615,385 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Air Sparging O&M: Years 1-80 | $9,419,078 |
| **Total Present Worth Cost** | **$43,785,571** |

| | |
|---|---|
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $75,232,208 |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 47,169,955 | 31,446,637 | 22,012,646 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual Containment System O & M Cost : Years 1-80 | 2,025,113 | 1,350,075 | 945,053 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 315,188 | 210,125 | 147,088 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Air Sparging O&M Cost : Years 1-80 | 855,806 | 570,538 | 399,376 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW Containment System O&M : Years 1-80 | 33,432,847 | 22,288,565 | 15,601,995 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 923,077 | 615,385 | 430,769 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Air Sparging O&M : Years 1-80 | 14,128,617 | 9,419,078 | 6,593,355 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 112,848,312 | 75,232,208 | 52,662,546 |

# COST ESTIMATES FOR ALTERNATIVE 6
# HYDRAULIC CONTAINMENT,
# FOCUSED EXTRACTION, AIR SPARGING AND SOIL EXCAVATION

## Cost Estimate for Groundwater Alternative 6: Focused Extraction With Air Sparging And Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 8 | Well | 24,000 | 192,000 | 4 |
| Extraction Well Pumps (installed) | 8 | Pump | 7,500 | 60,000 | 4 |
| Extraction Well Controls | 8 | Well | 1,200 | 9,600 | 4 |
| Extraction Well Piping (installed) | 14 | mile | 140,000 | 1,960,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| ***Subtotal, Containment Well System*** | | | | **2,226,600** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (1450 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,235,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total, Hydraulic Containment System Cost** | | | | **4,591,080** | |
| Air Sparging | | | | | |
| Horizontal Well Installation | | | | | |
| 15 Wells @ 300' Long x 60' Deep | 4500 | linear foot | 1,500 | 6,750,000 | 7,8 |
| Vapor Extraction Wells | | | | | |
| 90 Wells @ 30' Deep | 90 | each | 4,000 | 360,000 | 7,8 |
| Vapor/Air Separators | | | | | |
| 15 @ 600 cfm | 15 | each | 3,500 | 52,500 | 7,8 |
| Sparging Pumps | | | | | |
| 15 @ 500 cfm | 15 | each | 5,000 | 75,000 | 7,8 |
| Vacuum Pumps | | | | | |
| 90 @ 100 cfm | 90 | each | 3,000 | 270,000 | 7,8 |
| Carbon Adsorption Units | | | | | |
| 9 @ 1,100 cfm | 9 | each | 11,000 | 99,000 | 7,8 |
| Vacuum Gauges | 90 | each | 100 | 9,000 | 7,8 |
| Air flow meters | 90 | each | 300 | 27,000 | 7,8 |
| OVA Instruments | 2 | each | 10,000 | 20,000 | 7,8 |
| Building | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **7,712,500** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |

## Cost Estimate for Groundwater Alternative 6: Focused Extraction With Air Sparging And Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |
| Residuals Management | | | | | |
| Residuals Characterization (1 sample per 500 cy) | 6 | Each | $1,100 | $6,600 | 21 |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material (1/10 Excavation Volume) | 260 | Cubic Yard | $45 | $11,700 | 21 |
| ***Subtotal, Residuals Management*** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **14,435,356** | |
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Hyd. Con. Direct) | | | | 550,930 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hyd. Con. Direct) | | | | 367,286 | 4 |
| Contractor Profit (7% Hyd. Con. Direct) | | | | 321,376 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 459,108 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **2,253,700** | |

## Cost Estimate for Groundwater Alternative 6: Focused Extraction With Air Sparging And Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Air Sparging | | | | | |
| Mobilization/Set-up (8% Air Sp. Direct) | | | | 617,000 | 7,8 |
| Health & Safety (10% Air Sp.Direct) | | | | 771,250 | 7,8 |
| Piping and Insulation (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Electrical/Process Control (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Construction Services (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Engineering Design (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 7,8 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 7,8 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **5,196,750** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Total, Indirect Cost** | | | | **8,138,875** | |
| Contingencies (50% Direct and Indirect) | | | | 11,287,115 | |
| **Total Capital Cost** | | | | **33,861,346** | |

## Cost Estimate for Groundwater Alternative 6: Focused Extraction With Air Sparging And Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Containment System : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (8 wells, 7 transfer pumps @ 50 hp each) | | | | | |
| 750 hp x 0.75 kw/hp x 8760 hr/yr | 4,927,500 | kwhr | 0.07 | 344,925 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |

## Cost Estimate for Groundwater Alternative 6: Focused Extraction With Air Sparging And Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@1450gpm | 188,000 | lbs. | 1.00 | 188,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75.00 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **806,105** | |
| Contingency (25%) | | | | 201,526 | |
| **Total O&M Cost: Containment System : Years 1-80** | | | | **1,007,631** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 8 | Pump | 7,500.00 | 60,000 | 4 |
| Extraction Well Controls | 8 | Well | 1,200.00 | 9,600 | 4 |
| Transfer Pumps | 7 | Pump | 5,000.00 | 35,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **104,600** | |
| Contingency (25%) | | | | 26,150 | |
| **Total O&M Cost: Each 5 Years** | | | | **130,750** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000.00 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Air Sparging : Years 1-80** | | | | | |
| Carbon Purchase/Regeneration | 49,140 | lbs. | 2 | 98,280 | 3 |
| Energy | 2,700,000 | kwhr | 0.07 | 189,000 | 7,8 |
| System Maintenance | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Health & Safety | 183 | day | 50 | 9,150 | 7,8 |
| Maintenance Supplies | 1 | Lump Sum | 12,000 | 12,000 | 7,8 |
| Labor | | | | | |
| Technician | 1,040 | hour | 75 | 78,000 | 7,8 |
| Oversight Engineer | 200 | hour | 100 | 20,000 | 7,8 |
| **Subtotal, Air Sparging : Years 1-80** | | | | **456,430** | |
| Contingency (25%) | | | | 114,108 | |
| **Total Annual O&M Cost: Years 1-80** | | | | **570,538** | |
| **G. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| ***Subtotal, Point of Entry Treatment*** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 13 | Well | 24,000 | 312,000 | 4 |
| Extraction Well Pumps (installed) | 13 | Pump | 7,500 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200 | 15,600 | 4 |
| Extraction Well Piping (installed) | 20 | mile | 140,000 | 2,800,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,230,100** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (2770 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 12 | Pump | 5,000 | 60,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,260,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| ***Subtotal, Discharge System*** | | | | **84,480** | |
| **Total, Hydraulic Containment System Cost** | | | | **5,619,580** | |
| Air Sparging | | | | | |
| Horizontal Well Installation | | | | | |
| 15 Wells @ 300' Long x 60' Deep | 4500 | linear foot | 1,500 | 6,750,000 | 7,8 |
| Vapor Extraction Wells | | | | | |
| 90 Wells @ 30' Deep | 90 | each | 4,000 | 360,000 | 7,8 |
| Vapor/Air Separators | | | | | |
| 15 @ 600 cfm | 15 | each | 3,500 | 52,500 | 7,8 |
| Sparging Pumps | | | | | |
| 15 @ 500 cfm | 15 | each | 5,000 | 75,000 | 7,8 |
| Vacuum Pumps | | | | | |
| 90 @ 100 cfm | 90 | each | 3,000 | 270,000 | 7,8 |
| Carbon Adsorption Units | | | | | |
| 9 @ 1,100 cfm | 9 | each | 11,000 | 99,000 | 7,8 |
| Vacuum Gauges | 90 | each | 100 | 9,000 | 7,8 |
| Air flow meters | 90 | each | 300 | 27,000 | 7,8 |
| OVA Instruments | 2 | each | 10,000 | 20,000 | 7,8 |
| Building | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **7,712,500** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling | 26 | Each | $368 | $9,568 | 21 |
| (1 sample per 100cy) | | | | | |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization | 6 | Each | $50 | $300 | 21 |
| (1sample per 500 cy) | | | | | |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling | 26 | Each | $368 | $9,568 | 21 |
| (1 sample per 100 cy) | | | | | |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |
| Residuals Management | | | | | |
| Residuals Characterization | 6 | Each | $1,100 | $6,600 | 21 |
| (1 sample per 500 cy) | | | | | |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material | 260 | Cubic Yard | $45 | $11,700 | 21 |
| (1/10 Excavation Volume) | | | | | |
| **Subtotal, Residuals Management** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **15,463,856** | |
| **Indirect Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Construction Services (12% Hyd. Con. Direct) | | | | 674,350 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hyd. Con. Direct) | | | | 449,566 | 4 |
| Contractor Profit (7% Hyd. Con. Direct) | | | | 393,371 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 561,958 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **2,634,245** | |

**Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal II)**

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Air Sparging | | | | | |
| Mobilization/Set-up (8% Air Sp. Direct) | | | | 617,000 | 7,8 |
| Health & Safety (10% Air Sp.Direct) | | | | 771,250 | 7,8 |
| Piping and Insulation (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Electrical/Process Control (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Construction Services (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Engineering Design (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 7,8 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 7,8 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **5,196,750** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Total, Indirect Cost** | | | | **8,519,420** | |
| Contingencies (50% Direct and Indirect) | | | | 11,991,638 | |
| **Total Capital Cost** | | | | **35,974,913** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Containment System : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (13 wells, 12 transfer pumps @ 50 hp each) | | | | | |
| 1250 hp x 0.75 kw/hp x 8760 hr/yr | 8,212,500 | kwhr | 0.07 | 574,875 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@2770gpm | 269,000 | lbs. | 1.00 | 269,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75.00 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,117,055** | |
| Contingency (25%) | | | | 279,264 | |
| **Total O&M Cost: Containment System : Years 1-80** | | | | **1,396,319** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 13 | Pump | 7,500.00 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200.00 | 15,600 | 4 |
| Transfer Pumps | 12 | Pump | 5,000.00 | 60,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **173,100** | |
| Contingency (25%) | | | | 43,275 | |
| **Total O&M Cost: Each 5 Years** | | | | **216,375** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000.00 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Air Sparging : Years 1-80** | | | | | |
| Carbon Purchase/Regeneration | 49,140 | lbs. | 2 | 98,280 | 3 |
| Energy | 2,700,000 | kwhr | 0.07 | 189,000 | 7,8 |
| System Maintenance | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Health & Safety | 183 | day | 50 | 9,150 | 7,8 |
| Maintenance Supplies | 1 | Lump Sum | 12,000 | 12,000 | 7,8 |
| Labor | | | | | |
| Technician | 1,040 | hour | 75 | 78,000 | 7,8 |
| Oversight Engineer | 200 | hour | 100 | 20,000 | 7,8 |
| **Subtotal, Air Sparging : Years 1-80** | | | | **456,430** | |
| Contingency (25%) | | | | 114,108 | |
| **Total Annual O&M Cost: Years 1-80** | | | | **570,538** | |
| **G. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal II)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW Containment System O&M: Years 1-80 | $23,052,009 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $633,689 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Air Sparging O&M: Years 1-80 | $9,419,078 |
| G. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| **Total Present Worth Cost** | **$44,651,281** |

| | |
|---|---|
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$80,626,195** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 53,962,370 | 35,974,913 | 25,182,439 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual Containment System O & M Cost : Years 1-80 | 2,094,478 | 1,396,319 | 977,423 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 324,563 | 216,375 | 151,463 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Air Sparging O&M Cost : Years 1-80 | 855,806 | 570,538 | 399,376 |
| G. | Total Annual O & M Cost : Soil Exc./Thermal Treat. : (Years 1-80) | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW Containment System O&M : Years 1-80 | 34,578,013 | 23,052,009 | 16,136,406 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 950,533 | 633,689 | 443,582 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Air Sparging O&M : Years 1-80 | 14,128,617 | 9,419,078 | 6,593,355 |
| G. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 120,939,292 | 80,626,195 | 56,438,336 |



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# Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Hydraulic Containment System | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Hydraulic Containment/Focussed G.W. Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 13 | Well | 24,000 | 312,000 | 4 |
| Extraction Well Pumps (installed) | 13 | Pump | 7,500 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200 | 15,600 | 4 |
| Extraction Well Piping (installed) | 19 | mile | 140,000 | 2,660,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,090,100** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (3000 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 11 | Pump | 5,000 | 55,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,255,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total, Hydraulic Containment System Cost** | | | | **5,474,580** | |
| Air Sparging | | | | | |
| Horizontal Well Installation | | | | | |
| 15 Wells @ 300' Long x 60' Deep | 4500 | linear foot | 1,500 | 6,750,000 | 7,8 |
| Vapor Extraction Wells | | | | | |
| 90 Wells @ 30' Deep | 90 | each | 4,000 | 360,000 | 7,8 |
| Vapor/Air Separators | | | | | |
| 15 @ 600 cfm | 15 | each | 3,500 | 52,500 | 7,8 |
| Sparging Pumps | | | | | |
| 15 @ 500 cfm | 15 | each | 5,000 | 75,000 | 7,8 |
| Vacuum Pumps | | | | | |
| 90 @ 100 cfm | 90 | each | 3,000 | 270,000 | 7,8 |
| Carbon Adsorption Units | | | | | |
| 9 @ 1,100 cfm | 9 | each | 11,000 | 99,000 | 7,8 |
| Vacuum Gauges | 90 | each | 100 | 9,000 | 7,8 |
| Air flow meters | 90 | each | 300 | 27,000 | 7,8 |
| OVA Instruments | 2 | each | 10,000 | 20,000 | 7,8 |
| Building | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **7,712,500** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| *Thermal Treatment* | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |
| Residuals Management | | | | | |
| Residuals Characterization (1 sample per 500 cy) | 6 | Each | $1,100 | $6,600 | 21 |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material (1/10 Excavation Volume) | 260 | Cubic Yard | $45 | $11,700 | 21 |
| **Subtotal, Residuals Management** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **15,318,856** | |
| **Indirect Cost** | | | | | |
| *Hydraulic Containment System* | | | | | |
| Construction Services (12% Hyd. Con. Direct) | | | | 656,950 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hyd. Con. Direct) | | | | 437,966 | 4 |
| Contractor Profit (7% Hyd. Con. Direct) | | | | 383,221 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 547,458 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **2,580,595** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| *Air Sparging* | | | | | |
| Mobilization/Set-up (8% Air Sp. Direct) | | | | 617,000 | 7,8 |
| Health & Safety (10% Air Sp.Direct) | | | | 771,250 | 7,8 |
| Piping and Insulation (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Electrical/Process Control (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Construction Services (12% Air Sp. Direct) | | | | 925,500 | 7,8 |
| Engineering Design (10% Air Sp. Direct) | | | | 771,250 | 7,8 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 7,8 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 150,000 | 150,000 | 7,8 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 7,8 |
| **Subtotal, Air Sparging** | | | | **5,196,750** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Total, Indirect Cost** | | | | **8,465,770** | |
| Contingencies (50% Direct and Indirect) | | | | 11,892,313 | |
| **Total Capital Cost** | | | | **35,676,938** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Containment System : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (13 wells, 11 transfer pumps @ 50 hp each) | | | | | |
| 1200 hp x 0.75 kw/hp x 8760 hr/yr | 7,884,000 | kwhr | 0.07 | 551,880 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@3000gpm | 255,000 | lbs. | 1.00 | 255,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75.00 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,080,060** | |
| Contingency (25%) | | | | 270,015 | |
| **Total O&M Cost: Containment System : Years 1-80** | | | | **1,350,075** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 13 | Pump | 7,500.00 | 97,500 | 4 |
| Extraction Well Controls | 13 | Well | 1,200.00 | 15,600 | 4 |
| Transfer Pumps | 11 | Pump | 5,000.00 | 55,000 | 4 |
| ***Subtotal, O&M Cost: Each 5 Years*** | | | | ***168,100*** | |
| Contingency (25%) | | | | 42,025 | |
| ***Total O&M Cost: Each 5 Years*** | | | | ***210,125*** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000.00 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Air Sparging : Years 1-80** | | | | | |
| Carbon Purchase/Regeneration | 49,140 | lbs. | 2 | 98,280 | 3 |
| Energy | 2,700,000 | kwhr | 0.07 | 189,000 | 7,8 |
| System Maintenance | 1 | Lump Sum | 50,000 | 50,000 | 7,8 |
| Health & Safety | 183 | day | 50 | 9,150 | 7,8 |
| Maintenance Supplies | 1 | Lump Sum | 12,000 | 12,000 | 7,8 |
| Labor | | | | | |
| Technician | 1,040 | hour | 75 | 78,000 | 7,8 |
| Oversight Engineer | 200 | hour | 100 | 20,000 | 7,8 |
| **Subtotal, Air Sparging : Years 1-80** | | | | **456,430** | |
| Contingency (25%) | | | | 114,108 | |
| **Total Annual O&M Cost: Years 1-80** | | | | **570,538** | |
| **G. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

## Cost Estimate for Groundwater Alternative 6: Hydraulic Containment, Focused Groundwater Extraction, Air Sparging and Soil Excavation (Target Cleanup Goal III)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW Containment System O&M: Years 1-80 | $22,288,565 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $615,385 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Air Sparging O&M: Years 1-80 | $9,419,078 |
| G. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| **Total Present Worth Cost** | **$43,869,533** |

| | |
|---|---|
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$79,546,471** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 53,515,408 | 35,676,938 | 24,973,857 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual Containment System O & M Cost : Years 1-80 | 2,025,113 | 1,350,075 | 945,053 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 315,188 | 210,125 | 147,088 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Air Sparging O&M Cost : Years 1-80 | 855,806 | 570,538 | 399,376 |
| G. | Total Annual O & M Cost : Soil Exc./Thermal Treat. : (Years 1-80) | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW Containment System O&M : Years 1-80 | 33,432,847 | 22,288,565 | 15,601,995 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 923,077 | 615,385 | 430,769 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Air Sparging O&M : Years 1-80 | 14,128,617 | 9,419,078 | 6,593,355 |
| G. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 119,319,707 | 79,546,471 | 55,682,530 |

## COST ESTIMATES FOR ALTERNATIVE 7
## GROUNDWATER EXTRACTION

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction
## (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| ***Subtotal, Point of Entry Treatment*** | | | | **45,000** | |
| Groundwater Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 9 | Well | 24,000 | 216,000 | 4 |
| Extraction Well Pumps (installed) | 9 | Pump | 7,500 | 67,500 | 4 |
| Extraction Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Extraction Well Piping (installed) | 14 | mile | 140,000 | 1,960,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **2,259,300** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (2490 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,235,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| ***Total Direct Cost*** | | | | **4,623,780** | |
| **Indirect Cost** | | | | | |
| Construction Services (12% Direct) | | | | 554,854 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 369,902 | 4 |
| Contractor Profit (7%Direct) | | | | 323,665 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 462,378 | 4 |
| **Subtotal, Indirect Cost** | | | | **2,265,799** | |
| Contingencies (50% Direct and Indirect) | | | | 3,444,789 | |
| **Total Capital Cost** | | | | **10,334,368** | |

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | 213,335 | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | 266,669 | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (9 wells, 7 transfer pumps @ 50 hp each) | | | | | |
| 800 hp x 0.75 kw/hp x 8760 hr/yr | 5,256,000 | kwhr | 0.07 | 367,920 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |



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## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@2490gpm (Includes Reactivation, Transportation, and Carbon Replacement) | 568,000 | lbs. | 1.00 | 568,000 | 3 |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| *Subtotal, O&M Cost: Years 1-80* | | | | 1,209,100 | |
| Contingency (25%) | | | | 302,275 | |
| **Total O&M Cost: Years 1-80** | | | | 1,511,375 | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 9 | Pump | 7,500 | 67,500 | 4 |
| Extraction Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **113,300** | |
| Contingency (25%) | | | | 28,325 | |
| **Total O&M Cost: Each 5 Years** | | | | **141,625** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | 862,500 | |

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal I)

**3. Present Worth**

| | |
|---|---|
| **A. PW Groundwater Monitoring: Years 1-5** | **$7,796,296** |
| **B. PW Groundwater Monitoring: Years 6-80** | **$3,279,163** |
| **C. PW O&M: Years 1-80** | **$24,951,488** |
| **D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80** | **$414,772** |
| **E. PW O&M: Years 20, 40,60,80** | **$387,084** |
| **Total Present Worth Cost** | **$36,828,802** |
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$47,163,170** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | **Total Capital Cost** | 15,501,552 | 10,334,368 | 7,234,058 |
| 2. A. | **Total GW Monitoring Cost : Years 1-5** | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | **Total GW Monitoring Cost : Years 6-80** | 400,003 | 266,669 | 186,668 |
| C. | **Total Annual O & M Cost (Years 1-80)** | 2,267,063 | 1,511,375 | 1,057,963 |
| D. | **Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals** | 212,438 | 141,625 | 99,138 |
| E. | **Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals** | 1,293,750 | 862,500 | 603,750 |
| 3. A. | **PW Groundwater Monitoring : Years 1-5** | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | **PW Groundwater Monitoring : Years 6-80** | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | **PW O&M : Years 1-80** | 37,427,231 | 24,951,488 | 17,466,041 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 622,157 | 414,772 | 290,340 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 70,744,755 | 47,163,170 | 33,014,219 |



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# Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **I. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Groundwater Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 15 | Well | 24,000 | 360,000 | 4 |
| Extraction Well Pumps (installed) | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Extraction Well Piping (installed) | 18 | mile | 140,000 | 2,520,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,015,500** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (4200 GPM) | 1 | Lump Sum | 2,760,000 | 2,760,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 11 | Pump | 5,000 | 55,000 | 4 |
| **Subtotal, Treatment System** | | | | **3,635,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **6,779,980** | |
| **Indirect Cost** | | | | | |
| Construction Services (12% Direct) | | | | 813,598 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 542,398 | 4 |
| Contractor Profit (7%Direct) | | | | 474,599 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 677,998 | 4 |
| **Subtotal, Indirect Cost** | | | | **3,063,593** | |
| Contingencies (50% Direct and Indirect) | | | | 4,921,786 | |
| **Total Capital Cost** | | | | **14,765,359** | |

# Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | 213,335 | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | 266,669 | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (15 wells, 11 transfer pumps @ 50 hp each) | | | | | |
| 1300 hp x 0.75 kw/hp x 8760 hr/yr | 8,541,000 | kwhr | 0.07 | 597,870 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |



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# Cost Estimate for Groundwater Alternative 7: Groundwater Extraction
## (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@4200gpm (Includes Reactivation, Transportation, and Carbon Replacement) | 819,000 | lbs. | 1.00 | 819,000 | 3 |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,690,050** | |
| Contingency (25%) | | | | 422,513 | |
| **Total O&M Cost: Years 1-80** | | | | 2,112,563 | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Transfer Pumps | 11 | Pump | 5,000 | 55,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **185,500** | |
| Contingency (25%) | | | | 46,375 | |
| **Total O&M Cost: Each 5 Years** | | | | **231,875** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **1,380,000** | |
| Contingency (25%) | | | | 345,000 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **1,725,000** | |

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal II)

**3. Present Worth**

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $34,876,571 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $679,083 |
| E. PW O&M: Years 20, 40,60,80 | $774,169 |
| **Total Present Worth Cost** | **$47,405,281** |
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$62,170,640** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 22,148,038 | 14,765,359 | 10,335,751 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 3,168,844 | 2,112,563 | 1,478,794 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 347,813 | 231,875 | 162,313 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 2,587,500 | 1,725,000 | 1,207,500 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 52,314,856 | 34,876,571 | 24,413,599 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,018,625 | 679,083 | 475,358 |
| E. | PW O&M : Years 20, 40, 60, 80 | 1,161,253 | 774,169 | 541,918 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 93,255,960 | 62,170,640 | 43,519,448 |

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Groundwater Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 17 | Well | 24,000 | 408,000 | 4 |
| Extraction Well Pumps (installed) | 17 | Pump | 7,500 | 127,500 | 4 |
| Extraction Well Controls | 17 | Well | 1,200 | 20,400 | 4 |
| Extraction Well Piping (installed) | 19 | mile | 140,000 | 2,660,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,220,900** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (4910 GPM) | 1 | Lump Sum | 2,760,000 | 2,760,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, Treatment System** | | | | **3,645,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| **Total Direct Cost** | | | | **6,995,380** | |
| **Indirect Cost** | | | | | |
| Construction Services (12% Direct) | | | | 839,446 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Direct) | | | | 559,630 | 4 |
| Contractor Profit (7%Direct) | | | | 489,677 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Direct) | 1 | | | 699,538 | 4 |
| **Subtotal, Indirect Cost** | | | | **3,143,291** | |
| Contingencies (50% Direct and Indirect) | | | | 5,069,335 | |
| **Total Capital Cost** | | | | **15,208,006** | |

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | 213,335 | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | 266,669 | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (17 wells, 13 transfer pumps @ 50 hp each) | | | | | |
| 1500 hp x 0.75 kw/hp x 8760 hr/yr | 9,855,000 | kwhr | 0.07 | 689,850 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal III)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@4910gpm | 896,000 | lbs. | 1.00 | 896,000 | 3 |
| (Includes Reactivation, Transportation, and Carbon Replacement) | | | | | |
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,859,030** | |
| Contingency (25%) | | | | 464,758 | |
| **Total O&M Cost: Years 1-80** | | | | 2,323,788 | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 17 | Pump | 7,500 | 127,500 | 4 |
| Extraction Well Controls | 17 | Well | 1,200 | 20,400 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **212,900** | |
| Contingency (25%) | | | | 53,225 | |
| **Total O&M Cost: Each 5 Years** | | | | **266,125** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **1,380,000** | |
| Contingency (25%) | | | | 345,000 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **1,725,000** | |

## Cost Estimate for Groundwater Alternative 7: Groundwater Extraction (Target Cleanup Goal III)

. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $38,363,712 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $779,390 |
| E. PW O&M: Years 20, 40,60,80 | $774,169 |
| **Total Present Worth Cost** | **$50,992,729** |

| | |
|---|---|
| **4. TOTAL CAPITAL AND PRESENT WORTH COSTS** | **$66,200,735** |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | **Total Capital Cost** | 22,812,009 | 15,208,006 | 10,645,604 |
| 2. A. | **Total GW Monitoring Cost : Years 1-5** | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | **Total GW Monitoring Cost : Years 6-80** | 400,003 | 266,669 | 186,668 |
| C. | **Total Annual O & M Cost (Years 1-80)** | 3,485,681 | 2,323,788 | 1,626,651 |
| D. | **Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals** | 399,188 | 266,125 | 186,288 |
| E. | **Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals** | 2,587,500 | 1,725,000 | 1,207,500 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 57,545,568 | 38,363,712 | 26,854,598 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,169,085 | 779,390 | 545,573 |
| E. | PW O&M : Years 20, 40, 60, 80 | 1,161,253 | 774,169 | 541,918 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 99,301,103 | 66,200,735 | 46,340,515 |

## COST ESTIMATES FOR ALTERNATIVE 8
## GROUNDWATER EXTRACTION - SOIL EXCAVATION
## AND THERMAL TREATMENT

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Groundwater Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 9 | Well | 24,000 | 216,000 | 4 |
| Extraction Well Pumps (installed) | 9 | Pump | 7,500 | 67,500 | 4 |
| Extraction Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Extraction Well Piping (installed) | 14 | mile | 140,000 | 1,960,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **2,259,300** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (2490 GPM) | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, Treatment System** | | | | **2,235,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |

**Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal I)**

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Residuals Management | | | | | |
| Residuals Characterization (1 sample per 500 cy) | 6 | Each | $1,100 | $6,600 | 21 |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material (1/10 Excavation Volume) | 260 | Cubic Yard | $45 | $11,700 | 21 |
| **Subtotal, Residuals Management** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **$6,755,556** | |
| **Indirect Cost** | | | | | |
| Groundwater Extraction System | | | | | |
| Construction Services (12% Hy. Con. Direct) | | | | 554,854 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hy. Con. Direct) | | | | 369,902 | 4 |
| Contractor Profit (7% Hy. Con. Direct) | | | | 323,665 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Hy. Con. Direct) | 1 | | | 462,378 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **$2,265,799** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Subtotal, Indirect Cost** | | | | **2,954,224** | |
| Contingencies (50% Direct and Indirect) | | | | 4,854,890 | |
| **Total Capital Cost** | | | | **14,564,669** | |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| ***Total Annual Groundwater Monitoring Cost : Years 1-5*** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (9 wells, 7 transfer pumps @ 50 hp each) | | | | | |
| 800 hp x 0.75 kw/hp x 8760 hr/yr | 5,256,000 | kwhr | 0.07 | 367,920 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal I)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@2490gpm (Includes Reactivation, Transportation, and Carbon Replacement) | 568,000 | lbs. | 1.00 | 568,000 | 3 |
| *Troubleshooting* | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,209,100** | |
| Contingency (25%) | | | | 302,275 | |
| **Total O&M Cost: Years 1-80** | | | | **1,511,375** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 9 | Pump | 7,500 | 67,500 | 4 |
| Extraction Well Controls | 9 | Well | 1,200 | 10,800 | 4 |
| Transfer Pumps | 7 | Pump | 5,000 | 35,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **113,300** | |
| Contingency (25%) | | | | 28,325 | |
| **Total O&M Cost: Each 5 Years** | | | | **141,625** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 690,000 | 690,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **690,000** | |
| Contingency (25%) | | | | 172,500 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **862,500** | |
| **F. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal I)

3. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $24,951,488 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $414,772 |
| E. PW O&M: Years 20, 40,60,80 | $387,084 |
| F. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| Total Present Worth Cost | $36,912,764 |

| | |
|---|---|
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $51,477,434 |

### Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 21,847,004 | 14,564,669 | 10,195,269 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 2,267,063 | 1,511,375 | 1,057,963 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 212,438 | 141,625 | 99,138 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 1,293,750 | 862,500 | 603,750 |
| F. | Total Annual O & M Cost : Soil Excavation/Thermal Treatment : (Years 1-80) | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 37,427,231 | 24,951,488 | 17,466,041 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 622,157 | 414,772 | 290,340 |
| E. | PW O&M : Years 20, 40, 60, 80 | 580,626 | 387,084 | 270,959 |
| F. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 77,216,150 | 51,477,434 | 36,034,204 |

# Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Groundwater Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 15 | Well | 24,000 | 360,000 | 4 |
| Extraction Well Pumps (installed) | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Extraction Well Piping (installed) | 18 | mile | 140,000 | 2,520,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,015,500** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (4200 GPM) | 1 | Lump Sum | 2,760,000 | 2,760,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 11 | Pump | 5,000 | 55,000 | 4 |
| **Subtotal, Treatment System** | | | | **3,635,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Residuals Management | | | | | |
| Residuals Characterization (1 sample per 500 cy) | 6 | Each | $1,100 | $6,600 | 21 |
| Treated Soil Placement | 2600 | Cubic Yard | $5 | $13,000 | 21 |
| Oversize Material (1/10 Excavation Volume) | 260 | Cubic Yard | $45 | $11,700 | 21 |
| ***Subtotal, Residuals Management*** | | | | **$31,300** | |
| **Subtotal Soil Excavation and Treatment** | | | | **$2,131,776** | |
| **Total Direct Cost** | | | | **$8,911,756** | |
| **Indirect Cost** | | | | | |
| Groundwater Extraction System | | | | | |
| Construction Services (12% Hy. Con. Direct) | | | | 813,598 | 4 |
| Health & Safety | 1 | Lump Sum | 60,000 | 60,000 | 4 |
| Legal/Administration | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Mobilization/Demobilization (8% Hy. Con. Direct) | | | | 542,398 | 4 |
| Contractor Profit (7% Hy. Con. Direct) | | | | 474,599 | 4 |
| Procurement | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Remediation Work Plan | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Extraction System Design | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Groundwater Treatment Plans/Specifications | 1 | Lump Sum | 180,000 | 180,000 | 4 |
| Closure Plan | 1 | Lump Sum | 50,000 | 50,000 | 4 |
| Permits | 1 | Lump Sum | 75,000 | 75,000 | 4 |
| Process Control and Instrument. (10% Hy. Con. Direct) | 1 | | | 677,998 | 4 |
| **Subtotal, Hydraulic Containment System** | | | | **$3,063,593** | |
| Soil Excavation/Thermal Treatment | | | | | |
| Site Preparation/Restoration (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Health & Safety (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Contractor Profit (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Bonds and Insurance (1% Soil Rem. Direct) | | | | $21,318 | 21 |
| Permitting and Legal (5% Soil Rem. Direct) | | | | $106,589 | 21 |
| Design Engineering Thermal Treatment (Included in OU1) | | | | $0 | 21 |
| Soil Excavation Plans/Specifications (8% Soil Rem. Direct) | | | | $170,542 | 21 |
| Construction - Related Services (8% Soil Exc. only Direct) | | | | $6,257 | 21 |
| **Subtotal, Soil Excavation/Thermal Treatment** | | | | **$688,425** | |
| Equipment Salvage (Included in OU1 costs) | | | | | |
| Dismantling | | | | $0 | 21 |
| Pre-Process Equipment | | | | $0 | 21 |
| Pre-Process Structure | | | | $0 | 21 |
| **Subtotal, Equipment Salvage** | | | | **$0** | |
| **Subtotal, Indirect Cost** | | | | **3,752,018** | |
| Contingencies (50% Direct and Indirect) | | | | 6,331,887 | |
| **Total Capital Cost** | | | | **18,995,660** | |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry, Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (15 wells, 11 transfer pumps @ 50 hp each) | | | | | |
| 1300 hp x 0.75 kw/hp x 8760 hr/yr | 8,541,000 | kwhr | 0.07 | 597,870 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@4200gpm (Includes Reactivation, Transportation, and Carbon Replacement) | 819,000 | lbs. | 1.00 | 819,000 | 3 |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation
## (Target Cleanup Goal II)

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,690,050** | |
| Contingency (25%) | | | | 422,513 | |
| **Total O&M Cost: Years 1-80** | | | | **2,112,563** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 15 | Pump | 7,500 | 112,500 | 4 |
| Extraction Well Controls | 15 | Well | 1,200 | 18,000 | 4 |
| Transfer Pumps | 11 | Pump | 5,000 | 55,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **185,500** | |
| Contingency (25%) | | | | 46,375 | |
| **Total O&M Cost: Each 5 Years** | | | | **231,875** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **1,380,000** | |
| Contingency (25%) | | | | 345,000 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **1,725,000** | |
| **F. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

# Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation (Target Cleanup Goal II)

**3. Present Worth**

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $34,876,571 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $679,083 |
| E. PW O&M: Years 20, 40,60,80 | $774,169 |
| F. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| Total Present Worth Cost | $47,489,243 |

| | |
|---|---|
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $66,484,904 |

**Summary of Estimated Costs**

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 28,493,491 | 18,995,660 | 13,296,962 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | *Total GW Monitoring Cost : Years 6-80* | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 3,168,844 | 2,112,563 | 1,478,794 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 347,813 | 231,875 | 162,313 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 2,587,500 | 1,725,000 | 1,207,500 |
| F. | *Total Annual O & M Cost : Soil Excavation/Thermal Treatment : (Years 1-80)* | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 52,314,856 | 34,876,571 | 24,413,599 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,018,625 | 679,083 | 475,358 |
| E. | PW O&M : Years 20, 40, 60, 80 | 1,161,253 | 774,169 | 541,918 |
| F. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 99,727,355 | 66,484,904 | 46,539,433 |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation
## Target Cleanup Goal III

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **1. Capital Cost** | | | | | |
| **Direct Cost** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC Filtration Equipment | 10 | Family | 4,500 | 45,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **45,000** | |
| Grounwater Extraction Well System | | | | | |
| Extraction Wells (12" dia., 125 TD) | 17 | Well | 24,000 | 408,000 | 4 |
| Extraction Well Pumps (installed) | 17 | Pump | 7,500 | 127,500 | 4 |
| Extraction Well Controls | 17 | Well | 1,200 | 20,400 | 4 |
| Extraction Well Piping (installed) | 19 | mile | 140,000 | 2,660,000 | 4 |
| Surveying | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| **Subtotal, Containment Well System** | | | | **3,220,900** | |
| GAC Treatment System | | | | | |
| Treatability Study | 1 | Lump Sum | 30,000 | 30,000 | 3 |
| Pilot Study | 1 | Lump Sum | 150,000 | 150,000 | 4 |
| Treatment System (4910 GPM) | 1 | Lump Sum | 2,760,000 | 2,760,000 | 3 |
| Building | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| Storage Tank (0.8M gal) | 2 | tank | 270,000 | 540,000 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, Treatment System** | | | | **3,645,000** | |
| Discharge System | | | | | |
| Discharge Piping (installed) | 1 | mile | 84,480 | 84,480 | 4 |
| **Subtotal, Discharge System** | | | | **84,480** | |
| Soil Excavation and On-site Hauling | | | | | |
| Excavation | 2600 | Cubic Yard | $24 | $62,400 | 21 |
| Ordnance Management | | | 10% | $6,240 | 21 |
| Confirmation Sampling (1 sample per 100cy) | 26 | Each | $368 | $9,568 | 21 |
| **Subtotal, Soil Excavation** | | | | **$78,208** | |
| Thermal Treatment | | | | | |
| Pretreatment Processing (Included in OU1 costs) | | | | | |
| Grinder | | Lump Sum | $0 | $0 | 21 |
| Conveyor | | Lump Sum | $0 | $0 | 21 |
| Installation | | | $0 | $0 | 21 |
| Pre-Processing Structure (Included in OU1 costs) | | | | | |
| Structure | | Lump Sum | $0 | $0 | 21 |
| Floor | | Lump Sum | $0 | $0 | 21 |
| Installation | | Lump Sum | $0 | $0 | 21 |
| Trial Burn (Included in OU1 costs) | | Lump Sum | $0 | $0 | 21 |
| Thermal Treatment | | | | | |
| Soil Characterization (1sample per 500 cy) | 6 | Each | $50 | $300 | 21 |
| Treatment Process ($500/ton, 1.548 cy/ton) | 2600 | Cubic Yard | $774 | $2,012,400 | 21 |
| Treatment Verification Sampling (1 sample per 100 cy) | 26 | Each | $368 | $9,568 | 21 |
| Mobilization/Demobilization | | Lump Sum | $0 | $0 | 21 |
| **Subtotal, Thermal Treatment** | | | | **$2,022,268** | |



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## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation
## Target Cleanup Goal III

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| **2. Annual Cost** | | | | | |
| **A. Groundwater Monitoring : Years 1-5** | | | | | |
| Groundwater Monitoring (Quarterly Sampling) | | | | | |
| Project Management (4 events/yr.) | 380 | Person Hour | 115 | 43,700 | 1 |
| Groundwater Analyses (97 wells x 4 events/yr.) | 388 | Well | 2,000 | 776,000 | 1 |
| Mobilization/Demobilization (4 events/yr.) | 1,025 | Person Hour | 70 | 71,750 | 1 |
| Field Personnel (4 events/yr.) | 3,200 | Person Hour | 70 | 224,000 | 1 |
| Vehicles & Field Equipment (4 events/yr.) | 4 | Each | 28,800 | 115,200 | 1 |
| Data Management (4 events/yr.) | 350 | Person Hour | 80 | 28,000 | 1 |
| Data Validation (4 events/yr.) | 1,500 | Person Hour | 100 | 150,000 | 1 |
| Report (4 events/yr.) | 900 | Person Hour | 80 | 72,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 1-5** | | | | **1,480,650** | |
| Contingency (25%) | | | | 370,163 | |
| **Total Annual Groundwater Monitoring Cost : Years 1-5** | | | | **1,850,813** | |
| **B. Groundwater Monitoring : Years 6-80** | | | | | |
| Groundwater Monitoring (Annual Sampling) | | | | | |
| Project Management (1 event/yr.) | 57 | Person Hour | 115 | 6,555 | 1 |
| Groundwater Analyses (48 wells x 1 event) | 48 | Well | 2,000 | 96,000 | 1 |
| Mobilization/Demobilization (1 event/yr.) | 192 | Person Hour | 70 | 13,440 | 1 |
| Field Personnel (1 event/yr.) | 480 | Person Hour | 70 | 33,600 | 1 |
| Vehicles & Field Equipment (1 event/yr.) | 1 | Each | 25,000 | 25,000 | 1 |
| Data Management (1 event/yr.) | 53 | Person Hour | 80 | 4,240 | 1 |
| Data Validation (1 event/yr.) | 225 | Person Hour | 100 | 22,500 | 1 |
| Report (1 event/yr.) | 150 | Person Hour | 80 | 12,000 | 1 |
| **Subtotal, Groundwater Monitoring Cost : Years 6-80** | | | | **213,335** | |
| Contingency (25%) | | | | 53,334 | |
| **Total Annual Groundwater Monitoring Cost : Years 6-80** | | | | **266,669** | |
| **C. O&M COST : Years 1-80** | | | | | |
| Point of Entry Treatment Potable Water Supply | | | | | |
| GAC filtration unit | | | | | |
| Carbon Purchase | 10 | Family | 200 | 2,000 | |
| Carbon Testing | 10 | Family | 240 | 2,400 | |
| Labor | 10 | Family | 400 | 4,000 | |
| **Subtotal, Point of Entry Treatment** | | | | **8,400** | |
| Effluent Sampling | | | | | |
| Effluent Analyses | 52 | Sample | 2,000 | 104,000 | 4 |
| Effluent Sampling Personnel (4 hrs./wk) | 208 | Person Hour | 70 | 14,560 | 4 |
| Effluent Data Management (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Effluent Reporting (2 hrs./wk) | 104 | Person Hour | 80 | 8,320 | 4 |
| Remediation Management | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Extraction Well Maintenance | 1 | Lump Sum | 15,000 | 15,000 | 4 |
| Transfer Pump Maintenance | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Treatment System | | | | | |
| Electrical (17 wells, 13 transfer pumps @ 50 hp each) | | | | | |
| 1500 hp x 0.75 kw/hp x 8760 hr/yr | 9,855,000 | kwhr | 0.07 | 689,850 | 4 |
| Labor - 24 hr/wk x 52 wk/yr | 1,248 | Person Hour | 60 | 74,880 | 4 |
| Waste Materials Disposal | 1 | Lump Sum | 7,500 | 7,500 | 4 |
| Maintenance Materials | 1 | Lump Sum | 5,000 | 5,000 | 4 |
| Granular Activated Carbon (GAC)@4910gpm (Includes Reactivation, Transportation, and Carbon Replacement) | 896,000 | lbs. | 1.00 | 896,000 | 3 |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation Target Cleanup Goal III

| Cost Item | Quantity | Unit | Unit Cost,$ | Total Base Cost, $ | Reference |
|---|---|---|---|---|---|
| Troubleshooting | | | | | |
| 8 hrs/mo x 12 mo/yr | 96 | Person Hour | 75 | 7,200 | 4 |
| **Subtotal, O&M Cost: Years 1-80** | | | | **1,859,030** | |
| Contingency (25%) | | | | 464,758 | |
| **Total O&M Cost: Years 1-80** | | | | **2,323,788** | |
| **D. O&M Cost: Pumps and Control Replacement : 5 Year Intervals** | | | | | |
| Equipment Replacement | | | | | |
| Extraction Well Pumps | 17 | Pump | 7,500 | 127,500 | 4 |
| Extraction Well Controls | 17 | Well | 1,200 | 20,400 | 4 |
| Transfer Pumps | 13 | Pump | 5,000 | 65,000 | 4 |
| **Subtotal, O&M Cost: Each 5 Years** | | | | **212,900** | |
| Contingency (25%) | | | | 53,225 | |
| **Total O&M Cost: Each 5 Years** | | | | **266,125** | |
| **E. O&M Cost: GAC Treatment System Replacement: 20 Year Intervals** | | | | | |
| GAC Treatment System Replacement | 1 | Lump Sum | 1,380,000 | 1,380,000 | 3 |
| **Subtotal, O&M Cost: Each 20 Years** | | | | **1,380,000** | |
| Contingency (25%) | | | | 345,000 | |
| **Total Annual O&M Cost: Each 20 Years** | | | | **1,725,000** | |
| **F. O&M Cost: Soil Removal and Thermal Treatment'** | | | | | |
| Soil Removal and Thermal Treatment | 1 | Lump Sum | 100,000 | 100,000 | 4 |
| **Total Annual O&M Cost : Soil Removal and Thermal Treatment** | | | | **100,000** | |

## Cost Estimate for Groundwater Alternative 8: Groundwater Extraction and Soil Excavation
## Target Cleanup Goal III

`. Present Worth

| | |
|---|---|
| A. PW Groundwater Monitoring: Years 1-5 | $7,796,296 |
| B. PW Groundwater Monitoring: Years 6-80 | $3,279,163 |
| C. PW O&M: Years 1-80 | $38,363,712 |
| D. PW O&M: Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | $779,390 |
| E. PW O&M: Years 20, 40,60,80 | $774,169 |
| F. PW Soil Removal and Thermal Treatment O&M : Years 1-80 | $83,962 |
| Total Present Worth Cost | $51,076,691 |

| | |
|---|---|
| 4. TOTAL CAPITAL AND PRESENT WORTH COSTS | $70,514,998 |

### Summary of Estimated Costs

| | | +50% Range Base Cost, $ | Base Cost, $ | -30% Range Base Cost, $ |
|---|---|---|---|---|
| 1. | Total Capital Cost | 29,157,461 | 19,438,307 | 13,606,815 |
| 2. A. | Total GW Monitoring Cost : Years 1-5 | 2,776,219 | 1,850,813 | 1,295,569 |
| B. | Total GW Monitoring Cost : Years 6-80 | 400,003 | 266,669 | 186,668 |
| C. | Total Annual O & M Cost (Years 1-80) | 3,485,681 | 2,323,788 | 1,626,651 |
| D. | Total O&M Cost : Pumps and Control Replacement: 5 Year Intervals | 399,188 | 266,125 | 186,288 |
| E. | Total O&M Cost : GAC Treatment System Replacement: 20 Year Intervals | 2,587,500 | 1,725,000 | 1,207,500 |
| F. | Total Annual O & M Cost : Soil Excavation/Thermal Treatment : (Years 1-80) | 150,000 | 100,000 | 70,000 |
| 3. A. | PW Groundwater Monitoring : Years 1-5 | 11,694,443 | 7,796,296 | 5,457,407 |
| B. | PW Groundwater Monitoring : Years 6-80 | 4,918,745 | 3,279,163 | 2,295,414 |
| C. | PW O&M : Years 1-80 | 57,545,568 | 38,363,712 | 26,854,598 |
| D. | PW O&M : Years 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 | 1,169,085 | 779,390 | 545,573 |
| E. | PW O&M : Years 20, 40, 60, 80 | 1,161,253 | 774,169 | 541,918 |
| F. | PW Soil Excavtion/Thermal Treatment O&M : Years 1-80 | 125,943 | 83,962 | 58,773 |
| 4. | TOTAL CAPITAL AND PRESENT WORTH COSTS | 105,772,498 | 70,514,998 | 49,360,499 |

## APPENDIX M
## ASSUMPTIONS AND CALCULATIONS FOR AIR SPARGING EVALUATION

## APPENDIX M
## ASSUMPTIONS AND CALCULATIONS FOR AIR SPARGING EVALUATION

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Assumptions related to design of an in-situ aeration (air sparging) system are presented below. Supporting calculations are also presented in this Appendix. **Calculation 1** presents the mass of VOCs within the area of influence of one injection well. **Calculation 2** presents the average concentration of VOCs in extracted air required to remove the entire mass of VOCs from the area of influence of one horizontal injection well in 24 hours. **Calculation 3** presents an estimate of the time required for contaminated groundwater to pass into 50 percent of the horizontal area of influence of a horizontal injection well. Calculation 3 also presents an estimate of the length of time required for the groundwater plume to pass once across the horizontal wells shown in **Drawing M-1**. **Calculation 4** presents a range of estimates of the mass of VOCs which would be removed with the proposed air sparging system in one year.

### ASSUMPTIONS

- In-situ aeration of groundwater would be southeast of the Atlas Missile Area, across the shallow groundwater plume containing TCE.

- **Drawing M-1** in this Appendix shows the conceptual location of the air sparging wells across the leading edge of the groundwater plume.

- Horizontal injection wells shown on **Drawing M-1** are each 300 feet long, which was the same length as studies in the Savannah River Integrated Demonstration Site, Department of Energy, June 1992 (Savannah River Site). Many of the assumptions and results from the Savannah River Study were utilized to evaluate air sparging for the Mead site. A pilot study would be completed during the design phase of an air sparging system to determine variables such as well length and diameter, area of influence of wells, and rate of extraction of VOCs from an air sparging system.

- Each horizontal injection well system includes a 500 cfm pump to inject air into the system.

- Horizontal injection wells would be positioned at depths of approximately 80 feet.

- A total of 15 air sparging wells and 90 vertical extraction wells would be utilized in the in-situ aeration (air sparging) system.

- The area of influence of each horizontal injection well in groundwater is assumed to be 300 feet by 60 feet by 35 feet. This is the same area of influence seen in the Savannah River Site. A pilot study would define the actual area of influence for horizontal wells installed at this Site.

- Based on the average concentrations of TCE in the groundwater in the Atlas Missile Area (2,675 $\mu$g/L), approximately 105 pounds of TCE would be present within the area of influence of each horizontal injection well.

- Based on flow rates of the air injection and extraction wells, it is assumed that VOCs in the area of influence of the horizontal injection well would be removed in two days.

- The air sparging system would be operated in a pulsed manner to optimize recovery of VOCs. Based on the estimated groundwater velocity for this aquifer (2 feet/day), the estimated time the system would be off is 15 days. This would allow groundwater to move into 50 percent (30 feet) of the estimated horizontal area of influence of the horizontal injection well (60 feet). According to calculations, the air sparging system would be on 12 percent of the time and off 88 percent of the time.

- A total of 15 horizontal injection wells would recover an estimated 26 pounds of VOCs per well per day for a total of 16,380 pounds of VOCs per year based on an estimated combined 42 days of operation annually.

- An estimated 3 pounds of granular activated carbon (GAC) would be used for each pound of VOCs recovered for a total of 49,140 pounds of GAC per year. This GAC would be used to remove VOCs from air extracted from the air sparging system.

**CALCULATIONS**

1. Mass of VOCs within the area of influence of one air injection well.

Define ug. $ug := \frac{mg}{1000}$

One well - 500 cfm ($ft^3$/minute)

VOC concentration is 250 ug/liter.

Area of Influence = $(300 \cdot ft) \cdot (60 \cdot ft) \cdot (35 \cdot ft) = 1.784 \cdot 10^7 \cdot liter$

$$\left(1.784 \cdot 10^7 \cdot liter\right) \cdot \left(250 \cdot \frac{ug}{liter}\right) = 9.833 \cdot lb$$

9.833·lb VOC in area of influence of one air sparging well

2. The average concentration in extracted air required to remove the mass of VOCs from area of influence of one air sparging well.

Six - 100 cfm vapor extraction wells.

$$\frac{9.833 \cdot lb}{(6) \cdot \left(100 \cdot \frac{ft^3}{min}\right) \cdot (1 \cdot day)} = 182 \cdot \frac{mg}{m^3}$$

182 mg/m3 over 24 hours would be required to remove 9.833 lb of VOCs from area of influence of each horizontal injection well.

In the Savannah River study, an estimated average of 2,225 $mg/m^3$ was removed via the 575 cfm extraction well.

It appears feasible that the VOCs within the area of influence of each horizontal injection well could be removed in one day. For cost estimating purposes, it is assumed that it would take two days to remove these VOCs. A pilot study at the Site would provide data for recovery of VOCs from an air sparging system.

3. The particle velocity which has been calculated for groundwater at the Site is approximately 2 feet/day. The horizontal area of influence of the air sparging wells is estimated to be 60 feet, based on the results of the Savannah River Pilot Study. It is estimated that groundwater flow through one-half the horizontal area of influence of the wells would take 15 days (30 feet). It is assumed that it would take 30 years for one pass of the contaminated groundwater in the former Atlas Missile Area to cross the horizontal injection wells shown on **Drawing M-1**. For purposes of this evaluation, the project life was assumed to be 30 years.

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4. Mass of VOCs estimated to be removed with the proposed air sparging system in one year.

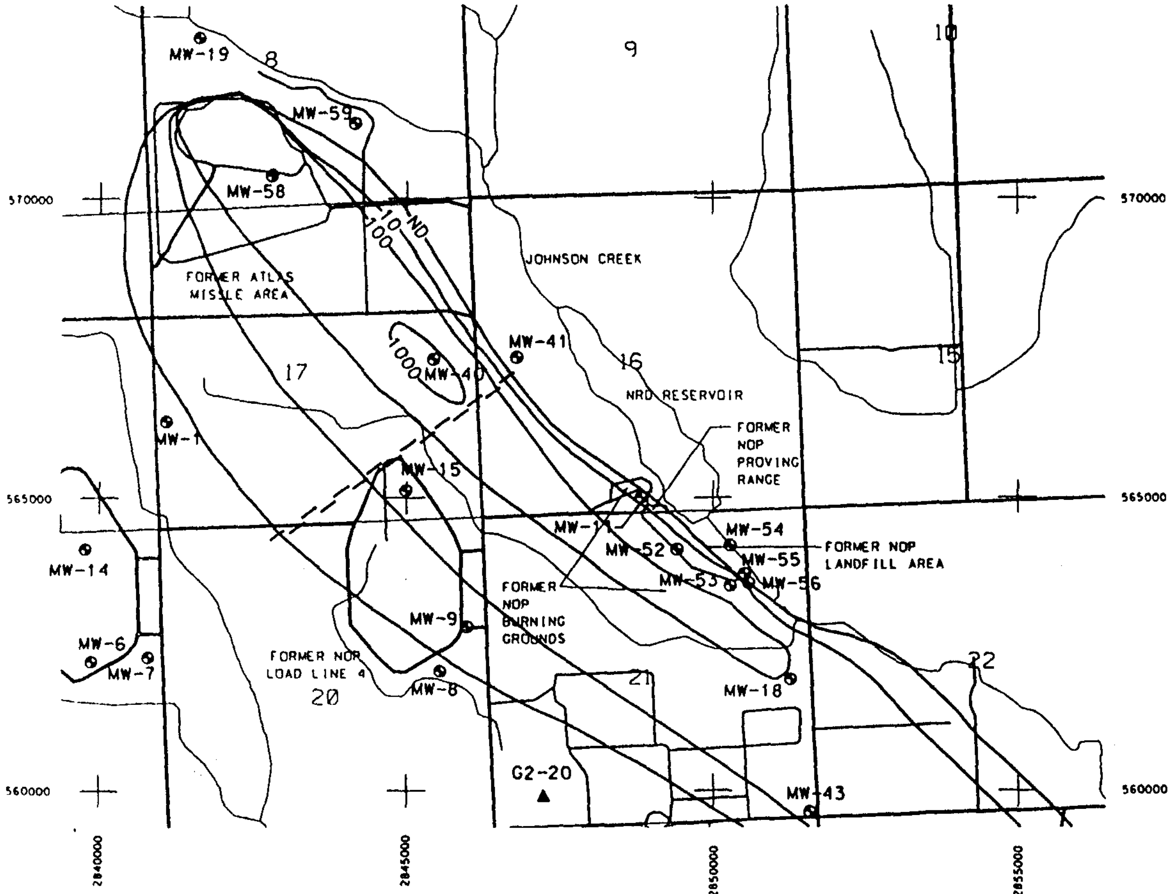
Estimated 9.833 lb of VOCs in the area of influence of each of the 15 air sparging wells. This is based on an average concentration (2,675 ug/liter) of TCE in shallow groundwater in the former Atlas Missile Area. The air sparging system would come on when contaminated groundwater had moved into 50 percent of the estimated horizontal area of influence (30 feet) of the injection well. This would result in 4.92 lb VOCs per well per day removed from groundwater. Assume that there are 15 air sparging wells.

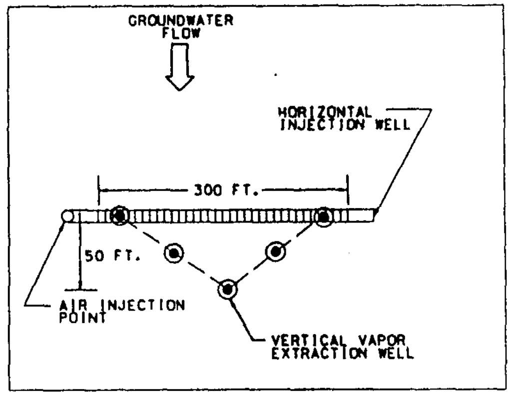
$$(15) \cdot (42 \cdot day) \cdot \left(4.92 \cdot \frac{lb}{day}\right) = 3100 \cdot lb$$

If it is assumed that water continues to flow horizontally even when the air sparging system is operating, the mass of VOCs removed by 15 wells in one years would be:

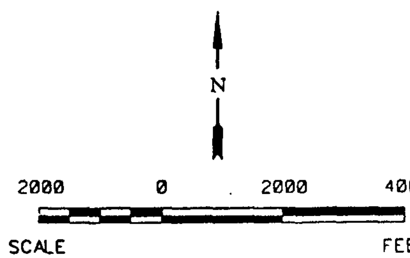
Groundwater velocity, 2 feet/day, times one year, 365 days - 730 feet/year
15 wells, each 300 feet long - 4,500 feet of horizontal wells

$$(4500 \cdot ft) \cdot \left(730 \cdot \frac{ft}{yr}\right) \cdot (35 \cdot ft) \cdot \left(2675 \cdot \frac{ug}{liter}\right) \cdot (1 \cdot yr) = 19200 \cdot lb$$




TYPICAL WELL CONFIGURATION
PLAN VIEW
(NOT TO SCALE)




## LEGEND:

| | |
|---|---|
| ——— | APPROXIMATE TCE CONCENTRATION CONTOUR IN $\mu$g/L, INTERMEDIATE PLUME |
| ⊙ | VERTICAL WELL |
| — | HORIZONTAL INJECTION WELL |
| ⊗ MW-10 | GROUNDWATER MONITORING WELL CLUSTER LOCATION |
| 36 | SECTION |
| T 14 N | TOWNSHIP 14 NORTH |
| R 9 E | RANGE 9 EAST |

NOTES:

1. IS HORIZONTAL WELLS 300 FEET LONG AND 60 FEET DEEP.
2. TCE CONCENTRATIONS SHOWN ON THIS DRAWING REPRESENT AUGUST 1992 GROUNDWATER SAMPLING DATA.
3. DETECTION LIMIT (ND) FOR TCE IS 1.0 $\mu$g/L.
4. NORTHING AND EASTING LINES ARE TIED TO NEBRASKA STATE PLANAR COORDINATES.

SOURCE: USGS 7.5 MIN QUADRANGLES (1969) FOR MEAD, ASHLAND EAST, ASHLAND WEST, AND WANN 1927 NAD, 1929 NGVD.

| Revisions | | | |
|---|---|---|---|
| Symbol | Descriptions | Date | Appr'd |
| | | | |

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Overland Park, Kansas

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|---|---|
| Designed by: M.D.F. | U.S. Army Corps of Engineers — FEASIBILITY STUDY FOR OPERABLE UNIT NO. 2 - GROUNDWATER FMR. NEBRASKA ORDNANCE PLANT - MEAD NE. |
| Drawn by: D.R.T. | AIR SPARGING SYSTEM CONCEPTUAL LAYOUT |
| Checked by: MDF | Scale: 1 IN = 2000 FT — Sheet number: 1 |
| Submitted by: [signature] | December 1994 — Dwg. No.: M-1 |

MCS FILE: 92FS-36

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