Summary of Infrastructure Information obtained by WEST Consultants

Agency:
Kansas City, Kansas

Infrastructure:
Bridge

Contact Person:
Abe Shiraci, Public Works Department Engineering Division

Telephone Number:
(816) 274-2079

Telephone discussion:
Only bridge is the Hwy 269 Bridge (Chouteau Bridge). The Bridge is over 100 year old. The bridge is in the process of being replaced (2002-2003). No known scour problems.

Material Received:
Bridge drawings

Summary of Infrastructure Information obtained by WEST Consultants

Company:
Williams Brothers Pipeline Company

Infrastructure:
Pipelines

Contact Person:
Rodney W. Kilgore, P.E.,
Manager of Pipeline Engineering,
Mid-Continent Region

Telephone Number:
(918) 599-4043
(918) 560-9199

Materials sent from WEST:
List of Pipelines
Vicinity Map of Project Area
Questionnaire

Material Received:
Letter explaining the status of the pipelines according to the latest field inspection. Answers to the questionnaire and location maps.

Comments:
Mr. Kilgore discusses the state of the pipelines in his letter. The company has six pipelines at approximately RM 372.3. All of these pipelines are spare except for one that accommodates a fiber optic telecommunications cable. According to a recent underwater inspection, some parts of the pipelines are exposed and therefore sensitive to any changes in bed elevation.

Correspondence material is included on following pages.

Williams

ENERGY SERVICES
1717 South Boulder Avenue
P.O. Box 21628
Tulsa, Oklahoma 74121-1628

February 4, 1999

West Consultants, Inc.
12509 Bel-Red Road, Suite 100
Bellevue, WA 98005

Subject: Questionnaire

Reference: Missouri River Levee Unit L385

Dear Mr. Thomas R. Grindeland,

Pursuant to your recent request, I respectfully submit the following for your information and kind consideration. As I understand, the Kansas City District is planning to construct a levee. Material for the levee will be dredged from the Missouri River channel. West Consultants, Inc., is assessing the potential impacts to the surrounding infrastructure.

Williams owns and operates several high-pressure refined petroleum products pipelines that traverse the Missouri River in the areas affected by the proposed levee project. Attached, please find Survey Drawing S-5692 that accurately depicts the alignment of our pipelines traversing the river. The corridor includes two 12" diameter and four 8" diameter pipelines. All of these pipelines, except for one of the 8" diameter pipelines, are spare. The subject 8" pipeline accommodates fiber-optic for telecommunications. The active pipelines traverse the river via the northbound Platte Purchase Bridge.

The pipeline corridor traversing the river below the channel was recently inspected by Central States Underwater. The inspection revealed a couple of sections of the pipelines that were exposed. The overall results of the inspection indicate that the pipelines are relatively shallow as they traverse the river. Therefore, dredging operations would pose a potentially hazardous situation.

The pipelines are manufactured from carbon steel and are designed in accordance with ANSI B31.4 and D.O.T. Part 195. The following is in response to the questionnaire provided:

1. Owner/Operator: Williams is the owner and operated for the pipelines traversing the Missouri River as indicated on the attached drawings.

2. Type of structure: Several high-pressure refined petroleum products pipelines. Products include distillates, gasolines, propane, and butane.

3. RM:

4. Years operated: One of the 8" pipelines was installed in 1931. The other pipelines were installed in 1950.

5. Describe any historic effects of dredging on the structure: To my knowledge, dredging of the channel has not be done since the pipelines were installed.

6. Observed changes in the river affecting the structure: Strong currents due to flood conditions have a detrimental affect on pipelines. The currents tend to change the depth of the main channel, often times exposing the pipelines. Floating debris gets hung on the exposed pipelines creating excessive stresses. All of the subject pipelines were installed using the conventional dredging method. Therefore, the pipelines' depth will not be sufficient to accommodate levee dredging operations.

7. Construction drawing of structure: Attached.

8. Historic monitoring data: Periodic underwater inspections to determine amount and magnitude of exposure.

9. What is critical feature of structure: Depth of pipelines under the river bed.

If you have any questions, please contact me at (918) 599-4043.

Sincerely,

Rodney W. Kilgore, P.E.
Manager of Pipeline Engineering
Mid-Continent Region

CC w/o attachments: K. Bodenhamer
B. Young
B. Lowry
T. Hampton
H. Wilhoit

Dale Schmidtberger, P.E.
The Larkin Group
9233 Ward Parkway, Suite 300
Kansas City, MO 64114

Richard L. Bateman
700 Federal Building
601 East 12th Street
Kansas City, MO 64106

Summary of Infrastructure Information obtained by WEST Consultants

Company:
Williams Brothers Natural Gas Company
Infrastructure:
Pipelines
Contact Person:
Doug Riney
Area Manager
Telephone Number:
(913) 422-6301
Comments:
Mr. Riney identified Williams Brothers Natural Gas Company on following map. No detailed information is available.

425-646-0570

Williams

GAS PIPELINE
Central

FAX TRANSMISSION

TO: SIT GARDARSSON DATE:

COMPANY: WEST CONSULTANTS

FROM: DOUG RINEY

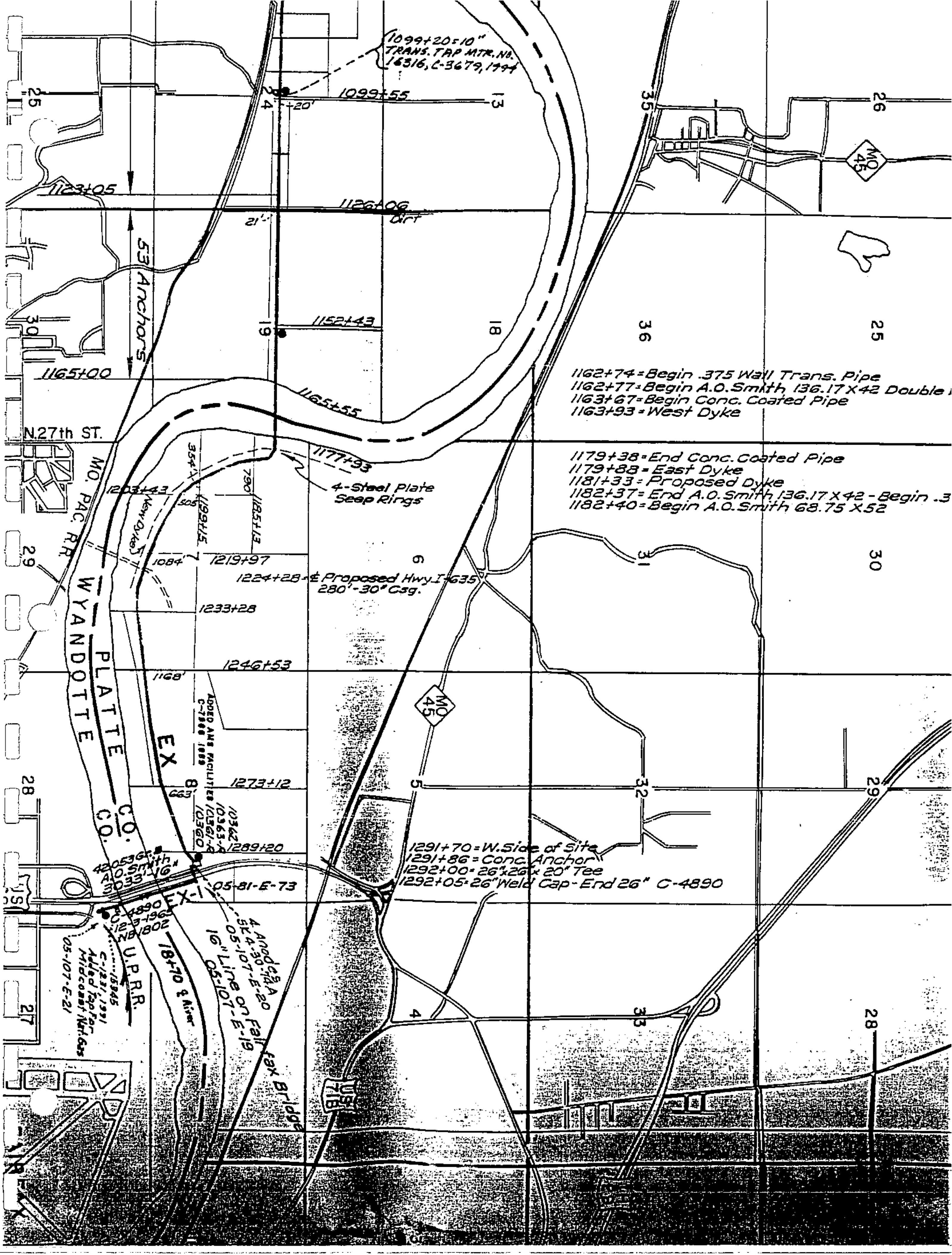
SUBJECT:

PAGES (including cover): 2

Notes:

ATTACHED IS A 2"/MILE MAP DEPICTING WILLIAMS 26" NATURAL GAS PIPELINE. IT APPEARS THAT THE LINE CROSSES THE MO. RIVER APPROXIMATELY 20 FEET NORTH OF THE 1/2 SECTION LINE OF SECTION 19-T10S-R25E WYANDOTTE COUNTY, KS INTO SECTION 7-T50N-R33W PLATTE COUNTY MO.

Williams Gas Pipeline Central, 8195 Cole Parkway, Shawnee, KS 66227
Phone: 913-422-6301 Fax: 913-422-4838



1099+20=10" TRANS. TAP MTR. NO. 16316, C-3679, 1494
1099+55
1123+05
1126+06
Dirt
53 Anchors
1152+43
1165+00
1165+55
N.27th ST.
1177+93
4-Steel Plate Seep Rings
MO. PAC. R.R.
1203+43
New Dyke
1199+15
1185+13
1219+97
1224+28 = ℄ Proposed Hwy. I-635 280'-30" Csg.
1233+28
1246+53
1273+12
1289+20
MO 45
1162+74 = Begin .375 Wall Trans. Pipe
1162+77 = Begin A.O.Smith 136.17 X 42 Double
1163+67 = Begin Conc. Coated Pipe
1163+93 = West Dyke
1179+38 = End Conc. Coated Pipe
1179+88 = East Dyke
1181+33 = Proposed Dyke
1182+37 = End A.O.Smith 136.17 X 42 - Begin .3
1182+40 = Begin A.O.Smith 68.75 X 52
1291+70 = W. Side of Site
1291+86 = Conc. Anchor
1292+00 = 26" x 26" x 20" Tee
1292+05 = 26" Weld Cap - End 26" C-4890
WYANDOTTE CO.
PLATTE CO.
EX
EX-1
05-81-E-73
U.P.R.R.
4 Anodes
05-107-E-20
16" Line on Fairfax Bridge
05-107-E-19
18+70 ℄ River
C-4890
C-1231, 1991 Added Tap for Midcoast Nat. Gas
05-107-E-21
US 71B
US 69

Summary of Infrastructure Information obtained by WEST Consultants

MEETING SUMMARY

Project: Missouri River Levee Unit L385 Sediment Analysis

Attendance: Tom Grindeland, WEST Consultants, Inc.
Sigurdur Gardarsson, WEST Consultants, Inc.
Ken Millsap, Plant Manager, Plant 11, Holliday Sand and Gravel

Date: 1/5/99

Location: Holliday Sand and Gravel, Plant 11.

Purpose: The purpose of the meeting was to gather information regarding dredging practices on the Missouri River in the vicinity of the project.

A meeting was held with the manager (Ken Milsap) of Holliday Sand and Gravel Plant No. 11. He indicated that the sediment characteristics and dredging impacts vary with the specific location along the channel. Fine sediments are found along the inside of bends and between dikes. Coarser sediments (gravels) are found closer to the main navigation channel.

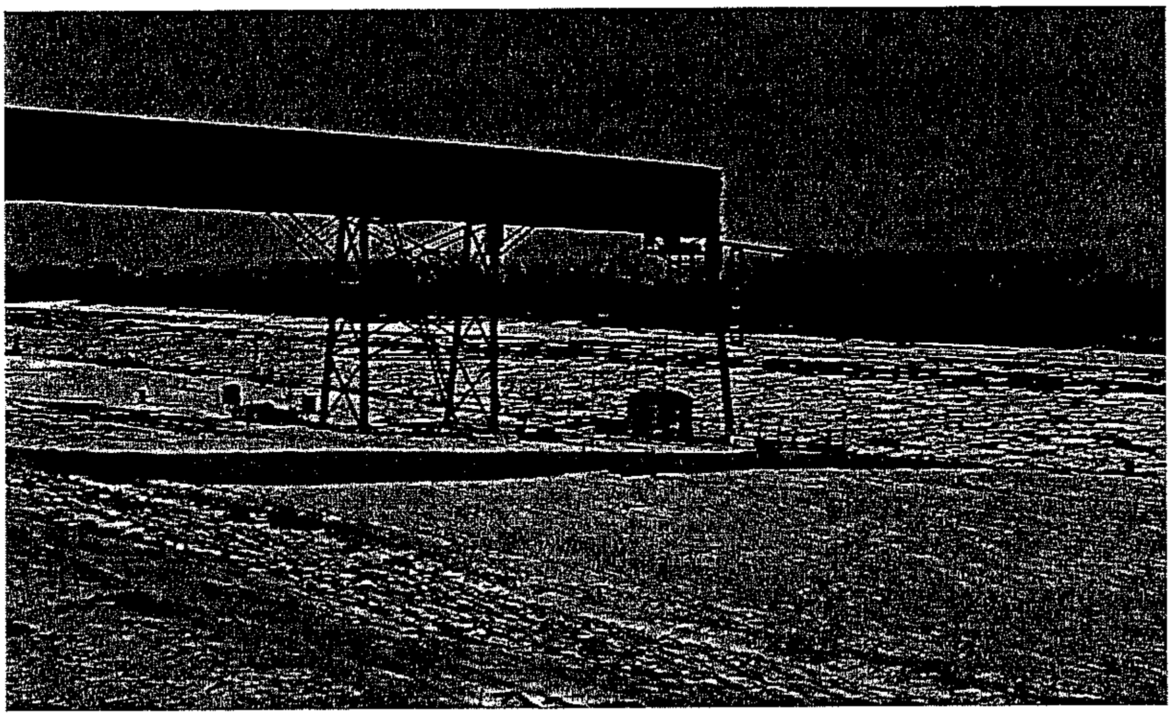
The company dredge is capable of dredging to a depth of 45 feet from the water surface. Accordingly, in a depth of 10 feet, the dredge can reach a depth of 35 feet. They sometimes dredge between dikes, within the specified constraints. Finer materials are generally found in those locations. Typically, a scour hole exists just downstream of the tip of each dike. The company dredge is often moored in this location as it prevents grounding of the dredge.

Locations dredged close to the navigation channel are said to fill rapidly with sediments. A dredge hole with a volume of 7,500 yards is said to fill in over night. The total amount of sediment dredged from the river at this location is about 1,000,000 tons/year. To his knowledge, the dredging has not impacted surrounding infrastructure. He had been at this site for 4 years.

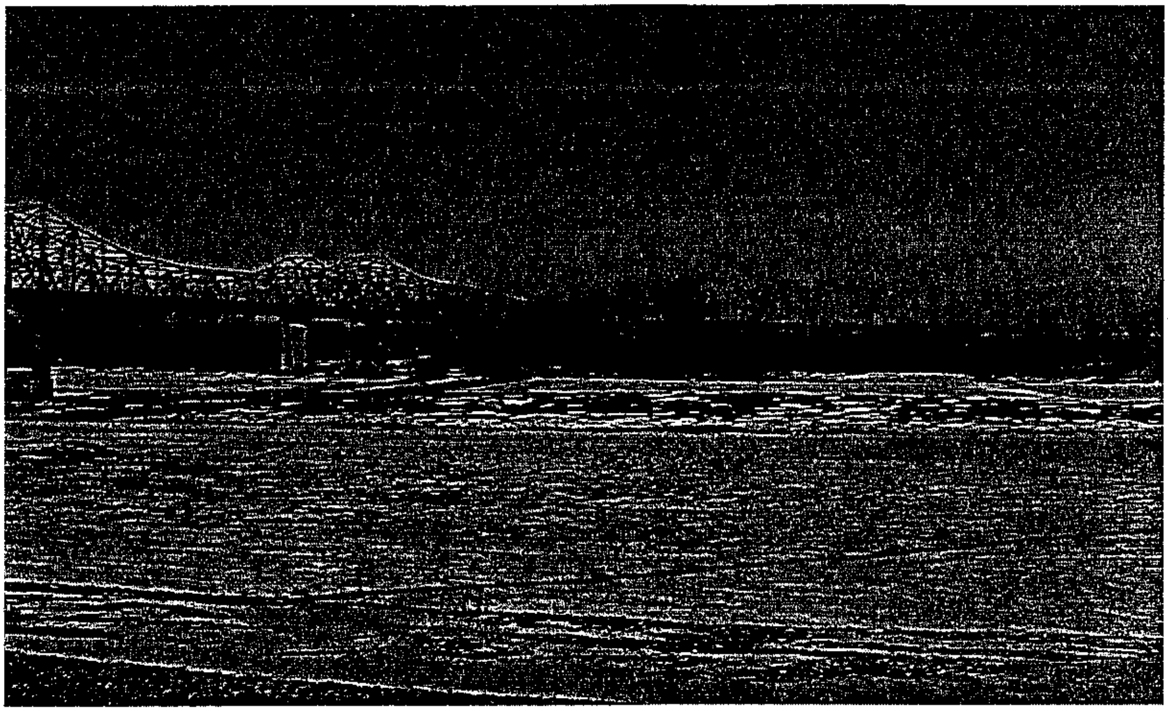
APPENDIX C

Photolog from Field Survey

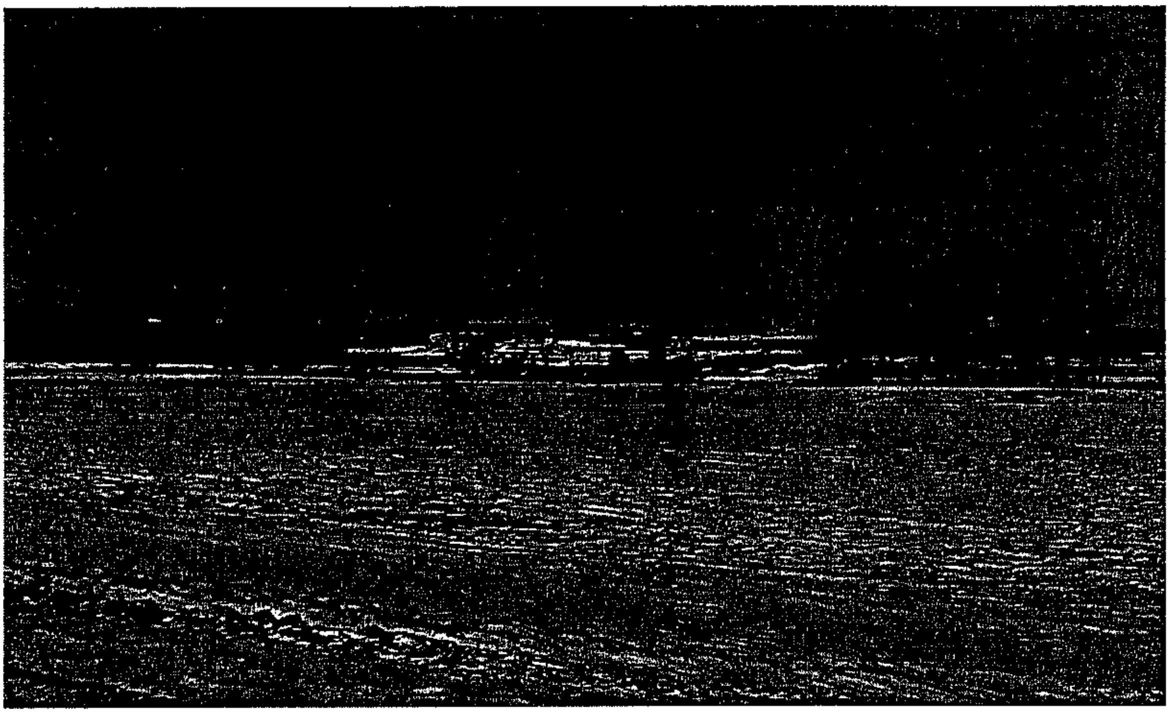
Looking downstream from Fairfax bridge (Hwy 69) (~RM 372.5). Dikes are clearly seen at the left bank (1/5/99).



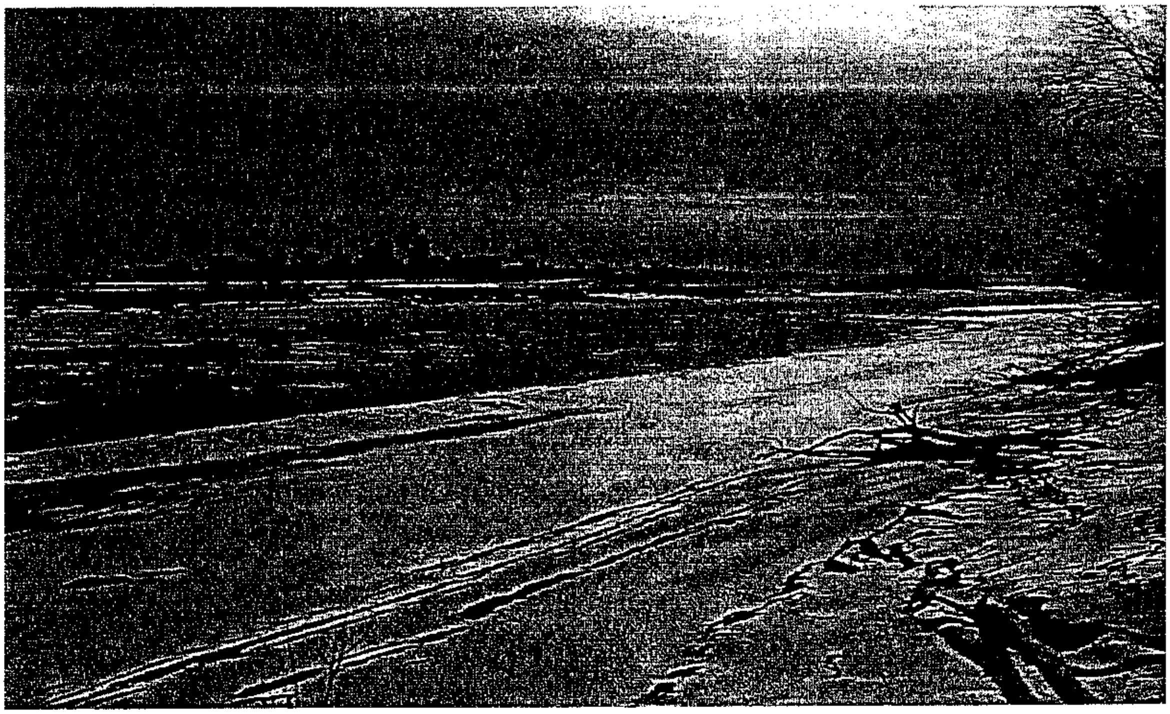
Looking upstream from the right bank towards the Union Equity Co-Op Dock at RM 372.9 (1/5/99).



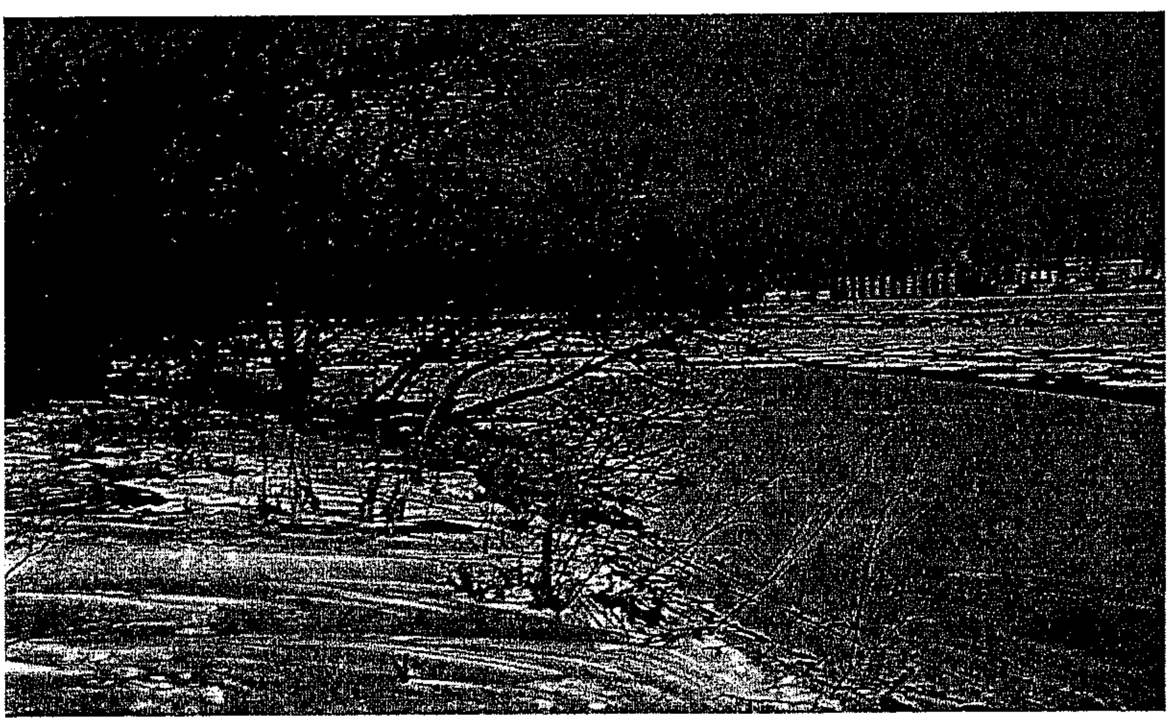
Looking upstream from the right bank towards Fairfax bridge (Hwy 69 bridge) about ½ mile upstream from the downstream end of the proposed Levee (~RM 372.5) (1/5/99).



Looking across Missouri River (to north), from the right bank, towards the location of the downstream end of the proposed Levee site (~RM 372). Arcosy Casino is in the center of the picture and the mouth of Line Creek is about 600 feet downstream of the Casino (1/5/99).

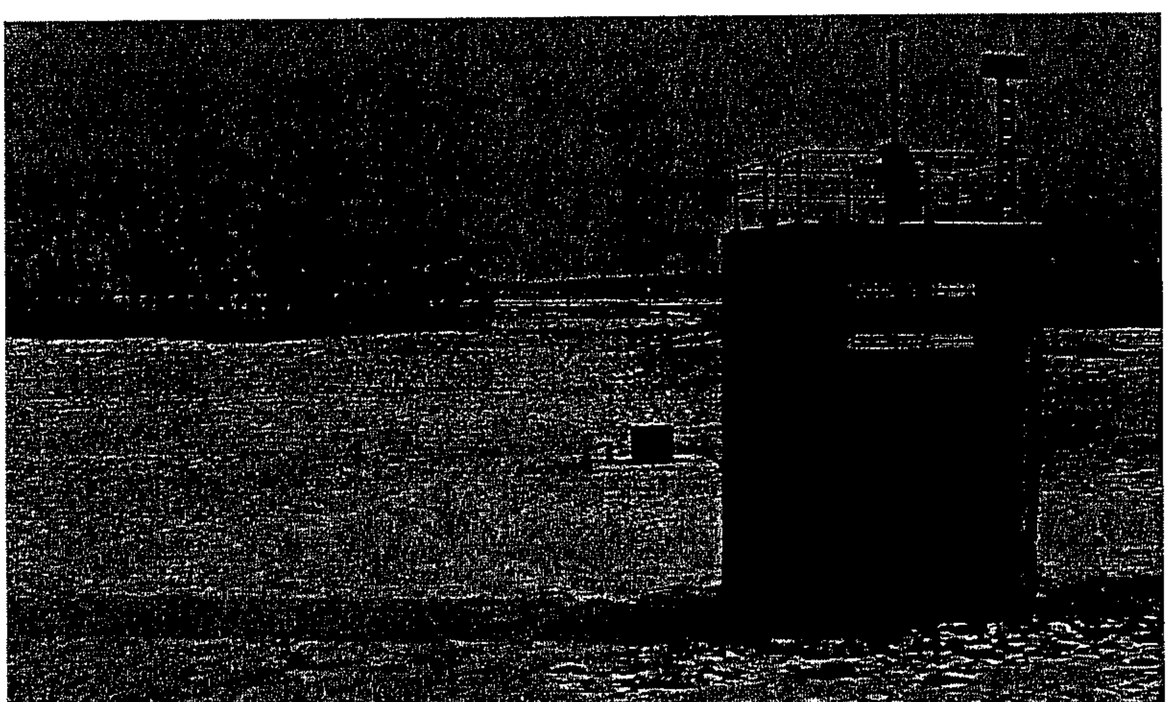


Looking downstream from the Worldcom cable crossing. A dike is seen at the right bank. Kansas City downtown is in the background (1/5/99).

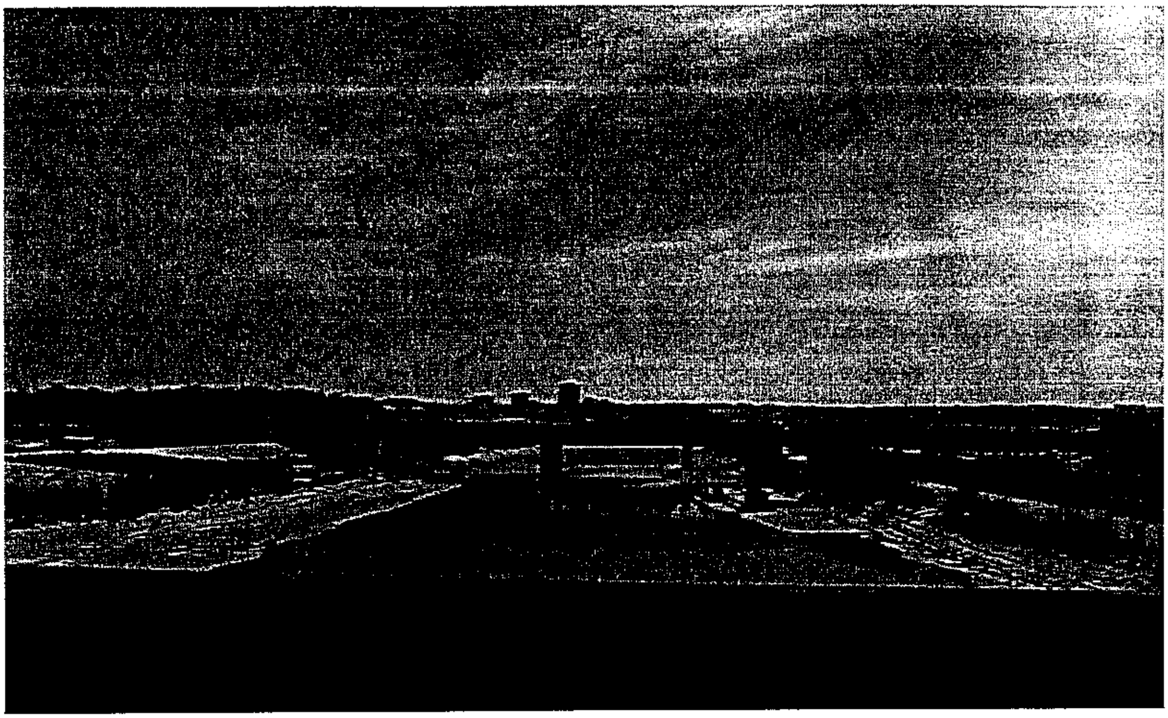


Looking upstream from the Worldcom cable crossing. A dike is seen at the middle of the picture (1/5/99).

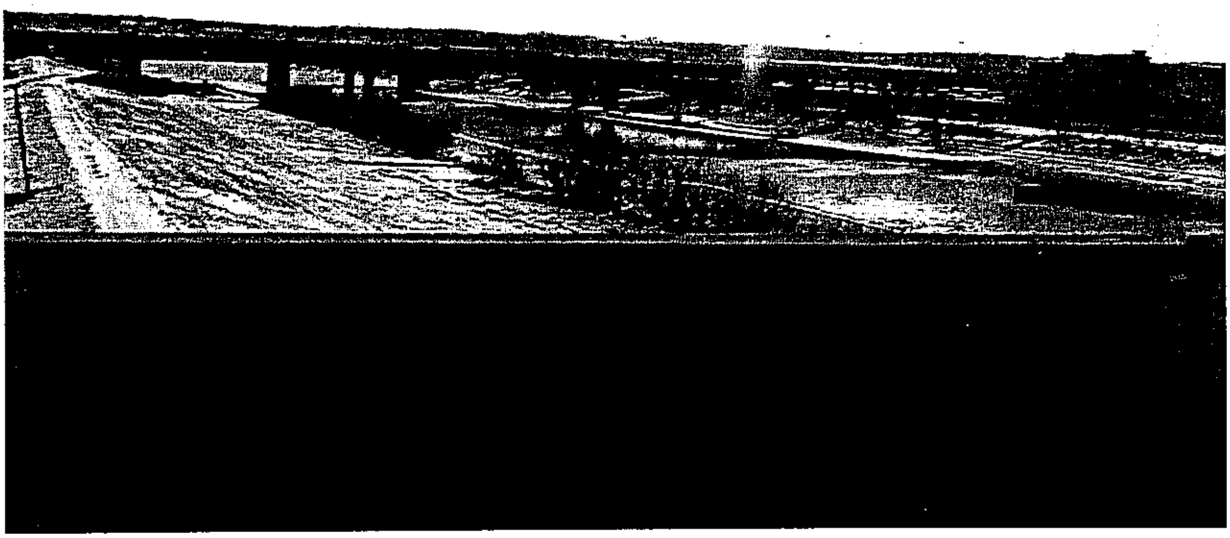
Warning sign regarding crossing of Worldcom fiber cable at ~RM 370 (1/5/99).



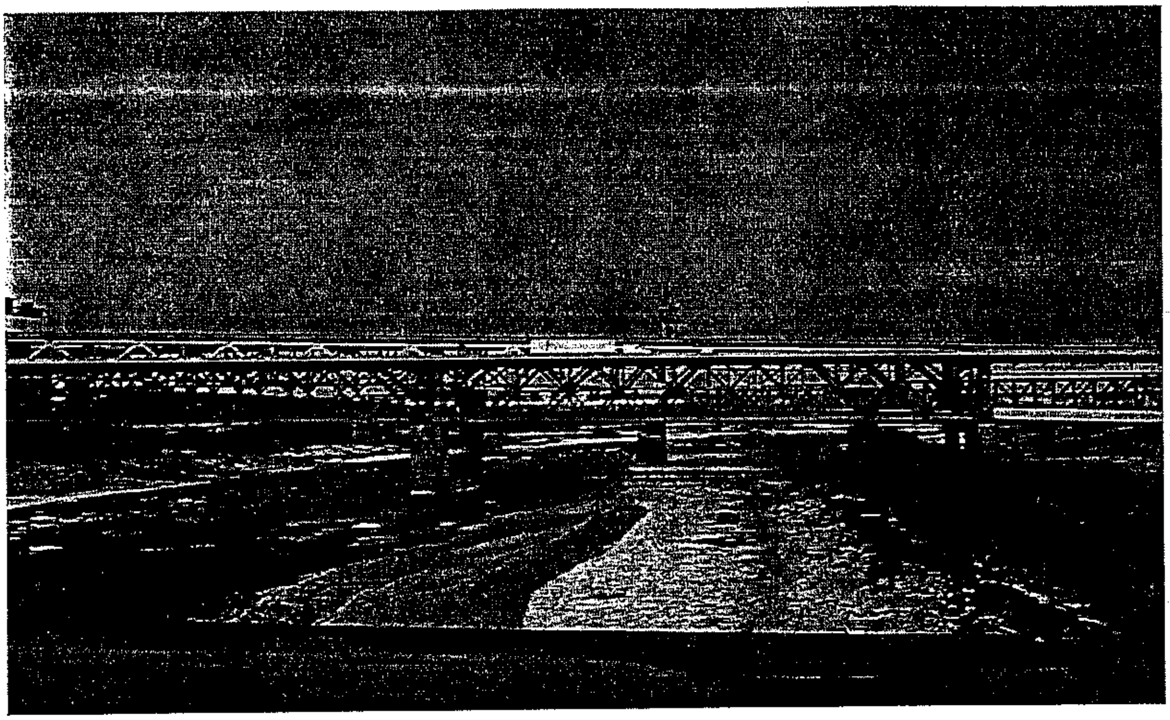
High water marks on the right bank about 2 miles downstream of the project site (~RM 370). The higher water mark is from the 1993 flood (elevation about 95 feet). The Missouri River is in the background (1/5/99).



Kansas River looking upstream (south) on Central Avenue Bridge (1/5/99).



Kansas River looking upstream (south) on Central Avenue Bridge (1/5/99).



Kansas River looking downstream (north) on James Street Bridge. The bridge on the picture is the I-70 Bridge, about ½ mile upstream of the confluence with Missouri River (1/5/99).

FINAL REPORT

MISSOURI RIVER LEVEE UNIT L385 SEDIMENT ANALYSIS

CONTRACT No.
DACW45-97-D-0026

Submitted to:
Department of the Army
Corps of Engineers
Kansas City District
700 Federal Building
Kansas City, MO 64106-2896

Prepared by:

WEST Consultants, Inc.
12509 Bel-Red Road, Suite 100
Bellevue, Washington 98005

May 1999

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1 Introduction

1.1 Background

The Missouri River originates in southwestern Montana and flows about 2,315 miles to join the Mississippi River near St. Louis, Missouri. The River Mile (RM) references used in this report are measured upstream from the confluence with the Mississippi River (1960's RMs). The project area is located at approximately RM 375. The Corps of Engineers has the responsibility under congressional authorization for the construction, operation and maintenance of facilities along the Missouri River for navigation, flood control and related purposes, including flow regulation and bank protection. The Missouri River Bank Stabilization and Navigation Project provides a continuous 9 feet deep and 300 feet wide navigational channel by maintaining a system of dikes and revetments, and performing dredging when necessary. During the navigation season, approximately from April to December, a flow of 41,000 cfs is maintained in the Missouri River at Kansas City by augmenting the natural river flow with releases from upstream reservoirs.

The Flood Control Act of 1944 (P.L. 534, 78th Congress, 2d Session) authorized the planning and construction of the Missouri Levee System. The Missouri River Levee Unit L385 is part of that flood control system. The L385 project area extends from RM 371.4 to 376.5 on the left bank of the Missouri River in southeastern Platte County at Riverside, Missouri, near Kansas City. The L385 project is also known as the Riverside-Quindaro Bend mainstem levee. The proposed levee will be located upstream of the confluence with the Kansas River. The river reach upstream and downstream of the project area is almost completely leveed. The proposed levee is on the left side of the river and will complete a levee section that extends from Kansas City upstream. The levee is designed to withstand a 500-year flood plus 3 feet. In 1993, the areas behind the proposed levee were flooded, including portions of Interstate 635. A general location map for the project is shown in Figure 1-1.

The design for the L385 project includes approximately 6.15 miles of levees along the Missouri River left bank and 0.5 mile of tieback levees along Line Creek. The L385 project area is from RM 371.4 to RM 376.5 on the left bank of the Missouri River in southeastern Platte County at Riverside, Missouri, near Kansas City. The study area is from RM 366.1 to RM 448.2 (1960 RMs). RMs 366.1 and 448.2 correspond to the river gauge locations in Kansas City, Missouri and St. Joseph, Missouri, respectively.

The L385 project design requires 3.0 to 3.5 million cubic yards of hydraulic dredge material for use as random fill. The dredge material will be obtained from the Missouri River. Dredging will not be allowed in the floodplain. Fill material shall be limited to granular material; fine sands and larger (SP, SW, GP & GW).

The purpose of the current study is to prepare a sediment availability analysis for the authorized construction of Missouri River Levee Unit L385. The analysis quantifies the impact of dredging for the project on the behavior and morphology of the river system in the vicinity of construction. Specifically, the potential impacts to the Missouri River Bank Stabilization and Navigation Project and infrastructure within the Kansas City Metropolitan area are evaluated.

1.2 Scope of Work

The scope of work includes an analysis of discharge and sediment transport measurement records, development of analytical estimates of sediment transport, review of historic hydrographic survey data and assessment of potential impacts to existing infrastructure in the project area (RM 371.4 to RM 376.5). The objective of the study is the development of recommendations for a feasible dredging plan. The work was conducted for the Kansas City District under contract No. DACW45-97-D-0026 as delivery order No. 10.

1.3 Organization of Report

This report is organized into six sections including this introduction. Section 2, Literature Review, reviews previous studies pertaining to sediment transport and geomorphology of the Missouri River. Section 3, Structures, describes the infrastructure within the study area identified from navigation charts for the Missouri River (USACE,). Section 4, Engineering Analysis, evaluates the sediment transport conditions and geomorphic stability of the Missouri River in the study area. The impacts of the proposed project are described and the time period required for obtaining the volume of material necessary for construction is analyzed. In Section 5, Conclusions and Recommendations, the results of the study are summarized and the basic recommendations of the study are defined. In Section 6, the references used in preparing the study are identified.

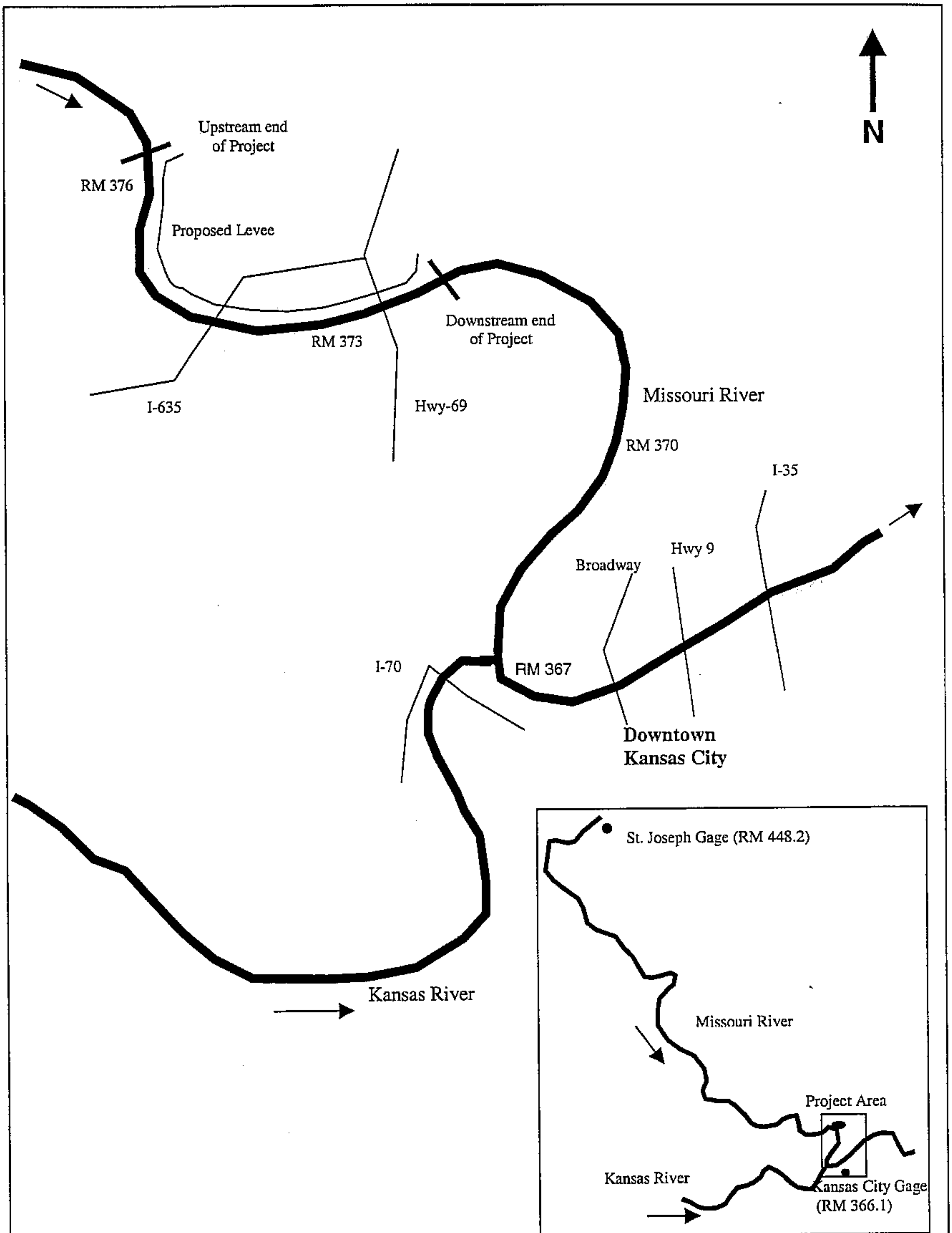

Figure 1-1: Schematic of the project area.

2 Literature Review

The hydrologic characteristics of the Missouri River have changed considerably during the 1900's (USACE, 1981). During this time, several reservoirs have been constructed on the Missouri River and its tributaries for sediment control and navigation purposes. The most significant dam on the lower Missouri River is Gavins Point Dam, located at RM 811, about 400 river miles upstream of the project area. The effects of this dam and others are clearly seen in Table 2-1. The sediment load along the Missouri River has decreased by factor of about 3 to 4 from before 1953 to after 1967. A complete listing of reservoir and dam construction prior to 1980 can be found in USACE (1981).

Table 2-1: Historic long term average annual suspended-sediment load (tons) (USACE, 1981).

Station	River Mile	Before 1953	1953-1967	After 1967
St. Joseph	448.2	257,258,650	64,421,855	53,359,955
Kansas City	366.1	327,940,800	80,380,280	68,334,792
De Soto	31.0*	77,188,913	16,355,527	14,166,258

*Kansas River miles

Shen (1977) conducted an analysis of temperature effects on stage-discharge relationships near Omaha. The motivation for the study is the suspected correlation between water temperature and shifts in stage-discharge relationship. The study is very detailed but does not yield a conclusive result about temperature effects on bed load transport.

Shen et. al. (1979 and 1986) studied bed material transport along the Missouri River at Yankton, Sioux City, Omaha and Nebraska City. Several transport methods were tested and it was concluded that of the general methods, Modified Einstein Method yielded the closest fit to the measured data. A part of the study was to analyze seasonal changes. It concluded that seasonal changes did not influence the bed material.

Mahmood (1980) conducted study similar to Shen (1979). The study concluded that the Modified Einstein Method yields good results for bed load estimates. The study involved sediment data for the Missouri River. Data was collected at Yankton, Ponca, Sioux City, Omaha and Nebraska City for data prior to 1979.

Vanoni (1977) and Simons and Senturk (1977) provided a comprehensive overviews of sediment transport theory and practice. These texts include discussion of the physics of sediment transport and as overviews of generally accepted methods to estimate sediment transport in rivers.

Ayres (1998) conducted a feasibility study for removal of material from the Missouri River for construction of a proposed bridge at Lexington, Missouri (about RM 315). The report concluded that the removal of material should not exceed about 20% of the bed material load. The report also points out that a large amount of material is already dredged out of the river at other locations. The study concludes that the proposed dredging for the bridge is not feasible for the proposed amounts within the required construction period. The report recommends a sediment modeling effort be undertaken to define specific impacts of the proposed dredging.

3 Structures

The project area is located within the Kansas City metropolitan area. Numerous bridges, pipelines, telecommunications lines and other infrastructure cross the river in the vicinity of the project. WEST contacted the owners of many of these structures in order to obtain historical information on the stability of the river and impacts of historic dredging on existing structures. The collected information was used to estimate the potential impacts of the proposed project on the infrastructure. A list of the infrastructure identified from the USACE Navigational Charts (USACE, undated) can be found in Appendix A.

The following owners of structures were contacted:

Missouri Department of Transportation
Kansas City, Kansas, Water Department
Kansas City, Missouri, Water Department
Skelly Oil Company
AT&T
MCI-Worldcom
Southwestern Bell Telephone
Kansas City, Kansas
Williams Brothers Pipeline Company
Williams Brothers Natural Gas Company

The following companies that conduct dredging along the Missouri River were also contacted:

Holliday Sand and Gravel
Capital Sand Company, Inc.

The records of contact can be found in Appendix B. The historic and anticipated impact on structures are discussed in Section 4.8.

4 Engineering Analysis

In the following sections, the sediment transport of the Missouri River in the study area is evaluated. This evaluation includes an analysis of discharge and sediment measurements at gages located upstream and downstream of the project area. Temporal and spatial channel bed elevation variations are evaluated based on historic hydrographic survey data. The locations, volumes and practices associated with historic dredging activities are reviewed.

4.1 Discharge and Sediment Concentration

Discharge data for the Missouri River was obtained from the United States Geological Survey (USGS). The study area is located between two USGS gages on the Missouri River. The upstream gage is located at St. Joseph (USGS gage No. 6818000) at RM 448.2, about 70 miles upstream of the project area. The downstream gage is located at Kansas City (No. 6893000), at RM 366.1, about 5 miles downstream of the project area, and about 1.5 miles downstream of the confluence with the Kansas River. The most downstream gage on the Kansas River is at De Soto (No. 6892350), it is located approximately 25 miles upstream of the confluence with the Missouri River.

The flow data for the gages on the Missouri River extend back to 1928. However, numerous dams have been constructed on the river during the period of record. The last of the mainstem dams was constructed in the early 1960's. Therefore, the analysis focuses on the time period from the mid-1960's to present. Figure 4-1 shows the daily discharge for the time period 1967 to 1998 for the Kansas City Gage. Figure 4-2 shows the discharge for the St. Joseph Gage for the same time period. In Table 4-1 several flow statistics for the gages are summarized.

The flow records (Figure 4-1 and Figure 4-2) show that the 1993 flood was by far the largest flood during the past 30 years. The 1973 flood is a distant second. The discharge at the Kansas City Gage is on average 20% higher than at the St. Joseph Gage. As seen in Table 4-1, the difference is largely due to the Kansas River, which enters the Missouri River about 1.5 miles upstream of the Kansas City Gage. Stage-discharge curves for both gages were obtained from the USGS and are shown in Figure 4-3. In Figure 4-4 the flow duration curves calculated from the daily mean flows are shown for both gages. These relations are used in calculating sediment transport in following sections.

Table 4-1: Flow characteristics for Missouri River at Kansas City and St. Joseph and for Kansas River at De Soto for the period 1967-1997. (Source: Daily mean flow from USGS).

Gage Locations	Drainage area (mi^2)	Mean daily discharge (cfs)	Median daily discharge (cfs)	Max daily discharge (cfs)	Min daily discharge (cfs)
Kansas City	485,200	60,704	53,300	529,000	6,690
St. Joseph	420,300	50,650	46,100	328,000	4,600
De Soto	59,756	8,800	4,260	167,000	504

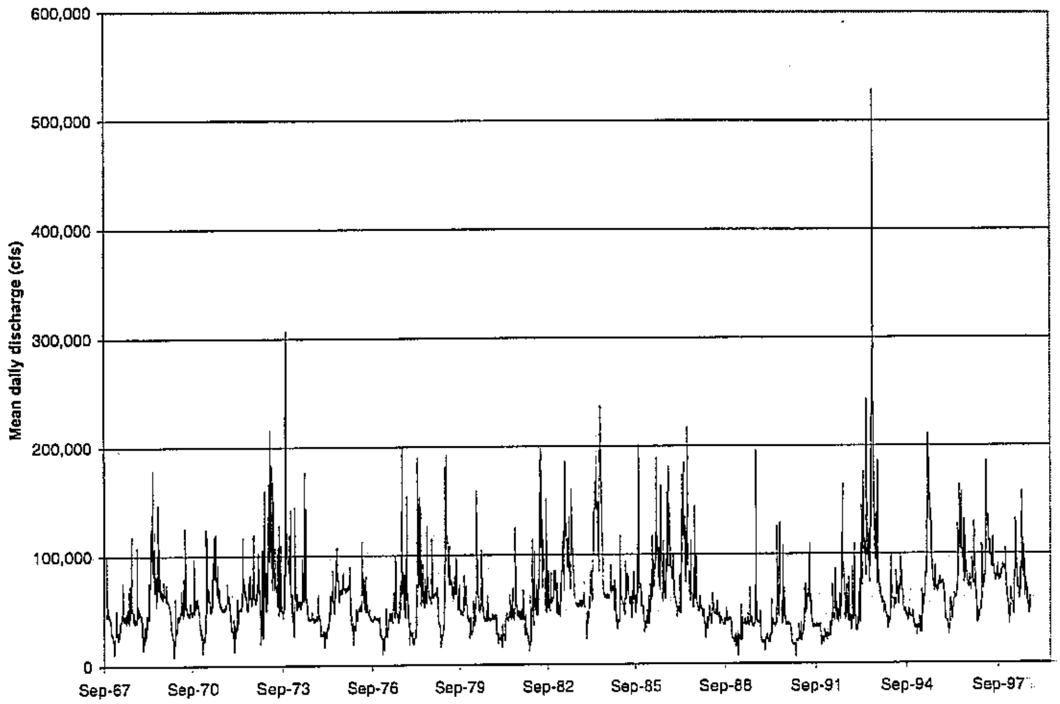

Figure 4-1: Mean daily discharge at the Kansas City Gage (USGS Gage No. 6893000).

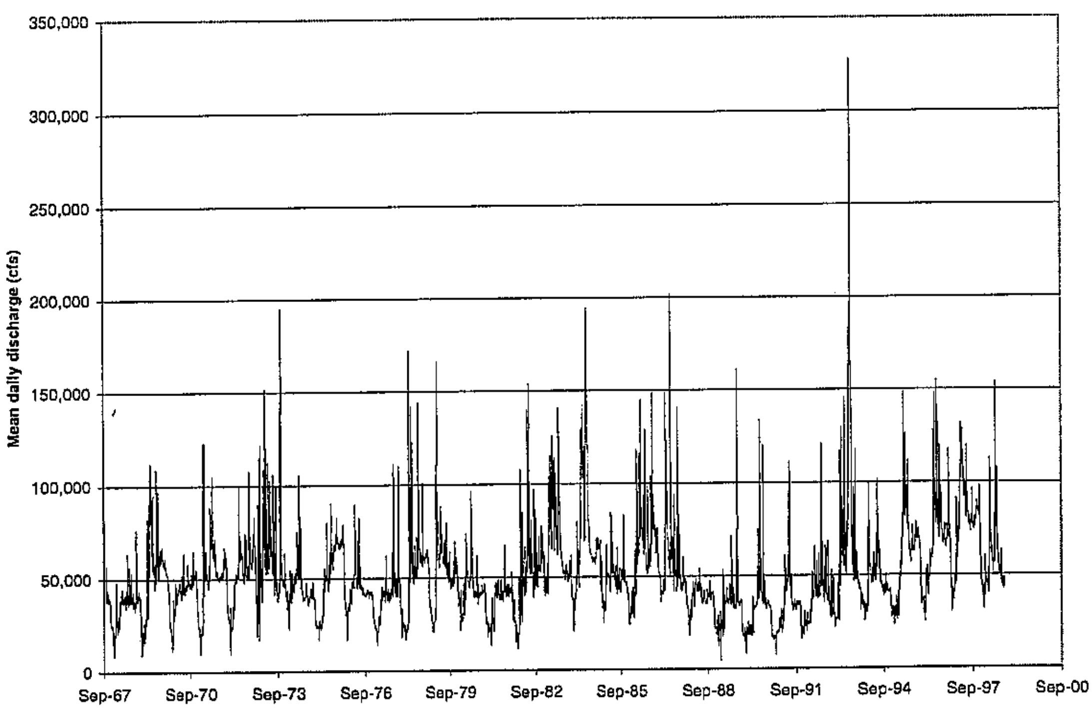

Figure 4-2: Mean daily discharge at St. Joseph Gage (USGS Gage No. 6818000).

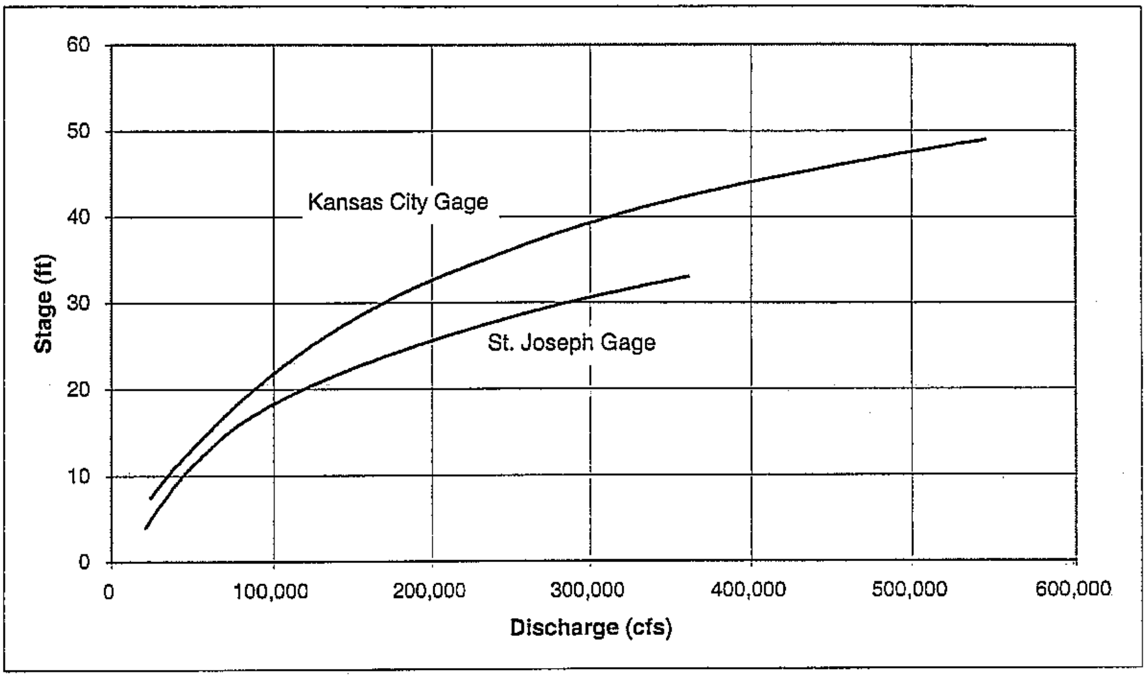

Figure 4-3: Rating curves for the Kansas City and the St. Joseph Gages (Source: USGS, created 1994).

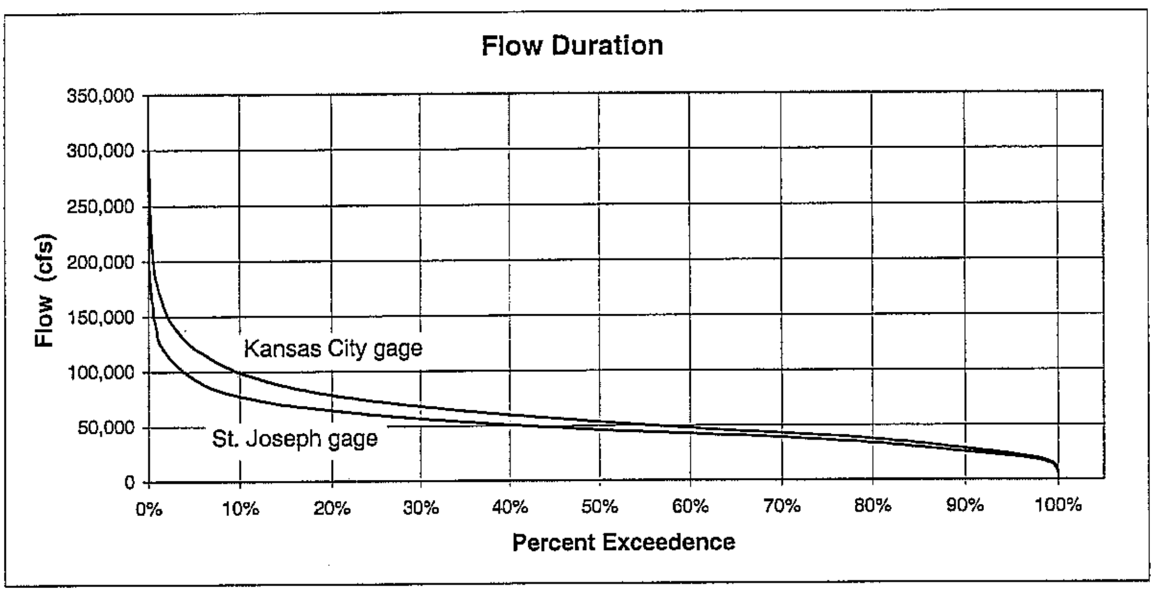

Figure 4-4: Flow duration curves for the Kansas City and the St. Joseph Gages based on the period 1967 to 1997.

4.2 Determination of Bed Material Concentration

The total sediment load is composed of wash load, suspended bed material load and bed load. Based on a comparison of size characteristics from suspended sediment samples and bed material samples, suspended bed material load is assumed to be the portion of the suspended sediment load that is coarser than 0.125 mm (fine sand sizes and coarser). The finer material is assumed to be wash load. The suspended bed material load was calculated based on the measured suspended load. The bed load was calculated by application of the Modified Einstein Method.

Suspended sediment data for the Kansas City Gage and the St. Joseph Gage were provided by the USGS. The available data covers the time periods 1965-1975 and 1991-1997. The suspended sediment samples for the first period were taken about once a week but less than once a month for the second period. Hence, the estimates of the suspended load are more representative of the first period. The data set for the first period did not include wash load. This was also observed by Ayres (1998). The present study is concerned with the bed material concentration so the analyses conducted for this report were not influenced.

The suspended bed material concentration is plotted against discharge for the Kansas City Gage in Figure 4-5 and for the St. Joseph Gage in Figure 4-6. The data plotted is an arithmetic average of the samples taken on a given day. It is seen that values for the period from 1991-1997 are slightly higher than those for the period from 1965-1975. It is not possible to draw any conclusion from this difference, as the data points for the 1991-1997 time period are too sparse.

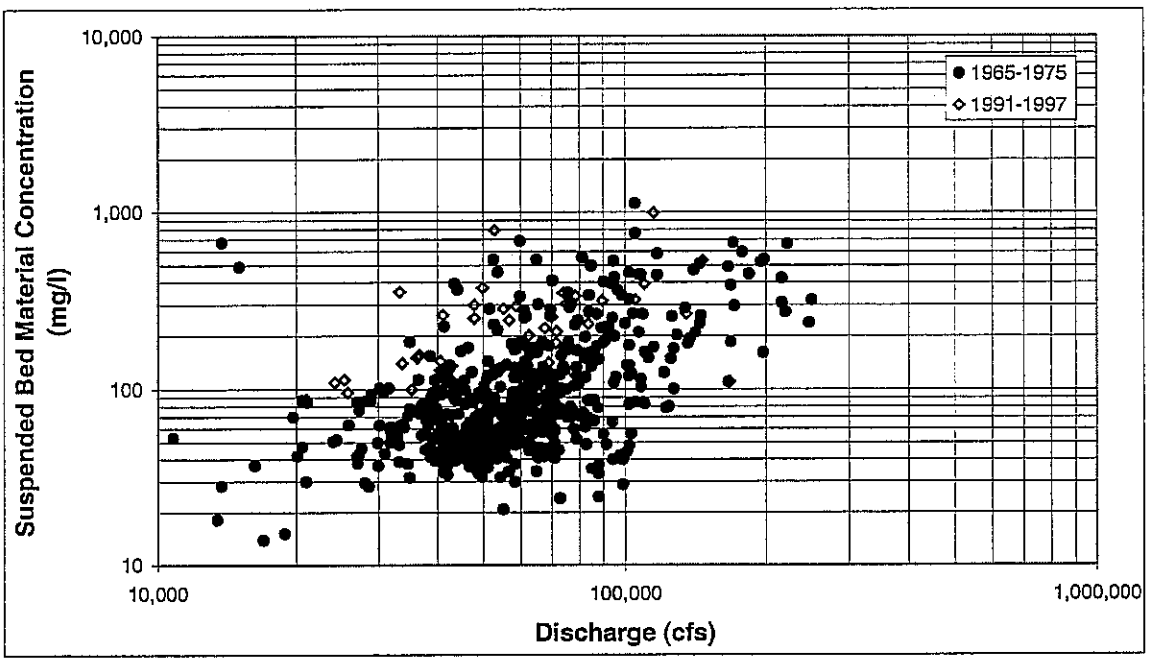

Figure 4-5: Suspended bed material concentration versus discharge at the Kansas City Gage.

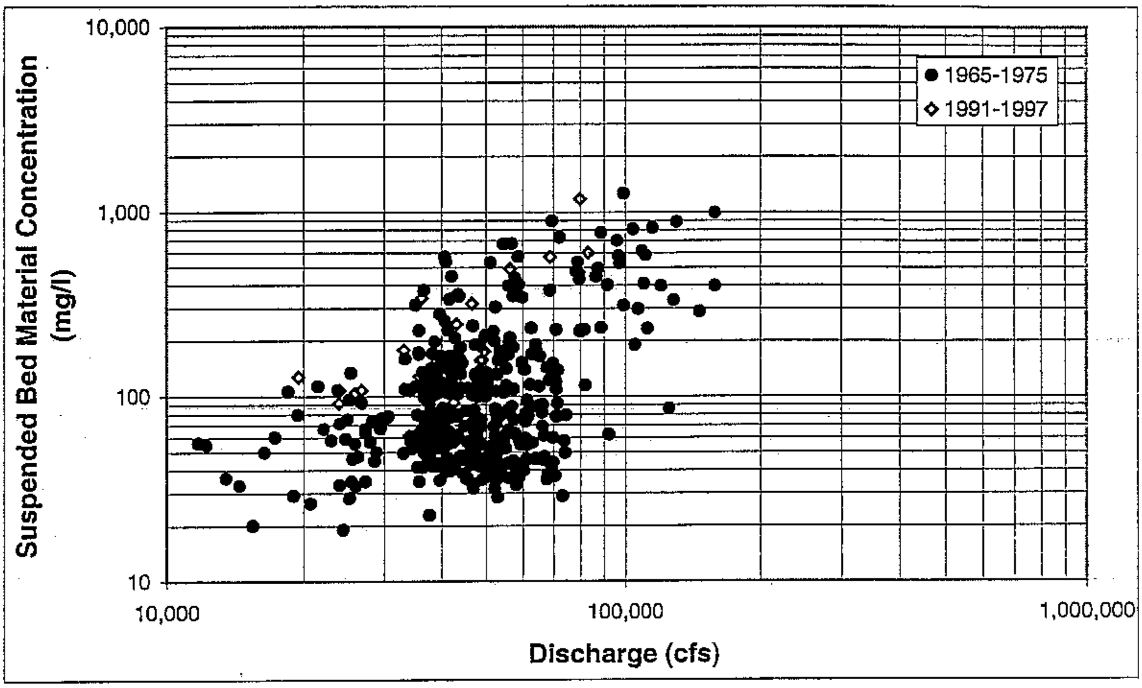

Figure 4-6: Suspended bed material concentration versus discharge at the St. Joseph Gage.

4.3 Bed Material Transport as a Function of Discharge

Measured suspended sediment concentrations were multiplied by the percentage of material coarser than 0.125 mm to obtain the concentration of suspended bed material sediments. The equation

$$Q_s = 2.697 \cdot 10^{-3}\, QC, \tag{1}$$

was used to calculate the suspended bed material load per day, where Q is the water discharge in cfs, C is the suspended bed material concentration in ppm, and Q_s is the suspended bed material load in ton/day. In Figure 4-7, Q_s versus Q is plotted for the Kansas City Gage for the available data. Similar data for the St. Joseph Gage is plotted in Figure 4-8. For both gages, a relationship was developed between Q_s and Q by using linear regression methods, and is represented in the figures by a straight line on the log-log graphs. The relationship is in the form

$$Q_s = aQ^b, \tag{2}$$

where a and b are constants. The values of a and b are given in Table 4-2.

Table 4-2: Regression coefficents for relations between discharge in cfs and sediment load in tons/day ($Q_s = a\, Q^b$).

	Q (cfs)	a	b	Correction*
Kansas City Gage	< 55,000	$1.73 \cdot 10^{-2}$	1.23	1.19
	55,000 – 150,000	$2.32 \cdot 10^{-7}$	2.25	1.26
	> 150,000	$9.85 \cdot 10^{-4}$	1.56	1.18
St. Joseph Gage	All	$1.06 \cdot 10^{-5}$	1.94	1.30

*Statistical bias correction, see Ferguson (1986).

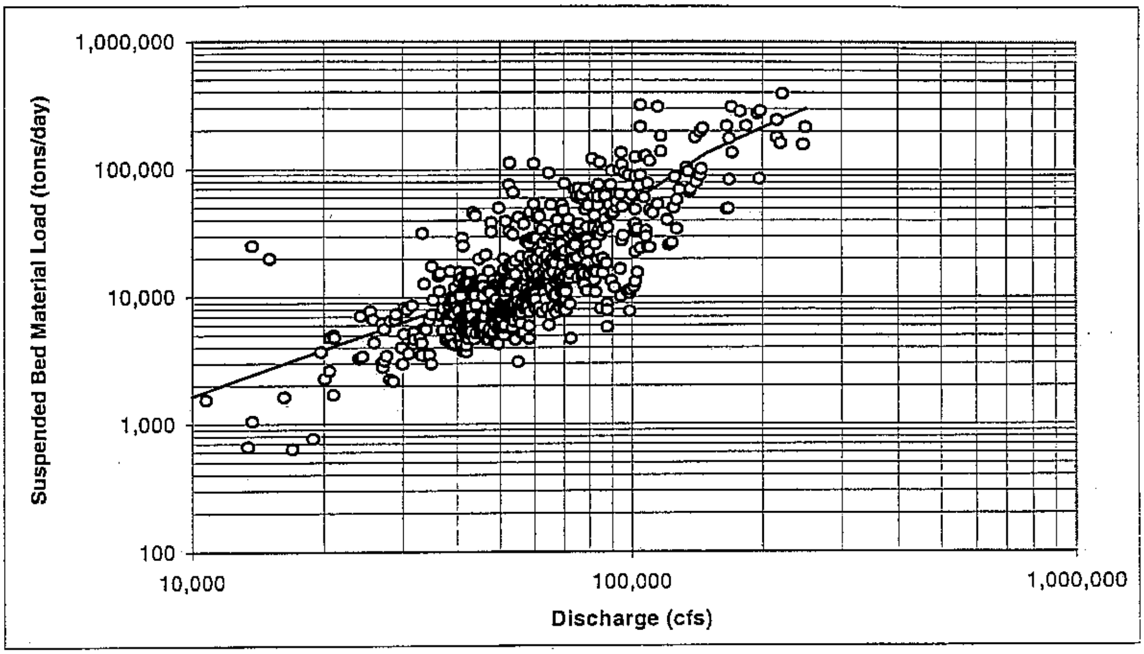

Figure 4-7: Suspended bed material load at the Kansas City Gage.

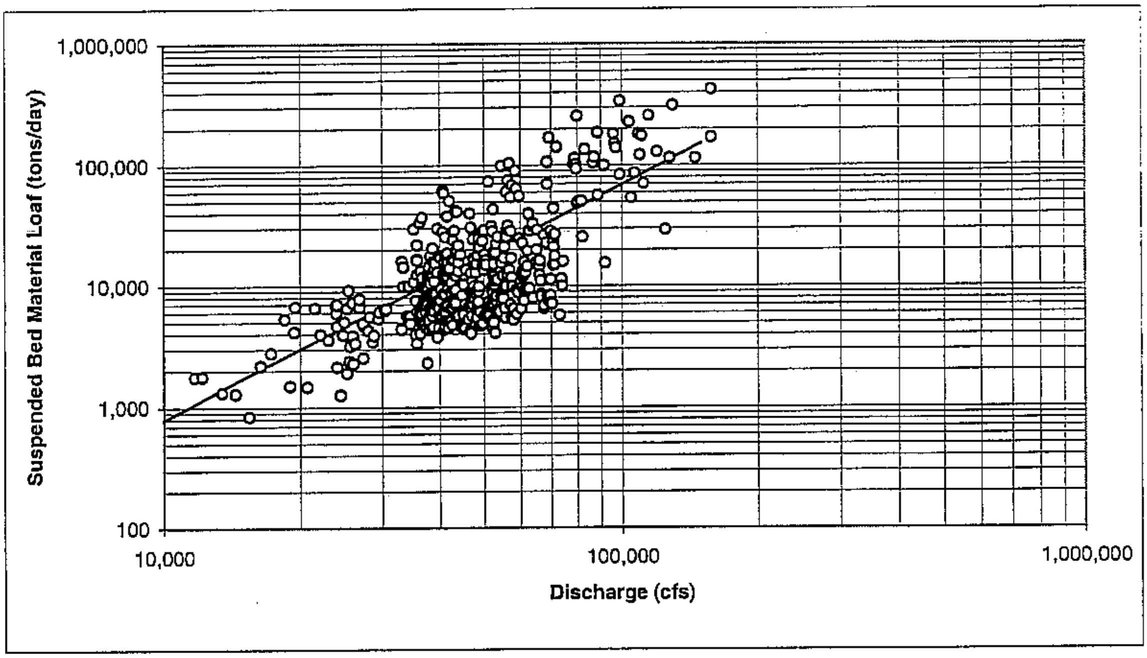

Figure 4-8: Suspended bed material load at the St. Joseph Gage.

4.3.1 Seasonal Effects

An analysis of seasonal effects on suspended bed material sediment concentration was performed to determine if suspended sediment concentration per unit discharge changes between seasons. Potential reasons for seasonal variability in sediment transport can be linked to changes in water viscosity due to temperature changes. The viscosity change will affect fall velocities but it is noted that for sand and coarser sediment sizes, the change is small (Vanoni, 1977).

The average monthly water temperatures determined for the Kansas City Gage (from the sediment data records) are shown in Figure 4-9. The average annual water temperature is about 46 °F. To determine temperature differences through the year, months were divided into two categories, months where the average monthly temperature was greater than the annual average (hot months) and months where the average monthly temperature is less than the annual average (cold months). The hot months were determined to be May-October and have an average temperature of about 59 °F. The cold months of November-April were determined to have an average temperature of about 34 °F.

As is seen in Figure 4-5, the suspended bed material sediment concentration is proportional to discharge. Since the magnitude of discharge is seasonal, it is necessary to normalize sediment concentration by discharge to examine seasonal effects. The suspended bed material concentration by unit discharge is plotted in Figure 4-10. The mean for the hot months is about $2.18 \cdot 10^{-3}$ mg/l/cfs versus $2.15 \cdot 10^{-3}$ mg/l/cfs for the cold months. This difference is less than 1.5% and is not considered significant.

Bed form characteristics may also change on a seasonal basis. Changes in bed forms may affect hydraulic and sediment transport conditions. Using typical values for high flow (Q = 70,000 cfs) along the Missouri River and the relationship shown in Figure 4-12, the expected bed form is "antidunes & flat bed". For typical low flow (Q = 28,000 cfs), the expected bed form was found to be "transition between antidunes & flat bed and dunes". (a bed slope of 1 ft/mile was used for the calculations). This indicates that changes in bed forms could potentially affect bed load sediment transport on a seasonal basis. However, the determination of the specific impacts due to seasonal bed form differences is hard to estimate and beyond the scope of this report. Shen (1977) conducted an analysis of temperature effects on the stage-discharge relationship near Omaha and concluded that temperature effects on bed load transport needed further study. Shen et. al. (1979 and 1986) studied bed material transport along Missouri River at Yankton, Sioux City, Omaha and Nebraska City and concluded that seasonal changes did not influence the size characteristics of the bed material.

Overall, the data analysis and discussion presented in this section suggest that seasonal effects on the suspended bed material transport are negligible. It is also noted that any seasonal effects on bed material transport must be considered in perspective to the relative magnitude of seasonal sediment transport. As seen in Figure 4-11, the average monthly flow for hot months is much greater than for cold months. Hence, the majority of sediment transport occurs in hot months.

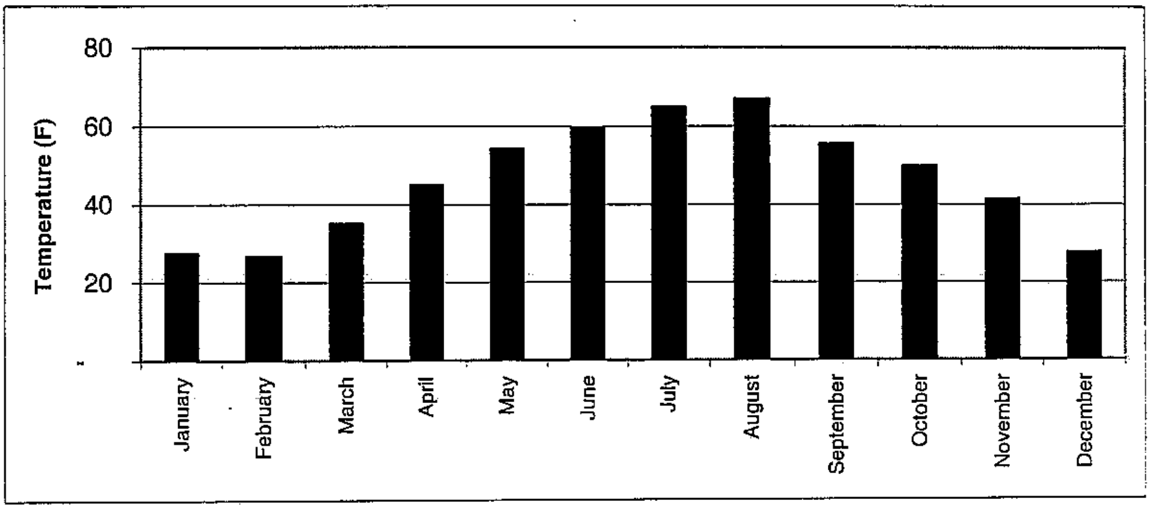

Figure 4-9: Average monthly water temperature at the Kansas City Gage.

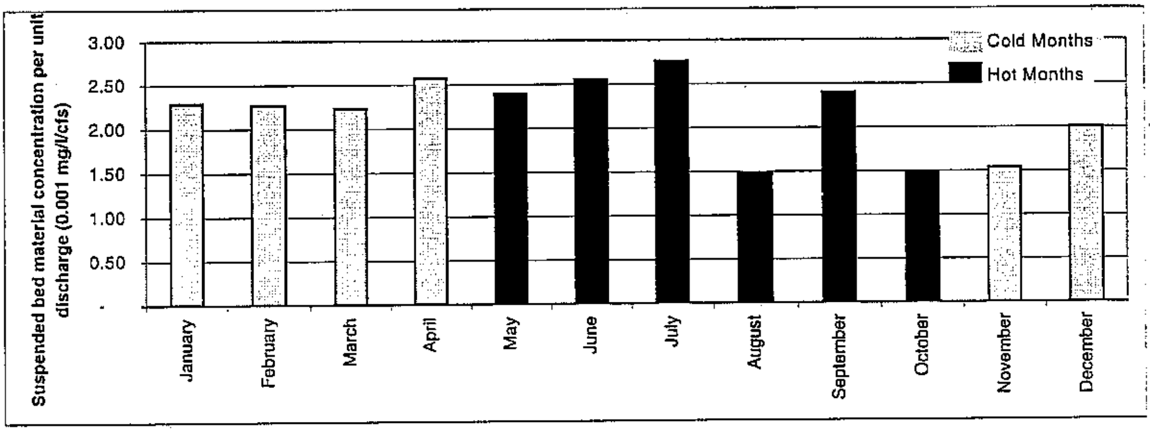

Figure 4-10: Average monthly suspended bed material concentration per unit discharge at the Kansas City Gage.

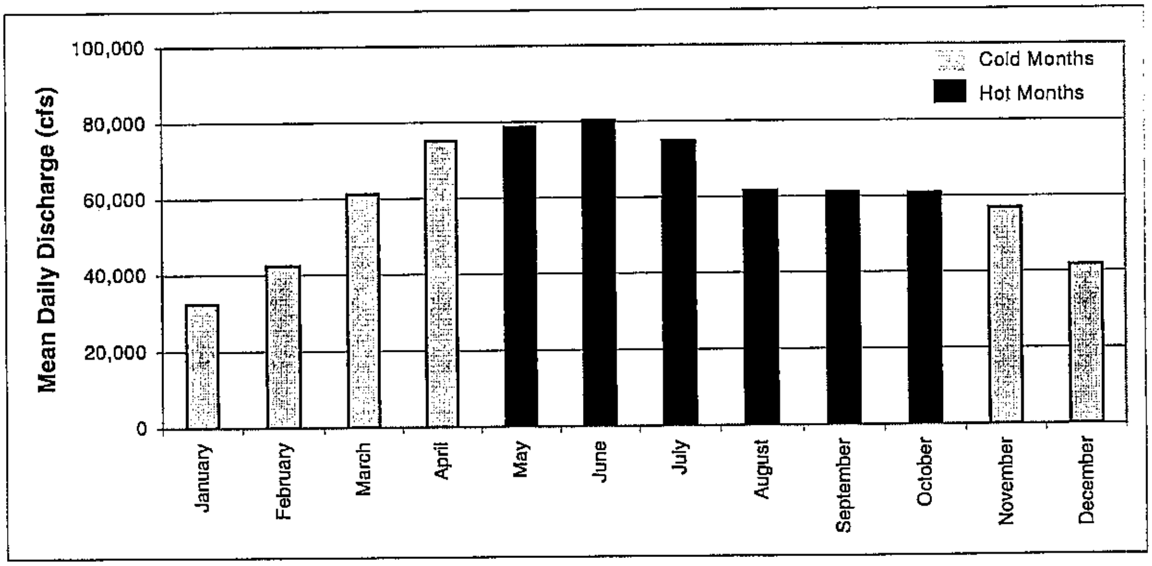

Figure 4-11: Mean daily discharge per month at the Kansas City Gage.

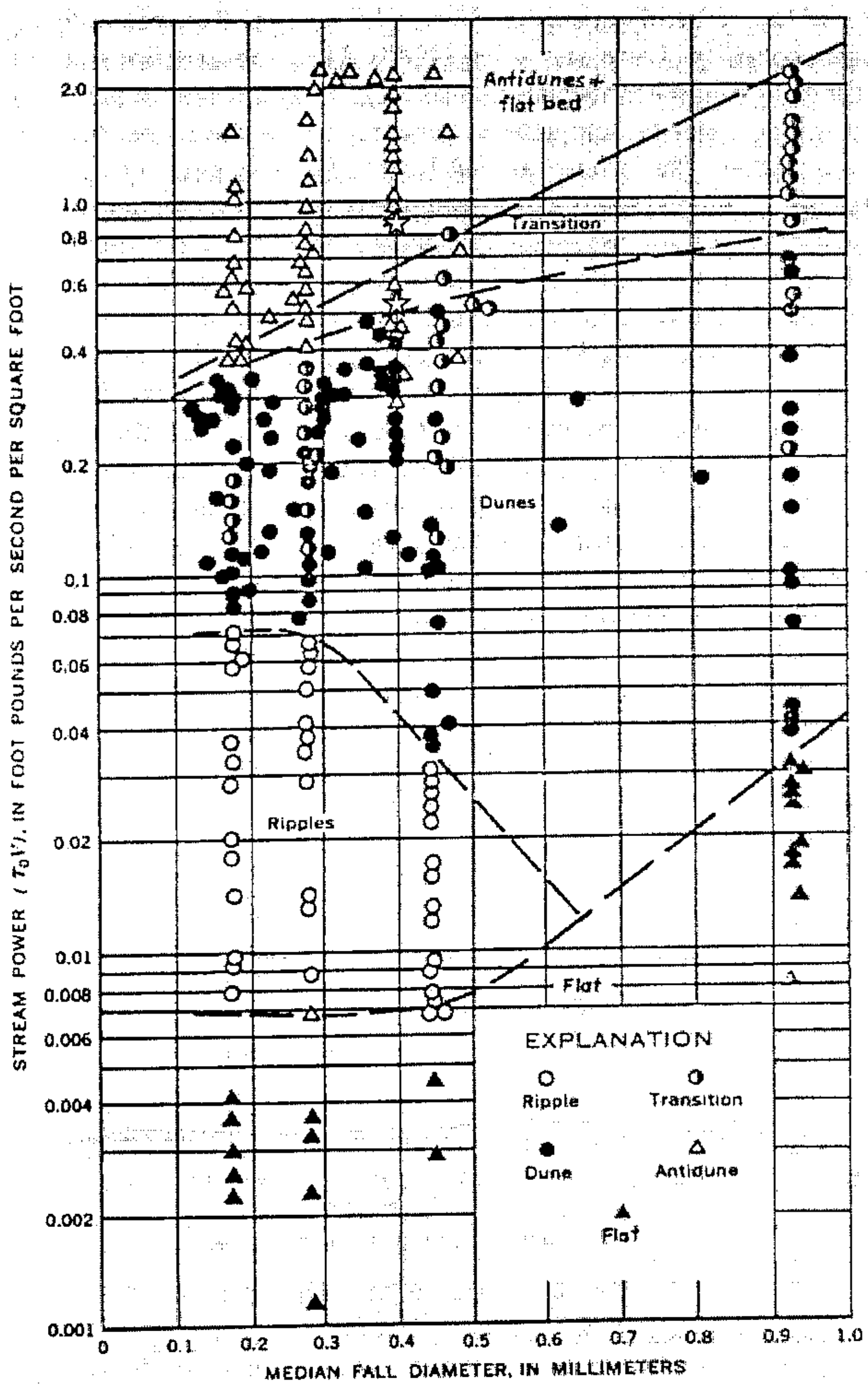

Figure 4-12: Relation of bed form to stream power and median fall diameter of bed sediment proposed by Simons and Richardson (1966) (from Vanoni, 1977). (Stars ☆ mark the calculated values).

4.4 Bed Load

The bed load transport along the Missouri River at the Kansas City and St. Joseph gages was estimated using the Modified Einstein Method (see e.g. Simons (1977) or Vanoni (1977)). The Modified Einstein Method was selected for use since it has rendered very good predictions of the total load for tributaries in the Missouri River basin (Simon & Senturk, 1977) and provides specific estimates of the transport rate for individual sediment size classes. Application of the method requires various information. These data are used in the following two subsections to develop estimates for the bed load at the Kansas City Gage and the St. Joseph Gage. The following data were developed to apply the method:

1. Discharge (Q) - duration curves were developed from the daily mean flow data for each gage (see Figure 4-4).

2. Relations between stage and discharge were obtained from the USGS (see Figure 4-3).

3. Relations between stage and flow area were developed from cross section data at the gage locations provided by the USACE. An area (A) vs. stage relation for each gage site was developed from the 1998 cross section. For each stage, an average channel width (B) was also measured from the cross section plot.

4. Bed material gradations were obtained from the USGS for both gage locations and are shown in Table 4-3. As seen from the tables, about 80% of the bed material (i_b) is in the fine sand to coarse sand range. About 60% of the average suspended load (i_s) (average for all discharges) is comprised of silt and clay-sized material and about 30% is in the fine sand size range.

Table 4-3: Bed material (i_b) and suspended sediment (i_s) distribution at the gages (from USGS; i_s is based on the 1991-1997 time period).

Sediment Sizes				Kansas City Gage		St. Joseph Gage	
D_{Low} (mm)		D_{high} (mm)	Class	i_b (%)	i_s (%)	i_b (%)	i_s (%)
0.002	-	0.0625	Silt	0.00	0.57	0.00	0.58
0.0625	-	0.125	Very Fine Sand	0.01	0.03	0.00	0.03
0.125	-	0.25	Fine Sand	0.24	0.32	0.31	0.31
0.25	-	0.5	Medium Sand	0.33	0.08	0.40	0.08
0.5	-	1	Coarse Sand	0.24	0.01	0.21	0.00
1	-	2	Very Coarse Sand	0.03	0.00	0.01	0.00
2	-	4	Very Fine Gravel	0.04	0.00	0.02	0.00
4	-	8	Fine Gravel	0.06	0.00	0.03	0.00
8	-	16	Medium Gravel	0.05	0.00	0.00	0.00
D_{35}				0.00098 ft		0.00092 ft	
D_{65}				0.00190 ft		0.00144 ft	

Table 4-4: Hydraulic data at the Kansas City Gage.

Elevation (ft) (1)	B (ft) (2)	Stage (ft) (3)	A (ft^2) (4)	Q (cfs) (5)	U (ft/s) (6)	d (ft) (7)	Time > Q (%) (8)	Low Q (cfs) (9)	High Q (cfs) (10)	Time> High Q (%) (11)	In Range (%) (12)
705	390	-1.4	1,260								
710	540	3.6	3,690	10,000	2.71	6.8	99.89	0	19,390	97.88	2.12
715	650	8.6	6,730	28,780	4.28	10.4	89.68	19,390	40,460	74.92	22.96
720	760	13.6	10,380	52,140	5.02	13.7	52.03	40,460	65,890	32.35	42.57
725	770	18.6	14,180	79,640	5.62	18.4	19.05	65,890	96,020	11.09	21.26
730	770	23.6	18,030	112,400	6.23	23.4	6.74	96,020	133,750	3.52	7.57
735	770	28.6	21,880	155,100	7.09	28.4	1.88	133,750	184,300	0.83	2.69
740	770	33.6	25,730	213,500	8.30	33.4	0.42	184,300	250,850	0.18	0.65
745	770	38.6	29,580	288,200	9.74	38.4	0.12	250,850			
Sum											99.82

(1) From USACE cross section data gage
(2) Width from USACE cross section data at gage
(3) Stage = Elevation - Gage datum
(4) Flow area obtained from USACE cross section data
(5) Discharge obtained from USGS stage-discharge curves
(6) Average velocity: U = Q / A
(7) Hydraulic depth: d = A / B
(8) Percentage of time flow is at or above Q
(9) and (10) The discharge range representative by Q
(11) Percentage of time flow is at or above Q
(12) Percentage of time discharge is in the discharge range shown in columns (9) and (10)

4.4.1 Kansas City Gage

Using the data described in the previous section, the hydraulic data shown in Table 4-4 was developed. For each average daily discharge and bed material size shown in Table 4-3 and Table 4-4, the bed load transport rate in tons per day was calculated by applying the Modified Einstein Method. The transport rates for each sediment size class was summed to give the total bed load transport for each discharge value evaluated. The flow duration curves were used to determine the average number of days in each flow range per year. The annual contribution of each flow range was determined by multiplying the number of days within the range and the associated transport per day. Results for each sediment class and flow are shown in Table 4-6. The average annual bed load transport at the Kansas City Gage was determined to be about 1.6 million tons. Utilizing the calculated daily bed load transport in Table 4-6, a curve of bed load transport per day versus mean daily discharge was developed and is presented in Figure 4-13. It is assumed that the bed load at the project site is about 0.8 of the bed load at the Kansas City Gage as it is downstream of the confluence with Kansas River and the project site is upstream. The ratio of the average Kansas River discharge to the average Kansas City gage discharge (on the Missouri River) is about 0.2.

4.4.2 St. Joseph Gage

The procedure described above was also applied to calculate the average annual bed load transport at the St. Joseph Gage location. Table 4-5 shows the hydraulic variables for the St. Joseph Gage and Table 4-7 summarizes the bed load transport estimates obtained from the Modified Einstein Method. As seen in Table 4-7, the average annual bed load is calculated to be about 0.9 million tons.

Table 4-5: Hydraulic data developed at the St. Joseph Gage.

Elevation (ft) (1)	B (ft) (2)	Stage (ft) (3)	A (ft^2) (4)	Q (cfs) (5)	U (ft/s) (6)	d (ft) (7)	Time > Q (%) (8)	Low Q (cfs) (9)	High Q (cfs) (10)	Time > High Q (%) (11)	In Range (%) (12)
790	600	1.81	4,820								
795	620	6.81	7,920	31,110	3.93	12.8	83.05	0	42,210	60.66	39.34
800	640	11.8	11,090	53,310	4.81	17.3	35.46	42,210	69,710	14.78	45.88
805	660	16.8	14,350	86,110	6.00	21.7	6.64	69,710	113,655	2.26	12.52
810	680	21.8	17,750	141,200	7.95	26.1	0.85	113,655	181,400	0.24	2.02
815	680	26.8	21,150	221,600	10.48	31.1	0.05	181,400	275,650	0.03	0.21
820	680	31.8	24,550	329,700	13.43	36.1		275,650			
Sum											99.97

(1) From USACE cross section data at gage

(2) Width from USACE cross section data at gage

(3) Stage = Elevation - Gage datum

(4) Flow area obtained from USACE cross section data

(5) Discharge obtained from USGS stage-discharge curves

(6) Average velocity: U = Q / A

(7) Hydraulic depth: d = A / B

(8) Percentage of time flow is at or above Q

(9) and (10) The discharge range representative by Q

(11) Percentage of time flow is at or above Q

(12) Percentage of time discharge is in the discharge range shown in columns (9) and (10)

Explanations for Table 4-6 and Table 4-7:

Q:	Discharge (cfs) chosen in equal stage increments (see Table 4-4 for the Kansas City Gage and Table 4-5 for the St. Joseph Gage)
Class:	Extended Wentworth Scale
D:	Representative diameter of the class (geometric mean) (ft)
i_b:	Portion of each class in the bed material
Q_{TBL}:	Total possible bed load for each class calculated using Modified Einstein Method (ton/day)
ΣQ_{TBL}:	Total possible bed load for all classes (ton/day)
% of year:	Percent of year the flow is represented by the discharge Q, from Figure 4-4
Q_{BL}:	Bed load per year for the flow rate represented by discharge Q

Table 4-6: Bed load calculations using Modified Einstein's Method for the Kansas City Gage (see explanation of symbols on page 21).

Q cfs	Class	D ft	i_b %	Q_{TBL} tons/day	ΣQ_{TBL} tons/day	% of year	Q_{BL} tons/year
213,500	Fine Sand	0.00058	0.24	723	13,991	3.5%	179,752
	Medium Sand	0.00116	0.33	2,812			
	Coarse Sand	0.00232	0.24	5,785			
	Very Coarse Sand	0.00464	0.03	1,005			
	Very Fine Gravel	0.00928	0.04	1,529			
	Fine Gravel	0.01856	0.06	1,651			
	Medium Gravel	0.03712	0.05	486			
112,400	Fine Sand	0.00058	0.24	406	6,746	7.6%	186,396
	Medium Sand	0.00116	0.33	1,580			
	Coarse Sand	0.00232	0.24	3,250			
	Very Coarse Sand	0.00464	0.03	519			
	Very Fine Gravel	0.00928	0.04	580			
	Fine Gravel	0.01856	0.06	367			
	Medium Gravel	0.03712	0.05	44			
79,640	Fine Sand	0.00058	0.24	324	5,139	21.3%	398,750
	Medium Sand	0.00116	0.33	1,262			
	Coarse Sand	0.00232	0.24	2,595			
	Very Coarse Sand	0.00464	0.03	392			
	Very Fine Gravel	0.00928	0.04	367			
	Fine Gravel	0.01856	0.06	189			
	Medium Gravel	0.03712	0.05	10			
52,140	Fine Sand	0.00058	0.24	259	3,942	42.6%	612,464
	Medium Sand	0.00116	0.33	1,006			
	Coarse Sand	0.00232	0.24	2,069			
	Very Coarse Sand	0.00464	0.03	287			
	Very Fine Gravel	0.00928	0.04	228			
	Fine Gravel	0.01856	0.06	92			
	Medium Gravel	0.03712	0.05	1			
28,780	Fine Sand	0.00058	0.24	152	2,210	23.0%	185,224
	Medium Sand	0.00116	0.33	593			
	Coarse Sand	0.00232	0.24	1,219			
	Very Coarse Sand	0.00464	0.03	141			
	Very Fine Gravel	0.00928	0.04	84			
	Fine Gravel	0.01856	0.06	21			
	Medium Gravel	0.03712	0.05	0			
10,000	Fine Sand	0.00058	0.24	25	335	2.1%	2,591
	Medium Sand	0.00116	0.33	97			
	Coarse Sand	0.00232	0.24	200			
	Very Coarse Sand	0.00464	0.03	11			
	Very Fine Gravel	0.00928	0.04	1			
	Fine Gravel	0.01856	0.06	0			
	Medium Gravel	0.03712	0.05	0			
Note: Q = 213,500 cfs represents all discharges above 133,750 cfs				Sum		100%	1,565,176

Table 4-7: Bed load calculations using Modified Einstein's Method for the St. Joseph Gage (see explanation of symbols on page 21).

Q cfs	Class	D (ft)	i_b %	Q_{TBL} tons/day	ΣQ_{TBL} ton/day	% of year	Q_{BL} tons/year
221,600	Fine Sand	0.00058	0.31	1,345	16,811	0.2%	14,726
	Medium Sand	0.00116	0.40	4,907			
	Coarse Sand	0.00232	0.21	7,220			
	Very Coarse Sand	0.00464	0.01	464			
	Very Fine Gravel	0.00928	0.02	1,176			
	Fine Gravel	0.01856	0.03	1,699			
	Medium Gravel	0.03712	0.00	0			
141,200	Fine Sand	0.00058	0.31	755	8,854	2.0%	65,280
	Medium Sand	0.00116	0.40	2,755			
	Coarse Sand	0.00232	0.21	4,054			
	Very Coarse Sand	0.00464	0.01	249			
	Very Fine Gravel	0.00928	0.02	541			
	Fine Gravel	0.01856	0.03	500			
	Medium Gravel	0.03712	0.00	0			
86,110	Fine Sand	0.00058	0.31	397	4,345	12.5%	198,563
	Medium Sand	0.00116	0.40	1,449			
	Coarse Sand	0.00232	0.21	2,130			
	Very Coarse Sand	0.00464	0.01	116			
	Very Fine Gravel	0.00928	0.02	166			
	Fine Gravel	0.01856	0.03	88			
	Medium Gravel	0.03712	0.00	0			
53,310	Fine Sand	0.00058	0.31	235	2,467	45.9%	413,099
	Medium Sand	0.00116	0.40	857			
	Coarse Sand	0.00232	0.21	1,256			
	Very Coarse Sand	0.00464	0.01	53			
	Very Fine Gravel	0.00928	0.02	51			
	Fine Gravel	0.01856	0.03	15			
	Medium Gravel	0.03712	0.00	0			
31,110	Fine Sand	0.00058	0.31	134	1,383	39.3%	198,567
	Medium Sand	0.00116	0.40	491			
	Coarse Sand	0.00232	0.21	720			
	Very Coarse Sand	0.00464	0.01	23			
	Very Fine Gravel	0.00928	0.02	14			
	Fine Gravel	0.01856	0.03	1			
	Medium Gravel	0.03712	0.00	0			
Note: Q = 221,600 cfs represents all discharges above 181,400 cfs				Sum		100%	890,236

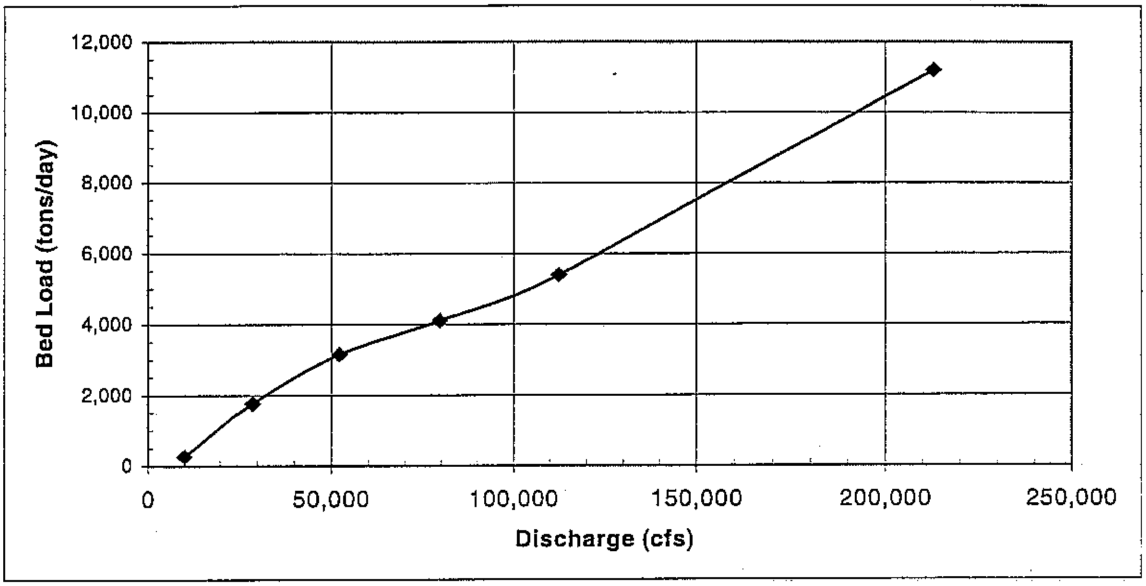

Figure 4-13: Daily bed load at the project site as function of daily mean discharge.

4.5 Annual Estimates of Total Bed Material Load

The relationships presented in Table 4-2 were applied to the records of daily mean flow for each gage to calculate the suspended bed material transport. The daily flows from 1967 to 1997 were used for both gages. Table 4-8 summarizes annual transport values at each gage over the period of discharge records. The mean annual bed material transport at the Kansas City Gage was calculated to be about 7.6 million tons/year and for the St. Joseph Gage to be about 6.8 million tons/year. Also listed in the table are the bed load values described in Section 4.4 and the ratio between the bed load and the suspended bed material load. For the Kansas City Gage, the ratio is 0.17 and for the St. Joseph Gage the ratio is 0.11.

The total bed material load was calculated by adjusting equation (2) with the bed load ratio. The equation becomes $Q_s = \alpha a Q^b$, where α is given by $\alpha = 1 + ratio$ where *ratio* is given in Table 4-8. It is assumed that α is constant although it depends somewhat on discharge. Using this method, the total bed material load for each of the last 30 years was determined. The results are plotted in Figure 4-14. Figure 4-15 shows the annual flow volumes for comparison purposes. The larger sediment volumes of the Kansas City Gage in comparison to the St. Joseph Gage for 1973 and 1993 are due to the higher water volumes as shown in Figure 4-15.

Table 4-8: Sediment transport at the gages.

			Kansas City Gage	St. Joseph Gage
Suspended Bed Material Load	Average year	tons/year	9,316,191	8,064,758
	Median year	tons/year	7,270,513	7,855,935
	Maximum year	tons/year	29,712,539	17,450,171
	Minimum year	tons/year	3,251,442	3,263,746
Bed Load	Average year	tons/year	1,565,176	890,236
Ratio			0.17	0.11

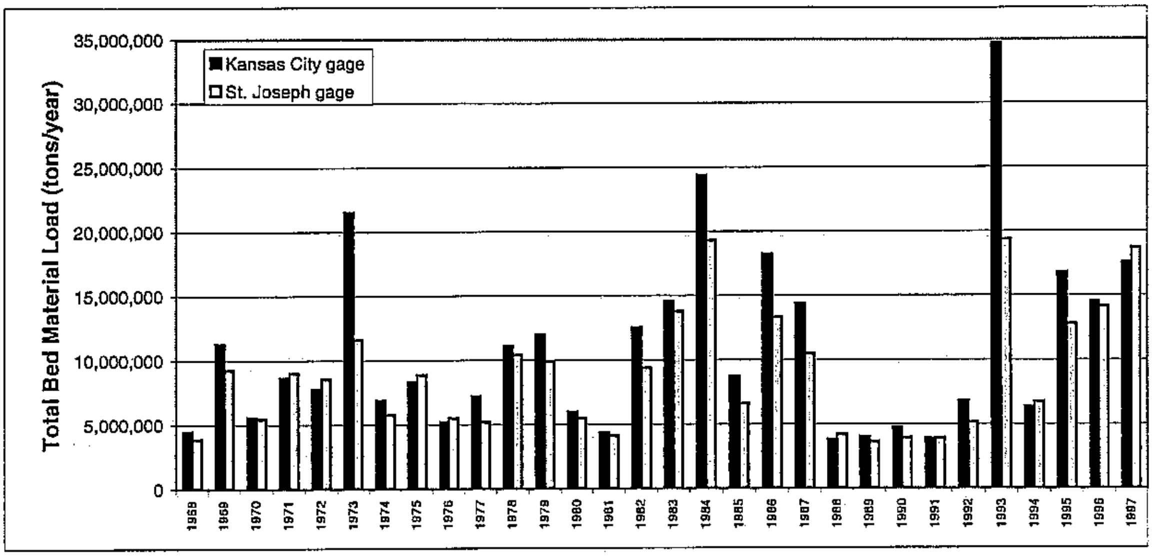

Figure 4-14: Total bed material load for both gages.

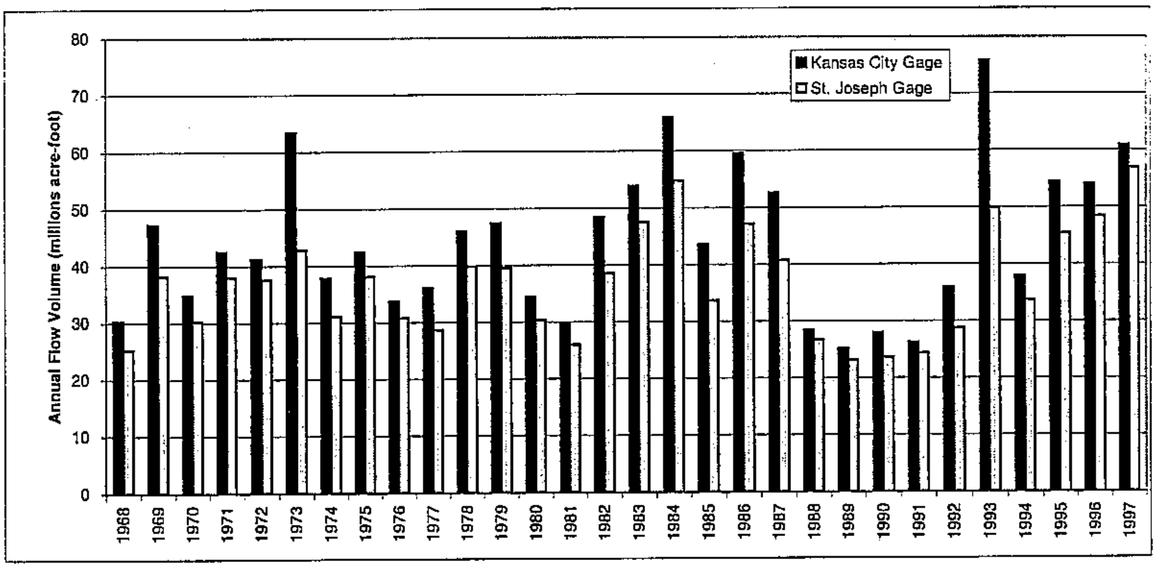

Figure 4-15: Annual flow volumes.

4.6 Evaluation of Historic Bed Level Changes

Historic bed level changes were analyzed based on USACE Missouri River hydrographic survey data supplied by the USACE. Survey data are available for the years 1967, 1971, 1975, 1978, 1983, 1987 and 1994. In Figure 4-16 the mean elevation determined for cross sections located along a 14-mile reach of the Missouri River are presented. The mean elevation of a cross section is calculated as the weighted average of the data points composing the cross section. The weighting is proportional to the distance between the data points. Six different plots are included on the figure to demonstrate the bed development over time. The figure includes cross sections located both upstream and downstream of the project area.

Plot (a) in Figure 4-16 shows a comparison of mean bed elevation for the years 1967, 1971 and 1994. Note that the mean elevation for 1967 is similar to 1994. Comparing plot (a) and plot (b) shows that the mean elevation of the bed substantially increased from 1971 to 1975. The increase is of the order of 5 to 8 feet between RMs 366 to 376. This river reach includes the project area. It is noted from Figure 4-15 that one of the highest annual flow and sediment volumes occurred in 1973. Plot (c) shows that the bed degraded from 1975 to 1978.

In plot (d), the 1983 mean bed elevation is seen to be very close to the 1967/1994 conditions. Plot (e) indicates that overall aggradation occurred between 1983 and 1987 and degradation from 1987 to 1994. It should be kept in mind that 1993 experienced the largest flow for the 30 year period of record and probably influenced the bed elevation. However, the 1971 bed elevation is very close to the 1994 bed elevation. This could suggest that the 1994 bed elevation is close to being the lowest natural state of the bed for this river reach. Plot (f) in Figure 4-16 (expanded plot is in Figure 4-17) shows the entire data set in one plot. It is observed that the range of mean depth fluctuations is on the order of 10-12 feet, and is larger at the downstream end of the reach, closer to the confluence with the Kansas River. The largest range observed is approximately at between RMs 372-374. This range coincides with dredging activities as is discussed in Section 4.7.

In Figure 4-18, the mean elevations for the river reach upstream of the project area (RM 380 to 450) is plotted. Trends similar to those in the vicinity of the study area are observed. From 1967-1971 degradation is observed and then aggradation from 1971 to 1978. The channel is seen to be relatively stable from 1978 until 1987. From 1987 to 1994 the channel is seen to degrade.

In Figure 4-19 and Figure 4-20, the historic thalweg elevations for the project area and study area are presented. Temporal trends similar to those observed for the mean depth are observed. However, the range of fluctuation is seen to be considerably larger than that noted for the mean elevations. In some cases, the fluctuations in thalweg elevation are on the order of 30 feet. The thalweg for the year 1971 is, in most cases, considerably lower than for other years. It is noted that the annual flow volumes shown in Figure 4-15 did not show any unusual flow magnitudes between the years 1967 and 1971.

In Figure 4-21, a qualitative correlation between flow and degradation/aggradation is plotted. The figure shows an average flow volume for each period divided by the average flow for the period from 1967 to 1997. Hence, a period with value of one would be an average flow period. It is seen from the figure, in below average flow periods, the bed tends to degrade and in above flow periods the bed tends to aggrade. It is worth noting that in the period with the largest flow on record (1993), the bed degraded. This probably occurred because the years before 1993 were below average water years.

In Figure 4-22, the thalweg elevations for the study area is plotted at every RM. A straight line was fitted through the data from the Kansas City Gage to the St. Joseph Gage. The line shows that the study area has nearly a uniform slope of about 1.0 ft/mile.

The thalweg elevations for the downstream end of the study reach, including the project area, are shown in Figure 4-23. In one instance (RM 371) the thalweg elevations fluctuate at least 20 feet. The three largest dips in the thalweg are coincident with three sharps bends in the reach. These bends are from upstream to downstream: Quindaro Bend (~RM 374.5), Kaw Bend (~RM 371.5), and Kansas River Bend (~RM 367.5). Figure 4-23 also shows the location of several structures in the river reach, including bridges, intakes, pipelines and cables. Further discussion of these structures is in Section 4.6.1. No specific influence of the structures on the river profile is evident.

It is noted that bed forms in the river could explain some of the observed bed elevation fluctuations. An estimate of the size of the bed forms was developed based on hydraulic variables. In Simons (1977) two methods of estimation are suggested: Allen (1963) and Goswami (1967). These methods result in predicted bed form heights of about 3 to 4 feet for Allen (1963) and of about 2 feet for Goswami (1967). The observed bed elevation variations are considerably larger than these estimates and are therefore attributed to influences other than bed forms.

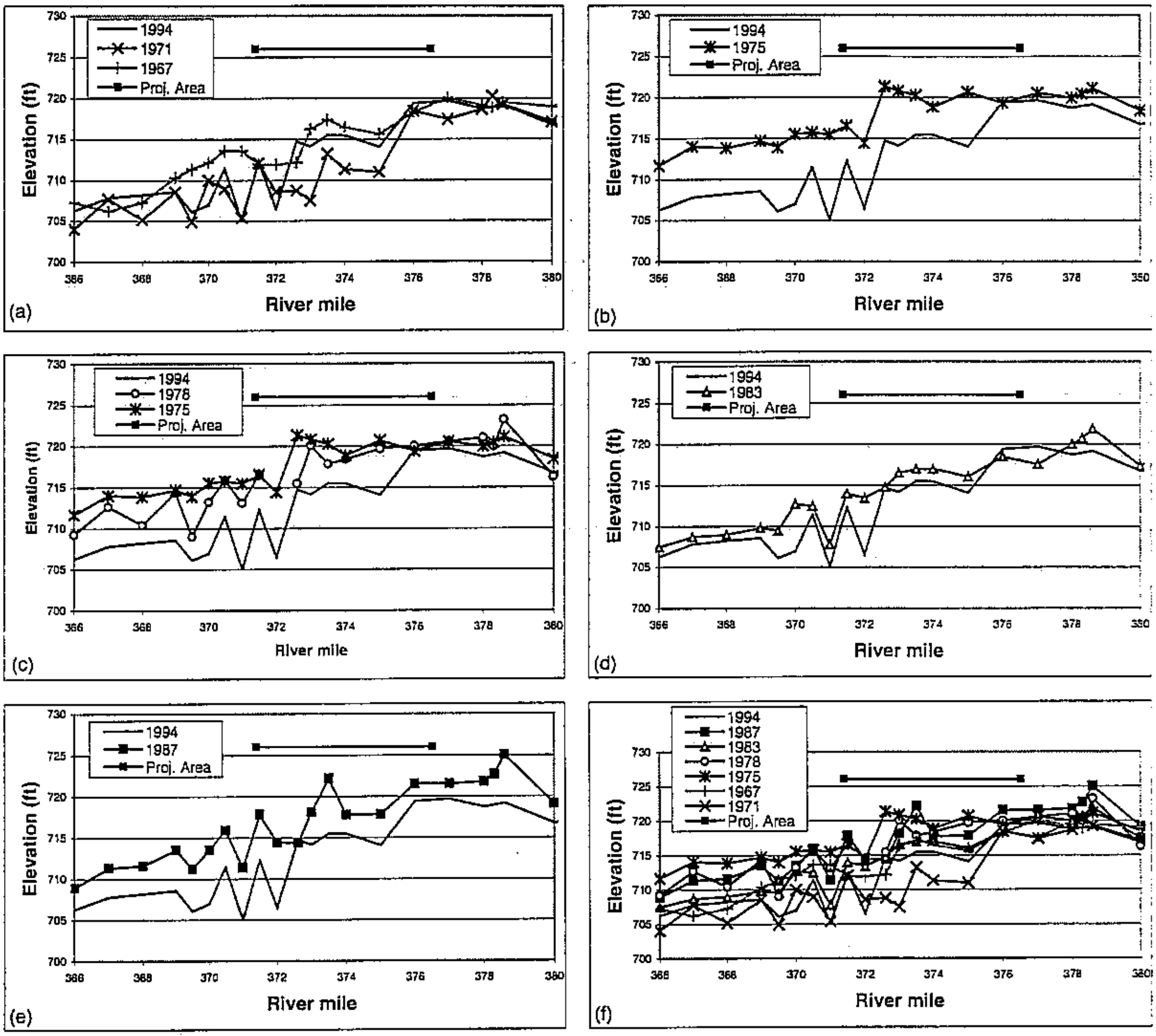

Figure 4-16: Mean elevations at cross sections located along 14 mile reach surrounding the project area.

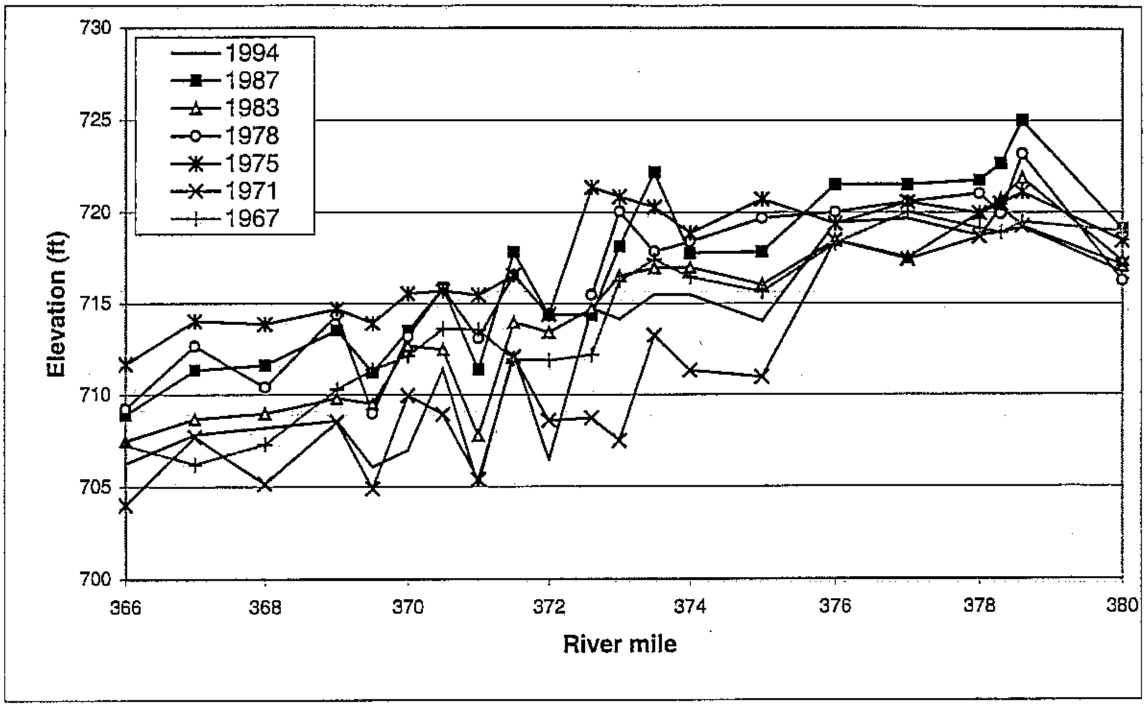

Figure 4-17: Mean elevations at the project site.

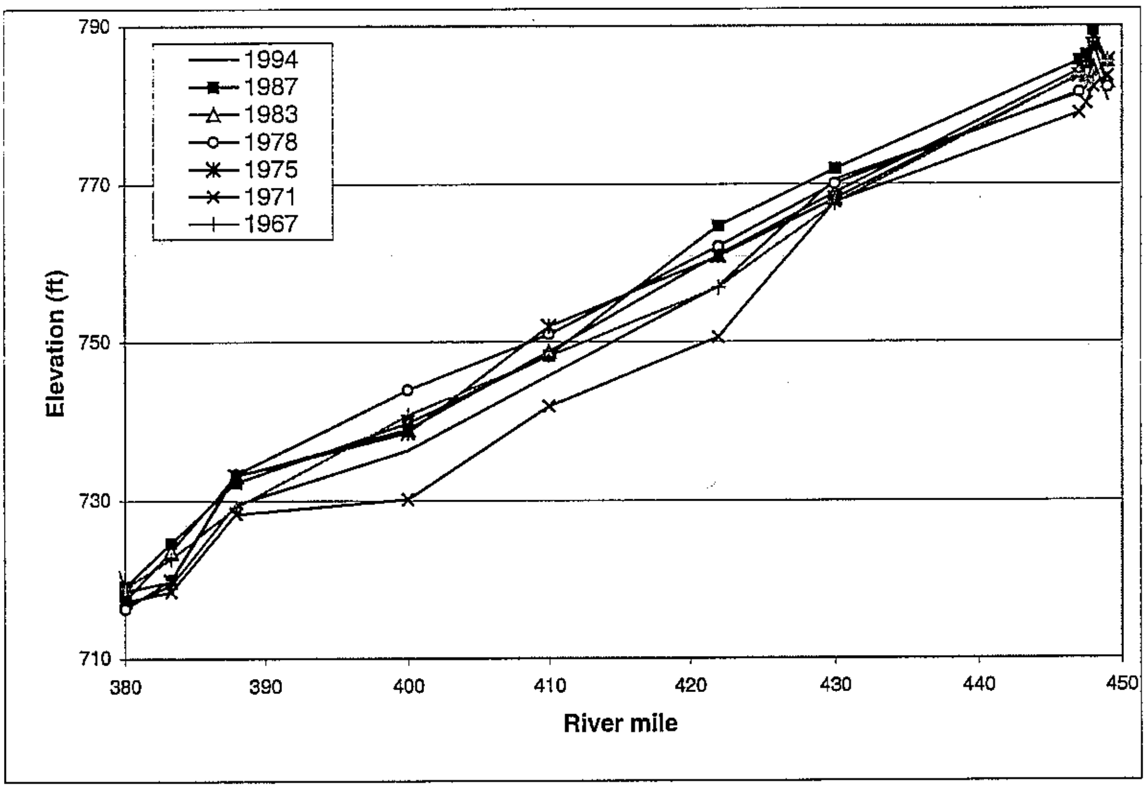

Figure 4-18: Mean elevations upstream of the project site. The upstream limit is located at the St. Joseph Gage.

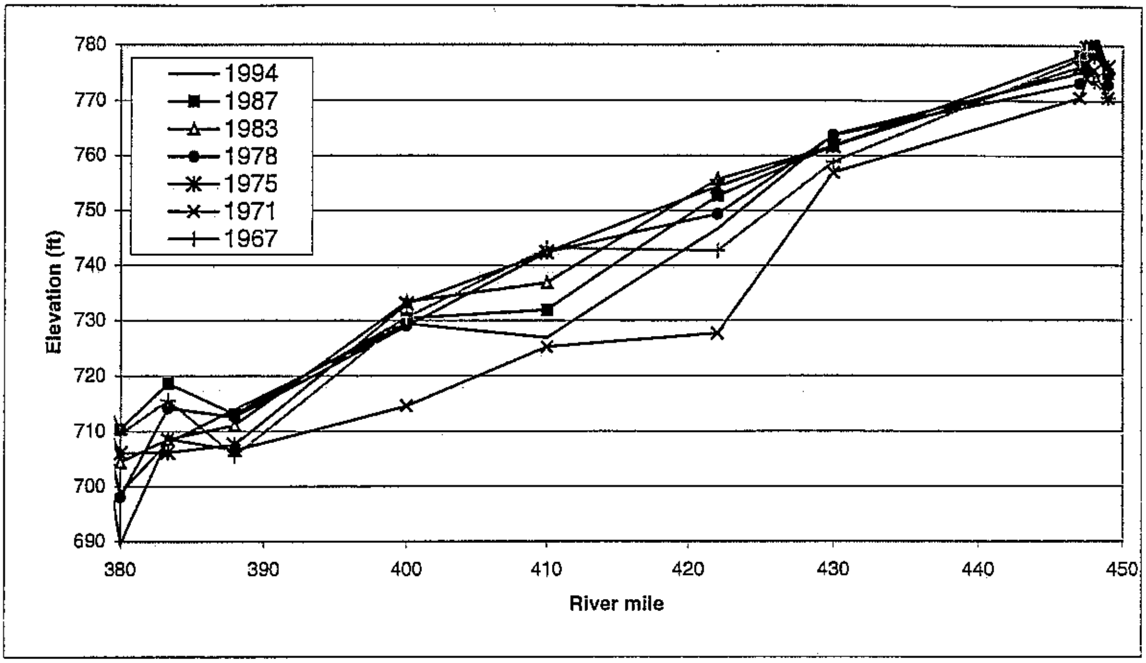

Figure 4-19: Thalweg elevation for the river reach surrounding the project site.

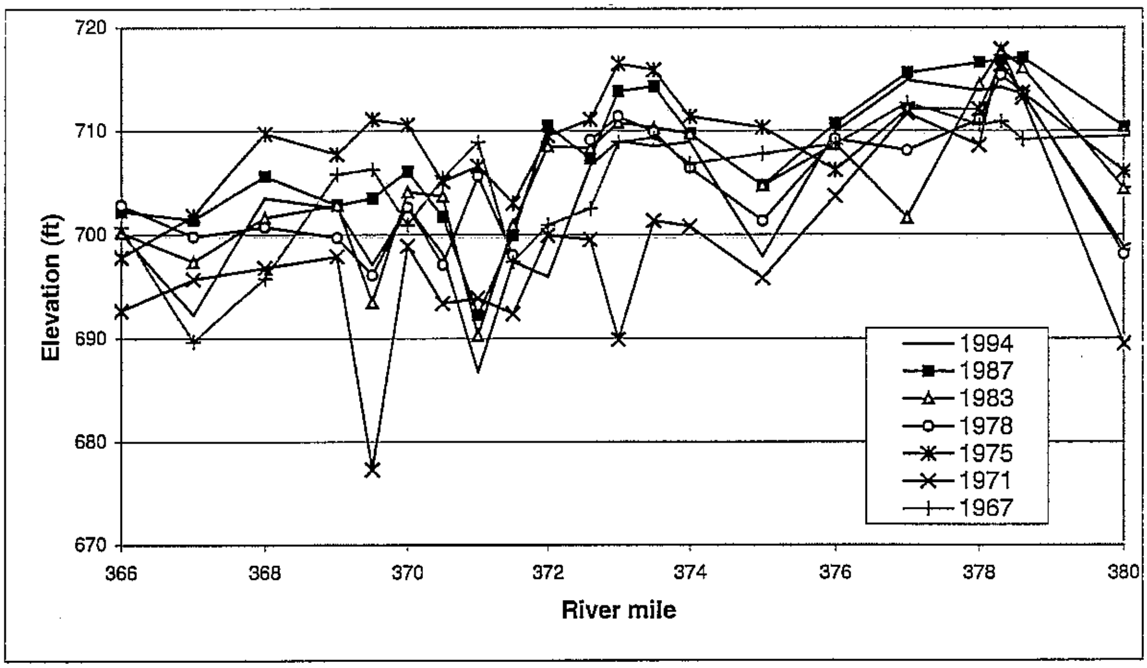

Figure 4-20: Thalweg elevations upstream of the project site.

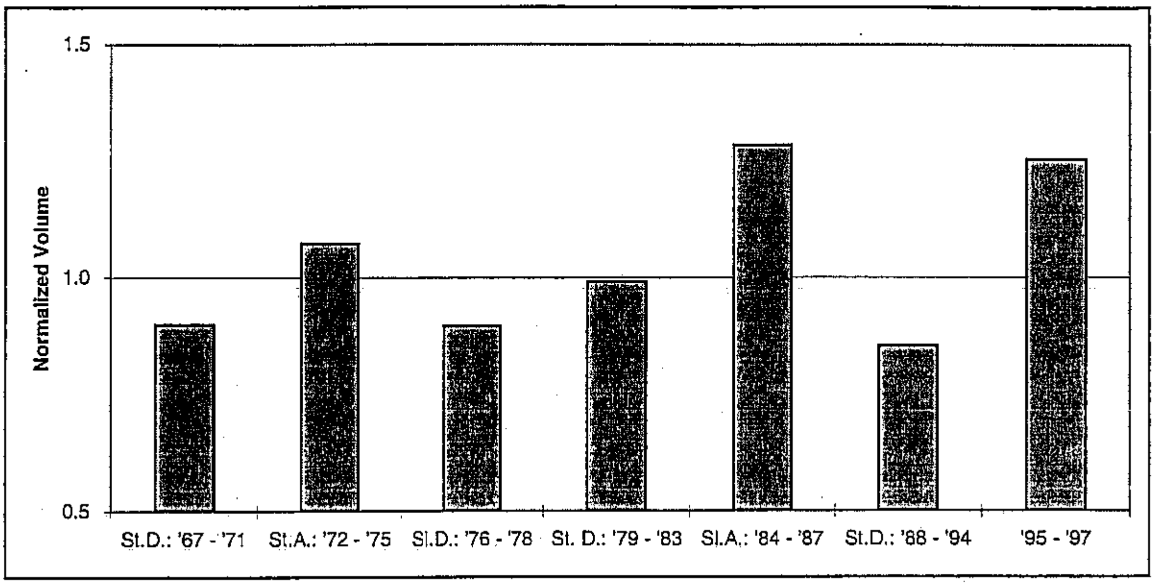

Figure 4-21: Correlation between degradation and flow volume (D is degradation, A is aggradation, St. is strong, and Sl is slight), 1.0 represent average flow conditions for the period.

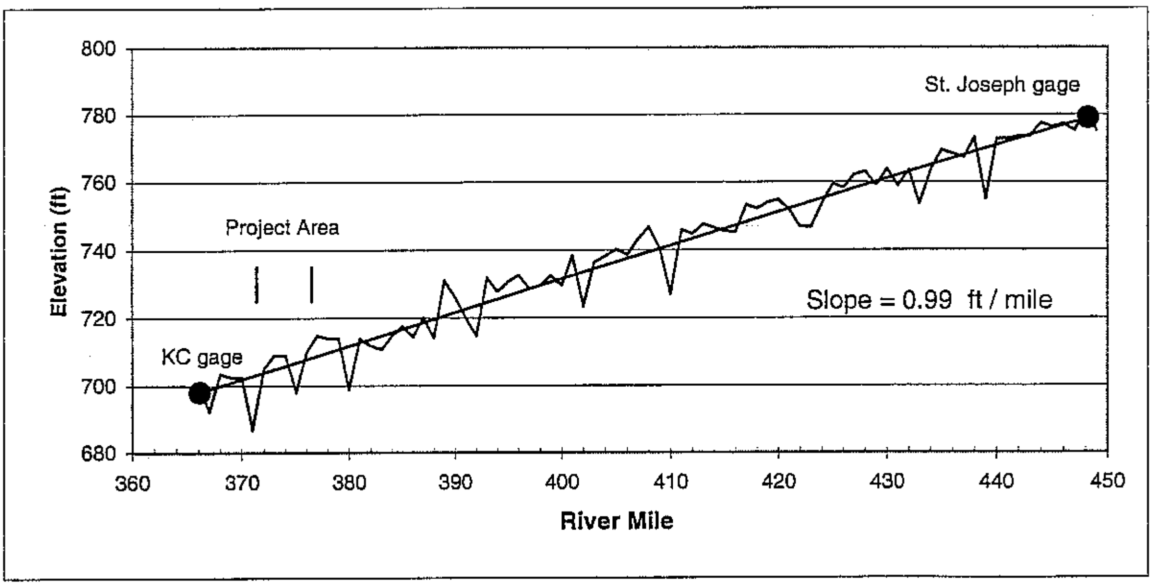

Figure 4-22: Thalweg elevation for the study area for 1994. The straight line through the data set depicts the slope of the river.

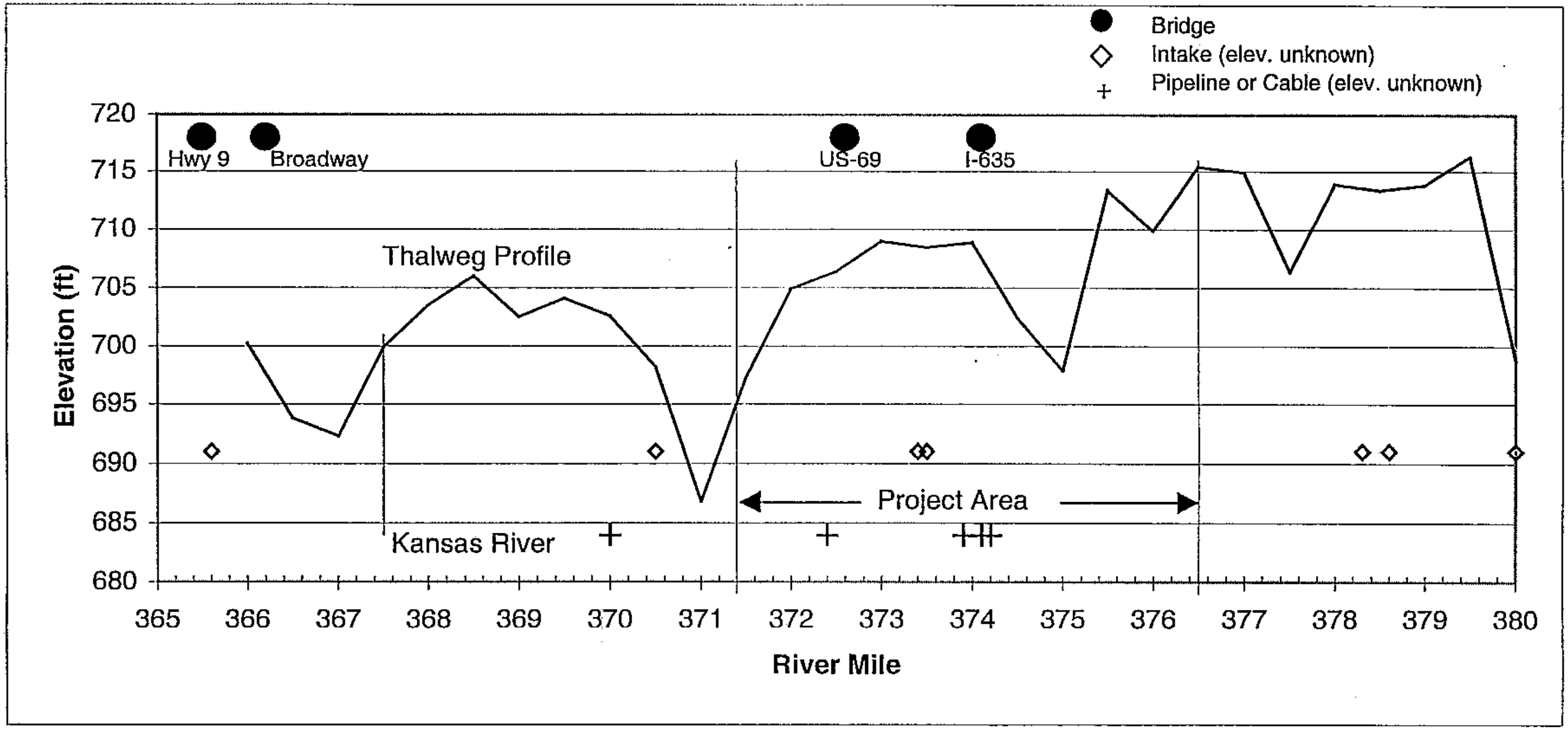

Figure 4-23: Thalweg elevation (1994) and structure locations in and around the project area. The specific elevations of the structures are unknown.

4.6.1 Infrastructure

Information obtained from the infrastructure owners indicate no significant infrastructure problems can be attributed to dredging and/or scour along the river reach. A complete listing of infrastructure is presented in Appendix A. The data obtained for bridges does not indicate any significant problems at the bridge sites. Table 4-9 lists thalweg elevations obtained from bridge drawings as well as soundings of thalweg elevations provided by USACE.

Table 4-9: Thalweg elevations from bridge drawings and channel sounding data.

Bridge Thalweg	Downstream →			← Project Area →								
Bridge RM	US-36 447.9	Hwy 92 397.6	I-435 383.3	I-635 374.1	US-69 &169 372.6	Kansas River 367.5	Broadway 366.2	HWY 9 365.5	I-35, I-29 364.7	I-435 360.3	Thalweg soundings 355.0	Thalweg soundings 350.0
1933					713.7							
1952									707.6			
1953		732.0										
1955							693.7					
1956					718.7							
1965										697.0		
1967	779.5	727.3	715.6	704.9	702.5	686.2	691.8	698.2	693.3	693.3	674.5	683.8
1968				704.0								
1974			710.0									
1978	778.1	734.7	714.2	707.5	710.1	690.2	700.0	701.4	695.6	696.7	686.1	688.8
1980								696.0				
1987	780.9	730.0	707.5	711.8	705.3	685.8	696.4	699.8	698.2	691.0	689.0	688.5
1990	766.0				708.0			702.0	692.0	687.0		
1991				707.0								
1994	778.0	732.2	708.0	707.0	706.5	687.8	696.4	694.8	697.2	691.8	686.5	687.6
1998				706.0	706.0							

There is a slight degradation trend noted at the bridges downstream of the Kansas River. Since about 1978, about 3 to 5 feet of degradation has occurred in this area. The elevations are plotted in Figure 4-24. This condition could possibly be linked to degradation on the Kansas River. According to Ken Stark, USACE Kansas City District, the Kansas River has degraded about 10 feet at a location 10 miles upstream of the confluence with the Missouri River since about 1977. However, the degradation observed on the Missouri River over the last 20 years is much smaller than 10 feet and could be explained by natural variability of the bed discussed in Section 4.6. No other consistent trends in thalweg elevation variations were detected.

The most important significant evidence of channel degradation identified from contacts with the owners of infrastructure in the vicinity of the project is the state of the Williams Brothers pipelines (see correspondence in Appendix B). It was determined that pipelines at RM 372.3 are exposed. This means that bed variations could potentially damage the pipelines. Only one of the pipelines is currently in use, it contains a telecommunications cable. This is discussed further in Section 4.8.

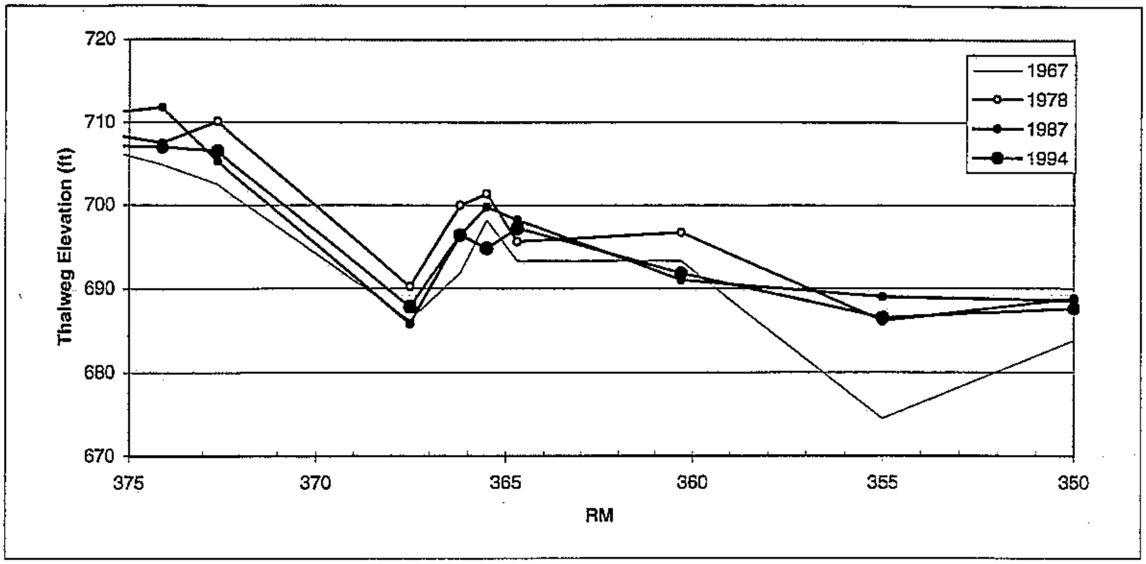

Figure 4-24: Thalweg elevations at bridges and within the project area.

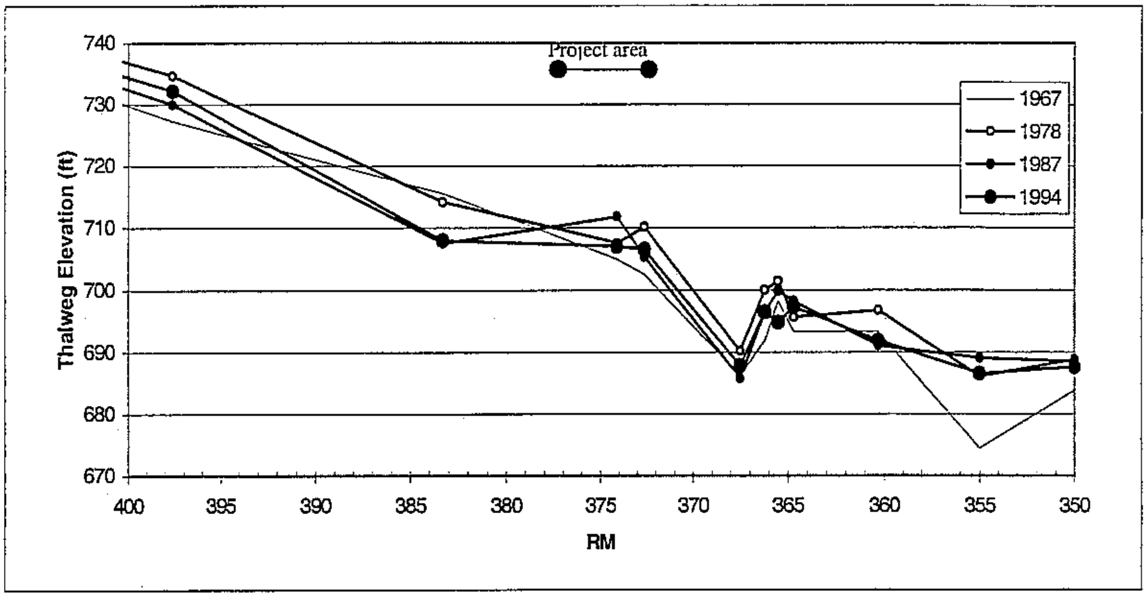

Figure 4-25: Thalweg elevations at bridges within study area.

4.6.2 Specific Gage Analysis

Data for the St. Joseph, Kansas City and Waverly gages was obtained from the USACE (USACE, 1994). The St. Joseph gage (Figure 4-26) and the Waverly gage (Figure 4-28) show increasing stage trends. As is discussed in USACE (1994) the stage at these locations is affected by land use along the river and the construction of dike fields that leads to deposition between the structures.

The stage at the Kansas City gage is shown in Figure 4-27. Unlike the upstream and downstream gages, the Kansas City gage stage trend has been decreasing. The USACE (1994) states the following:

> "The Kansas City stage trends reflect a general downward trend in experienced stages for discharges ranging from 20,000 cfs to 40,000 cfs since about 1940. This degradation or lowering of experienced stages is strongly related to the general confinement of the river in the Kansas City reach and the removal of material from the bed due to commercial sand and gravel dredging activities on both the Missouri and lower Kansas Rivers."

This conclusion suggests that dredging activities discussed in Section 4.7 (less than 5 miles upstream of the Kansas City gage) are an influence on degradation trends at the gage. This conclusion is in agreement with the results of the cross section analysis presented earlier in this section. Hence, increased dredging upstream of the gage, in the project area, would be expected to influence degradation in the downstream areas.

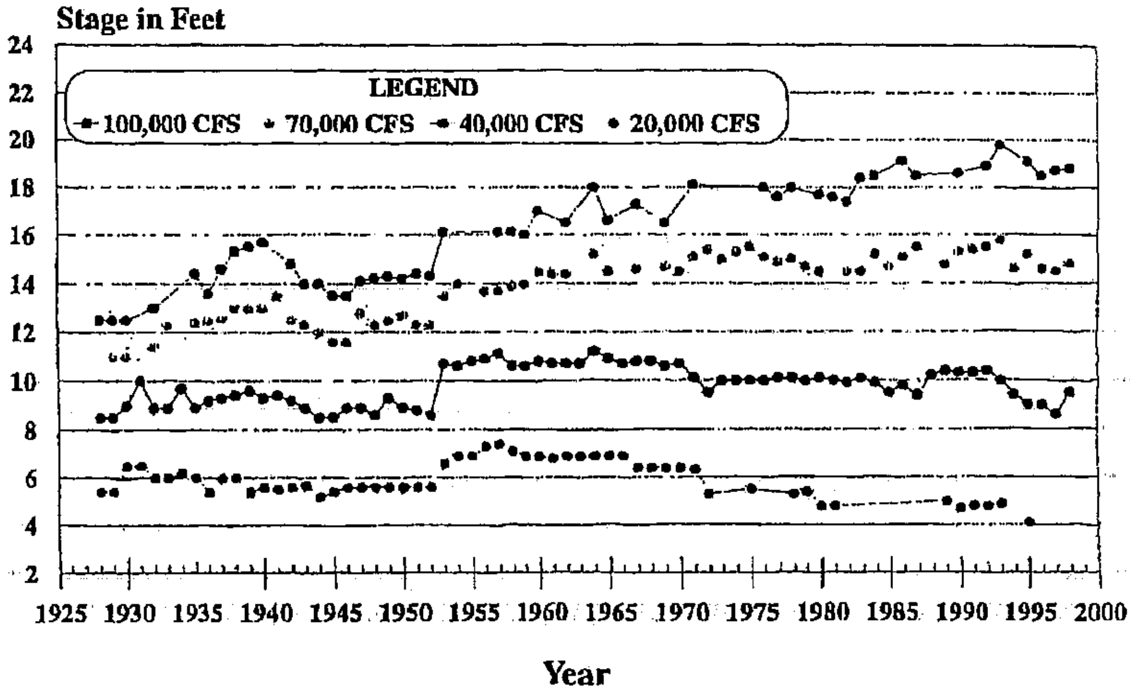

Figure 4-26: Missouri River Stage Trends at St. Joseph, Missouri (Gage Datum 788.19 feet msl, Flood Stage 17 feet, River Mile 448.2). (Source: USACE, 1994).

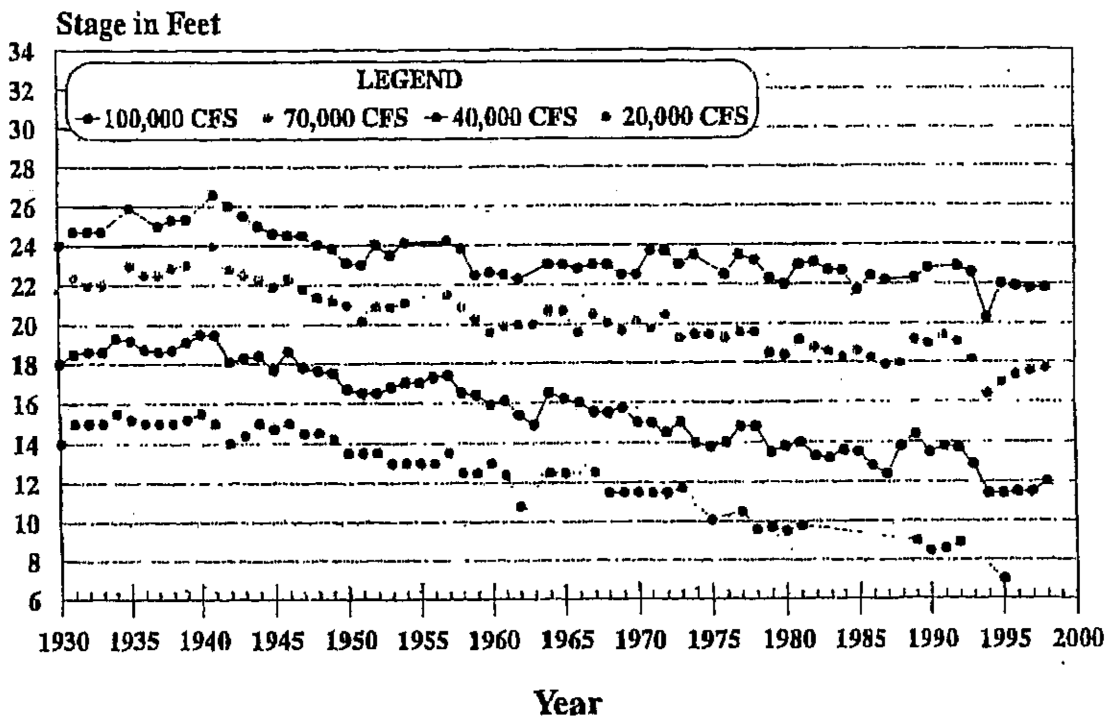

Figure 4-27: Missouri River Stage Trends at Kansas City, Missouri (Gage Datum 706.4 feet msl, Flood Stage 32 feet, River Mile 366.1). (Source: USACE, 1994).

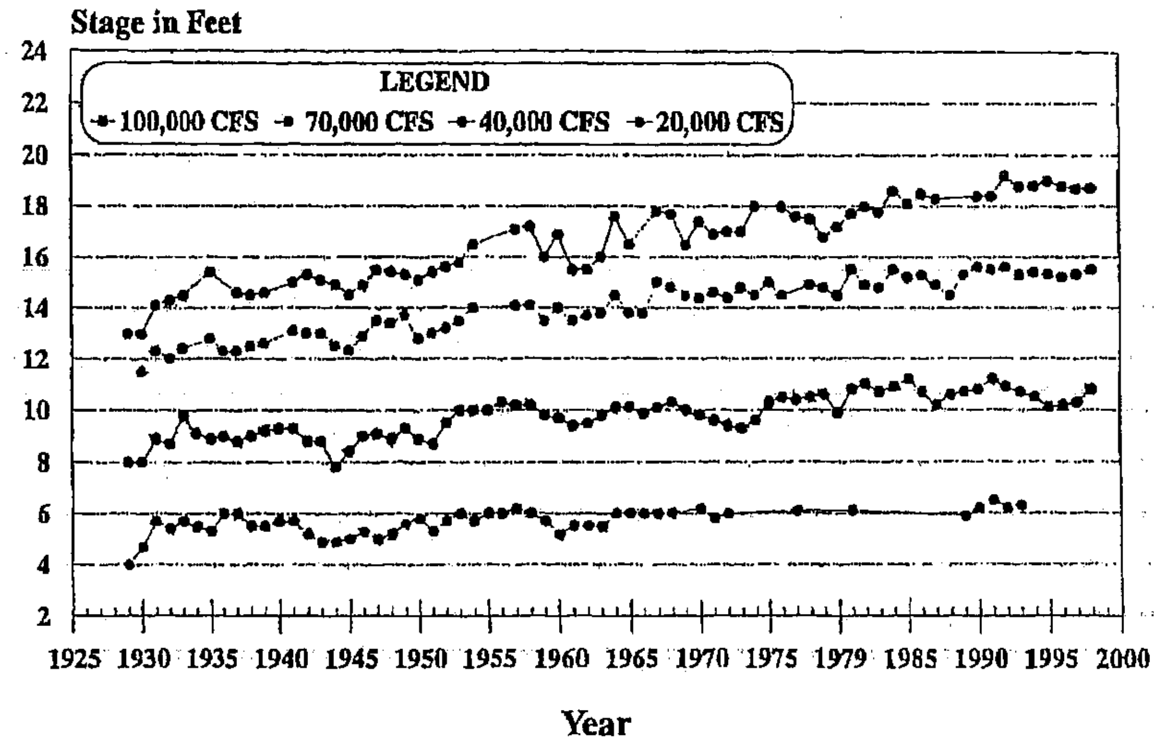

Figure 4-28: Missouri River Stage Trends at Waverly, Missouri (Gage Datum 646.0 feet msl, Flood Stage 20 feet, River Mile 293.4). (Source: USACE, 1994).

4.7 Determination of Annual Bed Material Extraction

Available dredging records for the study area were analyzed to determine the annual volume of bed material extraction. The data are summarized in Table 4-10. Only two companies were actively dredging during the time period 1994 to 1997: Holliday Sand & Gravel Company and Capital Sand Company. Kaw Valley Sand and Gravel has a permit to dredge but did not during the period covered by available records. The Corps of Engineers also dredge on an as-needed emergency basis to maintain navigation along the river. No records of Corps-related dredging activities in the study area are available. Table 4-10 lists specific river miles for Holliday Sand and Gravel Company dredging locations but from conversations with a representative of the company (Personal communication with Ken Milsap, 1999), the dredging extends at least 1 to 2 river miles upstream and downstream of these locations. The dredging data in Table 4-10 show that on average, for the river reach from RM 135 to RM 450, about 4 million tons were extracted annually from the river for the period from 1994 to 1997.

The only dredging that takes place within the project area is performed by the Holliday Sand & Gravel Company in the vicinity of RM 371.8. The average annual dredging amount at this location is about 1.3 millions tons. As an example of the distribution of dredge locations in the project area, the location and amount of dredging material for 1997 are plotted in Figure 4-29. The location between RMs 371 and RM 372 is just outside the companies processing plant and upstream of the Kaw Bend; the location at RM 373.2 is upstream of the Hwy 69 bridge (RM 372.5); the location between RM 374 and RM 375 is upstream of the I-635 bridge and several cable crossings (RM 374). The dredging location at RM 375.8 is upstream of the Quindaro Bend and Williams Brother pipeline crossing at RM 375.2. It is clear from this location list that the dredging locations are not only controlled by available material (locations of bends, etc.) but also the locations of structures.

Table 4-10: Historic dredging records for the study area (Source: USACE)

Company	Location	RM	1997 (ton)	1996 (ton)	1995 (ton)	1994 (ton)	Average (ton)
Holliday Sand		360	1,297,450	1,164,000	1,178,000	1,100,000	1,184,863
& Gravel		371.8	1,542,720	1,374,000	1,330,000	1,000,000	1,311,680
Company		447.7	334,750	364,000	298,000	370,000	341,688
	Jefferson City	135-155	0	780,000	800,000	800,000	793,333
Capital Sand	Rocheport	175-195	200,700	348,150	250,000	375,000	293,463
Company	Glasgow	220-235	92,700	102,200	150,000	150,000	123,725
	Carrollton	280-290	51,300	22,100	40,000	40,000	38,350
	Lexington	315-325	96,300	138,400	70,000	50,000	88,675
Sum			3,615,920	4,292,850	4,116,000	3,885,000	3,977,443

In order to obtain information regarding specific dredging practices, WEST contacted Ken Millsap, Plant Manager for the Holliday Sand and Gravel's dredging Plant 11, located in the project reach. Minutes of the conversations are included in Appendix B.

Details of the dredging practices employed include:

1) *Method of dredging*: Hydraulic dredging.
2) *Amount of material that can be extracted in a day*: 7,500 yd^3 is close to the maximum daily amount of material.
3) *Magnitude of the dredge hole that is created by extracting the maximum or a large quantity of material*: The depth of the dredge hole is dependent on the water level. The maximum reach of the dredge is about 45 feet below the water surface. Therefore, in a water depth of about 10 feet, the maximum depth is about 35 feet.
4) *Time for a dredge hole to fill in*: According to Mr. Millsap, a dredge hole of about 7,500 yd^3 in the main channel generally fills overnight or at most over a weekend.

The main channel has coarser material than channel areas closer to the bank. This would be expected due to differences in flow velocity within the channel. Material fills in at a much slower rate between dikes than in the main channel. There are usually scour holes located downstream of the dike tips. The dredge is often moored at those locations due to the greater water depths. They have not had any problems with channel or structure instability. The dredge operators are said to be very conscious of maintaining sufficient distance from structures.

In Figure 4-30 a comparison between daily dredge volumes in 1997 and mean daily discharge for low, average and high water years is plotted. For 1997, the dredging season was longer than the navigation season. It is also observed that the second half of the year has relatively constant flow rates (except for October 1987), which is probably due to flow regulation. It is also noted that for the low flow year (1990) shown, the flow is kept at about 40,000 cfs from September to the end of October for navigational purposes.

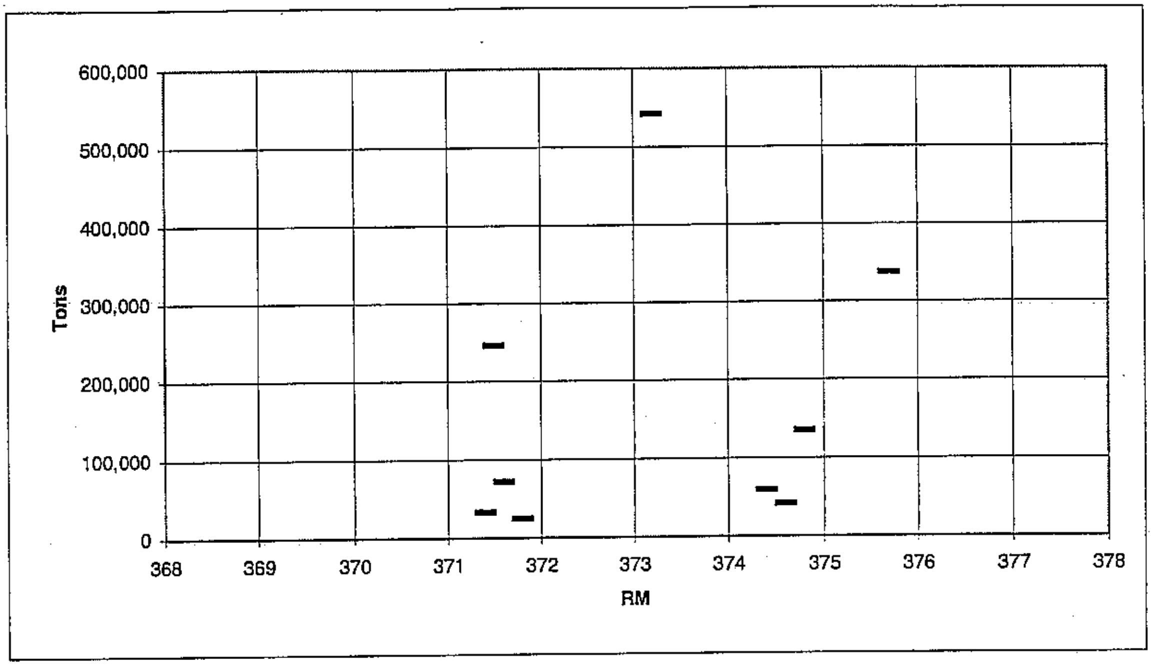

Figure 4-29: Dredge locations and amounts for 1997 within the project area (Source: USACE from data supplied from Holliday Sand and Gravel).

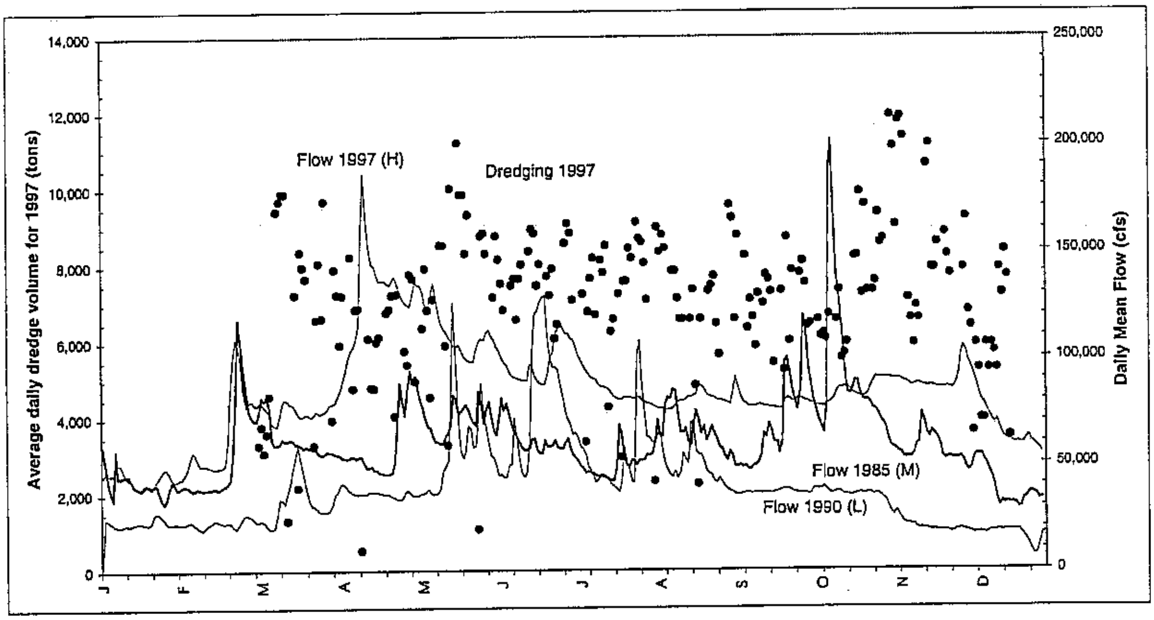

Figure 4-30: Mean daily dredging for 1997 in the project area and mean daily discharge for high (H), low (L) and average (M) water years.

4.8 *Anticipated Impacts*

In the following sections, the anticipated impacts associated with dredging for the proposed project are discussed. The historic changes to the channel and surrounding infrastructure and their relationship to dredging activities are described. Based on the historic conditions, the anticipated impacts associated with proposed dredging activities are characterized.

4.8.1 Historic Conditions

Available dredging data for the project reach extends back to 1994. During those 4 years (1994 to 1997) Holliday Sand and Gravel has dredged an average of 1.3 millions tons of material from the project area per year. This amount is approximately equal to the amount of bed load of the river and about 15% of the total average bed material load. It is not known how much material was dredged from the project area prior to 1994. The historic hydrographic survey and structure data obtained (see Chapter 3) revealed the following significant changes to the channel and infrastructure in the study area:

- Degradation of the thalweg averaging about 3 to 4 feet was observed downstream of the project site from 1978 to 1994, both at bridges and at RMs 355.0 and 360.0. The most significant degradation of about 4 to 7 feet is seen at the Broadway bridge and the State Highway-9 bridge since 1978. Based on the available data it is not possible to conclude that historic dredging is causing this degradation trend as it is within the range of historic bed fluctuations seen in other locations. In addition, it is not known how much material was removed from this area prior to 1994. However, it is recommended that the 1998 soundings data (not available at the time this report was prepared) be compared to the 1994 soundings data to see if the degradation trend is ongoing. It is probably unlikely that the trend continues, as the years 1994 to 1997 were above average water years. It must also be kept in mind that the 1993 flood was between a 200 to 300 year return period event at this location and therefore could have abnormally affected the bed.

- About half a mile upstream of the Holliday Sand and Gravel Plant 11 operation, the Williams Brothers Pipeline Company has a pipeline corridor that crosses the river channel at RM 372.4. Only one of the pipelines in the corridor is in use, hosting a telecommunication cable, the other pipelines are currently spare. According to Rodney W. Kilgore, P.E., manager of pipeline engineering, Mid-Continent Region, Williams Brother Pipelines, the latest inspection of those pipelines showed them to be exposed (A letter from Mr. Kilgore is included in the supporting material supplied to the USACE for this study). This condition could be due to a head cut propagating from the downstream dredging, reduced bed material load from upstream dredging, or normal fluctuations of the bed. It is noted that one of the pipelines at this location was installed in 1931 and the others were installed in the 1950's. According to Mr. Kilgore, the installation depth of these pipelines was probably about 4 feet below the bed, enough to fulfill the federal code requirements at the time. The shallow placement depth may not be deep enough to shield them from the observed fluctuations of the bed discussed in Section 4.6. It is therefore uncertain if the exposure is due to dredging or other natural influences.

The fact that the average annual dredging volume in the project area is approximately equal to 15% of the annual bed material load could be a cause for concern. According to Ken Stark, USACE Kansas City District, the Corps does not restrict the total volume of material a dredge operator can remove from the river under the current permitting system. However, a knowledgeable dredge operator probably understands the interplay of water volume and sediment load and plans accordingly. In our conversations with Ken Millsap, Holliday Sand and Gravel Plant Manager, he stated that a dredge hole of about 7,500 yd^3 would fill in over a weekend. Considering that this volume is about 3 to 4 times the bed load volume expected for an average day (~40% of the average daily bed material load), this statement is a likely fair estimate. It is worth noting that the period 1994 to 1997 were high flow and sediment transport volume years, as shown in Figure 4-14 and Figure 4-15. The average annual bed load transport for 1994-1997 was 2.7 million tons, which is well above average. If similar amounts of dredging continue to be taken in the project area without paying attention to flow volumes (sediment supply), a period of low flows (e.g. 1988-1991) could potentially lead to problems for infrastructure in the area. At the time of this study the 1998 soundings data were not available (the latest available was 1994). That data (1998) should be compared to the data given in this report to evaluate potential changes over the last four years. However, it is considered unlikely that any significant negative impacts will be observed, as the years 1994 to 1997 were relatively high flow and sediment transport years.

There are two bridge locations within the project area: US-69 & I-635 (see Appendix A for list of bridges). In Table 4-9 the thalweg elevations from available construction drawings and inspection reports for the bridges are summarized. It is seen that the thalweg elevation changes relatively little at these two bridges and no apparent trend is observed. The I-635 was built in the early 1970's. A slight trend for degradation was noted at the bridges downstream of the project area as previously discussed. The closest bridge upstream of the project area, I-435, is located about 8 miles upstream. It is observed from Table 4-9 that the thalweg elevation at the I-435 bridge has been relatively stable since 1987 after having degraded about 10 feet from 1967 to 1987. It is noted that the bridge was built in early 1970's and the noted degradation may be due to the channel adjustment caused by the bridge. The Highway 92 bridge is located about 25 miles upstream of the project and is not expected to be influenced by the dredging project.

Two water intakes owned by Kansas City Power and Light Company are within the project area (see Appendix A). Data for the water intakes were obtained and are provided separately to the USACE as supporting information for this study. Generally speaking, no historical problems have been associated with the water intakes and it is unlikely that dredging for the project will influence them. The most critical factor associated with the intakes is the water level in the river. As long as the channel bed does not degrade significantly, no impacts to the intakes should be expected.

Pipelines owned by two companies are located in the project area. Pipelines owned by the Williams Brothers Pipeline Company have already been discussed above. Skelly Oil Company has a pipeline crossing at river mile 373.9. According to Bill Diaz, Vice President, no information about the elevation or condition of the pipeline is available. The City of Kansas City, Missouri is noted to have a water tunnel (RM 365.9) and a sewage pipeline (RM 361.1) a short distance downstream of the project area. The city's Water Department was contacted repeatedly to collect information about these structures (see Appendix B). To date, no information has been received. It is recommended that further efforts be made to collect data about these structures to evaluate their condition. The closest pipeline crossing upstream of the project area is at RM 406.7, outside of the project's expected zone of influence.

There is one cable crossing marked on the navigation charts (USACE, undated) which is located a short distance downstream of the project area. It is denoted on the navigation charts as an AT&T cable. An interview with an AT&T contact person, P.J. McDermott, Outside Plant Cable Engineer, revealed that AT&T is not aware of any AT&T crossing in the area. When asked specifically about the marked crossing, he stated that AT&T did not have cable at that location. An MCI-WorldCom cable crossing is located at RM 370, also just downstream of the project area. It is not marked on the Navigation Charts but warning signs along the river bank were found during field inspection activities (see picture in Appendix C). A telephone conversation with Rick Stull, Outside Plant Manager, revealed that he does not think that the cable will be affected by dredging in the project area. The cable is contained in a pipeline (probably one marked as Williams Brothers pipeline on the navigational charts). Mr. Stull indicated that the pipeline is not buried very deep, but he does not know the depth. Mr. Stull requested that the USACE notify MCI-Worldcom before dredging for the project is started. The mailing address for Mr. Stull is contained in Appendix B.

Aerial photography (supplied by the USACE) of the project area were also analyzed. The photographs show four snapshots in time: 1965, 1979, 1986 and 1989. The photographs show that a significant amount of infrastructure has been added to the area since the mid 1960's. For example, the I-635 bridge was constructed between 1965 and 1979. The sequence shows that the geomorphic features, such as river width, have remained essentially the same over the last 30 years.

4.8.2 Proposed Dredging

In an average or low water year, the possibility of dredging considerably more than is currently dredged without impacts to the channel or surrounding infrastructure is limited. However, it is noted than in an above average water year, extra material will be available approximately proportional to the extra amount of water volume. Recommendations for a feasible dredging plan to be conducted over a number of years and that is bound by these limitations is discussed in Chapter 5.

Specific impacts to infrastructure in the vicinity of the project associated with dredging cannot be identified without details of the specific plan for dredging, detailed geometric and elevation data for the involved infrastructure, and a knowledge of the future activities of others that are permitted to dredge in the vicinity of the project. As described previously in Section 4.6.1, specific geometric and elevation data for several pipelines and cable crossings in the vicinity of the project are unavailable. Furthermore, to quantify specific erosion and sedimentation impacts of a dredging plan, a sediment routing model, such as HEC-6, would be needed. Such modeling is beyond the scope of the current study.

It is recommended that a monitoring program be employed to identify and mitigate impacts to infrastructure if either existing or increased levels of dredging in the study area are conducted. Because the average historic annual dredging volume represents a significant portion of the average annual bed material transport along the river (15 percent), some impact to the river channel would be expected. To date, the exposure of the pipelines at RM 372.4 has been identified as possible evidence of such impact. It is also noted that over the last four years (1994-1997) about 1.3 million tons of dredging has been conducted under above average water year conditions. It should be concluded that existing or increased levels of dredging would not improve this condition. Direct coordination with the Williams Brothers Pipeline Company to discuss mitigation requirements is recommended.

As is shown in Table 4-3, the bed material is 99 percent fine sand or coarser. The portion of the suspended sediment load that is fine sand or coarser is about 41 percent and equals about 9.3 million tons in an average year. As there is an interaction between the bed load and the suspended load it is expected that at least portion of the suspended load will assist in filling dredge holes and reduce impacts from dredging.

4.8.3 Scour Potential

Scour is a function of hydrology, the local hydraulics and the geometric configurations of the structure in question. Scour at any particular structure is generally composed of the following three components. Long term degradation of the channel, contraction scour and local scour.

Long term degradation was discussed in Section 4.6. A long term degradation trend was not observed in the historical data except downstream of the Kansas River. Natural bed level fluctuations of 10 to 15 ft were observed.

Estimation of the contraction scour component requires detailed data about the dredging, such as the location, rate and volume of the activity. Furthermore, assumptions would be required about the flow conditions at the time of the dredging. However, it is possible to discuss a potential worst case scenario. If the dredging would be conducted over a period of time so that none of the bed material load would pass the dredging location, a clear water scour condition would be established. In a low flow year, this would require dredging about two times the current maximum capacity of the Holliday Sand and Gravel Company. For such a case, the clear water scour, y_s, can be estimated as (Federal Highway Administration, 1995):

probability of obtaining the volume of material needed for the construction of the levee was calculated by determining the probability of getting I number of years of target sediment volume in an N year construction period. The calculation is shown in Table 4-12 for Case 1 and Table 4-13 for Case 2.

The results of the analysis are shown in Figure 4-31. The calculated probabilities for Case 1 are considered to be conservative since the procedure only counts the dredging of the target volume in a high volume year, although it may be possible to dredge more than the target. In addition, when a target volume is not met, the dredged volume counted is the base volume although it is possible that a volume between the base volume and target volume could be dredged. Hence, the probabilities given in Figure 4-31 for Case 1 should be looked at as a lower bound on the probabilities of obtaining the volume of material required to complete the levee.

The calculated probabilities for Case 2 are an estimate for the probabilities of obtaining the material for the levee. It is seen from Figure 4-31 that the probabilities for Case 2 are considerable higher than for Case 1. For a five year construction period the lower bound (Case 1) yields a 7 percent probability of completion but Case 2 yields a 63 percent probability. For a six year construction period Case 1 yields 41 percent versus 94 percent for Case 2. For seven year construction period Case 1 yields 81% probability and Case 2 yields 100 percent probability.

As seen from Figure 4-31, the probability of obtaining the required volume of material with the assumptions for Case 2 are over 90% for a construction period of six years. Based on this result, it is recommended that the plan for dredging incorporate a six year period. However, it is noted that although a six year plan is recommended, there is significant 60 percent probability for project completion in five years.

The three year period for dredging included in the original design for the project is considered to be unrealistically short. Even based on the historic record of dredging in the vicinity of the project by a sand and gravel company, and very favorable flow conditions, four to five years is the minimum time period possible.

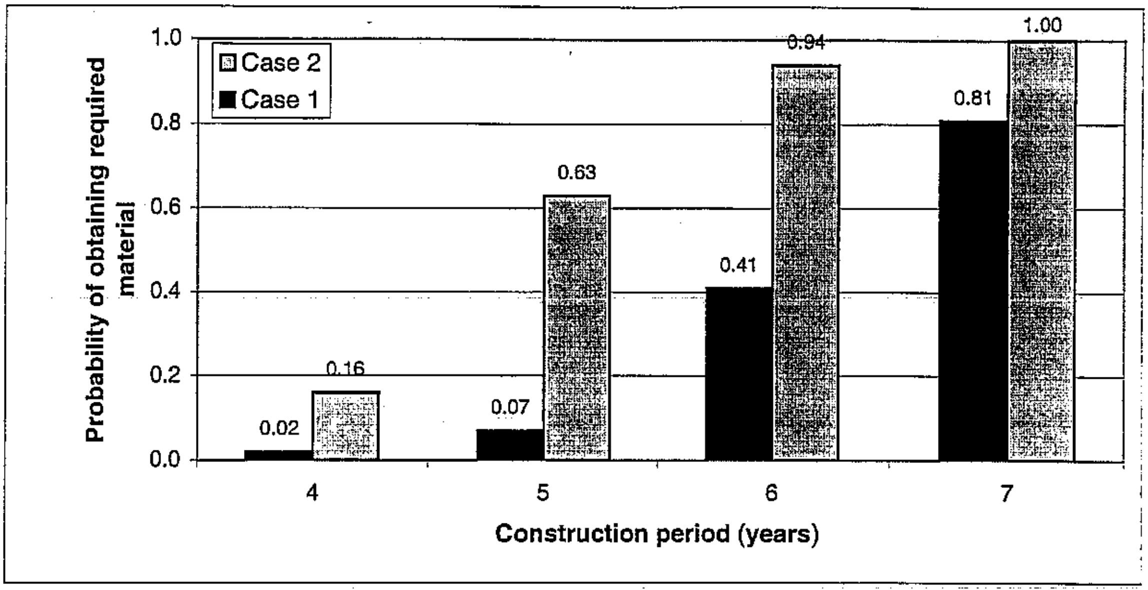

Figure 4-31: Probability of obtaining the required volume of material in a certain number of years (see calculations in Table 4-13).

Table 4-12: Probability calculations for Case 1 (see explanation of symbols on page 51).

Seven year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
7	0	0.38	0.04	3,500	1300	0	1.00	3,500
7	1	0.38	0.15	3,000	1300	1	0.96	4,300
7	2	0.38	0.28	2,500	1300	2	0.81	5,100
7	3	0.38	0.28	2,000	1300	3	0.54	5,900
7	4	0.38	0.17	1,500	1300	4	0.25	6,700
7	5	0.38	0.06	1,000	1300	5	0.08	7,500
7	6	0.38	0.01	500	1300	6	0.01	8,300
7	7	0.38	0.00	0	1300	7	0.00	9,100

Six year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
6	0	0.38	0.06	3,000	1300	0	1.00	3,000
6	1	0.38	0.21	2,500	1300	1	0.94	3,800
6	2	0.38	0.32	2,000	1300	2	0.73	4,600
6	3	0.38	0.26	1,500	1300	3	0.41	5,400
6	4	0.38	0.12	1,000	1300	4	0.15	6,200
6	5	0.38	0.03	500	1300	5	0.03	7,000
6	6	0.38	0.00	0	1300	6	0.00	7,800

Five year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
5	0	0.38	0.09	2,500	1300	0	1.00	2,500
5	1	0.38	0.28	2,000	1300	1	0.91	3,300
5	2	0.38	0.34	1,500	1300	2	0.63	4,100
5	3	0.38	0.21	1,000	1300	3	0.28	4,900
5	4	0.38	0.06	500	1300	4	0.07	5,700
5	5	0.38	0.01	0	1300	5	0.01	6,500

Four year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
4	0	0.38	0.15	2,000	1300	0	1.00	2,000
4	1	0.38	0.36	1,500	1300	1	0.85	2,800
4	2	0.38	0.33	1,000	1300	2	0.49	3,600
4	3	0.38	0.14	500	1300	3	0.16	4,400
4	4	0.38	0.02	0	1300	4	0.02	5,200

Three year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
3	0	0.38	0.24	1,500	1300	0	1.00	1,500
3	1	0.38	0.44	1,000	1300	1	0.76	2,300
3	2	0.38	0.27	500	1300	2	0.32	3,100
3	3	0.38	0.055	0	1300	3	0.05	3,900

Table 4-13: Probability calculations for Case 2 (see explanation of symbols on page 51).

Seven year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
7	0	0.38	0.04	5,250	1700	0	1.00	5,250
7	1	0.38	0.15	4,500	1700	1	0.96	6,200
7	2	0.38	0.28	3,750	1700	2	0.81	7,150
7	3	0.38	0.28	3,000	1700	3	0.54	8,100
7	4	0.38	0.17	2,250	1700	4	0.25	9,050
7	5	0.38	0.06	1,500	1700	5	0.08	10,000
7	6	0.38	0.01	750	1700	6	0.01	10,950
7	7	0.38	0.00	0	1700	7	0.00	11,900

Six year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
6	0	0.38	0.06	4,500	1700	0	1.00	4,500
6	1	0.38	0.21	3,750	1700	1	0.94	5,450
6	2	0.38	0.32	3,000	1700	2	0.73	6,400
6	3	0.38	0.26	2,250	1700	3	0.41	7,350
6	4	0.38	0.12	1,500	1700	4	0.15	8,300
6	5	0.38	0.03	750	1700	5	0.03	9,250
6	6	0.38	0.00	0	1700	6	0.00	10,200

Five year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
5	0	0.38	0.09	3,750	1700	0	1.00	3,750
5	1	0.38	0.28	3,000	1700	1	0.91	4,700
5	2	0.38	0.34	2,250	1700	2	0.63	5,650
5	3	0.38	0.21	1,500	1700	3	0.28	6,600
5	4	0.38	0.06	750	1700	4	0.07	7,550
5	5	0.38	0.01	0	1700	5	0.01	8,500

Four year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
4	0	0.38	0.15	3,000	1700	0	1.00	3,000
4	1	0.38	0.36	2,250	1700	1	0.85	3,950
4	2	0.38	0.33	1,500	1700	2	0.49	4,900
4	3	0.38	0.14	750	1700	3	0.16	5,850
4	4	0.38	0.02	0	1700	4	0.02	6,800

Three year construction time								
Probability (P) of getting, in N years, exactly I number of years with transport volume greater than p exceedance				Base volume	Probability (P') of getting I' or more "high volume" years			Volume obtained
N	I	p	P	10^3 t/year	p volume	I'	P'	10^3 tons
3	0	0.38	0.24	2,250	1700	0	1.00	2,250
3	1	0.38	0.44	1,500	1700	1	0.76	3,200
3	2	0.38	0.27	750	1700	2	0.32	4,150
3	3	0.38	0.05	0	1700	3	0.05	5,100

Explanation of symbols for Table 4-12 and Table 4-13:

N:	Number of construction years.
I:	Exact number of years volume will exceed the target volume.
p:	Exceedance probability for the target volume (from Figure 4-32).
P:	Probability of getting, in N years, exactly I years of volume exceeding the target volume (USACE 1992):

$$P = \frac{N!}{I!(N-I)!} p^I (1-p)^{N-I} .$$

Base volume:	Volume of sediment with I numbers of high volume years.
P volume:	The volume associated with p exceedance frequency.
I':	Number of high volume years.
P':	Probability of getting I' or more years exceeding the target volume.
Volume obtained:	Volume obtained with probability P' in N years.

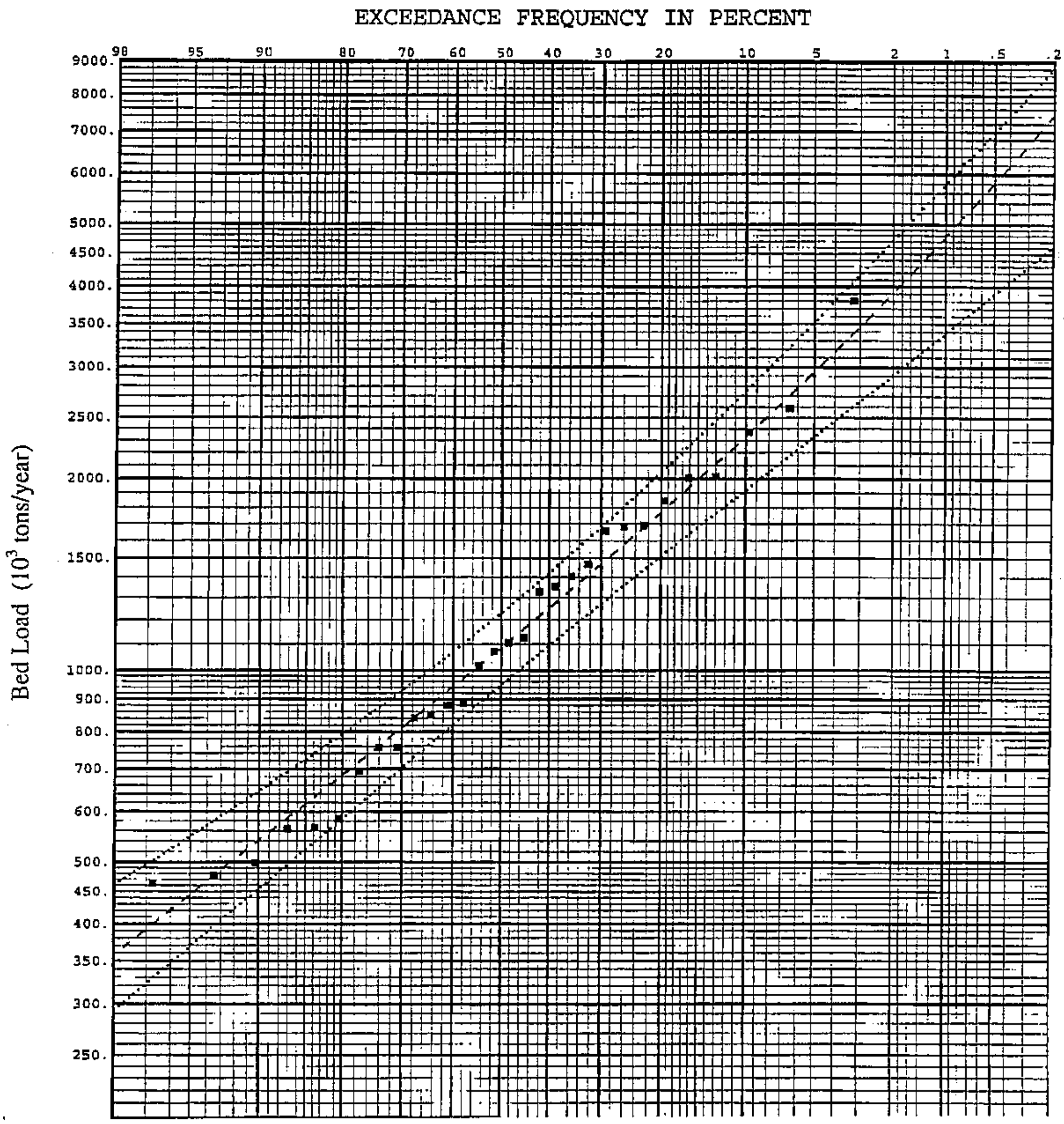

Figure 4-32: Exceedance probability for bed load transport (middle dashed line). The dotted lines represent the 5% and 95% confidence limits.

5 Conclusions and Recommendations

5.1 Conclusions

In the previous sections, a detailed evaluation of the sediment transport characteristics of the Missouri River study area between RM 366.1 and RM 448.2 was presented. The evaluation included an analysis of discharge and sediment transport measurement records, development of analytical estimates of sediment transport, review of historic hydrographic survey data, assessment of potential impacts to existing infrastructure in the project area (RM 371.4 to RM 376.5), and development of recommendations for a feasible dredging plan. Conclusions of the study are:

- The hydrologic and sediment transport characteristics of the Missouri River in the study area have changed considerably during this century as a result of the construction of dams, reservoirs, and other facilities along the Missouri River and its tributaries for navigation and flood control purposes. The long-term average annual suspended sediment load in the study area has been shown to have decreased by nearly a factor of 5 from before 1953 to after 1967 (USACE, 1981).

- Contacts made with owners of infrastructure crossing the river in the project area revealed few concerns about the historic stability of the river or the potential impacts of the proposed project. Few details about the specific dimensions or elevations associated with the involved infrastructure were obtained. The most significant concern identified is the existence of exposed pipelines in the channel (RM 372.3) near the downstream limit of the project area. The exposure of the pipelines has not been attributed to any human actions or trend in the morphology of the river. However, it is noted that dredging operations for a sand and gravel company have been conducted in the vicinity of the pipelines.

- Contacts with sand and gravel companies identified a variety of useful data and information about dredging procedures, sediment transport conditions, and river response to dredging activities. Both operators interviewed obtain sand and gravel by dredging sediments from the bed of the Missouri River. Coarser material is generally found near the navigation channel, while fine sand and silt is typically found in flow separation zones, such as between dikes. Dredged areas were estimated to typically refill within 1 to 2 days under average flow conditions. One of the companies has a dredging operation that is located near the downstream limit of the proposed project. Over the last four years, that company has dredged an average of 1.3 million tons of material per year from the river.

- Discharge and sediment measurements for USGS gages located upstream and downstream of the project area on the Missouri River and Kansas River were collected and evaluated. This analysis included gages at St. Joseph (RM 448.2) and

Kansas City (RM 366.1) along the Missouri River and at De Soto along the Kansas River. The Kansas City Gage is located about 5 miles downstream of the project area. Since the last dam on the Missouri River was constructed in the early 1960's, the analysis period for discharge and sediment measurement records was restricted to 1967 to 1998. The mean daily discharge at Kansas City was found to be about 20 percent higher that the flow at St. Joseph. The difference is considered to be largely due to contributions from the Kansas River, which enters the Missouri River about 1.5 miles upstream of the Kansas City Gage.

- Available sediment transport measurements were analyzed to estimate the suspended bed material concentration for each suspended sediment measurement and develop a relationship between water discharge and suspended bed material load. An evaluation of seasonal effects on suspended bed material concentration was also conducted. It was demonstrated that seasonal temperature fluctuations have a negligible effect on the suspended bed material concentration. Effects of temperature change on bed form conditions were also investigated. It was found that water temperature may slightly affect the expected bed forms along the river. Identification of specific impacts on sediment transport caused by the potential bed form changes is beyond the scope of the current study. However, it is noted that previous investigators (Shen, 1977) have concluded that the impacts of temperature effects on bed load transport along the Missouri River should be studied further.

- Estimates of bed load were developed by application of the Modified Einstein Method. The Modified Einstein Method was selected for use since it has rendered very good predictions of the total load for tributaries in the Missouri River basin (Simons & Senturk, 1977), incorporates suspended sediment concentration measurement data, and provides specific estimates of the transport rate for individual sediment size classes. Suspended bed material load estimates were determined from regression relations developed from suspended sediment measurements. The developed suspended sediment estimates for the Missouri River gages were found to be consistent with the trend of decreasing suspended sediment load previously identified by USACE (1981). The average annual bed load transport was estimated by the method to be about 0.9 million tons/year at the St. Joseph Gage and about 1.6 million tons/year at the Kansas City Gage. Considering that the Kansas City Gage is downstream of the Kansas River and the flow contribution of the Kansas River is about 20 percent of the total at the Kansas City Gage, the average annual bed load transport in the project area is approximately 1.3 million tons/year.

- Estimates of the average annual total bed material load were developed for both the St. Joseph and Kansas City Gages. The average annual total bed material load was estimated to be about 9.0 million tons/year at the St. Joseph Gage and about 10.9 million tons/year at the Kansas City Gage.

- Historic bed level changes throughout the study area were evaluated using USACE hydrographic survey data. Mean channel and thalweg elevations at cross sections throughout the study were plotted to define trends of aggradation and degradation over time. The data generally indicate that the river bed degrades during low flow years and aggrades during high flow years. Mean channel elevations, a parameter to describe the average elevation of the entire cross section, was found to fluctuate on the order of 10 to 12 feet through the study area. The largest fluctuations occur at the downstream end of the study reach, near the confluence with the Kansas River. The range of fluctuation was found to be greater for the channel thalweg elevation, in some cases it is on the order of 20-30 feet. The thalweg elevation in the year 1971 was found to be, in most cases, considerably lower than all other years. Within the project area, the thalweg elevation was noted to fluctuate on the order of 20 feet at one cross section. The largest dips in the thalweg elevation profile are associated with three sharp bends in the river plan form. Overall, the study area was found to have a relatively consistent slope of about 1 foot/mile.

- Historic bridge inspection survey data supplied by the Missouri Department of Transportation were also reviewed to assess trends of channel aggradation and degradation. The bridge data indicates a slight trend of degradation along the Missouri River downstream of the confluence with the Kansas River. However, the noted degradation is less than about 10 feet, which is within the range of variability previously noted for the thalweg from historic hydrographic survey data.

- The specific gage analysis shows decreasing stage trend at the Kansas City gage. The analysis showed increasing stage trend at gages upstream (St. Joseph gage) and downstream (Waverly gage) of the Kansas City gage. The decreasing trend at Kansas City gage has been attributed to general confinement of the river and removal of bed material by commercial sand and gravel dredging activities on both the Missouri and lower Kansas River. This suggests that dredging in the project area, a short distance upstream of the Kansas City gage, is influencing the bed at the Kansas City gage.

- Records of dredging within the study area were collected and reviewed. The available data is limited to the period of 1994 to 1997. The Holliday Sand & Gravel Company dredges along the river at locations that range from about RM 371 to 376, approximately the same reach of the river as the proposed project. Over a four year period, 1994 to 1997, the Holiday Sand & Gravel Company dredged an average of 1.3 million tons/year in the vicinity of proposed project. It is noted that this amount is equal to the estimated total bed load of the Missouri River in the project area and about 15 percent of the total bed material load.

- No specific impacts have been attributed to the rate of dredging represented by the available dredging records. However, the available dredging records do not correspond with the available hydrographic survey information. The exposure of pipelines at RM 372.3 is the only significant stability issue identified to be associated with infrastructure within the vicinity of the proposed project. The exact relation of this condition to historic dredging operations is not certain, but it is noted that the exposed pipelines are in the vicinity of historic dredging operations. From discussions with the owner of the pipeline, the exposure may also be related to a relatively shallow burial depth used in the construction of the pipeline.

- A trend for general overall aggradation or degradation of the channel bed in the project area was demonstrated to be related to the annual flow volume experienced by the river. In above average volume water years, the river tends to aggrade, while in low volume water years, the river degrades. The potential impacts of dredging are related to the rate of dredging and the specific hydrologic sequence experienced during the dredging activities. At existing or increased rates of dredging, impacts to the channel geometry would be expected if low flow conditions occurred. Under high flow conditions, increased rates of dredging could occur without adverse impact. Quantification of impacts to specific infrastructure would require details of the proposed dredging, geometry and elevation data for the involved infrastructure, knowledge of the future dredging activities by others, application of an appropriate sediment routing model and scenarios of flow conditions. Such an analysis is beyond the scope of the current study.

- The proposed project will reduce the bed material sediment supply to the Lexington Bridge site near RM 317.3. The project would be expected to aggravate the deficit in bed material sediment supply created by existing dredging operations occurring between the bridge site and the proposed project area. It is noted that the proposed project is about 55 miles upstream of the Lexington Bridge site. The river will try to make up any sediment supply deficit by erosion of the channel. Over a distance of 55 miles the average erosion depth represented by an upstream sediment supply deficit of 5.2 million tons is about equal to 0.4 feet. Practically, the impact will be dependent on the rate of dredging associated with the project and the bed material supply dictated by the hydrologic conditions experienced. If the recommendations, discussed in next section, are followed, minimal impact is expected at the Lexington Bridge as it is located more than 50 miles downstream.

5.2 Recommendations

In the following sections, recommendations are provided for the development of a feasible plan to dredge the Missouri River for material to construct the L385 levee unit project. A feasible plan must identify means to obtain 3.0 to 3.5 million cubic yards (4.9 million tons to 5.7 million tons) of dredge material for use as random fill. Suitable dredge material is limited to granular material, fine sand-sized and larger. The dredging plan must not significantly impact existing infrastructure within the project area. Based on these requirements, the following recommendations were developed:

5.2.1 General Recommendations

The following general recommendations are provided:

- A thorough monitoring program for Missouri River channel in the vicinity of the project should be developed and implemented as part of construction activities. A monitoring program would provide documentation of the baseline condition of the channel and infrastructure prior to the project. It would also allow project impacts to be quantified and tracked. If necessary, measures to mitigate project impacts could then be implemented in a timely and effective manner. If dredging operations by others are being conducted in the project area, the relative impacts of these dredging operations should be assessed.

- It is emphasized that the exposed pipelines located at RM 372.4 are at risk. Any impact from existing or increased dredging in the vicinity of the pipeline could influence their stability. Whether dredging is conducted in the project area for the proposed project or any other purposes, mitigation and monitoring actions are recommended. Direct coordination with the owner of the pipeline should be conducted to plan future dredging activities and requirements for mitigation and monitoring. Monitoring data for the pipelines should be evaluated.

- The plan to be developed for project-related dredging activities should recognize a variety of fundamental hydraulic, sediment transport, and geomorphic processes. The influences of the processes are generally reflected in the dredging procedures described by sand and gravel companies interviewed for this study. Recognition of these processes will aid in obtaining appropriately sized sediments and avoiding potential adverse impacts of dredging. Fundamental rules for dredging would include:

  - Coarser sized material is typically found in higher velocity flow areas. The highest velocities would typically be found in or near the designated navigation channel and along the outside of channel bends.

  - Finer sized material is typically found in low velocity flow areas. In general, the lowest velocities are furthest from the navigation channel. The finest sized material is often found in flow separation zones. Flow separation zones are typically located immediately downstream of obstructions to the flow, such as dikes.

  - Sediment is naturally deposited along the inside (concave side) of river bends. The greatest amount of sediment is deposited along the large river bends located in the study area.

  - Typical dredging related excavations of about 7,500 cubic yards (12,000 tons) in size are said to fill in over a weekend (three day period). As seen in Figure 4-13, this filling rate is consistent with the bed load sediment transport rate (4,000 tons/day) determined for average summer monthly flow conditions (70,000 cfs). Accordingly, the filling time will lengthen during lower flow periods.

- Permits for dredging along the Missouri River to obtain sand and gravel do not specify a maximum annual limit. Since the availability of sediment resources along the river are related to the conditions of flow, it is recommended that rational limitations be developed for each permit based on the conditions of flow experienced. Impacts to infrastructure and the environment may be avoided by instituting rational limits for dredging. It is noted that currently the average amount of dredging in the vicinity of the Kansas City gage is about 15 percent of the average bed material load and on the same magnitude as the average bed load (see Table 4-10, RM 371.8). It is also noted that pipelines are exposed in the vicinity of the project area and the Missouri River channel has degraded.

5.2.2 Impacts

It is recommended that the total amount of dredging conducted in the vicinity of the project not exceed about 15 percent of the bed material load. This is an amount approximately equal to the bed load transport associated with the specific flow conditions experienced. A variety of flow forecasting information could be used to plan sustainable dredging amounts. Over the period of record, the average annual bed load amount has been equal to 1.3 million tons/year. Dredging in excess of the bed load amount would be expected to cause impacts to the channel and potentially surrounding infrastructure. It is noted that in high flow years an amount of material in excess of the average annual bed load may be extracted.

Historic bed elevation information, bridge inspection data, and interviews with owners of infrastructure have not revealed any significant adverse impacts in the study area associated with historic dredging activities with the exception of the exposed pipelines at RM 372.4. It is noted that the available records of historic dredging amounts indicate that dredging volumes have exceeded the total bed load transport rate along the river in the Kansas City area. This implies that the deficit between sediment supply and dredging is being made up by erosion from the channel. The specific gage analysis shown in Figure 4-27 supports this conclusion. The fact that few impacts have been observed to date in the study area may be due to the large size of the river and above average flow conditions in recent years.

For example, dredging an amount equal to the annual bed load amount (assume 1.3 million tons), theoretically creates a deficit of supply for the downstream channel equal to that amount. If the channel bed erodes to meet that deficit over a 300-foot width and a 20 mile distance, the average depth of erosion over the reach would only be about 1 foot. Such an erosion depth is probably insignificant to most infrastructure and practically well within the average elevation fluctuation range of the channel bed. Overall, the magnitude of such an impact is insignificant when viewed as a single event; however, when considered cumulatively with all historic dredging activities the long-term impacts will undoubtedly be significant. The timing, location, and magnitude of impacts are dependent on the future conditions of flow experienced.

5.2.3 Period of Dredging

The ability to dredge the river to provide the required material volumes without impacts to the channel or surrounding infrastructure is directly related to the flow conditions experienced. To avoid impacts to the channel, it is recommended that the rate of dredging for the project not exceed the bed load transport rate associated with the flows experienced (see Figure 4-13). An analysis was conducted to evaluate the probability of experiencing bed load transport rates that equal or exceed the average bed load transport rate conditions. The probability of obtaining the required material volumes for construction of the levee over a certain numbers of years was determined. Two cases were analyzed to provide estimates of both a conservative and average periods required to obtain the necessary volume of material (see Section 4.9). Based on the results, it is recommended that the plan for dredging incorporate a 6 year construction period. A six year construction period was determined to have over a 90 percent probability of achieving the required volume under average conditions. It is also noted that a 5 year period has over a 60 percent probability of achieving the required volume of material. If an average conditions of 1.3 millions tons of bed load would occur every year for the next 4 years, a bed load of 5.2 million tons would be obtained, making it possible to finish the levee in four years.

The three year period for dredging included in the original design for the project is considered unrealistically short. Based on the historic record of dredging in the vicinity of the project by a sand and gravel company, 4 to 5 years is the minimum time period possible. It is also noted that pipelines in the vicinity of the project have been exposed under the historic rates of dredging in the project area.

If a construction period shorter than 6 years is required, it is recommended that a detailed HEC-6 analysis of the sediment transport conditions within the project area be conducted. A HEC-6 sediment routing would define the specific impacts to the channel and surrounding infrastructure associated with dredging exceeding the bed load sediment supply. The HEC-6 analysis could be used to access the potential significance of impacts and to define required mitigation measures.

5.2.4 Dredging Options

A total of five options were identified for obtaining the material required for the project. Each of the options involves different constraints on dredging activities, expected levels of impact, and construction periods. In the following sections, the various elements of each option are described. A summary of the options is provided in Table 5-1.

Option 1: Limited Existing Dredging

The use of material already being dredged by sand and gravel companies in the vicinity of the project, appears to be the most straightforward and achievable plan for obtaining the required material volumes for the project. Over the last four years the Holliday Sand & Gravel Company has dredged an annual average of 1.3 million tons/year of sand-sized and coarser material in the vicinity of the project. Under this option, the total amount of dredging would be limited to an average rate approximately equal to the bed load transport experienced. It is believed that regulating dredging activities based on the hydrologic conditions experienced and monitoring can mitigate potential impacts.

The period of construction associated with this option is recommended to be 6 years. Based on an assessment of risk, a period of 6 years was identified as having a probability of over 90 percent for achieving the required material volume. Considerably smaller probabilities of achieving the required volumes were identified to be associated with shorter time periods.

Utilization of a dredge operator familiar with the study area would also offer various other benefits. These would include specific knowledge about the flow and sediment transport characteristics along the reach and experience in dredging in the vicinity of the existing infrastructure. Employment of an operator with an existing permit to dredge in the project area would also avoid competition for obtaining the available resource

Option 2: Limited Existing and Project Specific Dredging
Option 2 consists of limiting the dredging conducting by both existing sand and gravel dredging operations and the proposed project. Under this option the total of dredging would be regulated to not exceed an average rate approximately equal to the bed load associated with the specific conditions of flow experienced. Impacts would be similar to those expected under Option 1. The required construction period associated with this option cannot be defined until the split of the available bed load between the existing sand and gravel dredging operation and the project is established. Considering that the existing operation has an existing permit to dredge in the vicinity of the project, negotiation of a limitation to their annual dredging volume may be problematic.

Option 3: Unlimited Existing Dredging and Limited Project Specific Dredging
This option considers the possibility that unlimited existing sand and gravel dredging operations and limited project specific dredging would be conducted. The existing operation is believed to have a permit that does not specify a limitation on the amount of material that can be dredged on an annual basis. Project specific dredging is assumed to be limited to the bed load for the specific flow conditions experienced. The impacts associated with Option 3 would be expected to be significant as the total dredging amount would likely exceed the average rate of bed load transport. The period of construction associated with this option is estimated to be 6 years.

Option 4: Unlimited Existing and Project Specific Dredging
This option considers the possibility of unlimited dredging for both existing operations and the project. It is equivalent to the plan for dredging associated with the original design for the project. Since the average rate of bed load transport would likely be exceeded under this option, significant adverse impacts are expected. The period of construction is expected to be 3 years.

Option 5: Limited Project Specific Dredging
Under this option, the permit for existing dredging operations would be suspended. All dredging activities conducting would be associated with the project and would be limited to the estimated bed load transport associated with the flow conditions experienced. Effectively, this alternative is the same as Option 1 with the exception that dredging operations are not conducted by the existing sand & gravel dredging operator. It is believed that regulating dredging activities based on the hydrologic conditions experienced and monitoring will mitigate potential significant adverse impacts. The

period of construction associated with this option is recommended to be 6 years. Based on an assessment of risk, a period of 6 years was identified as having a probability of over 90 percent for achieving the required material volume.

Table 5-1: Summary of dredging options.

		Option 1	Option 2	Option 3	Option 4	Option 5
Dredging Limitation	Existing operation	Bed load[1]	Portion of bed load[3]	Unlimited	Unlimited	Zero
	Project	Zero	Portion of bed load[3]	Bed load	Unlimited	Bed load
Impacts		Minimal[2] with monitoring	Minimal[2] with monitoring	Significant	Significant	Minimal[2] with monitoring
Estimated Construction Period (years)		6	Unknown[4]	6	3	6

[1] The existing operation provides its material for the project.
[2] Based on historic records. Mitigation of existing exposed pipelines at RM 372.3 required.
[3] Sum of existing operation dredging and project dredging not to exceed the bed load.
[4] Length of period depends on how the dredging is split between the Existing operation and Project.

5.2.5 Recommended Dredging Options

Based on the conditions described above for each dredging option, it is recommended that only Options 1, 2, and 5 be considered as feasible alternatives. Each of the three recommended options require that dredging amounts be limited to the bed load transport amount associated with the flow conditions experienced during dredging operations. Each of the three options would require actions to control competition for the available sand and gravel resource. The options range from adopting the entire production of the existing sand & gravel dredging operation in the study area to suspension of the existing permit to dredge in the project area.

6 References

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APPENDICES

APPENDIX A

List of structures

Bridges Within Study Area

Chart	Label	Structure Name	RM	R/L/C Bank	Notes
70	8	MO. PAC. R.R. Bridge	0.3	R	Kansas R.
70	7	Lewis and Clark Viaduct	0.4	L	Kansas R.
70	5	James St. Bridge	0.6	R	Kansas R.
70	4	K.C. Southern Ry. Bridge	1.0	R	Kansas R.
70	3	Central Ave. Bridge	1.3	R	Kansas R.
70	17	I-670 Hwy Bridge	1.5	R	Kansas R.
70	2	MO. PAC. R.R. Bridge	1.6	L	Kansas R.
70	1	U.P.P.R. Bridge	1.7	R	Kansas R.
73	1	Indep.-Liberty US 291 Hwy Br.	352.7	L	
71	4	Harry S. Truman R.R. Br.	359.3	R	
71	3	Kansas City, MO. Hwy I-435 Br.	360.3	L	
71	1	Chouteau Hwy Mo. 269 Br.	362.3	R	
70	13	Paseo Bridge, I-35, I-29	364.7	R	
70	16	Heart of America Bridge HWY 9	365.5	L	
70	12	A.S.B. Bridge	365.5	R	
70	10	Hannibal Ry. Bridge	366.1	R	
70	9	Broadway Bridge	366.2	R	
69	4	Fairfax Hwy US 69 & 169 Brs.	372.6	L	
69	1	Kansas City, Kansas I-635 Hwy. Br.	374.1	L	
67	2	Wolcott Kans I-435 Hwy. Bridge	383.3	R	
64	2	Leavenworth Hwy. 92 Bridge	397.6	L	
59	2	Atchison Hwy. US 59 Bridge	422.4	L	
59	1	Atchison Ry. Bridge	422.6	L	
55	1	St. Joseph Hwy. US 36 Bridge	447.9	R	
54	3	U.P.P.R. Bridge	448.2	R	

Intake Structures within the Study Area

Chart	Label	Structure Name	RM	R/L/C Bank
74	B	Independence Power Plant Intake	345.2	L
72	F	Kansas city Power and Light Intake (Hawthorne)	358.2	R
70	G	K. C. Power and Light Co. Intake	365.6	R
69	E	Kansas City, MO. Water Dept. Intake	370.5	L
69	B	Kansas City, KS. Power & Light Co. Intake	373.4	R
69	A	Kansas City, KS. Water Co. Intake	373.5	R
68	C	Mid-Continent Asphalt and Paving co. Intake	378.3	L
68	B	Nearman Bottoms Power Plant Intake	378.6	R
68	A	Johnson Co. Water Dist. No.1 Intake	380	R
64	B	Leavenworth Water Company Intake	397.4	R
61	A	Iatan Power Plant Water Intake	411	L
59	F	Atchison Water Dept Intake	422.4	R
59	A	Atchison Water Intake	423.4	R
55	D	St. Joseph Power and Light Co. Intake	445.9	L

Source: USACE Missouri River Navigation Charts.
Chart and Label refer to the Navigation Charts.
R/L/C Bank refers to location of the structure: R refers to right bank, L refers to left bank and C refers to a crossing (i.e. cable crossing).
All structures are along Missouri River unless noted.

Pipelines Within Study Area					
Chart	Label	Structure Name	RM	R/L/C Bank	Notes
70	6	City of K.C. Kansas (sewage pipeline)	0.5	R	Kansas River
72	2	American Oil Pipeline	356.6	C	
71	2	K.C. MO Sewage Pipelines	361.1	C	
70	11	K.C. MO. Water Tunnel	365.9	C	
69	6	Williams Brothers Pipelines	369.5	C	
69	5	Williams Brothers Pipelines	372.4	C	
69	7	Williams Brothers Pipeline (On Br)	372.6	L	
69	8	Mobile Oil Pipeline (On Br)	372.6	L	
69	3	Skelly Pipeline	373.9	C	
69	2	William Brothers Pipeline	374.2	C	
64	1	Williams Natural Gas Pipeline (On Bridge)	397.7	L	
62	1	Mid-America Pipelines (MCPCO)	406.7	C	
61	1	Hydrocarbon Pipeline Transport Inc. Pipeline	414.1	C	
59	3	Midwest Solvent Pipeline (On Bridge)	422.3	L	
56	1	Platte Pipleline co.	437.2	C	
55	2	Williams Natural Gas Pipeline (On Bridge)	448.2	R	
54	1	City of St. Joseph Water Line	450.4	C	

Power/Telcom Lines within Study Area				
Chart	Label	Structure Name	RM	R/L/C Bank
74	1	Independence Power Line (overhead)	344.9	C
73	2	K.C. Power & Light Power Line (overhead)	349.0	C
71	6	K.C. P. & L Power Line (overhead)	358.6	C
71	5	K.C. P. & L Power Line (overhead)	359.1	C
70	15	K.C. Power & Light Co.(overhead)	364.3	C
70	14	K.C. Power & Light Co.(overhead)	364.5	C
69	N/A	Worldcom Cable	370	C
69	9	AT & T Cable	371	L
67	1	K. C. Power and Light Co. Power Lines (overhead)	384	C
62	2	Missouri Public Service Power Line (overhead)	407.5	C
61	2	KCP & L and St. Joseph Powerlines (overhead)	410.6	R
58	2	AT & T Telephone Cable	431.2	C
58	1	AT & T Telephone Cable	431.3	C
54	2	St. Joseph Power and Light Power Line (overhead)	450.3	C

Source: USACE Missouri River Navigation Charts.
Chart and Label refer to the Navigation Charts.
R/L/C Bank refers to location of the structure: R refers to right bank, L refers to left bank and C refers to a crossing (i.e. cable crossing).
All structures are along Missouri River unless noted.

APPENDIX B

List of Contacts with Infrastructure Owners

Summary of Infrastructure Information obtained by WEST Consultants

Agency:

Missouri Department of Transportation

Infrastructure

Bridges

Contact Person:

Jim Burgess, District Bridge Engineer

Roger Schwartze, Assistant Division Engineer – Bridge Maintenance

Telephone Number:

(573) 751-8648

(573) 526-0875 (Fax)

Materials sent from WEST:

List of bridges

Vicinity map of project area

Material Received:

Bridge U.S. 36:	Inspection reports, inspection pictures and bridge drawings.
Bridge Hwy 92:	Bridge drawings.
Bridge I-435:	Bridge drawings.
Bridge I-635:	Inspection reports, inspection pictures and bridge drawings.
Bridge US-69:	Inspection reports, inspection pictures and bridge drawings.
Broadway Bridge:	Inspection reports and bridge drawings.
Bridge Hwy 9:	Inspection reports, inspection pictures and bridge drawings.
Bridge I-35:	Inspection reports, inspection pictures and bridge drawings.
Bridge I-435:	Inspection reports, inspection pictures and bridge drawings.

Comments:

None of the inspection reports documents any significant scour problems or bed degradation. Thalweg elevations were tabulated from the bridge drawings and are shown in **Error! Reference source not found.**.

Correspondence material is included on following pages.

Missouri
Department
of Transportation

MoDOT

Joe Mickes, Director

105 West Capitol Avenue
P.O. Box 270
Jefferson City, MO 65102
(573) 751-2551
Fax (573) 751-6555
www.modot.state.mo.us

January 20, 1999

Thomas R. Grindeland, P.E.
West Consultants, Inc.
12509 Bel-Red Road, Suite 100
Bellevue, WA 98005

Dear Mr. Grindeland:

Attached is information you requested on stream data we have for Missouri River Bridges. There are a number of bridges within the study area that are the responsibility of the Kansas Department of Transportation and we do not have information available for those structures. Also, the Chouteau Missouri River Bridge is under the jurisdiction of the city of Kansas City and we do not have information available. The old A.S.B. bridge is also the responsibility of the railroad and not under our jurisdiction. We hope the information we are providing will be helpful. If you need additional information or clarification please feel free to contact me at 573-751-8648.

Sincerely,

Roger Schwartze

Roger Schwartze
Assistant Division Engineer - Bridge Maintenance

jr

Maintenance
Bridge Maintenance
Missouri River Bridges
General

Summary of Infrastructure Information obtained by WEST Consultants

Agency:

Kansas City, Kansas, Water Department

Infrastructure

Water Intakes

Contact Person:

Patrick J. Cassidy,
Supervisor – Environmental Compliance and Remediation
Board of Public Utilities

Telephone Number:

(913) 573-9856
(913) 573-9851 (Fax)

Materials sent from WEST:

List of water intakes
Vicinity map of project area
Questionnaire

Material Received:

Quindaro Power Station (RM 373.4):
Reply to the Questionnaire and drawings.
Nearman Creek Power Station (RM 377.75):
Reply to the Questionnaire and drawings.

Comments:

No historical problems are noted.
Critical feature of the structures is a minimum acceptable water surface elevation:

Quindaro Power Station:	716.0 ft
Nearman Creek Power Station:	724.0 ft

Correspondence material is included on following pages.

*

Questionnaire

Company (name/address): BOARD OF PUBLIC UTILITIES NEARMAN CREEK POWER STATION 4240 NORTH 55th STREET KANSAS CITY, KANSAS 66104
Contact Person: DARRELL D. DORSEY, SUPT.
Phone number: (913) 573-9784
Date: 1-14-98
How contacted (Meeting/phone/other): TOM GRINDELAND, PE, WEST CONSULTANTS

1. Owner/Operator: BOARD OF PUBLIC UTILITIES (BPU)

2. Type of Structure: RIVER WATER INLET FOR COOLING WATER SYSTEM.

3. RM: ~377.75 - MISSOURI RIVER

4. Years operated: 18 YEARS

5. Describe any historic effects of dredging on the structure: NONE RECALLED

6. Observed changes in the river affecting the structure: DREDGING PROJECT SHOULD BE NO MORE THAN 1.5M DOWNSTREAM FROM NEARMAN ∴ NO IMPACT PREDICTED.

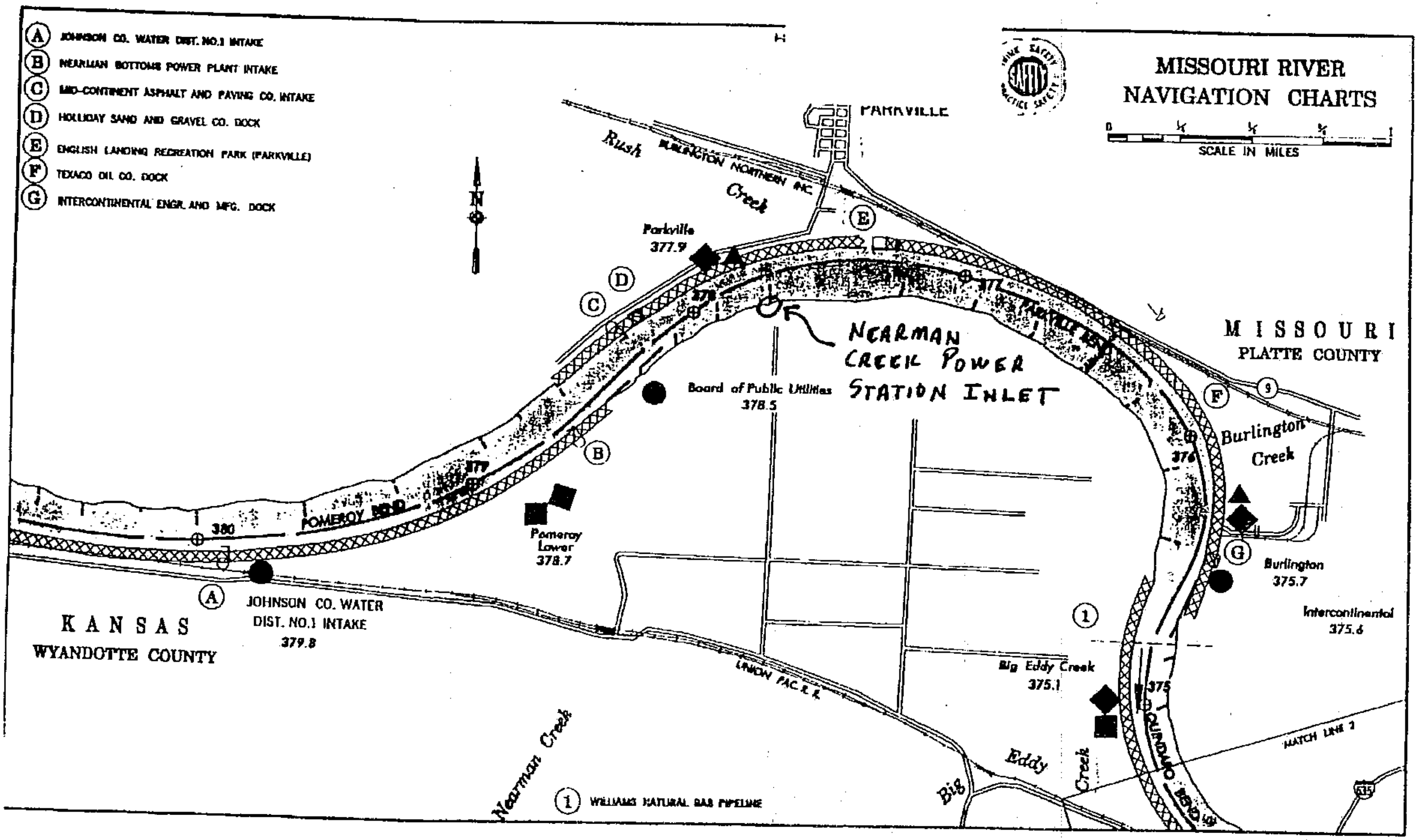
7. Construction drawing of structure:
   ATTACHED

8. Historic monitoring data: ?

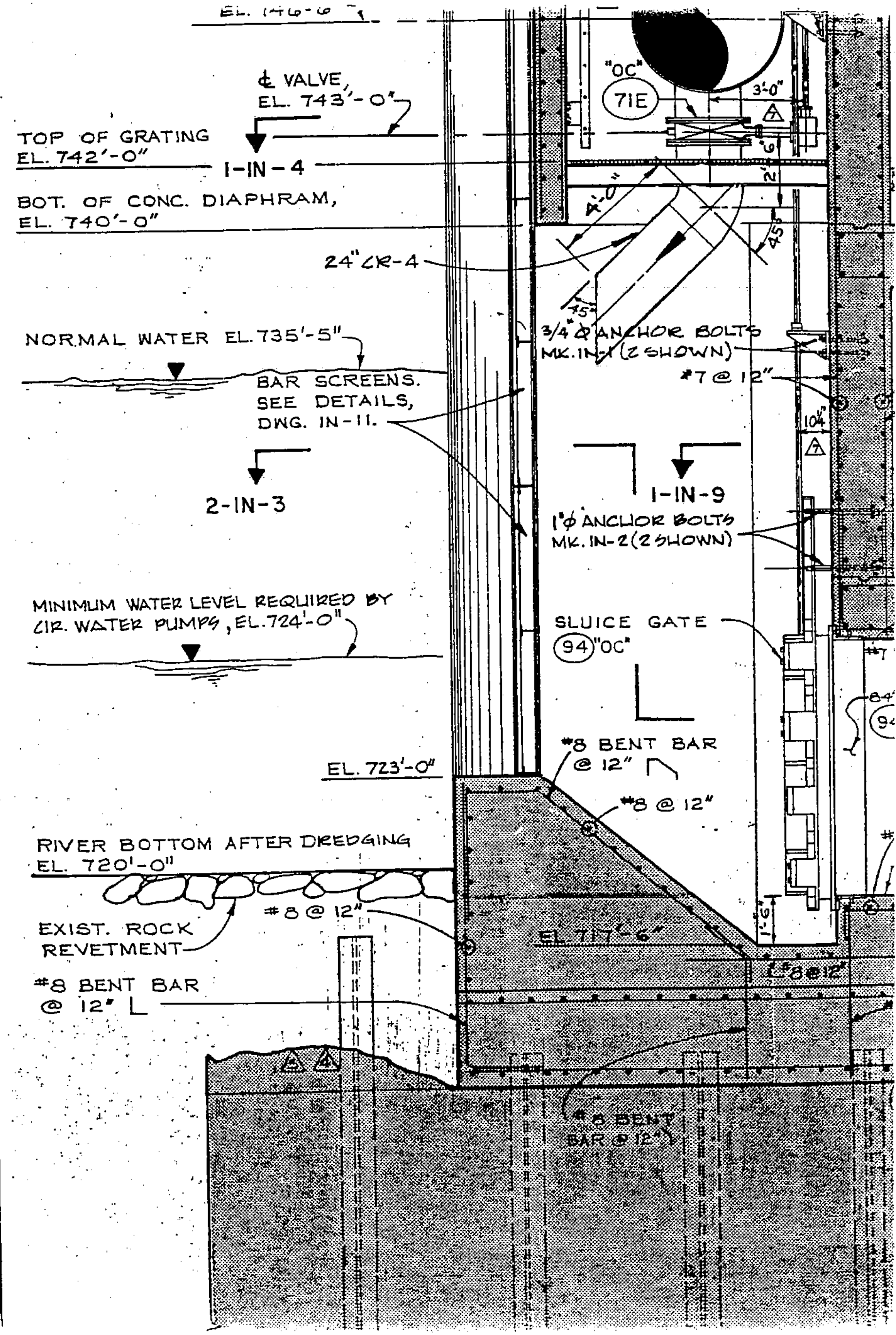
9. What is critical feature of structure (i.e., footing elevation, intake elevation):

   THE INLET DRAWS IN ABOUT 200 MGD FOR COOLING PURPOSES AT THE COAL-FIRED POWER STATION. MINIMUM ACCEPTABLE RIVER ELEVATION: 724.0

* FORM COMPLETED BY: PATRICK CASSIDY, BPU
(913) 573-9856


MISSOURI RIVER
NAVIGATION CHARTS
SCALE IN MILES
0
¼
½
¾
1
A JOHNSON CO. WATER DIST. NO.1 INTAKE
B NEARMAN BOTTOMS POWER PLANT INTAKE
C MID-CONTINENT ASPHALT AND PAVING CO. INTAKE
D HOLLIDAY SAND AND GRAVEL CO. DOCK
E ENGLISH LANDING RECREATION PARK (PARKVILLE)
F TEXACO OIL CO. DOCK
G INTERCONTINENTAL ENGR. AND MFG. DOCK
N
PARKVILLE
Rush Creek
BURLINGTON NORTHERN INC.
Parkville
377.9
NEARMAN CREEK POWER STATION INLET
Board of Public Utilities
378.5
MISSOURI
PLATTE COUNTY
Burlington Creek
Burlington
375.7
Intercontinental
375.6
POMEROY BEND
PARKVILLE BEND
QUINDARO BEND
380
379
378
377
376
375
Pomeroy Lower
378.7
JOHNSON CO. WATER
DIST. NO.1 INTAKE
379.8
KANSAS
WYANDOTTE COUNTY
UNION PAC. R. R.
Big Eddy Creek
375.1
Nearman Creek
Big Eddy Creek
1 WILLIAMS NATURAL GAS PIPELINE
MATCH LINE 2
9
635

2/5



EL. 746'-6"
℄ VALVE, EL. 743'-0"
"OC"
71E
3'-0"
TOP OF GRATING EL. 742'-0"
1-IN-4
BOT. OF CONC. DIAPHRAM, EL. 740'-0"
4'-0"
2'-6"
45°
24" CR-4
45°
3/4"⌀ ANCHOR BOLTS MK. IN-1 (2 SHOWN)
NORMAL WATER EL. 735'-5"
BAR SCREENS. SEE DETAILS, DWG. IN-11.
#7 @ 12"
10¼"
2-IN-3
1-IN-9
1"⌀ ANCHOR BOLTS MK. IN-2 (2 SHOWN)
MINIMUM WATER LEVEL REQUIRED BY CIR. WATER PUMPS, EL. 724'-0"
SLUICE GATE
94 "OC"
EL. 723'-0"
#8 BENT BAR @ 12"
#8 @ 12"
RIVER BOTTOM AFTER DREDGING EL. 720'-0"
EXIST. ROCK REVETMENT
#8 @ 12"
EL. 717'-6"
1'-6"
#8 @ 12"
#8 BENT BAR @ 12"
#8 BENT BAR @ 12"

INTAKE

QUINDARO POWER STATION
BOARD OF PUBLIC UTILITIES
3601 NORTH 12TH STREET
KANSAS CITY, KS 66104

Questionnaire

Company (name/address):
Contact Person: JOHN MEINDERS, PLANT SUPT.
Phone number: (913) 573-9301
Date: 1-19-98
How contacted (Meeting/phone/other): TOM GRINDELAND, PE WEST CONSULTANTS.

1. Owner/Operator: BOARD OF PUBLIC UTILITIES KANSAS CITY, KANSAS

2. Type of Structure: RIVER WATER INTAKE FOR ONCE-THROUGH COOLING WATER SUPPLY TO COAL-FIRED POWER STA.

3. RM:
RIVER MILE: 373.4

4. Years operated: CURRENT PLANT: 1964.
PREVIOUS PLANTS: SINCE ≈ 1910.

5. Describe any historic effects of dredging on the structure: NONE KNOWN.

6. Observed changes in the river affecting the structure: NONE KNOWN.

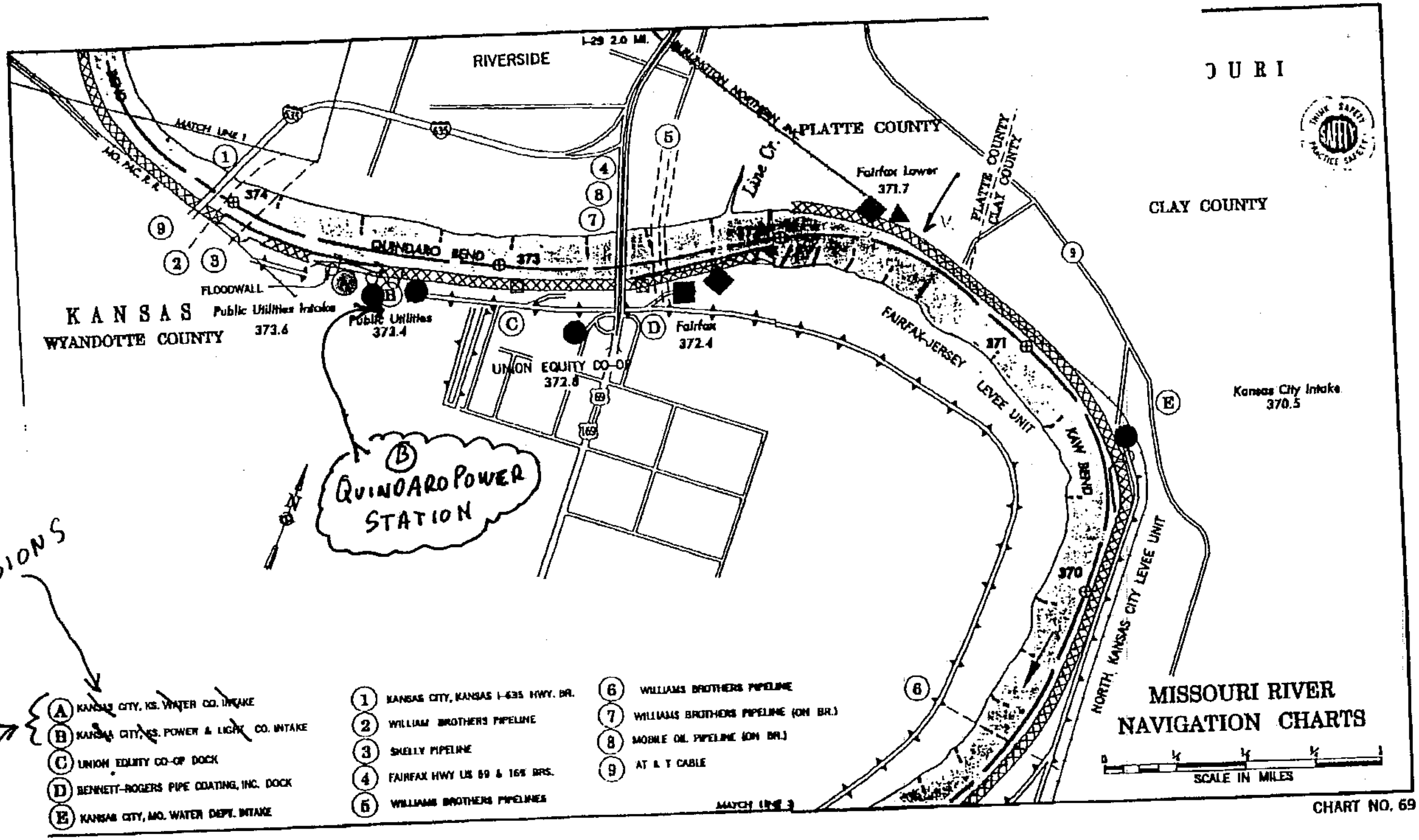
7. Construction drawing of structure:
INTAKE DRAWING ATTACHED.

8. Historic monitoring data: ?

9. What is critical feature of structure (i.e., footing elevation, intake elevation):

* MINIMUM ACCEPTABLE RIVER ELEVATION TO OPERATE INTAKE PUMPS: 716.0

FORM COMPLETED BY: PATRICK J. CASSIDY
SUPERVISOR
(913) 573-9856



(A) B.P.U., KANSAS CITY, KS, WATER PLANT INTAKE

(B) B.P.U., KANSAS CITY, KS, QUINDARO POWER STA. INTAKE

3/5

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS
Kansas City, Missouri

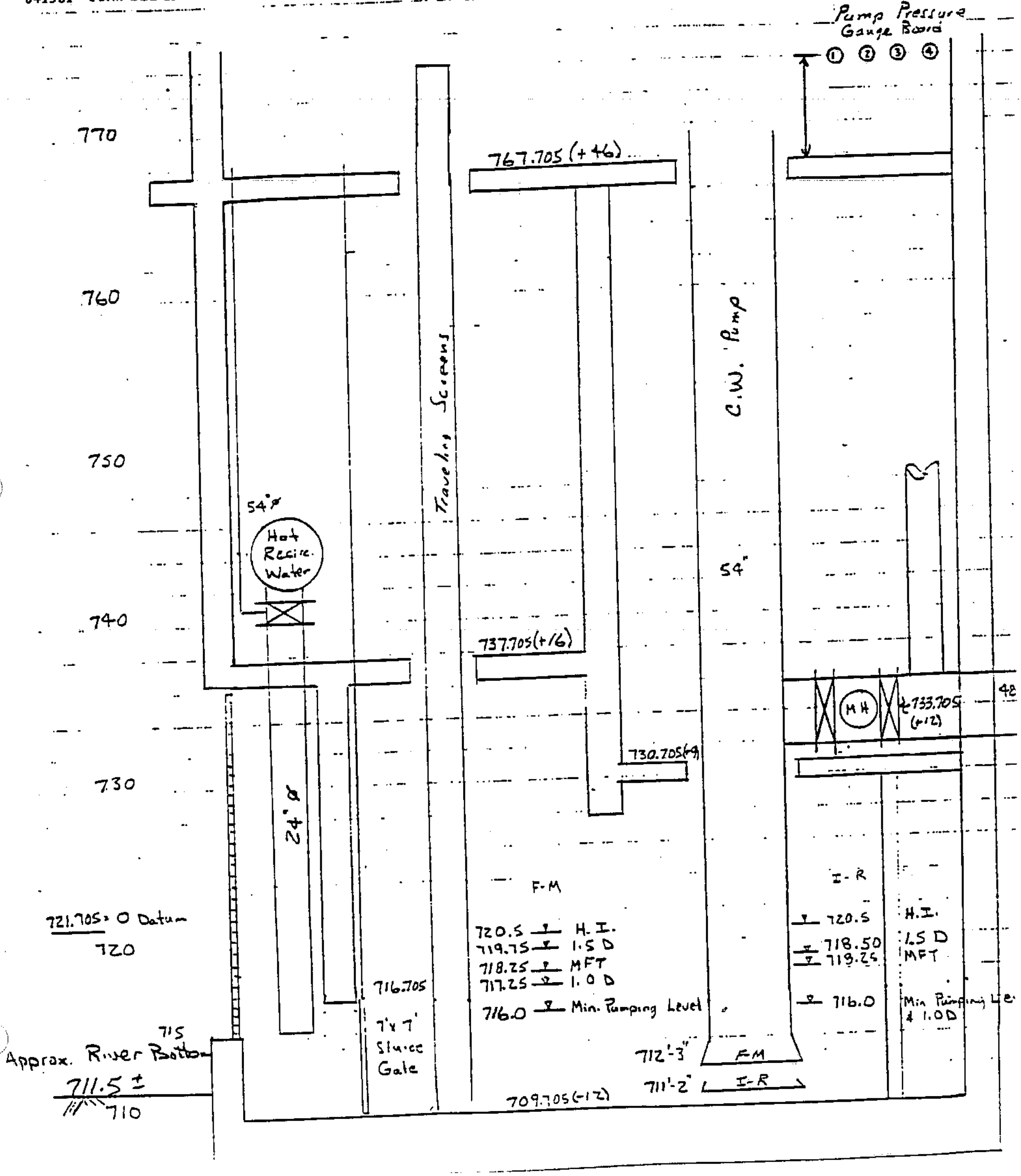
041581 Form GCO-29

Client KCK BPU QUINDARO POWER STA. Page 1 Of 1

Project No. 88-096-4-019-01 Date 12-1-89 Made By R. Verring

Intake Structure Checked By ____

Preliminary ____ Final ____



Summary of Infrastructure Information obtained by WEST Consultants

Agency:
Kansas City, Missouri Water Department
Infrastructure:
Water intakes
Contact Person:
Jeff Badds
Telephone Number:
(816) 454-6233
(816) 454-9916 (Fax)
Materials sent from WEST:
List of water intakes
Vicinity map of project area
Questionnaire
Material Received:
No information was forthcoming.
Comments:

Summary of Infrastructure Information obtained by WEST Consultants

Company:
Skelly Oil Company

Infrastructure:
Pipeline

Contact Person:
Bill Diaz, Vice President

Telephone Number:
(913) 491-9558

Comments:
Mr. Diaz stated that no information is available.

Summary of Infrastructure Information obtained by WEST Consultants

Company:

AT&T

Infrastructure:

Cables

Contact Person:

P.J. McDermott, Outside Plant Cable Engineer

Telephone Number:

(816) 391-5077

Materials sent from WEST:

Vicinity map of project area

Questionnaire regarding the marked AT&T cable crossing (navigational charts) at RM 374.1

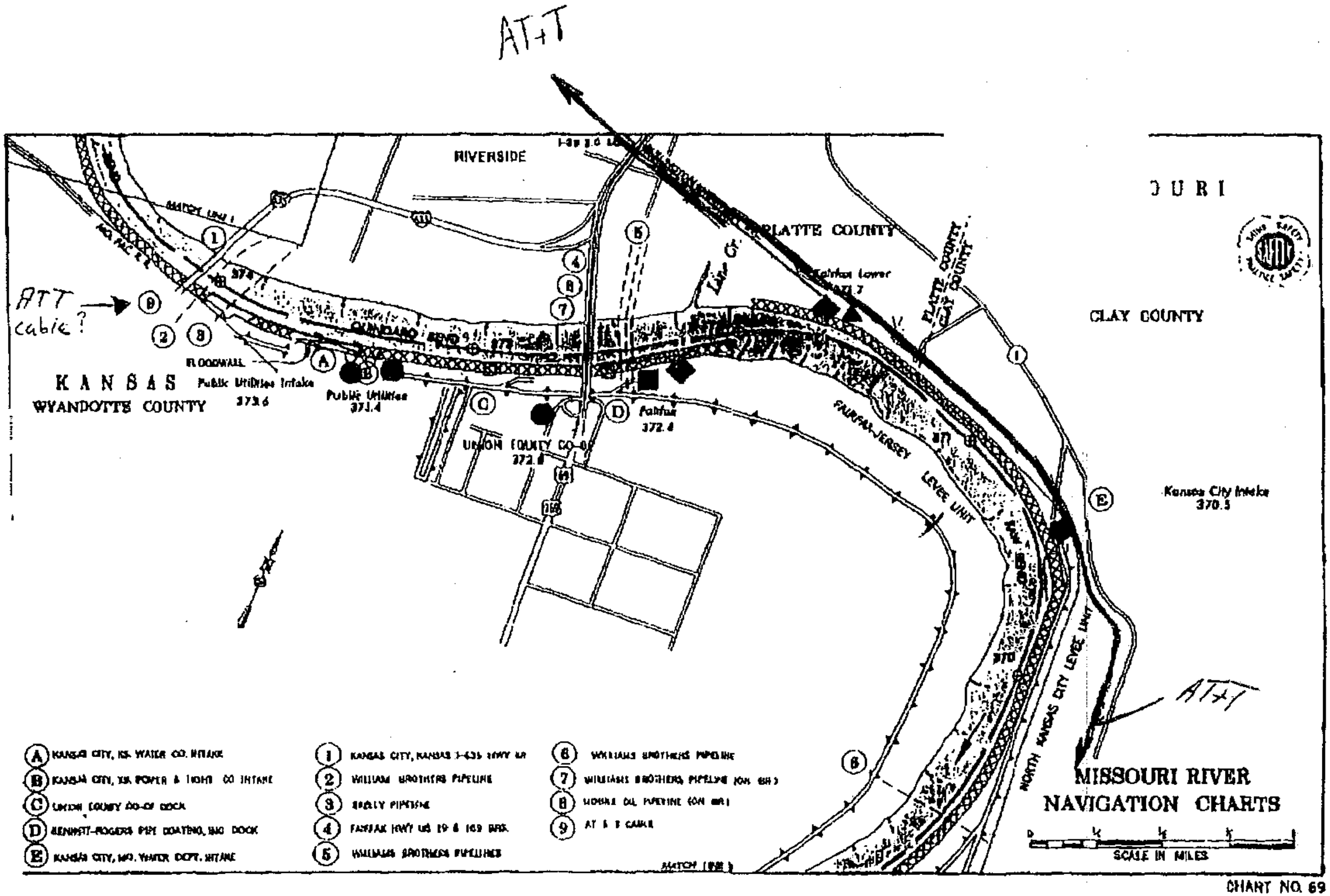
Material Received:

Map marking the only known AT&T cable in the area.

Comments:

That cable does not cross the river and Mr. McDermott stated that AT&T does not have cable crossing the river at RM 374.1.

Correspondence material is included on following pages.


AT+T
RIVERSIDE
PLATTE COUNTY
CLAY COUNTY
PLATTE COUNTY
CLAY COUNTY
Fairfax Lower
KANSAS
WYANDOTTE COUNTY
FLOODWALL
Public Utilities Intake
373.6
Public Utilities
371.4
UNION COUNTY CO-OP
372.8
Fairfax
372.4
Kansas City Intake
370.5
FAIRFAX-JERSEY LEVEE UNIT
NORTH KANSAS CITY LEVEE UNIT
ATT cable?
AT+T
MISSOURI RIVER
NAVIGATION CHARTS
SCALE IN MILES
CHART NO. 69
KANSAS CITY, KS. WATER CO. INTAKE
UNION COUNTY CO-OP DOCK
KANSAS CITY, MO. WATER DEPT. INTAKE
WILLIAMS BROTHERS PIPELINE
WILLIAMS BROTHERS PIPELINES
FAIRFAX HWY US 69 & 169 BRS.

3/5

Summary of Infrastructure Information obtained by WEST Consultants

Company:
Capital Sand Company, Inc.
Infrastructure:
Missouri River dredging operator
Contact Person:
Ray Bohlken, General Manager
Telephone Number:
(573) 634-3020
(573) 636-5734 (Fax)
Materials sent from WEST:
Dredging Questionnaire
Material Received:
Answers to the Questionnaire
Comments:
The responses are consistent with the information provided by Holliday Sand Company regarding their dredging practices that is discussed in this report.

Correspondence material is included on following pages.

Questionnaire

1. How many dredging operations do you conduct on the Missouri River or Kansas River?

   We operate two dredges on the Missouri River

2. What are the locations of the dredging operations?(nearest river mile)

   65 - 143 - 186 - 192 - 226 - 290 - 317

3. How much material is dredged at each location annually? (tons)

   enclosed 1998 Report.

4. What method of dredging is used? (i.e., hydraulic dredging, clam shell, other)

   Hydraulic

5. What amount of material is typically extracted in one day?

   5000 tons.

6. What is the maximum amount of material that can be extracted in one day?

   Largest dredge capable of 1200 tph.

7. What are typical dimensions of the dredge hole that is created by the extracting the typical amount of material in one day?(depth, width, length)

   area 200' wide - 300 ft - depth hard to determine

8. How long does it typically take for the dredge hole to fill in?

   2 to 3 days.

9. What is the estimated in-place density of dredged materials?

   117 lbs cuft.

10. What are the typical size characteristics of the dredged materials?(fine sand, medium sand, coarse sand, gravel)

    + 3/8 - 5%
    3/8 - 1/8 - 30%
    1/8 - 200 - 65%

Capital Sand Company, Inc.
P.O. Box 104990
Jefferson City, Missouri 65110 4990
(573) 634-3020
Fax (314) 636-5724

"Aggregates for the Construction Industry"

Department of the Army
Kansas City District Corps of Engineers
700 Federal Building
Kansas City, MO 64106

Subject: Annual Production Report 1998
Attn.: Mr. Mark Frazier – Regulatory Project Manager

Dear Sir:

Capital Sand Company, Inc. dredged the following tonnage's in 1998.

Osage River

River Mile	Tonnage
0-5	7000 tons
20-22	3000 tons
	10,000 tons

Missouri River

River Mile	Tonnage
60-70	150000 tons
140-150	775000 tons
172-192	200000 tons
192-193	8000 tons
220-230	124000 tons
283-303	24000 tons
314-324	164000 tons
	1,455,000 tons

If additional information is necessary, please contact my office at 573-634-3020.

Sincerely,

F. Ray Bohlken
General Manager

RB/bb

Summary of Infrastructure Information obtained by WEST Consultants

Company:
MCI-Worldcom

Infrastructure:
Cable crossing

Contact Person:
Rick Stull, Outside Plant Manager

Telephone Number:
(918) 590-2158

Materials sent from WEST:

The contact was only in form of telephone conversation:
Discussed the Worldcom cable crossing at RM 369.5 (is marked on the banks of the river by large signs, see field photolog). It is located about two RMs downstream of the project site. Mr. Stull does not think that the cable will be affected by dredging that far upstream. The cable is in a pipeline (probably the one marked as Williams Brother pipeline on the Navigational Charts) that is not buried very deep, but Mr. Stull does not know the depth.

Comments:

Mr. Stull requests that MCI-Worldcom be notified when dredging starts. The mailing address is:

MCI-Worldcom
One Ok Plaza
100 West 5th Street, Suite 715
Tulza, Oklahoma 74103-4294

Summary of Infrastructure Information obtained by WEST Consultants

Company:
Southwestern Bell Telephone
Infrastructure:
Cable
Contact Person:
Ken Morse, MGR. Engineering Design
Telephone Number:
(816) 325-5652
(816) 325-5688 (Fax)
Comments:
Mr. Morse confirmed that Southwestern Bell does not have cables in the vicinity of the project area. The closest crossing is about 4 miles downstream of the Kansas River.

Correspondence material is included on following pages.