Blacksnake Creek Section 205 Feasibility Study
St. Joseph, Missouri

Appendix C
Report of Hydrologic and Hydraulic Conditions

US Army Corps of Engineers
Kansas City District

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1 INTRODUCTION

The Blacksnake Creek watershed located in the City of St. Joseph, Missouri, is a source of flooding in the developed downstream reach of the creek. Consequently, the city is investigating flood damage reduction measures for the Blacksnake Creek watershed, which includes a proposed detention basin at Karnes Road.

The objective of this study is to develop information and data that the City of St. Joseph can use to make decisions regarding a potential Blacksnake Creek detention basin design project. The scope of this study includes hydrologic modeling with HEC-HMS (Version 3.5) and hydraulic modeling with HEC-RAS (Version 4.1.0) to develop water surface profiles for the 1, 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 Annual Chance Exceedance (ACE) storm events.

1.1 STUDY AREA

Information on the study area was gathered from previous reports completed by Black & Veatch (1998) and URS (2001), which were provided to Kansas City District, US Army Corps of Engineers (CENWK). The following sections describe the extent of the drainage area, land use, flood concerns, and other basin characteristics.

The City of St. Joseph, Missouri, is located in Buchanan County in northwestern Missouri. Blacksnake Creek watershed is part of the St. Joseph storm water drainage area, and covers 8.2 square miles of the approximate 50.4 square miles in the entire St. Joseph drainage area. Blacksnake Creek watershed drains generally from north to the southwest. The creek ultimately empties into the Missouri River. Only the extreme downstream portion of the watershed is within the current Missouri River floodplain. Figures 1 and 2 illustrate the relation of Blacksnake Creek to the entire drainage basin and provide a detailed overview of the study area.

1.2 DRAINAGE AREA DESCRIPTION

Blacksnake Creek watershed is an ungaged basin that includes both closed and open drainage systems. The open systems are predominately located in the upper half of the watershed. Blacksnake Creek is an open channel from its headwaters downstream to Karnes Road. At Karnes Road the creek enters the combined sewer system (CSS), which consists of approximately 20 miles of combined sewers with an average pipe size of 48 inches. During times of low flow, the CSS conveys all flows to a 48-inch reinforced concrete pipe (RCP) through which the flow enters a wastewater treatment plant located at the Missouri River. However, during heavy rains the CSS is overwhelmed and stormwater drain by overland flow through developed areas of the City.

1.2.1 LAND USE AND SOILS

The land use of the watershed is divided between predominately urban land use in the lower basin, which encompasses approximately the southern half of the watershed, and a mix of suburban residential and rural land use in the upper, northern half of the basin. Blacksnake Creek watershed is 57% residential, 6% commercial/industrial, 12% parks, 20% agriculture, and 5% other. The composite impervious percent for the watershed is 29%. Future plans for the upper half of

Blacksnake Creek watershed entail conversion of the existing agricultural lands to more urban/residential development.

Soils in the watershed are primarily Marshall-Contrary soils characterized by well drained soils, with slopes from 2% to 20%. These are predominately silt-loam soils. Near the confluence with the Missouri River, the soils are floodplain soils that are poorly drained and predominately clay.

FIGURE 1 ST JOSEPH MISSOURI WATERSHEDS

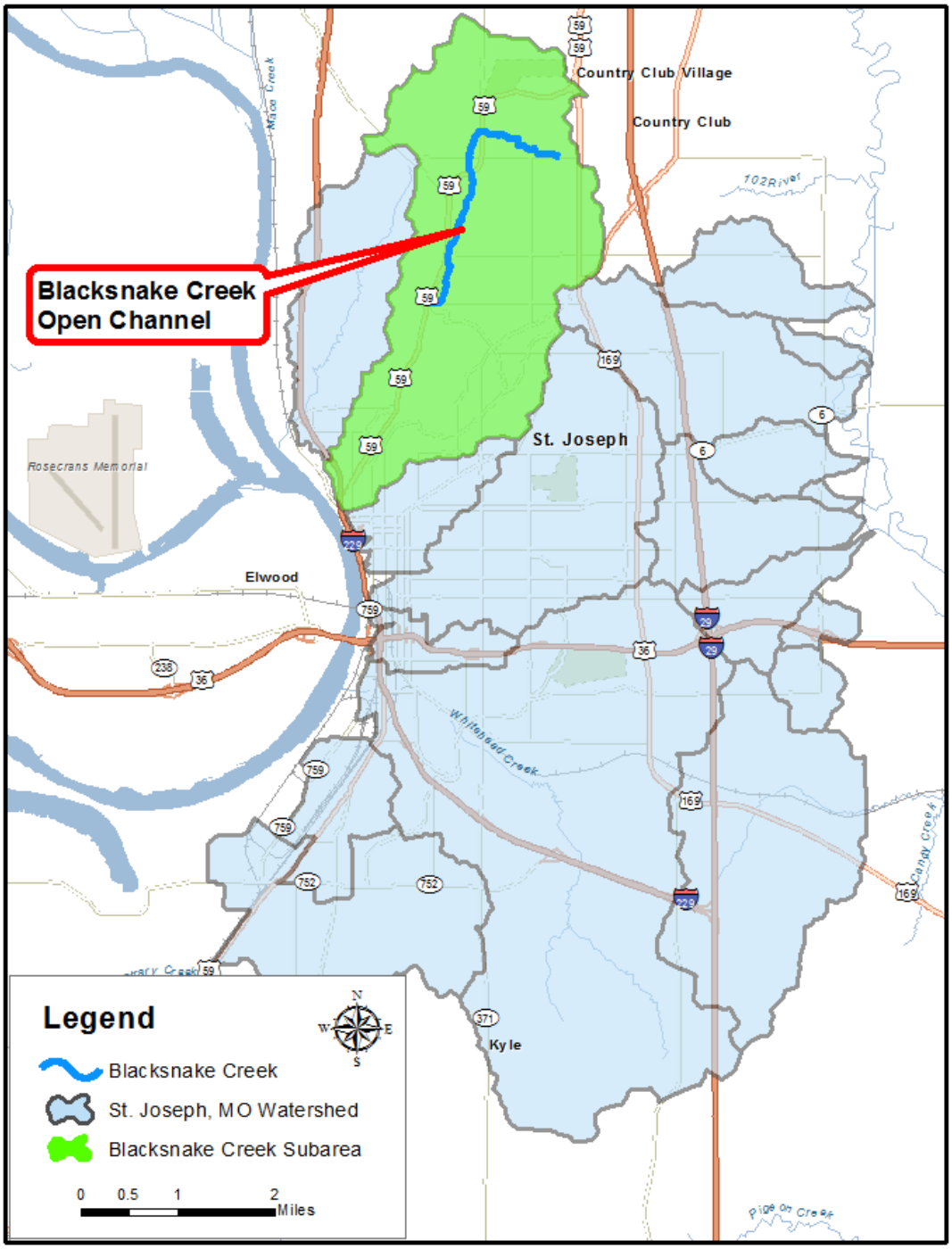
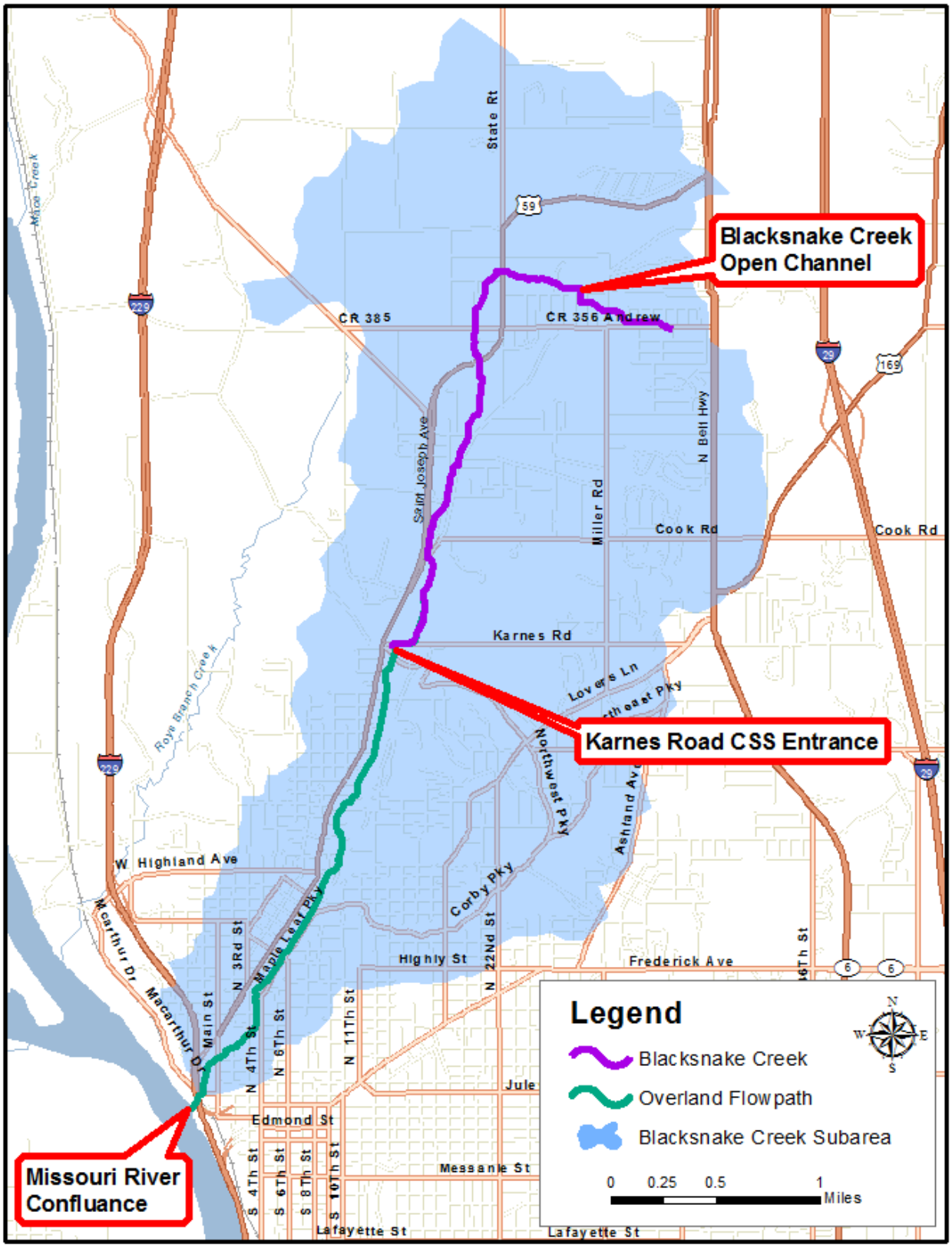


FIGURE 2 BLACKSNAKE CREEK WATERSHED



1.2.2 Flood Concerns

Flooding is a significant issue in the Blacksnake Creek watershed. The main cause of flooding in the basin is flash flooding, which occurs during local storm events over the basin. The inlet capacity at the junction of the creek and the CSS at Karnes Road is exceeded by runoff from the upper watershed during intense storm events. When the CSS inlet is at capacity, water overtops Karnes Road and floods overland into downstream neighborhoods and streets, ultimately flowing into the Missouri River.

The area of most concern is the lower, urbanized portion of the basin, southwest of Karnes Road. This section experiences the most flooding and is served by the CSS. The URS report states, "Approximately 200 homes and businesses are located within the 0.01-ACE floodplain for the Blacksnake Creek below Karnes Road (based on preliminary delineation of the Blacksnake Creek Q3 flood evaluations)." (URS, 2001).

2 Hydrology

2.1 Hydrologic Model Development

A hydrologic evaluation of the Blacksnake Creek watershed in St. Joseph, Missouri, was conducted using the US Army Corps of Engineers, Hydrologic Engineering Center (HEC) Hydrologic Modeling System (HMS), Version 3.5, computer model. The HEC-HMS model was used to simulate the existing conditions runoff hydrographs resulting from rainfalls corresponding to the 1, 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 ACE storm events. The hydrology model development methodology contains six primary components: subarea delineation, rainfall, surface runoff volume, runoff distribution, channel routing, and watershed storage.

2.2 Subarea Delineation

The formation of drainage areas is the first component needed for the hydrologic analysis and sets up the framework for the HMS model. The Blacksnake Creek watershed had been previously studied using the XP-SWMM model. The XP-SWMM model was initially created in 1998 as part of a program to evaluate flooding problems and flood mitigation options in the Blacksnake Creek watershed. For the previous study, the watershed was delineated into 120 subareas, with an average area of 45 acres each. The SWMM subarea delineation was reviewed and verified, using GIS software and two-foot contour data provided by the City of St. Joseph. The SWMM subareas were aggregated to form larger subareas (approximately 160 acres each) for use in the HMS model for this study. Figure 3 shows the Blacksnake Creek watershed and the delineated HMS subareas. Table 1 shows the correlation between the HMS subareas and the SWMM subareas.

2.2.2 Blacksnake Creek Naming Convention:

Subareas draining to Blacksnake Creek were each given a unique alphanumeric name with the format BS-##. "BS" is the two-letter code for the Blacksnake Creek Watershed. "##" is a two-digit subarea identification number. The naming convention was similar for the routing reaches, junctions, and other component elements. Prefix codes "R" and "J" were used to designate

routing reach and junction elements, respectively. The assigned identification number corresponds with the basin number. These alphanumeric names were used in the HMS model, as well as in the GIS shapefiles, and in the results tables.

FIGURE 3 BLACKSNAKE CREEK WATERSHED AND SUBAREAS

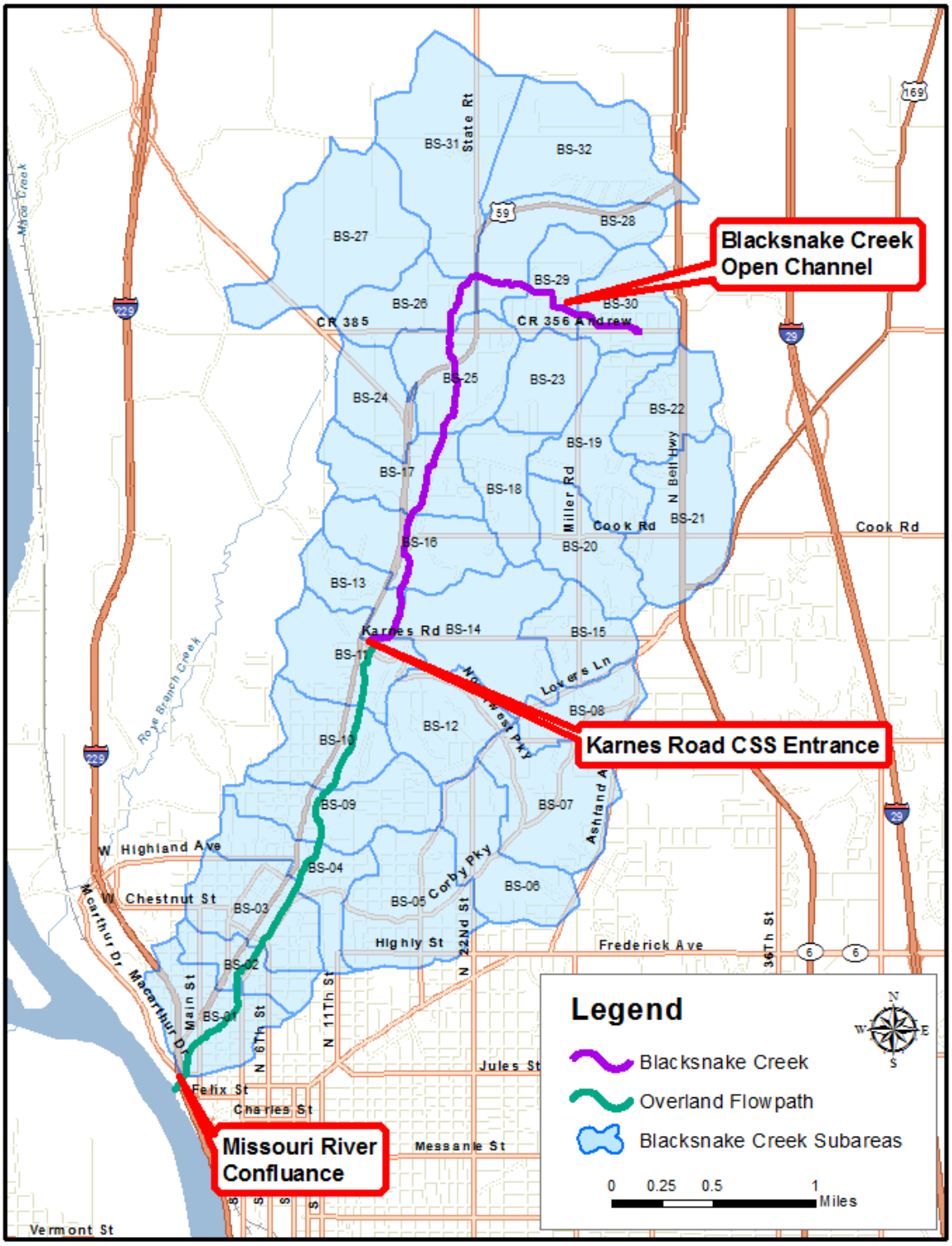


TABLE 1 SUBAREA AGGREGATION

HEC-HMS Subarea ID	Area (Acres)	XP-SWMM Subarea ID	Area (Acres)
BS-01	161	73-5	24.11
		57-6	31.12
		BSS-26	38.54
		BSS-30	67.67
BS-02	84	40-3	22.00
		BSS-21	39.83
		25-6	22.40
BS-03	169	45-9	31.79
		51-8	39.72
		50-3	15.83
		51-3	4.82
		BSS-19B	43.97
		115-1	9.48
		48-28	19.32
		48-23	3.64
BS-04	137	123-22	19.61
		BSS-18	83.61
		67-10	13.18
		52-11	20.48
BS-05	231	GAS-9	112.70
		97-2	42.00
		GAS-17	75.91
BS-06	169	121-1	38.87
		GAS-4	59.28
		166-22	37.69
		166-19A	9.76
		138-21	23.03
BS-07	217	BS-1030	29.86
		BS-1050	26.16
		GAS-1	161.10
BS-08	102	BS-1000	77.48
		BS-1008	24.23
BS-09	176	139-1	66.12
		BSS-13	35.82
		BSS-16	46.35
		139-49	22.07
		127-11	6.08

HEC-HMS Subarea ID	Area, (Acres)	XP-SWMM Subarea ID	Area (Acres)
BS-10	152	127-70	38.49
		BSS-11	85.80
		127-43	27.91
BS-11	164	BSS-2	95.94
		76-12	9.17
		BSS-5	59.14
BS-12	154	225-1	35.56
		BS-1160	60.88
		BS-1120	19.44
		BS-1100	21.38
		BS-1180	16.27
BS-13	89	BS-815	42.02
		BS-835	24.31
		BSS-0	22.68
BS-14	238	BS-985	85.46
		BS-996	50.06
		BS-992	102.30
BS-15	109	BS-940	16.69
		BS-900	6.16
		BS-940A	3.26
		BS-940B	3.11
		BS-975	3.26
		BS-945	38.19
		BS-955	27.99
BS-16	172	BS-795	21.92
		BS-805	46.47
		BS-192	103.80
BS-17	154	BS-775	64.16
		BS-179	79.25
		BS-785	10.88
BS-18	119	BS-675	119.20
BS-19	177	BS-400	13.20
		BS-420	38.28
		BS-660	55.85
		BS-380	8.93
		BS-640	32.22
		BS-630	28.74

TABLE 1 SUBAREA AGGREGATION (CONTINUED)

HEC-HMS Subarea ID	Area (Acres)	XP-SWMM Subarea ID	Area (Acres)
BS-20	137	BS-540	55.98
		BS-503	4.25
		BS-502	9.78
		BS-510	9.29
		BS-500	57.79
BS-21	208	BS-240	26.93
		BS-250	7.09
		BS-620	43.01
		BS-275	15.67
		BS-228	34.44
		BS-230	2.05
		BS-202	22.94
		BS-220	5.97
		BS-200	11.78
		BS-217	38.02
BS-22	128	BS-345	54.08
		BS-300	26.86
		BS-335	16.81
		BS-355	23.63
		BS-360	7.07
BS-23	118	BS-550	111.90
		BS-547	6.40
BS-24	107	BS-700	9.24
		BS-710	14.16
		BS-709	19.56
		BS-720	5.84
		BS-732	32.36
		BS-726	1.63
		BS-740	16.81
		BS-750	7.34
BS-25	169	BS-160	99.72
		BS-150	69.39
BS-26/ BS-27	431	BS-140	431.00
BS-28	157	BS-120	157.00
BS-29	110	BS-109	65.97
		BS-90	14.72
		BS-100	8.98
		BS-106	20.62
BS-30	131	BS-80	47.38
		BS-32	25.40
		BS-50	19.37
		BS-60	9.06
		BS-30	16.50
		BS-10	13.18
BS-31/ BS-32	583	BS-130	583.20

2.3 RAINFALL

The Soil Conservation Service (SCS) design storm with a Type II distribution was used to simulate rainfall events for each return interval. (Note that the Soil Conservation Service (SCS) is now called the Natural Resources Conservation Service or NRCS). This method requires the rainfall depth for a storm duration of 24 hours. The 24-hour rainfall amounts were obtained from the Rainfall Frequency Atlas of the Midwest (Bulletin 71, dated 1992) and are summarized in Table 2. Rainfall amounts representing the nine different return intervals were input into the HMS model.

TABLE 2 RAINFALL DEPTH

Return Period (ACE)	Rainfall Depth for 24-Hour Storm (Inches)
1	2.53
0.5	3.27
0.2	4.25
0.1	4.98
0.04	5.89
0.02	6.58
0.01	7.30
0.004	8.26*
0.002	8.98*

* Values calculated from liner extrapolation

2.3.1 RAINFALL UPDATE

As noted in Section 2.3 the rainfall depths used in the Blacksnake Creek HEC-HMS model were obtained from Bulletin 71, dated 1992. However, since the initial development of the Blacksnake Creek HEC-HMS model, updated rainfall estimates for the Midwestern States were published by the National Oceanic and Atmospheric Administration (NOAA) in 2013. The report is titled "NOAA Atlas 14 – Precipitation Frequency Atlas of the United States – Volume 8 – Version 2.0: Midwestern States". Because this update was released prior to finalizing the feasibility study report the rainfall depths have been modified to reflect the most current data. The new rainfall amounts are summarized in Table 3.

TABLE 3 UPDATED RAINFALL DEPTH COMPARISON (24-HOUR DURATION)

Return Period (ACE)	Bulletin 71 (inches)	NOAA Atlas 14 (inches)	Change in Depth
1	2.53	2.93	0.40
0.5	3.27	3.41	0.14
0.2	4.25	4.24	-0.01
0.1	4.98	4.99	0.01
0.04	5.89	6.10	0.21
0.02	6.58	7.03	0.45
0.01	7.30	8.02	0.72
0.004	8.26*	9.34	1.08
0.002	8.98*	10.6	1.62

* Values calculated from liner extrapolation
** Values calculated from liner interpolation

The updated NOAA Atlas 14 rainfall depths were used in the HEC-HMS model to calculate peak stormwater flow rates.

2.4 RUNOFF VOLUME

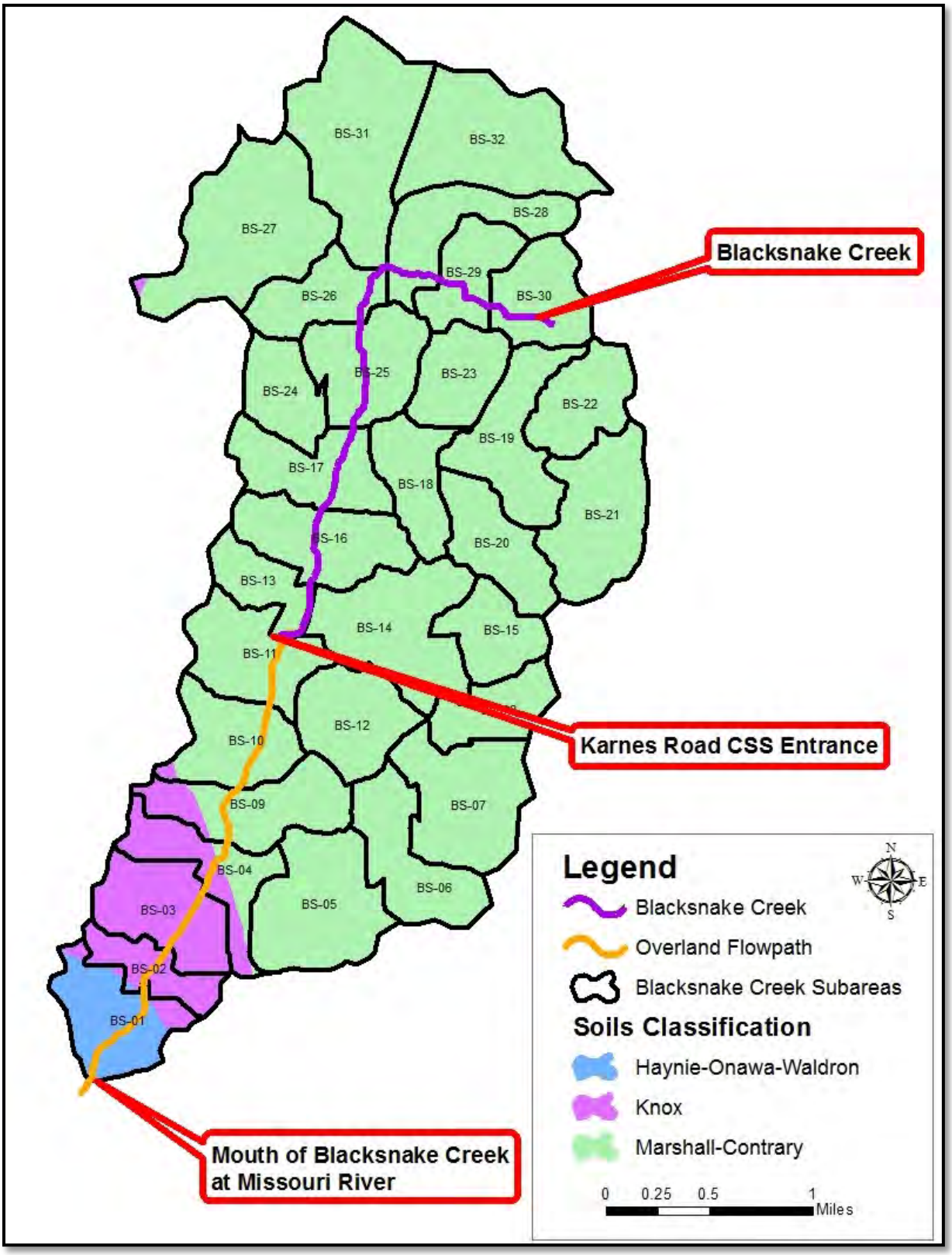
The SCS Curve Number Loss Rate option in the HMS model was used to generate runoff volumes for each subarea. The SCS option uses an initial abstraction value, percent impervious, and a pervious curve number (CN) to estimate runoff volumes from each subarea for a particular design rainfall event.

Initial abstraction is defined as losses from rainfall before runoff begins. Initial abstraction is a function of the CN and was calculated in HMS using the following equation:

$$Ia = 0.2(1000/CN - 10)$$

For the runoff calculation, a CN for pervious area was determined. The CN is a function of the land use condition and hydrologic soil group (HSG). The land use characteristics of the pervious area in the Blacksnake Creek watershed were assumed to be open space and fair condition. Blacksnake Creek watershed is comprised of soils in three different soil type classifications: Haynie-Onawa-Waldron, Marshall-Contrary, and Knox. This information was provided by the City of St. Joseph in a GIS layer electronic file, and was verified using the NRCS Soil Survey of Buchanan County, Missouri. These soils are classified as silty-loam soils and have a HSG "B" classification. Figure 4 shows the soil types and their locations in the Blacksnake Creek watershed. The pervious CN used for all Blacksnake Creek subarea basins was a composite value of 69. This CN value is for HSG "B" classification assuming open area and fair soil condition characteristics, and was obtained using "*Table 2-2a: Runoff Curve Numbers for Urban Areas*" from SCS Technical Release No. 55.

FIGURE 4 BLACKSNAKE CREEK WATERSHED SOIL CLASSIFICATIONS



Percent impervious data for each subarea was extracted from the SWMM model subarea electronic shapefile. These data were used to calculate a composite percent impervious for each HMS subarea. The composite percent impervious values were then verified using aerial photos, site visit pictures and notes, and land use information. The percent impervious values for HMS subareas are provided in Table 4.

TABLE 4 COMPOSITE PERCENT IMPERVIOUS VALUES FOR HMS SUBAREAS

Subarea ID	Percent Impervious	Subarea ID	Percent Impervious	Subarea ID	Percent Impervious
BS-01	53	BS-12	28	BS-23	35
BS-02	55	BS-13	44	BS-24	27
BS-03	48	BS-14	27	BS-25	35
BS-04	49	BS-15	35	BS-26	4
BS-05	30	BS-16	30	BS-27	4
BS-06	26	BS-17	22	BS-28	3
BS-07	20	BS-18	36	BS-29	15
BS-08	29	BS-19	38	BS-30	32
BS-09	45	BS-20	35	BS-31	12
BS-10	39	BS-21	61	BS-32	12
BS-11	18	BS-22	49		

2.5 RUNOFF HYDROGRAPHS

The Clark Unit Hydrograph option in HEC-HMS was used to distribute the runoff volume. This method requires a time of concentration value (Tc) and a basin storage coefficient (R) for each subarea.

The time of concentration is generally defined as the time required for a drop of water to travel from the most hydrologically remote point in the subcatchment (or subarea) to the point of collection, which in the Blacksnake Creek HMS model is the subarea outlet. The time of concentration for each subarea was calculated using a combination of the Kirpich formula for overland flow paths and the Manning's formula for open channels and closed conduits.

Overland flow paths were developed in GIS for each subarea. For each subarea, a runoff flow path length (L) and an average watershed slope (S) were calculated in GIS. Using these values, the Kirpich formula was used to calculate time of concentration in minutes for each subarea.

Kirpich formula: $t_c = 0.0078 L^{0.77} S^{-0.385}$, min

L = length of open channel, ft.
S = average watershed slope, ft/ft.

For subareas with closed conduits, and open channels with defined cross-sections, travel times were calculated based on flow path length and flow velocity. Manning's equation was used to

estimate average flow velocities for both open channels and pipe flow. Average flow velocity in open channels was determined for bank-full flow conditions, using channel slope and the cross-sectional geometry. Average flow velocity in pipes was determined assuming pipes at full capacity. The pipe data was extracted from the SWMM model.

The basin storage coefficient, R, for each subarea was calculated using the following equations:

$R = 1.0 * T_c$ for fan-shaped subarea
$R = 1.67 * T_c$ for average-shaped subarea
$R = 2.33 * T_c$ for linear-shaped subarea

The subarea shape was determined using engineering judgment and available mapping. The values for time of concentration (Tc) and basin storage coefficient (R) for HMS subareas are listed in Table 5.

TABLE 5 TIME OF CONCENTRATION (T_C) AND BASIN STORAGE COEFFICIENT ®

Subarea ID	T_c (hr)	R (hr)	Subarea ID	T_c (hr)	R (hr)	Subarea ID	T_c (hr)	R (hr)
BS-01	0.18	0.30	BS-12	0.22	0.52	BS-23	0.26	0.43
BS-02	0.16	0.26	BS-13	0.36	0.60	BS-24	0.19	0.45
BS-03	0.16	0.27	BS-14	0.32	0.74	BS-25	0.23	0.54
BS-04	0.19	0.31	BS-15	0.24	0.40	BS-26	0.30	0.49
BS-05	0.22	0.51	BS-16	0.24	0.41	BS-27	0.39	0.65
BS-06	0.21	0.35	BS-17	0.25	0.42	BS-28	0.57	1.33
BS-07	0.23	0.39	BS-18	0.32	0.54	BS-29	0.19	0.31
BS-08	0.23	0.54	BS-19	0.36	0.84	BS-30	0.26	0.43
BS-09	0.17	0.28	BS-20	0.22	0.52	BS-31	0.61	1.42
BS-10	0.20	0.47	BS-21	0.16	0.26	BS-32	0.42	0.98
BS-11	0.18	0.29	BS-22	0.24	0.55			

2.6 CHANNEL ROUTING (MUSKINGUM-CUNGE)

The Muskingum-Cunge Routing method was used in the HMS model to route runoff through the watershed. An eight-point channel cross section was developed for each routing reach using the ArcView profiler tool and the Digital Elevation Model (DEM) created from two-foot contour data. Channel length and slope were also determined using this tool. The channel lengths and slopes for the subarea routing reaches are listed in Table 6.

TABLE 6 CHANNEL LENGTH AND SLOPE FOR HMS ROUTING REACHES

Reach ID	Length (Feet)	Slope (ft/ft)
R-01	3,078	0.007
R-02	901	0.002
R-03	1,728	0.004
R-04A	1,341	0.011
R-04B	1,288	0.003
R-05	2,918	0.009
R-06	1,344	0.011
R-07	3,612	0.020
R-09	1,129	0.011
R-10	2,640	0.002
R-11A	706	0.015
R-11B	1,644	0.009
R-13	918	0.005
R-14A	3,234	0.016
R-14B	906	0.002
R-16	2,018	0.002

Reach ID	Length (Feet)	Slope (ft/ft)
R-17	1,081	0.010
R-17A	1,141	0.012
R-18	1,197	0.005
R-18A	613	0.006
R-18B	757	0.017
R-19	984	0.001
R-19A	1,466	0.014
R-20	1,033	0.002
R-21	684	0.018
R-24	736	0.031
R-25	1,247	0.011
R-25A	2,753	0.006
R-26	1,740	0.009
R-27	2,017	0.008
R-28	1,457	0.004
R-29	1,707	0.014

2.7 WATERSHED STORAGE

Existing conditions in the Blacksnake Creek watershed do not include any storage areas designated for flood risk management. Modeling and evaluation of detention storage for flood risk management purposes would be appropriately addressed in a future conditions analysis.

Currently, there are no defined storage areas for Blacksnake Creek watershed existing conditions. Analysis of future conditions would evaluate and model the impact of a detention storage located directly upstream of Karnes Road and the CSS inlet, and the effect this detention would have on flood risk management in the lower portion of the Blacksnake Creek watershed. However, it should be noted that future conditions modeling is not part of the Blacksnake Creek study covered by this report.

2.8 MODEL VERIFICATION

The HEC-HMS model results were compared to the Missouri Urban Regression Curve shown in Figure 5 (Figure 5602-2, Section 5600, *Storm Drainage Systems and Facilities*, Kansas City Metropolitan Chapter, APWA, November 2005). A basin development factor (BDF) of 9 was chosen because it best reflects the development in the Blacksnake Creek study area. Based on this curve, the 0.01-ACE discharge was estimated and compared for two locations within the watershed: at the basin outlet to the Missouri River (Junction J-01 in the HMS model) and at Karnes Road (Junction J-13 in the HMS model). The hydrologic model results were within +/- 10% of the regression equation values. These results are shown in Table 7. Because the Blacksnake Creek watershed is an ungaged system there are no records of measured stream flows to compare to computed discharges.

FIGURE 5 MISSOURI REGRESSION CURVES – RURAL AND URBAN

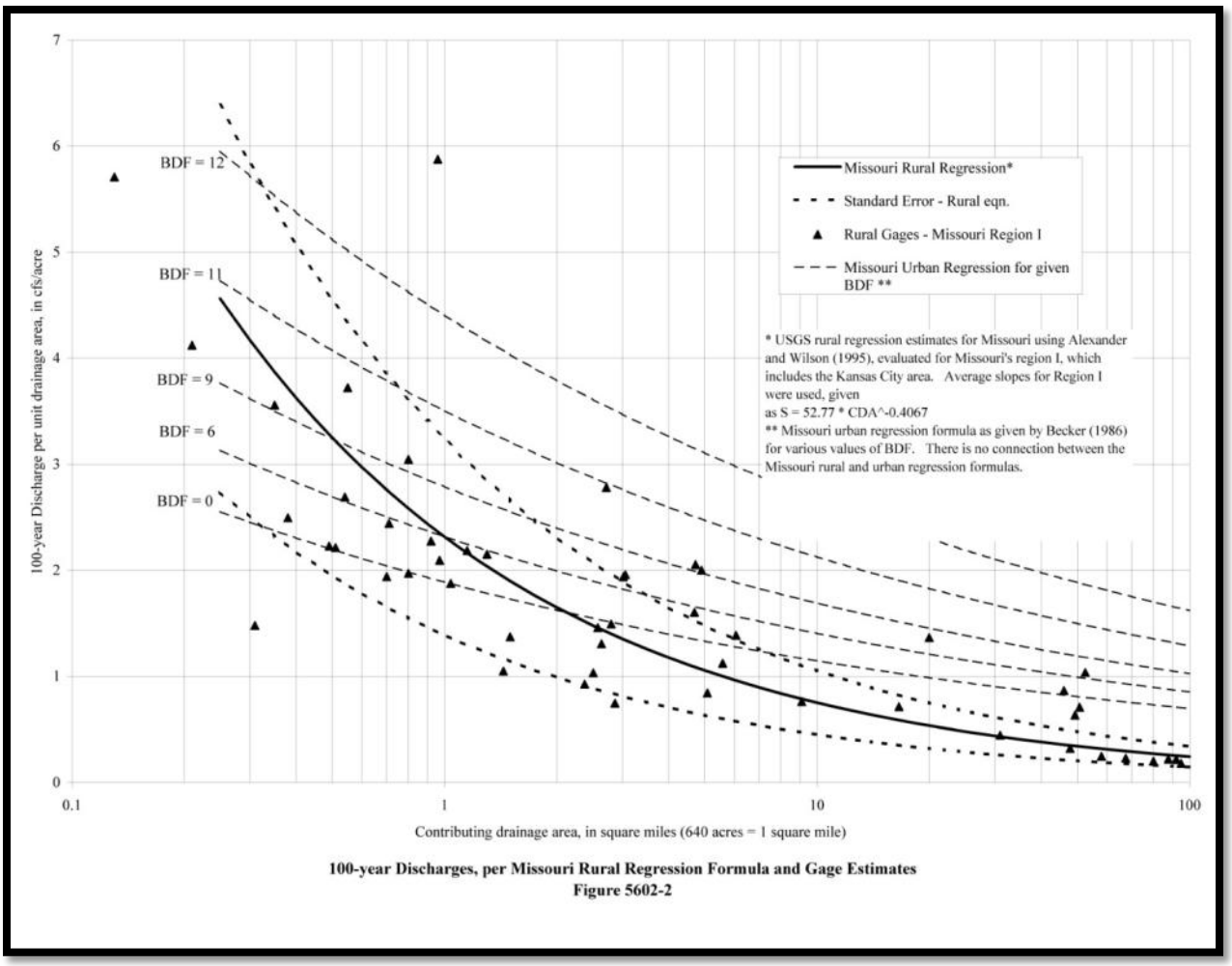


TABLE 7 HEC-HMS MODELING RESULTS COMPARISON

Hydrologic Location ID	Description	0.01 ACE (cfs)	Area (sq. mi.)	Area (acre)	(cfs/ac)	Missouri Urban Regression, 0.01 ACE (cfs/acre)
Junction 01	Basin Outlet at Missouri River	10325	8.21	5,254	1.96	1.72
Junction 13	Karnes Road-End of Open Channel	7296	5.22	3,338	2.18	1.92

2.9 MODEL RESULTS

Table 8 presents the HEC-HMS modeling results for existing conditions at the junctions located at Karnes Road and at the confluence with the Missouri River. Frequency flow rates from HMS were

used to develop the hydraulic model input. The hydraulic model is described in Section 3, which follows.

TABLE 8 HEC-HMS MODELING RESULTS

Hydrologic Location ID	Description	Existing Conditions Peak Flow Rates (cfs)								
		1 ACE	0.5 ACE	0.2 ACE	0.1 ACE	0.04 ACE	0.02 ACE	0.01 ACE	0.004 ACE	0.002 ACE
Junction 13	Karnes Road	1533	1996	2856	3705	4978	6069	7296	8988	10715
Junction 01	Confluence with Missouri River	2069	2725	3943	5135	6994	8578	10325	12717	15099

3 HYDRAULICS

3.1 HYDRAULIC MODEL DEVELOPMENT

Hydraulic modeling was performed using HEC-RAS Version 4.1.0 steady state option. This section provides a description of the methodology used to develop the RAS hydraulic model for the Blacksnake Creek Feasibility Study. The objective was to produce a detailed hydraulic model that reflects the complexities in local topography, provides an effective tool for assessing flood risk, and can be used to evaluate options for reducing flood risk. Based on existing topography and land use conditions, the RAS model simulates the watershed's primary stormwater flow path in the lower portion of the basin. The model extends from just upstream of Karnes Road to the confluence with the Missouri River. The RAS model calculates water surface elevations (WSE) for the design storms described previously in this report.

The paragraphs of this section present descriptions of the development process for the Blacksnake Creek RAS model. Topics include the procedures for developing RAS model parameters and creating the Blacksnake Creek RAS model. Use of the RAS steady state flow option is discussed. RAS results are tabulated and evaluated.

3.2 HEC-RAS MODEL

HEC-RAS model data requirements can be summarized into ten model parameters. Table 9 lists the ten parameters and the methods used to develop the data requirements. These model parameters were developed using a combination of manual procedures, and the automation tools ArcGIS and HEC-GeoRAS in conjunction with GIS data. The following paragraphs describe the HEC-RAS model development procedures.

TABLE 9 HEC-RAS PARAMETER DEVELOPMENT

HEC-RAS Model Parameter	Development Method	Data Requirements
Stream network	ArcGIS	Stream centerline coverage with unique stream reach names
Cross sections (river station and geometry data)	ArcGIS and HEC-GeoRAS	Triangular irregular network (TIN), cross section cut line coverage
Downstream reach lengths (channel and overbanks)	ArcGIS and HEC-GeoRAS	Stream centerline and overbank (left and right) flow path coverage
Manning's n-values	ArcGIS	Manning's n-value assigned based on orthophotos and field observations
Crossings	Manual input using field survey data where available	Roadway profile and bridge opening
Expansion and contraction coefficients	Manual input using standard values and engineering judgment	Contours and cross section cut line coverage
Boundary conditions	Manual input	Known WSE boundary condition
Ineffective flow areas	Manual input using RAS standard procedures and engineering judgment	Contours and cross section cut line coverage
Blocked obstructions	Manual input using RAS standard procedures and engineering judgment	Aerial photography and site visit photos
Channel bank stations	Manual input using RAS standard procedures and engineering judgment	Cross section geometry (station and elevation data)

3.2.1 STREAM NETWORK, CROSS SECTIONS, AND REACH LENGTHS

The first step in developing the RAS model was creation of a RAS geometry file containing the stream centerline, cross section river stations and geometry, and downstream reach lengths for the channel and overbanks. The stream centerline defines the main channel. The model extends from 1,500 feet upstream of Karnes Road to the mouth of Blacksnake Creek at the Missouri River.

Primary drainage for low flow in this reach is currently provided by a closed conduit combined sewer system (CSS). The entrance to the CSS is located at Karnes Road. The Blacksnake Creek watershed upstream of Karnes Road drains into the CSS at this location. There is no defined channel that conveys flows downstream of Karnes Road. Flows in the RAS model below Karnes Road, which exceed the capacity of the CSS, are routed via overland flow.

The Blacksnake Creek RAS model does not include the CSS. The CSS below Karnes Road is a network of closed conduits of various shapes and sizes. These flow conditions cannot be modeled using RAS steady flow. In order to simulate the overland flow in the Blacksnake Creek watershed

below Karnes road, flows into the RAS model are reduced by the inflow into the CSS at Karnes Road. HMS flows into the RAS model below Karnes Road are reduced by the capacity of the CSS. The capacity of the CSS was calculated from the results of the SWMM model, which modeled flows in the network of conduits of the CSS. An average capacity of the CSS below Karnes Road was calculated from the SWMM results and used to develop the flows into the RAS model below Karnes Road.

To represent the geometry of the Blacksnake Creek basin downstream of Karnes Road in HEC-RAS, channel cross-sections were developed using the available two-foot contour information. Cross section river stations mark the location of the cross section along the overland flow path in feet measured upstream from the Blacksnake Creek confluence. Cross section geometry includes station and elevation data. Downstream reach lengths define the distance to the next downstream cross section along the assumed stream channel location, and along the left and right overbanks.

This study used HEC-GeoRAS in conjunction with ArcGIS to prepare an export file of the stream and cross section geometry data values, which were directly imported by RAS. This was used to create a geospatially referenced RAS geometry file.

HEC-GeoRAS is a public domain software program developed by USACE HEC. HEC-GeoRAS uses the following data to create the export file:

3.2.1.1 Triangular Irregular Network (TIN)

The TIN was created from the St. Joseph two-foot contour data using ArcGIS. The TIN is a surface representing the ground topography and is used in conjunction with the cross section cut line coverage to develop station and elevation information for cross section geometry data. A ground surface elevation was recorded at each station along the cross section cut line that crosses a TIN edge.

3.2.1.2 Stream Centerline Coverage

The stream centerline coverage was manually digitized in ArcGIS at the thalweg of the main overland flow path. Available aerial photographs, contour data, and the XPSWMM hydraulic network developed in a previous study were used as guidelines in the development process. HEC-GeoRAS requires a river name and reach name be assigned to each line segment. For the purpose of this study, the river name was assigned “Blacksnake Creek” and the reach name was assigned “Surface.”

3.2.1.3 Cross Section Cut Line Coverage

The cross section cut line coverage is a GIS line coverage that identifies the location and extent of each cross section. The cross section cut line coverage was generated in ArcGIS. Available aerial photographs and contour information were used to lay out the cross section cut lines. Also, the St. Joseph, Missouri, Buchanan County FEMA FIS study (September 1984) was used as a guide in determining the extent of the cross sections.

Cross section cut lines were located in order to represent the average geometry of the stream reach. Cut lines were placed along the stream centerline at changes in geometry, slope, channel width, overbank roughness, and discharge.

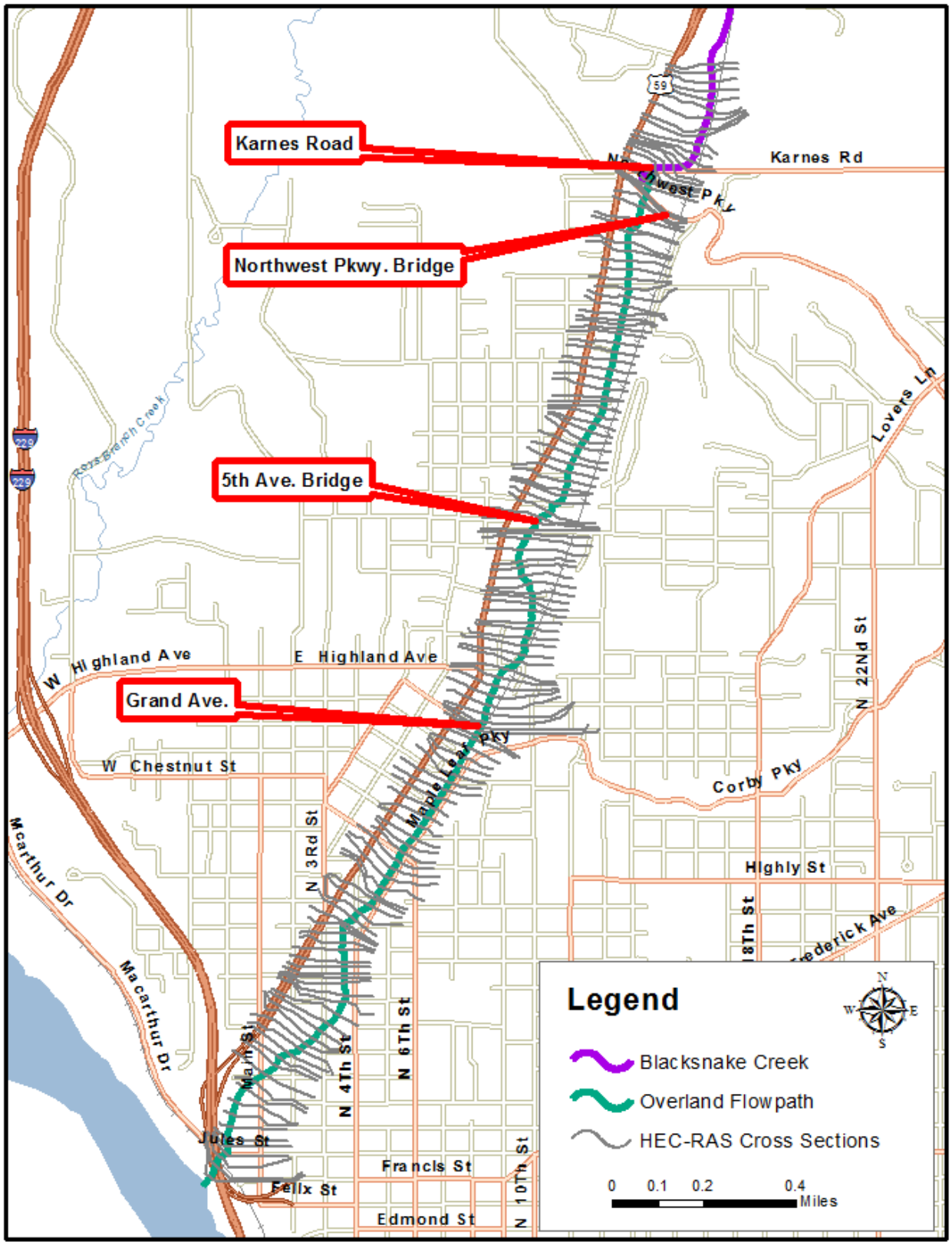
Aerial photographs and field reconnaissance confirm that many obstructions in the form of houses and buildings from residential, commercial, and industrial development exist along the primary overland flow path for Blacksnake Creek. To capture accurately the location and geometry of these obstructions in the HEC-RAS model, cut lines to define cross-sections were placed approximately every 100 feet or less.

Figure 6 shows the layout of the cross section cut lines. The cross section cut lines are oriented from left to right looking downstream. Each cross section is defined by the station-elevation data and the Manning's n-values. The river station for each cross section is the cumulative distance in feet measured from the designated point of confluence of Blacksnake Creek and the Missouri River, upstream to the cross section's location.

3.2.1.4 Overbank Flow Path Coverage

The overbank flow path coverage is a GIS line coverage that represents the average left and right overbank flow paths between each cross section. The overbank flow path coverage is used to determine the downstream reach lengths for the left and right overbanks. Available aerial photographs and the contour information were used as a guide to locate manually the overbank flow paths. In general, the overbank flow path was located on the top of the channel bank at each side of the designated stream centerline.

FIGURE 6 BLACKSNAKE CREEK HYDRAULIC LAYOUT



3.2.2 Manning's n-Values

The Manning's n-values at each cross section were estimated using digital aerial and field photographs. Manning's n-values were selected to represent land surface characteristics as listed in Table 10. The initial n-values were used as a model starting point and were adjusted within the range, if needed, to simulate site specific characteristics. Horizontally-varied Manning's n-values may be input in the HEC-RAS model to capture changes in land use spanning the cross section.

Table 10 Land Surface Characteristics and Associated Manning's n-Values[1]

Land Surface Type	Initial n Value	Range of n-Value
Grass, urban and maintained	0.030	0.025 to 0.035
Trees and brush	0.090	0.035 to 0.160
Brush	0.060	0.035 to 0.160
Residential/Commercial areas2	0.120	0.045 to 0.120
Open field, medium to tall grass	0.035	0.025 to 0.060
Pavement	0.020	0.013 to 0.025
Open Water	0.025	0.016 to 0.033

[1] Source: Open Channel Hydraulics, Chow 1959.
[2] These n-values will be used in developed areas to account for the loss of conveyance caused by buildings.

In order to account for conveyance loss in developed urban areas, the overbank n-values were increased outside of the normal range where there is obstruction from buildings located within the floodplain. The n-values in these areas range from 0.050 to 0.12. A value of 0.050 was used for areas with open space and manicured turf grass. A value of 0.12 was used for fully developed areas with obstructions from homes and buildings. If significant blockage is caused by buildings in the flood fringe, the developed areas were also modeled utilizing blocked obstructions.

3.2.3 Bridge/Roadway Crossings

There are three main bridge/roadway structures that cross the main Blacksnake Creek overland flowpath. These structures are shown on Figure 6; Fifth Avenue Bridge, Northwest Parkway Bridge, and Grand Avenue. During the initial site visit, it was confirmed that the bridge structures do not cross directly over the main overland flow path. They are located on the far left overbank with an average linear distance of over 500 feet from the channel centerline. Based on field observations and model results, the parallel flow path does not effectively convey flow. The site visit report and photos can be found in Appendix B.

For modeling of future conditions, Northwest Parkway Bridge and Fifth Avenue Bridge were added to the model. The eight-foot CMP pedestrian tunnel adjacent to the Northwest Parkway Bridge was also added to the model at cross-section 13384. The multiple opening analysis function in HEC-RAS was used. The computed WSEs were not found to be sensitive to the inclusion or exclusion of the pedestrian tunnel and the two bridges. Possible explanations for this include the structures' elevations, geometry, and distances from the channel centerline.

3.2.4 EXPANSION AND CONTRACTION COEFFICIENTS

The expansion and contraction coefficients were estimated based on the ratio of expansion and contraction of the effective flow area in the floodplain occurring at cross sections and at roadway crossings. Typical coefficients used in the model are listed in Table 11. The expansion and contraction coefficients were input manually using the HEC-RAS cross section editor.

TABLE 11 EXPANSION AND CONTRACTION COEFFICIENTS[1]

Transition Type	Expansion Coefficient	Contraction Coefficient
Gradual	0.3	0.1
Bridge/Roadway Crossing/Obstruction	0.5	0.3
Abrupt	0.8	0.6

[1] Data from HEC-RAS Hydraulic Reference Manual, Page 3-21

In the Blacksnake Creek model, expansion and contraction coefficients were increased at cross-sections that had multiple blocked obstructions or blocked obstructions causing narrowed flow area. The expansion and contraction coefficients of cross-sections directly upstream and downstream of obstructions were also altered to account for the decreased flow area.

3.2.5 BOUNDARY CONDITIONS

A required input for the hydraulic model was specification of a downstream boundary condition. The Blacksnake Creek watershed is much smaller than the watershed of the main stem Missouri River. Peak flow conditions for these two streams result from different hydrologic conditions. Flood conditions on the Missouri River are the result of large regional weather patterns that produce extended, successive precipitation events.

Peak flood conditions in the considerably smaller Blacksnake Creek watershed are produced by intense, localized precipitation events. The coincident occurrence of both conditions is unlikely and statistically independent.

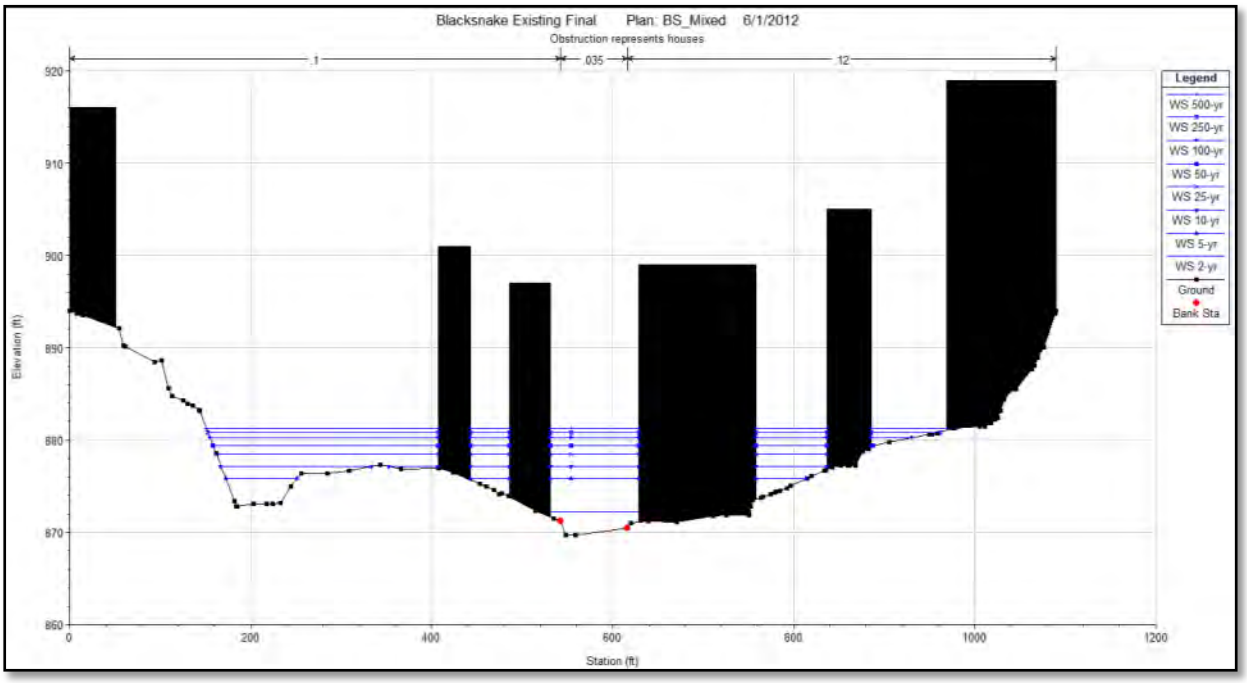
Anecdotal information available from previous reports, and information available to USACE Kansas City District, indicates that on multiple occasions intense, local precipitation in the Blacksnake Creek watershed has occurred while stages in the Missouri River remained below the elevation estimated to have a 0.5 ACE recurrence interval. In addition, due to the steep natural topography near the mouth of Blacksnake Creek, which drops approximately 30 feet over the last 400 feet of the overland flow path, WSEs for Blacksnake Creek are not sensitive to WSEs on the Missouri River for more frequent floods.

For the purpose of this analysis, it was assumed that the Missouri River stage would be no greater than what would be seen for a 0.5 ACE recurrence interval. The 0.5 ACE WSE of 808 feet was determined from the effective FEMA Flood Insurance Study applicable to the Missouri River at the mouth of Blacksnake Creek. This elevation was specified as the downstream boundary condition in the Blacksnake Creek HEC-RAS model.

3.2.6 Blocked Obstructions and Ineffective Flow Areas

Blocked obstructions and ineffective flow areas were determined using the cross section plots, aerial photos, and information collected during field visits. These RAS options were used to simulate buildings, houses, and other large obstructions in the Blacksnake Creek overland flow path. They were input manually using the HEC-RAS cross section editor. Figure 7 shows a typical cross section with multiple blocked obstructions.

Figure 7 Typical Cross Section with Multiple Blocked Obstructions



3.2.7 Channel Bank Stations

The bank stations were located and entered manually by graphically editing the cross sections within HEC-RAS. The bank stations were placed based on review of the GIS generated cross section geometries, the site visit photos and report, and the typical open channel section for developed areas.

3.3 Steady Flow Water Surface Profiles

Stream profiles were developed depicting the 1, 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 ACE WSEs. Frequency flows used were based on output from the HEC-HMS model, which was discussed in Section 2 of this report. Flow change locations were developed with consideration of HEC-HMS junctions, and input into HEC-RAS at geographically correct load points.

Flow change locations downstream of Karnes Road (Junction J-13) include only overland flow. The HEC-RAS model does not include a simulation of the CSS. All flows modeled below Karnes Road are routed via the overland flow path. Flows in the RAS model below Karnes Road are the HMS flows reduced by the average full flow capacity of the CSS, which was calculated to be 1803 cfs. A base flow of 5 cfs is used where this subtraction of flow would result in a negative flow condition. The

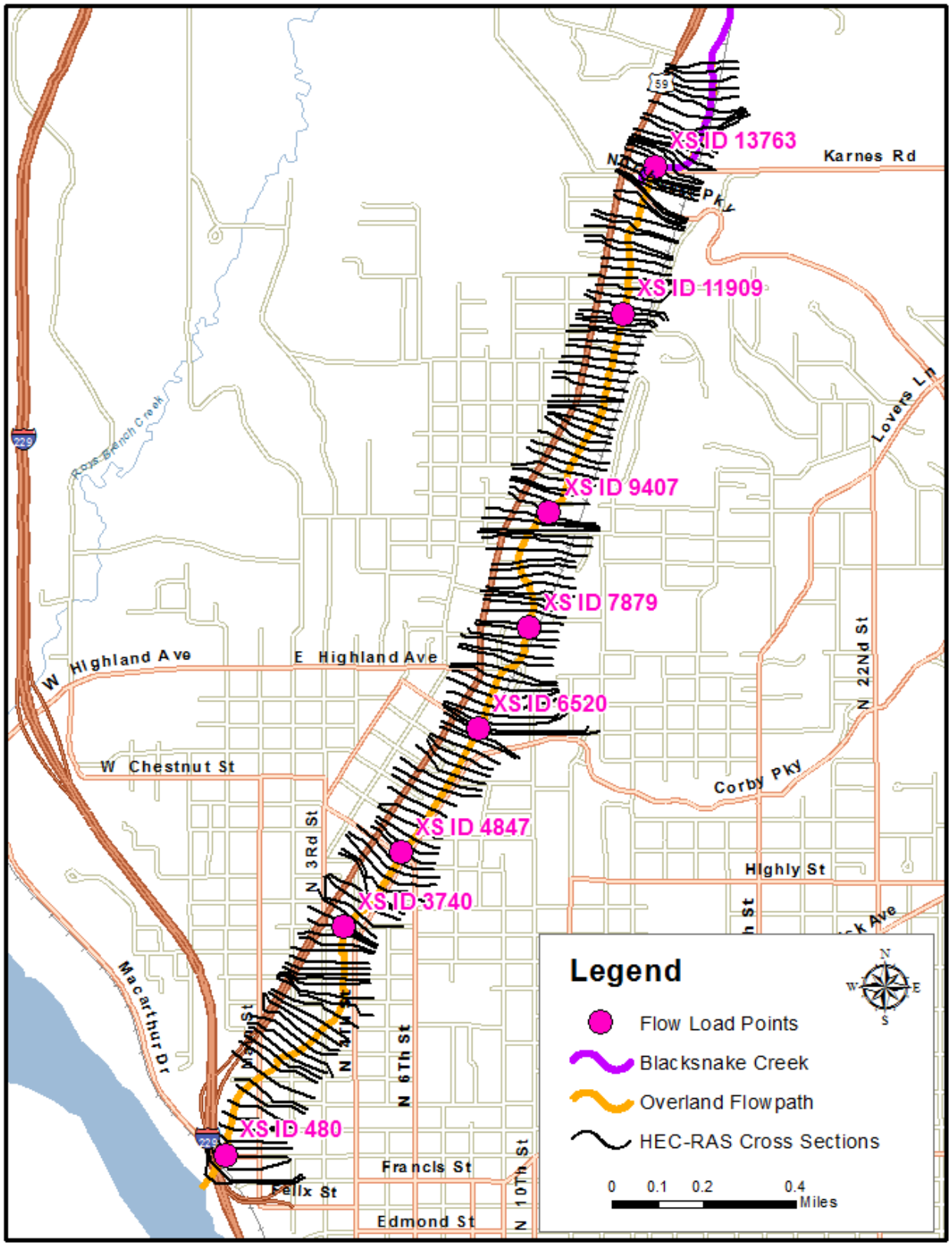
amount of flow at each load point is listed in Table 12. The cross section location of the flow load points in HEC-RAS are shown in Figure 8.

TABLE 12 FLOWS USED IN EXISTING CONDITIONS HEC-RAS MODEL

		Event (ACE)/Peak Flow (cfs)								
HEC-HMS Junction ID	**XS* Station ID**	**1**	**0.5**	**0.2**	**0.1**	**0.04**	**0.02**	**0.01**	**0.004**	**0.002**
J-16	15365	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527	1485	1933	2770	3595	4835	5899	7100	8754	10447
J-13	13763	5	192	1053	1901	3175	4265	5493	7185	8911
J-11	11909	5	343	1272	2191	3577	4756	6082	7912	9774
J-10	9407	5	366	1312	2242	3662	4867	6214	8065	9937
J-09	7879	5	427	1401	2359	3824	5067	6452	8360	10285
J-04	6520	198	829	1995	3139	4914	6421	8082	10365	12650
J-03	4847	230	872	2061	3227	5040	6580	8279	10611	12939
J-02	3740	236	881	2077	3250	5073	6626	8340	10687	13026
J-01	480	266	922	2139	3332	5190	6774	8522	10914	13295

*XS = cross section

FIGURE 8 BLACKSNAKE CREEK FLOW LOADING POINTS



3.4 MODEL RESULTS

Figure 9 illustrates the generated WSE profiles for selected design events from the HEC-RAS model. These are also given in Table 13 for five selected cross-sections. Table 13 also lists the peak flow in cfs, and the average velocity in ft/s, for the selected cross-sections.

TABLE 13 EXISTING CONDITIONS HEC-RAS MODEL RESULTS AT SELECTED CROSS-SECTIONS

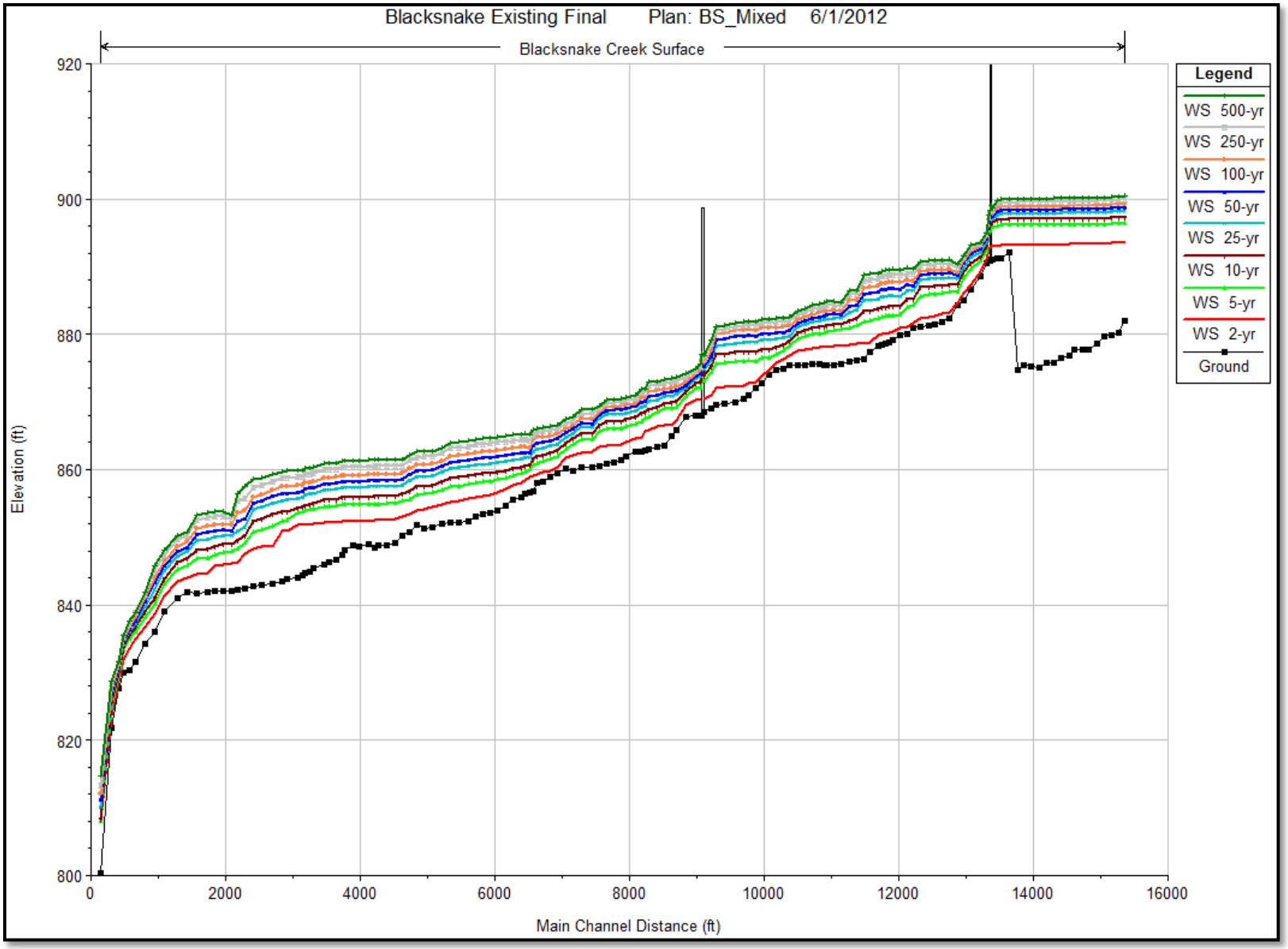
Cross Section	Description	Return Period (ACE)	Q Total* (cfs)	W.S. Elev* (ft)	Vel Chnl* (ft/s)
15365	Upstream of Karnes Road	1	1331	893.44	2.2
		0.5	1732	894.84	3.0
		0.2	2489	896.57	3.1
		0.1	3234	897.44	3.5
		0.04	4369	898.43	3.8
		0.02	5350	899.13	4.0
		0.01	6458	899.83	4.2
		0.004	7983	900.68	4.5
		0.002	9559	901.45	4.6
13763	Karnes Road	1	5	893.01	0.0
		0.5	192	894.47	0.1
		0.2	1053	896.3	0.6
		0.1	1901	897.16	0.9
		0.04	3175	898.11	1.2
		0.02	4265	898.79	1.4
		0.01	5493	899.46	1.5
		0.004	7185	900.27	1.7
		0.002	8911	901.03	1.9
8987	5th Street	1	5	868.36	0.3
		0.5	366	870.62	1.6
		0.2	1312	872.03	3.9
		0.1	2242	872.78	4.8
		0.04	3662	873.62	5.8
		0.02	4867	874.09	6.5
		0.01	6214	874.47	7.4
		0.004	8065	875.19	8.4
		0.002	9937	875.9	8.9

TABLE 13 EXISTING CONDITIONS HEC-RAS MODEL RESULTS AT SELECTED CROSS-SECTIONS (CONTINUED)

Cross Section	Description	Return Period (ACE)	Q Total* (cfs)	W.S. Elev* (ft)	Vel Chnl* (ft/s)
6520	Grand Avenue	1	198	858.07	0.6
		0.5	829	859.11	4.0
		0.2	1995	860.01	7.3
		0.1	3139	860.72	8.8
		0.04	4914	861.95	9.6
		0.02	6421	862.91	10.5
		0.01	8082	864.05	10.7
		0.004	10365	865.52	10.1
		0.002	12650	866.96	9.5
1284	Robidoux Street (US of Missouri River)	1	236	842.25	0.0
		0.5	881	843.77	3.9
		0.2	2077	845.24	6.8
		0.1	3250	846.31	8.4
		0.04	5073	847.44	10.4
		0.02	6626	848.31	11.6
		0.01	8340	849.5	12.4
		0.004	10687	850.42	13.3
		0.002	13026	851.32	14.3

* Q Total = total flow, cfs
W.S. Elev = water surface elevation , feet
Vel Chnl = velocity in the channel, fps

FIGURE 9 EXISTING CONDITIONS WSE PROFILES



3.5 COMPARISON OF RAS AND FEMA FIS WSE

After the HEC-RAS model was developed, the WSEs calculated in HEC-RAS were compared to the WSEs in the St. Joseph, Missouri, Buchanan County FEMA FIS study (September 1984). Table 14 provides a comparison of the resulting RAS model WSEs to those from the FIS study at two locations along Blacksnake Creek – Karnes Road and Grand Avenue.

TABLE 14 WSE COMPARISONS OF BLACKSNAKE CREEK

Location	Design Event (ACE)	HEC-RAS WSE (ft)	FEMA FIS WSE (ft)	Difference (ft)
Karnes Road (13763)	0.1	897.16	N/A[1]	N/A[1]
	0.04	898.79	894.8	4.0
	0.01	899.46	895.5	4.0
	0.002	901.03	896.9	4.1
Grand Avenue (6520)	0.1	860.72	N/A[1]	N/A[1]
	0.04	862.91	860.0	2.9
	0.01	864.05	860.5	3.5
	0.002	866.96	861.4	5.6

Note 1: The FIS assumed that the 0.1 ACE storm flow did not exceed the capacity of the CSS, as such no FIS WSE was created for this storm event by FEMA.

The increases in WSE at hydraulic locations in Table 3-6 were likely due to the additional detail, available information, and assumptions used for this study compared to FEMA FIS. For example:

- Updated topography was used to define cross-sections for the overland flow path
- Urban development has occurred since the FEMA FIS study
- Updated hydrology was developed to define the flood flows used in the hydraulic model.
- The FEMA FIS study assumed the 0.1 ACE discharge to flow underground into the CSS.

4 H&H EVALUATION OF ALTERNATIVES

Eight structural flood mitigation alternatives were considered for Blacksnake Creek. The structural measures considered included the excavation of a detention basin and construction of a detention dam, levee, and floodwall. Initial plan formulation included the development and engineering review of four dry detention plans for the area north of Karnes Road and east of St. Joseph Avenue. Each proposed alternative are briefly outlined below.

Alternative 1 - Alternative 1 raises Karnes Road to elevation 905 NGVD to act as a detention dam but includes no excavation of the existing basin to increase storage. This alternative also includes construction of a levee and a floodwall upstream of Karnes Road to provide protection to existing residences and structures. The levee would be located to the east of and parallel to St. Joseph

Avenue. The floodwall would be located farther upstream, just to the north of Savannah Road. In this alternative, an overflow spillway at Karnes Road would be the point of overtopping.

Alternative 2 - Alternative 2, in addition to the features of Alternative 1, would excavate the detention basin within the Blacksnake Creek floodplain north of Karnes Road between St. Joseph Avenue and an abandoned railroad right-of-way to increase the detention capacity.

Alternative 3 - Alternative 3 would increase the detention capacity of Alternative 2 by extending the detention area to the east of the abandoned railroad right-of-way. The abandoned railroad right-of-way would be removed to access the additional detention volume to the east.

Alternative 4 - Alternative 4 would increase the detention capacity of Alternative 3 by removing a portion of Karnes Road, extending the levee downstream of Karnes Road to Northwest Parkway, and additional excavation within the basin area. This alternative does not include the replacement of Karnes Road. In this alternative, an overflow spillway at Northwest Parkway would be the point of overtopping.

Alternative 5 - The Blacksnake Creek floodplain north of Karnes Road between St. Joseph Avenue and an abandoned railroad right-of-way would be excavated to increase the detention capacity. The abandoned railroad right-of-way along the east side of the basin would be removed to access additional detention volume to the east. An overflow spillway would be constructed at an elevation of 895 NGVD on Karnes Road. In this alternative, an overflow spillway at Karnes Road would be the point of overtopping.

Alternative 6 - Alternative 6 would increase the detention capacity of Alternative 5 by excavating the area between Karnes Road and Northwest Parkway. Culverts would be constructed to provide a connection between the areas north and south of the Karnes Road. In this alternative, an overflow spillway constructed at an elevation of 895 NGVD at Northwest Parkway would be the point of overtopping.

Alternative 7 - Alternative 7 would increase the detention capacity of Alternative 6 by expanding the basin north of Karnes Road to the west. This alternative would require the purchase and demolition of the residences on the west side of the basin along St. Joseph Avenue. In this alternative, an overflow spillway constructed at an elevation of 895 NGVD at Northwest Parkway would be the point of overtopping.

Alternative 8 - Alternative 8 modifies Alternative 6 by removing Karnes Road. The removal of Karnes Road reduces the construction cost by eliminating the need to raise, reconstruct, and armor the road, and for the installation of culverts to provide a hydraulic connection between the basin areas north and south of the road. This alternative was not included in the H&H modeling tables and figures because the results are identical to Alternative 6.

4.1 ALTERNATIVES HYDROLOGY

The HEC-HMS model developed for the existing conditions evaluation noted in Section 2 was used to evaluate each of the proposed alternatives noted above. The primary modification made to the HEC-RAS model included adding a storage node (DP-1) at Karnes Road to model the effects of the proposed detention basins. For each alternative elevation-storage curves were developed based on the proposed excavation extents and were used to define the storage node in each model (Table 15 and Table 16).

TABLE 15 ELEVATION-STORAGE CURVES FOR ALTERNATIVES 1-4

Elevation (feet)	Storage (Acre-feet)			
	Alternative 1	Alternative 2	Alternative 3	Alternative 4
873.50	0.00	0.00	0.00	0.00
874.75	0.03	1.81	3.19	4.04
876.00	0.12	7.23	12.75	16.14
878.00	0.32	14.47	25.49	32.28
880.00	1.34	29.95	52.37	66.25
882.00	2.96	46.41	80.77	102.05
884.00	5.32	63.86	110.79	139.75
886.00	8.56	83.23	143.27	180.21
888.00	13.18	103.57	177.10	222.30
890.00	19.65	124.91	212.30	266.08
892.00	29.62	149.53	250.09	312.75
894.00	45.64	176.23	289.66	361.56
896.00	69.32	208.09	330.93	412.32
898.00	101.23	243.41	373.63	464.75
900.00	138.60	282.08	417.77	518.85
902.00	180.94	325.12	464.04	575.45
904.00	227.63	372.43	519.55	635.06
905.00	252.62	397.66	538.35	664.86
906.00	277.61	422.89	557.15	694.66
907.00	302.61	448.12	575.94	724.47
908.00	327.60	473.35	594.74	754.27

TABLE 16 ELEVATION-STORAGE CURVES FOR ALTERNATIVES 5-7

Elevation (feet)	Storage (Acre-feet)			
	Alternative 5	Alternative 6[1]	Alternative 7	Alternative 8[1]
873.50	0.00	0.00	0.00	0.00
875.00	3.74	4.61	7.07	4.61
876.50	14.98	18.42	28.27	18.42
878.00	29.95	36.85	56.54	36.85
880.00	61.69	75.78	115.28	75.78
882.00	95.34	116.92	176.39	116.92
884.00	131.01	160.42	239.91	160.42
886.00	168.97	206.55	305.62	206.55
888.00	208.53	254.55	373.16	254.55
890.00	249.64	304.38	442.52	304.38
892.00	292.42	356.18	513.91	356.18
894.00	336.90	410.03	587.46	410.03
895.00	359.14	436.95	624.24	436.95
896.00	381.37	463.87	661.01	463.87
897.00	403.61	490.80	697.79	490.80
898.00	425.85	517.72	734.56	517.72
899.00	448.09	544.64	771.34	544.64
900.00	470.32	571.57	808.11	571.57

1 Hydrology and Hydraulic results of Alternative 8 are identical to Alternative 6

Table 17 presents the HEC-HMS modeling results for existing conditions at the junctions located at Karnes Road and at the confluence with the Missouri River. The flow rates noted in the table are the HMS flows reduced by the average full flow capacity of the CSS, which was calculated to be 1803 cfs.

TABLE 17 HEC-HMS 0.01 ACE MODELING RESULTS FOR ALTERNATIVES

Hydrologic Model ID	Location	0.01 ACE Peak Overland Flow Rates (cfs)[1]								
		Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6[2]	Alt-7	Alt-8[2]
Junction DP-1	Karnes Road	5493	4328	3174	1881	202	3127	2220	295	2220
Junction 01	Missouri River Confluance	8522	5461	4514	4489	4463	4356	4347	4300	4347

1 Flows reduced by CSS capacity of 1803 cfs
2 Hydrology and Hydraulic results of Alternative 8 are identical to Alternative 6

4.2 ALTERNATIVES HYDRAULICS

The HEC-RAS model developed for the existing conditions evaluation noted in Section 3 was used to evaluate each of the proposed alternatives. As noted the HEC-RAS model only models the reach down stream of Karnes Road, which is all overland flow that exceeds the capacity of the CSS system. As such, the only modifications made to the HEC-RAS model included modifying the flow files for each alternative. Flows in the RAS model below Karnes Road are the HMS flows reduced by the average full flow capacity of the CSS, which was calculated to be 1803 cfs. A base flow of 5 cfs is used where this subtraction of flow would result in a negative flow condition. The amount of flow and the cross section location of the flow load points in HEC-RAS are provided in Attachment 3. Water Surface Profiles and velocity results from the HEC-RAS model are listed in Tables 18 & 19 respectively.

TABLE 18 HEC-RAS 0.01 ACE WSES AT SELECTED CROSS SECTIONS

Cross Section	Location	Water Surface Elevation (feet)								
		Existing	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7	Alt-8
15365	Upstream of Karnes Road	899.8	899.3	899.3	898.1	897.3	898.7	898.3	897.4	898.3
13763	Karnes Road	899.4	898.8	898.8	897.0	894.2	898.0	897.3	894.5	897.3
8987	5th Street	874.5	874.0	874.0	872.5	871.1	873.5	872.9	870.8	872.9
6520	Grand Avenue	864.1	862.2	862.2	861.0	861.0	861.4	860.9	860.9	860.9
1284	Rubidoux Street	849.5	847.6	847.6	847.0	847.0	847.0	846.9	846.9	846.9

TABLE 19 HEC-RAS 0.01 ACE VELOCITIES AT SELECTED CROSS SECTIONS

Cross Section	Location	Velocities (ft/s)								
		Existing	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7	Alt-8
15365	Upstream of Karnes Road	4.4	4.8	4.8	6.0	7.0	5.3	5.8	6.9	5.8
13763	Karnes Road	1.7	1.5	1.5	0.9	0.2	1.2	1.0	0.2	1.0
8987	5th Street	8.2	6.7	6.7	4.5	2.7	5.8	5.0	2.5	5.0
6520	Grand Avenue	10.4	10.1	10.1	9.1	9.1	9.5	9.0	8.9	9.0
1284	Rubidoux Street	12.9	11.1	11.1	9.5	9.4	9.5	9.3	9.2	9.3

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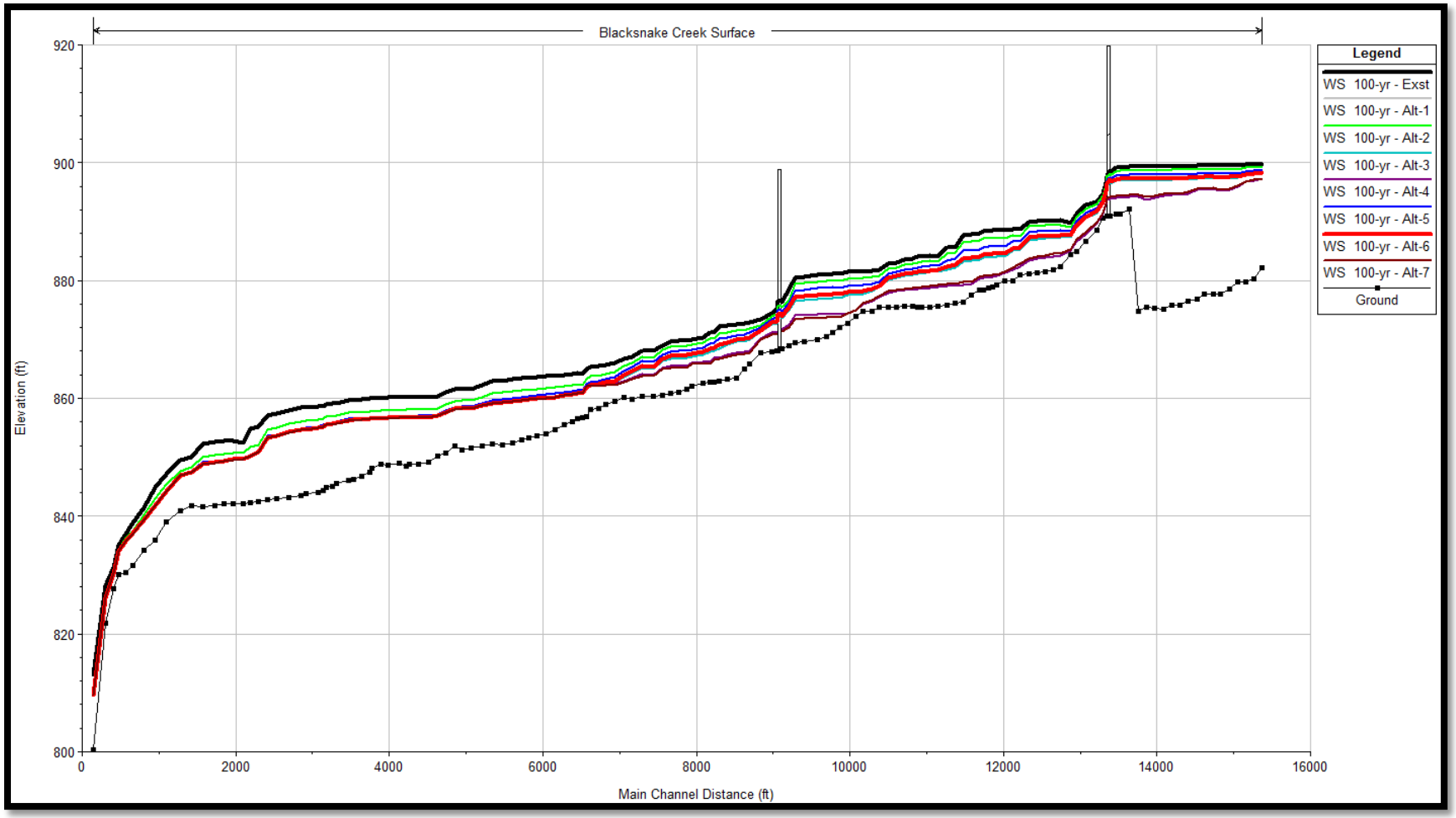
The generated WSE profiles for the 0.01 ACE design event from the HEC-RAS models are depicted in Figure 10 for each alternative.

FIGURE 10 0.01 ACE WSE PROFILES FOR EXISTING CONDITIONS AND ALTERNATIVES



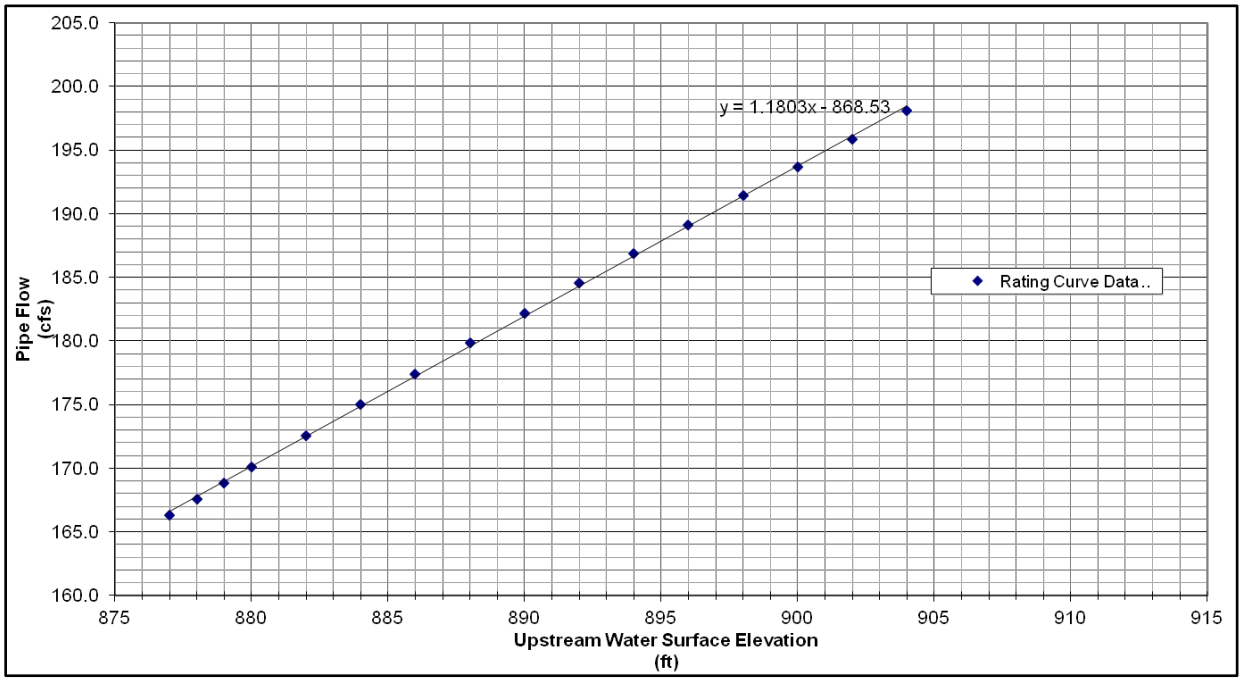
Hydrology and Hydraulic results of Alternative 8 are identical to Alternative 6

4.3 CONSIDERATION OF PROPOSED CSS IMPROVEMENTS

The City of St. Joseph, Missouri, contracted with Black & Veatch engineering firm to develop potential alternatives to remove a portion of the Blacksnake Creek flows from the city's combined sewer system (CSS). For documentation, see the report by Black & Veatch entitled, City of St. Joseph, Missouri, Facilities Plan: Technical Memorandum No. TM-CSO-5, Stormwater Separation Conduits, dated January 15, 2010. The recommended alternative from that report was titled Alternative B, which would divert some Blacksnake Creek flows through a stormwater separation conduit. The proposed inlet of this conduit is located at Karnes Road, just upstream of where Blacksnake Creek flows into the existing Karnes Road CSS entrance.

The City requested that the Kansas City District evaluate flood control Alternatives 1 through 8 with the addition of the proposed stormwater conduit Alternative B. For the purposes of this evaluation, the proposed stormwater separation conduit Alternative B will be called "Outlet B". To assist with evaluating the impacts of Outlet B, Black & Veatch prepared a rating curve for the stormwater separation conduit (Figure 11). The rating curve was used to estimate the peak flow that would be carried by the proposed stormwater conduit.

FIGURE 11 OUTLET B RATING CURVE



The addition of Outlet B was found to either have no effect or provides a slightly lower water surface profile of overland flows downstream of Karnes Road. The amount of flow and the cross section location of the flow load points including the effects of Outlet Bin are provided in Attachment 5. This was the only CSS alternative that was provided for evaluation.

Attachment 1 - Existing Conditions HEC-HMS Model Results

Hydologic Element	Drainage Area (sqmi)	Peak Discharge (cfs)								
		1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
BS-01	0.2522	216.0	264.0	351.6	434.1	560.2	668.3	785.1	942.7	1094.3
BS-03	0.2634	223.6	276.0	372.0	462.9	602.4	722.3	852.1	1027.4	1196.2
BS-04	0.2139	169.4	208.5	280.3	348.2	452.1	541.5	638.1	768.6	894.2
BS-05	0.3603	156.3	201.1	286.0	368.3	496.4	608.1	729.8	895.2	1055.2
BS-06	0.2635	133.2	173.8	250.9	325.6	442.1	543.6	654.1	804.3	949.5
BS-07	0.3392	142.3	189.8	280.7	369.4	509.0	630.8	764.0	945.1	1120.5
BS-08	0.1589	65.2	84.2	120.2	155.2	209.8	257.3	309.1	379.5	447.6
BS-09	0.2757	220.4	273.6	371.4	464.2	606.8	729.6	862.5	1042.1	1215.1
BS-10	0.2378	128.9	161.8	223.2	282.0	373.0	451.7	537.3	653.2	765.1
BS-11	0.2567	123.8	166.7	248.6	328.5	453.7	563.5	683.3	846.3	1004.1
BS-12	0.2399	100.6	130.1	186.1	240.5	325.4	399.2	479.9	589.6	695.8
BS-13	0.1391	66.5	82.5	112.2	140.6	184.3	222.0	262.9	318.3	371.8
BS-14	0.3716	118.1	152.9	219.6	284.6	386.5	475.3	572.4	704.4	832.3
BS-15	0.1701	93.2	118.2	165.1	210.1	279.9	340.5	406.4	495.6	581.9
BS-16	0.2691	134.7	173.2	245.7	315.8	424.8	519.4	622.6	762.8	898.4
BS-17	0.2411	101.3	133.9	196.4	257.4	352.8	436.0	526.9	650.6	770.3
BS-18	0.1863	84.2	106.5	148.3	188.7	251.2	305.4	364.4	444.4	521.7
BS-19	0.2769	97.5	122.3	169.1	214.3	284.4	345.2	411.4	501.3	588.2
BS-20	0.2142	101.1	128.1	178.9	227.8	303.6	369.4	440.9	538.1	632.1
BS-21	0.3249	332.2	401.2	525.6	641.8	818.2	968.9	1131.1	1349.5	1559.4
BS-22	0.2007	113.7	139.8	187.8	233.3	303.3	363.5	428.6	516.7	601.7
BS-23	0.1849	97.0	123.0	171.8	218.7	291.5	354.6	423.2	516.3	606.2
BS-24	0.1671	75.0	97.6	140.4	182.1	247.0	303.6	365.2	449.0	530.1
BS-25	0.2642	121.2	153.7	214.7	273.5	364.7	443.9	530.1	647.0	760.0
BS-26	0.1858	41.3	61.5	101.5	141.7	205.6	262.0	324.0	408.7	491.4
BS-27	0.4869	88.0	130.7	216.2	302.1	439.1	560.6	694.2	877.2	1055.1
BS-28	0.2453	25.3	37.8	63.2	89.1	130.7	167.9	208.9	265.2	320.3
BS-29	0.1723	74.3	101.5	153.9	205.3	286.2	356.9	434.2	539.4	641.3
BS-30	0.2045	101.5	129.8	183.1	234.7	314.8	384.4	460.2	563.0	662.3
BS-31	0.4897	66.0	91.4	141.6	192.1	272.7	344.0	422.5	530.2	635.2
BS-32	0.4216	74.8	104.1	161.9	219.6	311.6	392.8	482.1	604.3	723.2
J-01	8.2094	2069.4	2725.2	3942.5	5135.1	6993.7	8577.8	10325.4	12717.0	15098.6
BS-02	0.1316	125.1	152.5	202.3	249.1	320.4	381.5	447.4	536.3	621.8
J-02	7.9572	2039.4	2684.9	3880.9	5053.6	6876.5	8429.8	10143.0	12490.1	14829.6
J-03	7.8256	2033.3	2675.5	3864.7	5030.4	6843.4	8383.2	10082.9	12414.7	14742.4
J-04	7.5622	2001.3	2632.5	3798.7	4942.7	6717.1	8224.1	9885.6	12168.4	14453.2
J-05	1.1219	410.4	549.4	819.3	1084.3	1502.4	1869.3	2270.6	2816.8	3350.2
J-06	0.7616	290.6	391.1	585.1	775.9	1075.9	1337.6	1625.2	2015.6	2394.3
J-07	0.4981	187.8	251.3	374.1	494.6	684.1	849.8	1030.7	1278.0	1517.9
J-08	0.1589	65.2	84.2	120.2	155.2	209.8	257.3	309.1	379.5	447.6
J-09	6.2264	1702.0	2230.4	3204.8	4162.1	5627.4	6870.1	8255.4	10163.3	12088.4
J-10	5.9507	1656.1	2169.0	3115.1	4045.0	5465.1	6670.7	8017.4	9868.9	11740.6
J-11	5.7129	1643.9	2146.3	3075.6	3994.1	5380.3	6559.7	7885.9	9715.4	11577.8
J-12	0.2399	100.6	130.1	186.1	240.5	325.4	399.2	479.9	589.6	695.8
J-13	5.2163	1533.4	1995.5	2856.2	3704.5	4978.2	6068.6	7296.3	8988.2	10714.6

Attachment 1 - Existing Conditions HEC-HMS Model Results

Hydologic Element	Drainage Area (sqmi)	Peak Discharge (cfs)								
		1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-14	5.0772	1484.6	1932.5	2770.1	3595.4	4835.3	5899.2	7100.2	8754.1	10447.3
J-15	0.1701	93.2	118.2	165.1	210.1	279.9	340.5	406.4	495.6	581.9
J-16	4.5355	1330.9	1732.4	2489.1	3233.5	4369.1	5350.0	6457.8	7982.8	9558.5
J-17	4.2664	1268.8	1669.9	2439.6	3194.4	4365.4	5357.9	6441.2	7921.0	9347.7
J-18	1.3879	723.9	899.3	1224.6	1537.9	2042.5	2442.8	2875.9	3458.4	4024.7
J-19	1.0167	551.5	680.3	917.6	1144.1	1517.7	1801.8	2110.8	2525.9	2928.8
J-19A	0.7398	518.4	634.8	849.0	1051.9	1362.6	1630.1	1914.1	2295.5	2661.0
J-20	0.5256	418.3	508.5	672.2	826.4	1061.4	1265.2	1478.1	1763.2	2035.4
J-22	0.2007	113.7	139.8	187.8	233.3	303.3	363.5	428.6	516.7	601.7
J-23	0.1849	97.0	123.0	171.8	218.7	291.5	354.6	423.2	516.3	606.2
J-24	0.1671	75.0	97.6	140.4	182.1	247.0	303.6	365.2	449.0	530.1
J-25	2.4703	519.9	716.5	1101.8	1485.6	2081.3	2606.8	3187.2	3981.8	4754.1
J-26	2.2061	437.7	609.4	947.8	1285.1	1814.3	2282.0	2796.3	3502.5	4190.1
J-27	0.4869	88.0	130.7	216.2	302.1	439.1	560.6	694.2	877.2	1055.1
J-28	1.5334	315.6	428.1	647.4	865.5	1210.7	1514.2	1846.7	2300.1	2740.9
J-29	0.3768	163.0	215.0	314.5	412.1	564.8	699.0	845.4	1044.4	1238.0
J-30	0.2045	101.5	129.8	183.1	234.7	314.8	384.4	460.2	563.0	662.3
R-01	7.9572	2036.3	2680.4	3875.8	5047.0	6868.2	8420.4	10131.5	12476.2	14812.7
R-02	7.8256	2021.4	2660.7	3845.8	5006.9	6810.8	8348.0	10041.7	12364.5	14680.7
R-03	7.5622	1996.2	2625.1	3790.0	4932.5	6704.0	8208.4	9869.7	12149.2	14428.0
R-04A	1.1219	410.1	548.9	818.0	1082.9	1499.7	1865.3	2265.9	2811.6	3342.6
R-05	0.7616	289.8	390.0	583.2	773.1	1071.6	1332.5	1617.1	2007.1	2384.8
R-06	0.4981	187.4	251.0	373.5	493.7	682.7	848.2	1029.0	1275.8	1514.2
R-07	0.1589	65.1	84.0	120.0	154.9	209.4	256.7	308.4	378.8	446.5
R-04B	6.2264	1691.6	2216.7	3187.2	4138.8	5599.9	6840.6	8220.3	10116.1	12030.0
R-09	5.9507	1655.6	2168.1	3113.9	4043.3	5463.2	6669.0	8013.3	9864.9	11737.2
R-10	5.7129	1601.9	2096.7	3011.6	3909.1	5279.4	6445.0	7745.4	9535.2	11346.6
R-11A	0.2399	100.5	129.8	185.9	240.2	325.1	399.0	479.7	588.8	694.9
R-11B	5.2163	1531.6	1993.7	2853.4	3700.9	4975.3	6065.6	7291.8	8982.0	10708.9
R-14A	0.1701	92.9	117.8	164.5	209.5	279.0	339.3	405.2	494.0	579.8
R-13	5.0772	1482.2	1930.7	2767.4	3591.7	4830.8	5892.1	7087.0	8735.1	10419.5
R-14B	4.5355	1322.1	1722.2	2472.1	3210.2	4319.4	5274.2	6349.2	7832.5	9354.4
R-16	4.2664	1249.7	1627.1	2339.4	3039.1	4107.2	5029.9	6071.1	7505.1	8988.9
R-17	4.0253	1199.3	1575.2	2296.3	3002.7	4095.9	5026.3	6040.5	7429.9	8768.0
R-24	0.1671	75.0	97.5	140.2	181.8	246.8	303.3	364.8	448.7	529.3
R-25	2.4703	519.6	716.0	1101.0	1484.0	2079.8	2605.5	3184.8	3979.3	4750.4
R-17A	1.3879	723.1	898.1	1223.6	1535.3	2040.5	2438.8	2872.7	3454.7	4019.8
R-18A	1.0167	550.6	678.8	915.8	1142.1	1515.1	1799.5	2107.2	2519.5	2921.8
R-18B	0.1849	96.9	122.8	171.6	218.5	291.3	354.1	422.5	515.3	605.1
R-18	1.2016	642.1	794.7	1078.7	1351.0	1793.8	2138.4	2512.8	3015.8	3504.4
R-20	0.2007	108.5	133.5	179.5	223.3	294.0	349.3	408.3	488.1	565.0
R-19A	0.5256	417.2	507.0	670.5	824.5	1059.2	1260.9	1473.2	1757.3	2028.9
R-19	0.7398	457.8	562.9	756.9	941.5	1249.0	1479.0	1726.5	2058.0	2379.2
R-25A	2.2061	435.3	606.1	942.7	1279.2	1806.6	2271.1	2783.7	3486.3	4170.7
J-17A	4.0253	1200.1	1576.4	2297.8	3004.8	4098.6	5029.1	6043.9	7438.9	8783.9

Attachment 1 - Existing Conditions HEC-HMS Model Results

Hydologic Element	Drainage Area (sqmi)	Peak Discharge (cfs)								
		1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-18A	1.2016	646.2	800.9	1085.9	1360.0	1805.2	2152.0	2529.4	3034.7	3526.5
R-27	0.4869	87.7	130.3	215.4	301.0	437.8	558.6	691.9	874.2	1050.1
R-26	1.5334	315.1	427.4	646.4	864.1	1207.8	1509.4	1840.5	2292.2	2731.4
R-29	0.2045	101.1	129.5	182.6	234.1	314.0	383.2	458.9	561.6	660.5
R-28	0.3768	160.1	211.2	308.6	404.1	553.3	683.7	826.8	1022.5	1211.6
J-21	0.3249	332.2	401.2	525.6	641.8	818.2	968.9	1131.1	1349.5	1559.4
R-21	0.3249	331.5	400.7	524.6	640.8	816.7	967.5	1129.1	1345.7	1554.7

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	15365	1-yr	1331	893.00	2.74	485.11	67.14
Surface	15365	2-yr	1732	894.55	2.87	610.05	108.58
Surface	15365	5-yr	2489	896.46	3.11	907.33	209.96
Surface	15365	10-yr	3234	897.35	3.47	1156.16	316.98
Surface	15365	25-yr	4369	898.36	3.85	1495.03	350.83
Surface	15365	50-yr	5350	899.07	4.13	1751.56	370.10
Surface	15365	100-yr	6458	899.76	4.39	2011.61	380.98
Surface	15365	250-yr	7983	900.63	4.69	2346.75	394.56
Surface	15365	500-yr	9559	901.39	4.98	2653.34	407.94
Surface	15261	1-yr	1331	892.80	3.88	352.94	64.92
Surface	15261	2-yr	1732	894.36	3.99	497.74	136.12
Surface	15261	5-yr	2489	896.39	3.65	1023.20	315.43
Surface	15261	10-yr	3234	897.30	3.76	1319.59	330.51
Surface	15261	25-yr	4369	898.32	4.01	1664.07	342.85
Surface	15261	50-yr	5350	899.03	4.23	1909.85	349.10
Surface	15261	100-yr	6458	899.72	4.49	2153.10	358.34
Surface	15261	250-yr	7983	900.58	4.85	2471.44	383.50
Surface	15261	500-yr	9559	901.34	5.09	2765.34	385.83
Surface	15159	1-yr	1331	892.73	3.43	407.67	81.09
Surface	15159	2-yr	1732	894.32	3.43	570.33	127.05
Surface	15159	5-yr	2489	896.36	3.19	1093.92	295.89
Surface	15159	10-yr	3234	897.26	3.38	1365.23	302.91
Surface	15159	25-yr	4369	898.28	3.71	1676.01	310.74
Surface	15159	50-yr	5350	898.98	4.00	1896.16	317.31
Surface	15159	100-yr	6458	899.66	4.31	2116.02	325.92
Surface	15159	250-yr	7983	900.49	4.85	2402.54	381.77
Surface	15159	500-yr	9559	901.24	5.25	2706.19	430.88
Surface	15054	1-yr	1331	892.67	3.22	455.71	81.01
Surface	15054	2-yr	1732	894.27	3.28	606.16	110.42
Surface	15054	5-yr	2489	896.28	3.44	945.75	217.22
Surface	15054	10-yr	3234	897.15	3.87	1170.64	289.76
Surface	15054	25-yr	4369	898.14	4.37	1489.63	351.75
Surface	15054	50-yr	5350	898.84	4.69	1751.72	398.69
Surface	15054	100-yr	6458	899.53	4.98	2039.85	438.10
Surface	15054	250-yr	7983	900.38	5.30	2441.41	503.47
Surface	15054	500-yr	9559	901.16	5.47	2844.37	536.82
Surface	14939	1-yr	1331	892.59	3.19	439.99	76.73
Surface	14939	2-yr	1732	894.19	3.30	614.78	195.46
Surface	14939	5-yr	2489	896.25	3.16	1121.54	290.42
Surface	14939	10-yr	3234	897.13	3.45	1404.06	352.32
Surface	14939	25-yr	4369	898.13	3.81	1792.67	422.42
Surface	14939	50-yr	5350	898.83	4.05	2103.27	463.57
Surface	14939	100-yr	6458	899.52	4.26	2434.30	498.95
Surface	14939	250-yr	7983	900.37	4.48	2878.71	541.08
Surface	14939	500-yr	9559	901.14	4.70	3315.04	593.56

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	14829	1-yr	1331	892.56	2.63	517.27	96.73
Surface	14829	2-yr	1732	894.18	2.66	823.79	240.14
Surface	14829	5-yr	2489	896.23	2.68	1376.17	320.74
Surface	14829	10-yr	3234	897.11	3.00	1678.47	364.85
Surface	14829	25-yr	4369	898.09	3.45	2070.98	425.47
Surface	14829	50-yr	5350	898.78	3.76	2373.75	450.46
Surface	14829	100-yr	6458	899.46	4.07	2687.72	479.47
Surface	14829	250-yr	7983	900.29	4.50	3109.45	545.36
Surface	14829	500-yr	9559	901.05	4.82	3544.42	597.89
Surface	14729	1-yr	1331	892.60	1.39	1347.00	239.19
Surface	14729	2-yr	1732	894.22	1.38	1749.41	260.86
Surface	14729	5-yr	2489	896.26	1.65	2405.48	405.43
Surface	14729	10-yr	3234	897.14	1.92	2784.82	460.11
Surface	14729	25-yr	4369	898.13	2.29	3276.18	529.38
Surface	14729	50-yr	5350	898.82	2.54	3658.37	569.09
Surface	14729	100-yr	6458	899.50	2.80	4059.42	612.95
Surface	14729	250-yr	7983	900.34	3.09	4596.64	688.03
Surface	14729	500-yr	9559	901.10	3.33	5137.19	734.38
Surface	14610	1-yr	1331	892.57	1.52	972.07	234.88
Surface	14610	2-yr	1732	894.20	1.50	1431.81	331.69
Surface	14610	5-yr	2489	896.25	1.55	2338.08	589.94
Surface	14610	10-yr	3234	897.13	1.68	2883.04	642.23
Surface	14610	25-yr	4369	898.12	1.89	3541.65	692.69
Surface	14610	50-yr	5350	898.81	2.05	4040.82	740.16
Surface	14610	100-yr	6458	899.49	2.19	4555.72	771.75
Surface	14610	250-yr	7983	900.33	2.36	5219.08	805.02
Surface	14610	500-yr	9559	901.09	2.51	5840.38	828.82
Surface	14527	1-yr	1485	892.56	1.39	1155.81	248.46
Surface	14527	2-yr	1933	894.19	1.43	1668.73	374.98
Surface	14527	5-yr	2770	896.24	1.47	2727.63	631.37
Surface	14527	10-yr	3595	897.12	1.62	3303.40	678.31
Surface	14527	25-yr	4835	898.11	1.84	4006.30	746.62
Surface	14527	50-yr	5899	898.80	1.99	4539.63	790.97
Surface	14527	100-yr	7100	899.48	2.14	5091.70	824.81
Surface	14527	250-yr	8754	900.32	2.30	5791.75	843.74
Surface	14527	500-yr	10447	901.08	2.45	6438.81	857.34
Surface	14408	1-yr	1485	892.51	1.94	788.78	134.16
Surface	14408	2-yr	1933	894.15	2.02	1140.37	307.29
Surface	14408	5-yr	2770	896.21	1.99	2014.54	531.75
Surface	14408	10-yr	3595	897.08	2.15	2513.02	609.41
Surface	14408	25-yr	4835	898.07	2.36	3144.07	662.46
Surface	14408	50-yr	5899	898.76	2.51	3608.73	680.50
Surface	14408	100-yr	7100	899.44	2.67	4073.92	692.65
Surface	14408	250-yr	8754	900.27	2.86	4658.74	707.91
Surface	14408	500-yr	10447	901.03	3.03	5199.43	722.00

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	14304	1-yr	1485	892.49	2.01	819.83	161.10
Surface	14304	2-yr	1933	894.12	2.10	1161.53	318.81
Surface	14304	5-yr	2770	896.19	2.02	2080.15	533.29
Surface	14304	10-yr	3595	897.07	2.18	2581.22	604.70
Surface	14304	25-yr	4835	898.05	2.40	3197.22	639.30
Surface	14304	50-yr	5899	898.74	2.56	3643.48	654.01
Surface	14304	100-yr	7100	899.42	2.74	4097.00	680.85
Surface	14304	250-yr	8754	900.25	2.93	4670.54	696.07
Surface	14304	500-yr	10447	901.01	3.11	5201.42	710.44
Surface	14199	1-yr	1485	892.49	1.65	989.17	233.62
Surface	14199	2-yr	1933	894.12	1.70	1428.34	354.29
Surface	14199	5-yr	2770	896.19	1.70	2369.32	515.51
Surface	14199	10-yr	3595	897.06	1.90	2838.91	570.48
Surface	14199	25-yr	4835	898.04	2.16	3439.46	627.40
Surface	14199	50-yr	5899	898.73	2.33	3873.50	634.10
Surface	14199	100-yr	7100	899.41	2.51	4303.96	643.21
Surface	14199	250-yr	8754	900.24	2.74	4846.41	663.94
Surface	14199	500-yr	10447	900.99	2.94	5350.16	673.16
Surface	14089	1-yr	1485	892.48	1.64	1106.65	307.39
Surface	14089	2-yr	1933	894.12	1.59	1659.57	363.51
Surface	14089	5-yr	2770	896.19	1.62	2498.68	456.66
Surface	14089	10-yr	3595	897.06	1.83	2916.74	534.69
Surface	14089	25-yr	4835	898.03	2.16	3467.88	583.94
Surface	14089	50-yr	5899	898.72	2.36	3878.39	609.66
Surface	14089	100-yr	7100	899.39	2.56	4294.38	628.84
Surface	14089	250-yr	8754	900.22	2.79	4823.55	646.56
Surface	14089	500-yr	10447	900.97	3.00	5314.05	661.69
Surface	13970	1-yr	1485	892.43	2.11	902.87	257.99
Surface	13970	2-yr	1933	894.09	1.93	1450.54	422.28
Surface	13970	5-yr	2770	896.17	1.77	2494.82	577.15
Surface	13970	10-yr	3595	897.05	1.92	3042.32	653.56
Surface	13970	25-yr	4835	898.03	2.14	3696.70	683.42
Surface	13970	50-yr	5899	898.71	2.30	4172.55	705.27
Surface	13970	100-yr	7100	899.38	2.44	4648.68	710.78
Surface	13970	250-yr	8754	900.21	2.64	5249.09	733.34
Surface	13970	500-yr	10447	900.97	2.80	5804.37	744.84
Surface	13866	1-yr	1485	892.41	2.06	948.91	334.00
Surface	13866	2-yr	1933	894.08	1.89	1596.16	497.29
Surface	13866	5-yr	2770	896.17	1.60	2886.57	676.57
Surface	13866	10-yr	3595	897.04	1.70	3492.77	706.98
Surface	13866	25-yr	4835	898.02	1.87	4193.35	725.47
Surface	13866	50-yr	5899	898.71	2.02	4695.16	737.81
Surface	13866	100-yr	7100	899.38	2.16	5192.64	742.79
Surface	13866	250-yr	8754	900.21	2.32	5810.90	748.93
Surface	13866	500-yr	10447	900.96	2.48	6375.00	754.49

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	13763	1-yr	5	892.45	0.01	1082.86	303.85
Surface	13763	2-yr	192	894.11	0.17	1642.79	385.15
Surface	13763	5-yr	1053	896.18	0.60	2943.89	706.94
Surface	13763	10-yr	1901	897.05	0.90	3573.70	737.16
Surface	13763	25-yr	3175	898.03	1.23	4302.00	754.71
Surface	13763	50-yr	4265	898.71	1.46	4821.38	761.96
Surface	13763	100-yr	5493	899.38	1.67	5333.20	764.91
Surface	13763	250-yr	7185	900.21	1.91	5967.34	768.64
Surface	13763	500-yr	8911	900.96	2.12	6544.28	772.01
Surface	13642	1-yr	5	892.40	2.00	3.19	26.42
Surface	13642	2-yr	192	894.09	0.93	248.17	238.45
Surface	13642	5-yr	1053	896.16	1.31	1351.05	674.81
Surface	13642	10-yr	1901	897.03	1.64	1945.52	696.51
Surface	13642	25-yr	3175	898.00	2.01	2624.90	708.15
Surface	13642	50-yr	4265	898.67	2.28	3107.04	712.59
Surface	13642	100-yr	5493	899.34	2.52	3580.55	713.53
Surface	13642	250-yr	7185	900.16	2.82	4165.47	714.68
Surface	13642	500-yr	8911	900.90	3.08	4695.63	715.73
Surface	13526	1-yr	5	891.93	0.35	14.45	37.70
Surface	13526	2-yr	192	894.04	1.16	230.03	230.36
Surface	13526	5-yr	1053	896.12	1.94	1109.20	588.72
Surface	13526	10-yr	1901	896.97	2.37	1632.04	627.87
Surface	13526	25-yr	3175	897.93	2.82	2245.95	648.81
Surface	13526	50-yr	4265	898.61	3.13	2688.86	668.56
Surface	13526	100-yr	5493	899.27	3.43	3134.89	683.17
Surface	13526	250-yr	7185	900.08	3.76	3698.85	700.06
Surface	13526	500-yr	8911	900.82	4.05	4220.79	712.08
Surface	13467	1-yr	5	891.91	0.46	10.83	27.36
Surface	13467	2-yr	192	893.99	1.76	152.48	147.77
Surface	13467	5-yr	1053	896.06	2.81	882.05	565.13
Surface	13467	10-yr	1901	896.92	3.17	1378.48	585.50
Surface	13467	25-yr	3175	897.88	3.61	1954.24	611.29
Surface	13467	50-yr	4265	898.55	3.92	2369.97	624.64
Surface	13467	100-yr	5493	899.21	4.22	2785.64	637.73
Surface	13467	250-yr	7185	900.03	4.56	3310.99	651.68
Surface	13467	500-yr	8911	900.76	4.86	3795.18	663.22
Surface	13384	1-yr	5	891.84	0.93	5.39	12.79
Surface	13384	2-yr	192	893.86	2.57	104.17	93.91
Surface	13384	5-yr	1053	895.83	3.67	356.52	183.08
Surface	13384	10-yr	1901	896.54	4.95	498.70	217.42
Surface	13384	25-yr	3175	897.28	6.45	674.12	260.51
Surface	13384	50-yr	4265	897.77	7.50	807.49	284.91
Surface	13384	100-yr	5493	898.22	8.54	941.54	309.18
Surface	13384	250-yr	7185	898.79	9.71	1123.99	334.95
Surface	13384	500-yr	8911	899.29	10.73	1296.91	357.14

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	13358	1-yr	5	891.67	2.07	2.41	6.26
Surface	13358	2-yr	192	893.34	5.46	53.49	67.25
Surface	13358	5-yr	1053	894.93	7.38	188.36	154.13
Surface	13358	10-yr	1901	895.53	8.23	296.08	200.44
Surface	13358	25-yr	3175	896.25	9.81	455.39	245.42
Surface	13358	50-yr	4265	896.72	10.87	572.24	278.50
Surface	13358	100-yr	5493	897.17	11.89	690.65	303.12
Surface	13358	250-yr	7185	897.72	13.03	844.35	324.52
Surface	13358	500-yr	8911	898.22	14.03	988.67	338.26
Surface	13295	1-yr	5	890.77	1.65	3.04	40.02
Surface	13295	2-yr	192	891.34	4.02	48.58	102.08
Surface	13295	5-yr	1053	892.37	6.63	189.53	177.82
Surface	13295	10-yr	1901	893.07	7.57	356.35	295.94
Surface	13295	25-yr	3175	893.84	8.43	628.32	427.64
Surface	13295	50-yr	4265	894.28	9.23	818.60	446.71
Surface	13295	100-yr	5493	894.68	10.06	1001.70	464.32
Surface	13295	250-yr	7185	895.06	11.44	1182.04	483.66
Surface	13295	500-yr	8911	895.62	11.93	1467.88	539.42
Surface	13217	1-yr	5	888.94	1.20	4.16	22.14
Surface	13217	2-yr	192	889.71	4.55	54.41	108.36
Surface	13217	5-yr	1053	890.85	7.54	222.72	182.39
Surface	13217	10-yr	1901	891.48	9.21	354.20	230.30
Surface	13217	25-yr	3175	892.31	10.26	583.54	323.58
Surface	13217	50-yr	4265	892.93	10.54	809.89	426.41
Surface	13217	100-yr	5493	893.32	11.42	973.25	517.46
Surface	13217	250-yr	7185	893.75	12.54	1163.91	533.27
Surface	13217	500-yr	8911	894.28	12.92	1406.27	554.29
Surface	13069	1-yr	5	886.85	1.82	2.85	31.08
Surface	13069	2-yr	192	887.89	2.66	112.84	146.90
Surface	13069	5-yr	1053	889.61	4.25	435.90	230.57
Surface	13069	10-yr	1901	890.53	5.49	686.53	330.07
Surface	13069	25-yr	3175	891.55	6.09	1034.30	359.67
Surface	13069	50-yr	4265	892.17	6.66	1263.54	383.04
Surface	13069	100-yr	5493	892.76	7.24	1498.40	409.04
Surface	13069	250-yr	7185	893.45	7.95	1789.37	427.68
Surface	13069	500-yr	8911	894.01	8.68	2032.12	435.16
Surface	12955	1-yr	5	885.36	1.18	4.23	14.49
Surface	12955	2-yr	192	886.59	5.75	33.39	33.06
Surface	12955	5-yr	1053	888.38	7.74	199.41	150.70
Surface	12955	10-yr	1901	889.22	8.97	351.85	207.75
Surface	12955	25-yr	3175	890.12	10.34	564.80	281.22
Surface	12955	50-yr	4265	890.73	11.02	751.05	326.43
Surface	12955	100-yr	5493	891.23	11.90	924.83	361.11
Surface	12955	250-yr	7185	891.83	12.94	1152.98	413.63
Surface	12955	500-yr	8911	892.37	13.64	1391.84	458.42

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	12873	1-yr	5	884.51	1.66	3.01	42.99
Surface	12873	2-yr	192	885.06	4.14	46.84	90.19
Surface	12873	5-yr	1053	886.28	6.72	174.19	119.84
Surface	12873	10-yr	1901	887.29	7.40	308.14	144.61
Surface	12873	25-yr	3175	888.37	8.51	494.71	192.75
Surface	12873	50-yr	4265	889.02	9.46	627.64	215.42
Surface	12873	100-yr	5493	889.70	10.28	787.16	251.17
Surface	12873	250-yr	7185	890.73	10.61	1070.88	299.84
Surface	12873	500-yr	8911	891.85	10.53	1455.89	394.40
Surface	12745	1-yr	5	882.69	0.74	6.79	35.43
Surface	12745	2-yr	192	884.22	1.83	118.27	96.15
Surface	12745	5-yr	1053	886.20	3.82	414.55	243.37
Surface	12745	10-yr	1901	887.33	4.49	755.28	350.87
Surface	12745	25-yr	3175	888.60	4.96	1288.99	480.10
Surface	12745	50-yr	4265	889.42	5.12	1693.55	500.21
Surface	12745	100-yr	5493	890.25	5.27	2116.24	529.43
Surface	12745	250-yr	7185	891.34	5.36	2734.88	587.23
Surface	12745	500-yr	8911	892.43	5.38	3381.82	601.40
Surface	12649	1-yr	5	882.29	1.23	4.07	17.95
Surface	12649	2-yr	192	884.08	2.01	97.44	85.82
Surface	12649	5-yr	1053	886.02	3.90	356.70	220.96
Surface	12649	10-yr	1901	887.16	4.51	684.60	342.79
Surface	12649	25-yr	3175	888.48	4.74	1229.02	451.46
Surface	12649	50-yr	4265	889.31	4.95	1614.67	477.66
Surface	12649	100-yr	5493	890.14	5.15	2021.87	513.69
Surface	12649	250-yr	7185	891.24	5.27	2640.17	579.43
Surface	12649	500-yr	8911	892.34	5.29	3285.22	592.58
Surface	12539	1-yr	5	881.77	1.03	4.87	19.93
Surface	12539	2-yr	192	883.80	2.53	75.94	65.35
Surface	12539	5-yr	1053	885.89	3.34	501.81	377.38
Surface	12539	10-yr	1901	887.12	3.30	984.08	402.59
Surface	12539	25-yr	3175	888.46	3.58	1548.36	456.97
Surface	12539	50-yr	4265	889.28	3.90	1940.15	498.37
Surface	12539	100-yr	5493	890.11	4.17	2376.10	557.37
Surface	12539	250-yr	7185	891.20	4.40	2994.91	570.65
Surface	12539	500-yr	8911	892.30	4.54	3630.19	584.01
Surface	12440	1-yr	5	881.63	0.57	8.82	27.67
Surface	12440	2-yr	192	883.65	2.29	119.65	120.92
Surface	12440	5-yr	1053	885.83	2.97	688.45	365.93
Surface	12440	10-yr	1901	887.07	3.24	1180.89	426.37
Surface	12440	25-yr	3175	888.41	3.65	1787.40	482.82
Surface	12440	50-yr	4265	889.23	4.03	2205.26	539.93
Surface	12440	100-yr	5493	890.06	4.36	2671.23	575.45
Surface	12440	250-yr	7185	891.16	4.80	3318.10	598.87
Surface	12440	500-yr	8911	892.27	4.86	3984.83	601.88

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	12329	1-yr	5	881.53	0.63	7.99	24.89
Surface	12329	2-yr	192	883.35	3.32	64.53	87.96
Surface	12329	5-yr	1053	885.60	4.22	494.46	331.72
Surface	12329	10-yr	1901	886.93	4.03	1067.53	470.29
Surface	12329	25-yr	3175	888.31	4.10	1731.44	495.12
Surface	12329	50-yr	4265	889.13	4.40	2151.04	519.74
Surface	12329	100-yr	5493	889.95	4.86	2592.21	556.59
Surface	12329	250-yr	7185	891.06	5.03	3217.77	571.07
Surface	12329	500-yr	8911	892.18	5.12	3864.74	586.39
Surface	12219	1-yr	5	881.13	2.02	2.47	19.37
Surface	12219	2-yr	192	882.33	5.87	32.71	30.92
Surface	12219	5-yr	1053	884.25	8.52	159.66	87.65
Surface	12219	10-yr	1901	885.25	10.32	255.09	114.68
Surface	12219	25-yr	3175	886.64	11.08	471.85	213.48
Surface	12219	50-yr	4265	887.60	11.23	706.47	260.86
Surface	12219	100-yr	5493	888.68	10.86	1033.64	341.50
Surface	12219	250-yr	7185	890.09	10.24	1553.67	392.76
Surface	12219	500-yr	8911	891.37	9.90	2117.99	486.39
Surface	12124	1-yr	5	880.55	0.66	8.77	44.09
Surface	12124	2-yr	192	881.81	3.14	89.84	76.68
Surface	12124	5-yr	1053	883.89	5.45	436.37	286.64
Surface	12124	10-yr	1901	885.14	5.75	800.26	299.66
Surface	12124	25-yr	3175	886.71	6.07	1293.08	328.17
Surface	12124	50-yr	4265	887.72	6.74	1640.44	368.96
Surface	12124	100-yr	5493	888.75	7.03	2026.04	377.20
Surface	12124	250-yr	7185	890.11	7.33	2545.71	388.92
Surface	12124	500-yr	8911	891.35	7.79	3046.13	421.90
Surface	12010	1-yr	5	880.14	1.08	4.63	28.19
Surface	12010	2-yr	192	881.34	3.12	63.77	63.54
Surface	12010	5-yr	1053	882.94	6.64	203.98	122.86
Surface	12010	10-yr	1901	884.18	7.42	424.77	208.23
Surface	12010	25-yr	3175	885.99	7.36	957.39	381.51
Surface	12010	50-yr	4265	887.28	6.96	1496.18	451.07
Surface	12010	100-yr	5493	888.47	6.70	2038.52	458.04
Surface	12010	250-yr	7185	889.93	6.60	2713.73	466.59
Surface	12010	500-yr	8911	891.22	6.71	3347.90	497.82
Surface	11909	1-yr	5	879.42	0.92	5.44	42.03
Surface	11909	2-yr	343	880.83	3.49	107.99	97.60
Surface	11909	5-yr	1272	882.71	4.70	396.68	283.85
Surface	11909	10-yr	2191	884.17	4.30	872.75	355.95
Surface	11909	25-yr	3577	886.05	4.00	1581.02	393.57
Surface	11909	50-yr	4756	887.31	4.08	2128.15	454.88
Surface	11909	100-yr	6082	888.49	4.15	2668.73	462.88
Surface	11909	250-yr	7912	889.93	4.52	3367.95	534.51
Surface	11909	500-yr	9774	891.22	4.79	4163.13	655.73

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	11853	1-yr	5	879.09	0.77	6.51	50.01
Surface	11853	2-yr	343	880.68	2.72	162.32	167.21
Surface	11853	5-yr	1272	882.68	3.36	661.37	312.59
Surface	11853	10-yr	2191	884.14	3.49	1158.78	356.55
Surface	11853	25-yr	3577	886.02	3.80	1859.50	428.60
Surface	11853	50-yr	4756	887.29	3.92	2412.70	440.35
Surface	11853	100-yr	6082	888.46	4.13	2935.02	446.86
Surface	11853	250-yr	7912	889.91	4.39	3610.56	532.22
Surface	11853	500-yr	9774	891.20	4.76	4408.69	643.56
Surface	11799	1-yr	5	878.85	0.67	8.03	67.14
Surface	11799	2-yr	343	880.59	2.50	191.41	160.49
Surface	11799	5-yr	1272	882.62	3.34	669.08	252.41
Surface	11799	10-yr	2191	884.07	3.77	1052.39	279.11
Surface	11799	25-yr	3577	885.93	4.32	1602.31	331.40
Surface	11799	50-yr	4756	887.17	4.65	2039.30	359.27
Surface	11799	100-yr	6082	888.34	4.97	2462.10	366.48
Surface	11799	250-yr	7912	889.77	5.35	3028.37	458.80
Surface	11799	500-yr	9774	891.06	5.65	3664.92	523.26
Surface	11744	1-yr	5	878.71	0.59	10.53	65.09
Surface	11744	2-yr	343	880.54	2.06	322.14	226.69
Surface	11744	5-yr	1272	882.59	3.11	817.14	250.49
Surface	11744	10-yr	2191	884.04	3.72	1201.78	290.56
Surface	11744	25-yr	3577	885.90	4.43	1818.47	372.56
Surface	11744	50-yr	4756	887.15	4.78	2297.82	388.04
Surface	11744	100-yr	6082	888.31	5.13	2753.23	392.56
Surface	11744	250-yr	7912	889.75	5.54	3408.97	507.92
Surface	11744	500-yr	9774	891.04	5.89	4071.34	516.44
Surface	11693	1-yr	5	878.56	1.04	4.81	26.93
Surface	11693	2-yr	343	880.33	3.38	169.75	155.71
Surface	11693	5-yr	1272	882.34	4.68	519.16	189.07
Surface	11693	10-yr	2191	883.76	5.45	814.97	221.07
Surface	11693	25-yr	3577	885.56	6.36	1261.02	298.85
Surface	11693	50-yr	4756	886.80	6.76	1659.64	327.92
Surface	11693	100-yr	6082	887.96	7.14	2041.72	330.36
Surface	11693	250-yr	7912	889.39	7.61	2593.97	431.59
Surface	11693	500-yr	9774	890.67	8.00	3167.64	450.65
Surface	11577	1-yr	5	877.67	1.34	3.74	20.56
Surface	11577	2-yr	343	879.52	5.16	85.13	74.02
Surface	11577	5-yr	1272	881.97	5.49	533.42	235.60
Surface	11577	10-yr	2191	883.51	5.87	902.81	244.29
Surface	11577	25-yr	3577	885.38	6.54	1405.64	299.35
Surface	11577	50-yr	4756	886.64	6.95	1786.56	305.34
Surface	11577	100-yr	6082	887.80	7.47	2180.75	386.48
Surface	11577	250-yr	7912	889.23	8.04	2744.04	403.30
Surface	11577	500-yr	9774	890.50	8.56	3269.58	420.66

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	11473	1-yr	5	876.70	1.68	2.98	10.90
Surface	11473	2-yr	343	879.43	2.43	219.30	140.09
Surface	11473	5-yr	1272	881.90	3.64	669.57	194.43
Surface	11473	10-yr	2191	883.42	4.51	973.15	208.03
Surface	11473	25-yr	3577	885.28	5.43	1409.35	253.42
Surface	11473	50-yr	4756	886.53	6.00	1732.63	267.36
Surface	11473	100-yr	6082	887.68	6.61	2086.53	335.45
Surface	11473	250-yr	7912	889.08	7.30	2560.40	340.28
Surface	11473	500-yr	9774	890.32	7.93	2982.53	342.84
Surface	11370	1-yr	5	876.34	0.72	6.91	29.03
Surface	11370	2-yr	343	879.24	2.98	119.27	50.56
Surface	11370	5-yr	1272	881.26	5.97	276.05	100.12
Surface	11370	10-yr	2191	882.36	7.96	400.67	132.67
Surface	11370	25-yr	3577	883.80	9.81	611.54	161.62
Surface	11370	50-yr	4756	884.78	10.99	784.25	181.42
Surface	11370	100-yr	6082	885.66	12.13	944.91	182.85
Surface	11370	250-yr	7912	886.72	13.48	1176.08	248.41
Surface	11370	500-yr	9774	887.70	14.55	1431.38	284.47
Surface	11260	1-yr	5	876.22	0.50	9.93	31.55
Surface	11260	2-yr	343	879.11	2.73	127.06	51.84
Surface	11260	5-yr	1272	880.98	5.82	263.20	114.03
Surface	11260	10-yr	2191	881.99	7.80	449.18	255.42
Surface	11260	25-yr	3577	883.60	8.42	887.76	284.43
Surface	11260	50-yr	4756	884.68	8.87	1203.74	300.05
Surface	11260	100-yr	6082	885.63	9.51	1495.34	315.04
Surface	11260	250-yr	7912	886.79	10.11	1936.77	409.05
Surface	11260	500-yr	9774	887.87	10.59	2394.37	442.09
Surface	11148	1-yr	5	876.19	0.33	15.33	31.96
Surface	11148	2-yr	343	878.98	2.76	132.09	67.00
Surface	11148	5-yr	1272	880.68	5.86	290.33	135.55
Surface	11148	10-yr	2191	881.57	7.89	420.12	164.80
Surface	11148	25-yr	3577	882.56	10.16	612.65	207.86
Surface	11148	50-yr	4756	883.29	11.46	770.51	223.26
Surface	11148	100-yr	6082	884.03	12.53	941.27	231.32
Surface	11148	250-yr	7912	884.99	13.60	1163.45	233.39
Surface	11148	500-yr	9774	885.89	14.49	1390.40	299.22
Surface	11039	1-yr	5	876.18	0.25	19.71	31.25
Surface	11039	2-yr	343	878.88	2.42	190.26	149.80
Surface	11039	5-yr	1272	880.59	4.32	518.71	255.64
Surface	11039	10-yr	2191	881.52	5.46	767.99	283.09
Surface	11039	25-yr	3577	882.60	6.59	1091.89	312.33
Surface	11039	50-yr	4756	883.40	7.20	1345.07	314.28
Surface	11039	100-yr	6082	884.21	7.78	1598.15	316.21
Surface	11039	250-yr	7912	885.22	8.44	1918.69	321.38
Surface	11039	500-yr	9774	886.16	8.98	2270.48	392.55

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	10934	1-yr	5	876.18	0.27	18.45	28.41
Surface	10934	2-yr	343	878.67	3.31	135.51	151.20
Surface	10934	5-yr	1272	880.33	5.21	560.97	304.35
Surface	10934	10-yr	2191	881.30	6.07	874.32	345.71
Surface	10934	25-yr	3577	882.42	6.65	1260.43	347.74
Surface	10934	50-yr	4756	883.24	7.03	1547.41	349.25
Surface	10934	100-yr	6082	884.05	7.44	1832.54	350.76
Surface	10934	250-yr	7912	885.08	7.90	2227.48	426.54
Surface	10934	500-yr	9774	886.04	8.27	2640.43	430.43
Surface	10888	1-yr	5	876.17	0.50	9.99	24.28
Surface	10888	2-yr	343	878.61	3.07	162.21	130.82
Surface	10888	5-yr	1272	880.25	4.99	567.40	320.62
Surface	10888	10-yr	2191	881.21	5.86	903.61	381.28
Surface	10888	25-yr	3577	882.34	6.40	1346.81	406.28
Surface	10888	50-yr	4756	883.17	6.73	1691.12	422.39
Surface	10888	100-yr	6082	883.99	7.08	2044.25	438.58
Surface	10888	250-yr	7912	885.01	7.68	2554.32	536.61
Surface	10888	500-yr	9774	885.97	8.01	3096.79	595.71
Surface	10815	1-yr	5	876.13	0.50	9.98	30.66
Surface	10815	2-yr	343	878.52	2.70	149.07	119.55
Surface	10815	5-yr	1272	880.12	4.44	501.50	272.58
Surface	10815	10-yr	2191	881.05	5.45	777.59	322.80
Surface	10815	25-yr	3577	882.14	6.16	1132.65	334.13
Surface	10815	50-yr	4756	882.94	6.65	1409.89	360.38
Surface	10815	100-yr	6082	883.75	7.02	1704.98	361.88
Surface	10815	250-yr	7912	884.81	7.42	2126.43	457.31
Surface	10815	500-yr	9774	885.78	7.76	2570.08	459.08
Surface	10707	1-yr	5	876.09	0.35	14.17	30.53
Surface	10707	2-yr	343	878.43	2.22	228.16	165.84
Surface	10707	5-yr	1272	879.97	4.02	522.67	249.01
Surface	10707	10-yr	2191	880.89	4.84	753.98	254.88
Surface	10707	25-yr	3577	881.96	5.78	1032.41	270.90
Surface	10707	50-yr	4756	882.75	6.37	1253.15	286.45
Surface	10707	100-yr	6082	883.56	6.91	1493.29	302.29
Surface	10707	250-yr	7912	884.59	7.48	1836.54	378.05
Surface	10707	500-yr	9774	885.53	7.97	2193.50	380.86
Surface	10603	1-yr	5	876.07	0.44	11.38	21.18
Surface	10603	2-yr	343	878.23	3.12	164.21	122.00
Surface	10603	5-yr	1272	879.70	4.84	423.65	209.53
Surface	10603	10-yr	2191	880.57	5.77	610.78	233.78
Surface	10603	25-yr	3577	881.57	6.89	849.24	238.88
Surface	10603	50-yr	4756	882.33	7.60	1030.65	240.23
Surface	10603	100-yr	6082	883.10	8.27	1216.76	241.61
Surface	10603	250-yr	7912	884.08	9.02	1490.67	322.30
Surface	10603	500-yr	9774	884.99	9.64	1784.98	328.40

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	10499	1-yr	5	876.03	0.63	7.89	15.79
Surface	10499	2-yr	343	878.01	3.08	168.40	138.28
Surface	10499	5-yr	1272	879.41	4.87	418.16	195.48
Surface	10499	10-yr	2191	880.27	5.82	593.70	211.97
Surface	10499	25-yr	3577	881.25	6.97	820.60	243.71
Surface	10499	50-yr	4756	882.01	7.65	1005.72	245.07
Surface	10499	100-yr	6082	882.78	8.28	1196.44	246.45
Surface	10499	250-yr	7912	883.78	9.00	1473.75	325.59
Surface	10499	500-yr	9774	884.69	9.59	1774.62	333.27
Surface	10376	1-yr	5	875.72	2.14	2.33	16.19
Surface	10376	2-yr	343	877.17	5.44	126.60	164.92
Surface	10376	5-yr	1272	878.33	8.18	346.43	211.44
Surface	10376	10-yr	2191	878.98	10.03	486.31	225.66
Surface	10376	25-yr	3577	880.00	11.03	740.44	263.84
Surface	10376	50-yr	4756	880.99	11.00	1000.95	265.84
Surface	10376	100-yr	6082	881.78	11.68	1212.07	267.45
Surface	10376	250-yr	7912	882.77	12.53	1479.32	269.48
Surface	10376	500-yr	9774	883.65	13.36	1757.15	352.23
Surface	10290	1-yr	5	875.23	0.68	7.82	42.45
Surface	10290	2-yr	343	876.57	4.45	139.31	151.46
Surface	10290	5-yr	1272	877.60	7.26	343.78	253.14
Surface	10290	10-yr	2191	878.41	7.52	574.57	291.80
Surface	10290	25-yr	3577	879.74	7.00	984.88	322.68
Surface	10290	50-yr	4756	880.85	6.75	1344.94	328.16
Surface	10290	100-yr	6082	881.68	7.14	1618.82	331.19
Surface	10290	250-yr	7912	882.72	7.62	1964.54	334.57
Surface	10290	500-yr	9774	883.63	8.11	2335.11	428.68
Surface	10175	1-yr	5	874.96	0.57	10.61	88.40
Surface	10175	2-yr	343	876.05	2.73	180.38	224.45
Surface	10175	5-yr	1272	876.96	4.62	400.39	265.00
Surface	10175	10-yr	2191	878.04	4.70	723.97	309.71
Surface	10175	25-yr	3577	879.55	4.57	1235.37	375.81
Surface	10175	50-yr	4756	880.72	4.58	1689.15	394.12
Surface	10175	100-yr	6082	881.56	4.96	2023.42	400.22
Surface	10175	250-yr	7912	882.61	5.40	2462.39	467.61
Surface	10175	500-yr	9774	883.53	5.81	2922.58	514.74
Surface	10072	1-yr	5	874.08	1.81	2.86	32.16
Surface	10072	2-yr	343	874.95	5.23	89.12	141.46
Surface	10072	5-yr	1272	876.56	4.35	472.85	297.40
Surface	10072	10-yr	2191	877.84	3.98	888.88	341.75
Surface	10072	25-yr	3577	879.45	3.84	1505.07	412.46
Surface	10072	50-yr	4756	880.64	3.83	2003.98	423.06
Surface	10072	100-yr	6082	881.49	4.14	2364.07	429.50
Surface	10072	250-yr	7912	882.54	4.49	2828.48	461.13
Surface	10072	500-yr	9774	883.47	4.81	3282.72	525.12

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	9967	1-yr	5	872.75	0.11	9.66	101.89
Surface	9967	2-yr	343	874.27	1.58	300.34	236.02
Surface	9967	5-yr	1272	876.52	2.02	1105.87	477.96
Surface	9967	10-yr	2191	877.82	2.20	1751.48	520.45
Surface	9967	25-yr	3577	879.43	2.41	2594.25	524.72
Surface	9967	50-yr	4756	880.63	2.56	3224.78	527.80
Surface	9967	100-yr	6082	881.48	2.87	3671.86	529.98
Surface	9967	250-yr	7912	882.53	3.23	4240.04	555.68
Surface	9967	500-yr	9774	883.46	3.56	4807.45	650.24
Surface	9868	1-yr	5	872.16	0.91	5.49	35.90
Surface	9868	2-yr	343	873.48	5.50	62.51	50.40
Surface	9868	5-yr	1272	875.99	5.48	442.03	306.22
Surface	9868	10-yr	2191	877.46	5.18	936.08	356.98
Surface	9868	25-yr	3577	879.13	5.29	1565.85	385.05
Surface	9868	50-yr	4756	880.34	5.46	2034.92	389.21
Surface	9868	100-yr	6082	881.14	6.08	2345.86	391.95
Surface	9868	250-yr	7912	882.14	6.80	2757.34	440.00
Surface	9868	500-yr	9774	883.01	7.46	3159.85	474.16
Surface	9769	1-yr	5	871.35	1.25	4.01	30.21
Surface	9769	2-yr	343	873.45	1.75	240.48	189.30
Surface	9769	5-yr	1272	876.04	2.12	1113.30	495.14
Surface	9769	10-yr	2191	877.49	2.37	1849.42	520.12
Surface	9769	25-yr	3577	879.15	2.68	2722.59	527.62
Surface	9769	50-yr	4756	880.36	2.90	3364.37	531.77
Surface	9769	100-yr	6082	881.16	3.30	3792.49	546.65
Surface	9769	250-yr	7912	882.17	3.76	4379.11	610.46
Surface	9769	500-yr	9774	883.04	4.19	4916.01	616.49
Surface	9696	1-yr	5	870.69	1.10	4.55	24.77
Surface	9696	2-yr	343	873.30	2.74	199.07	147.54
Surface	9696	5-yr	1272	875.93	3.30	873.55	397.00
Surface	9696	10-yr	2191	877.38	3.65	1471.43	425.97
Surface	9696	25-yr	3577	879.04	4.08	2202.55	452.21
Surface	9696	50-yr	4756	880.26	4.32	2754.04	456.34
Surface	9696	100-yr	6082	881.04	4.88	3114.09	476.77
Surface	9696	250-yr	7912	882.02	5.50	3617.85	533.92
Surface	9696	500-yr	9774	882.88	6.05	4078.26	539.49
Surface	9580	1-yr	5	870.34	0.67	7.43	32.06
Surface	9580	2-yr	343	873.18	2.35	249.97	225.94
Surface	9580	5-yr	1272	875.89	2.56	1328.43	448.53
Surface	9580	10-yr	2191	877.34	2.91	1986.10	458.70
Surface	9580	25-yr	3577	879.00	3.34	2782.23	497.06
Surface	9580	50-yr	4756	880.22	3.60	3403.06	519.65
Surface	9580	100-yr	6082	880.99	4.08	3816.35	555.24
Surface	9580	250-yr	7912	881.97	4.63	4377.67	579.98
Surface	9580	500-yr	9774	882.82	5.12	4873.39	583.86

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	9407	1-yr	5	870.02	0.67	7.48	35.27
Surface	9407	2-yr	366	873.12	1.56	276.52	143.84
Surface	9407	5-yr	1312	875.76	2.69	810.15	274.98
Surface	9407	10-yr	2242	877.13	3.51	1269.76	442.45
Surface	9407	25-yr	3662	878.75	4.15	2020.62	466.73
Surface	9407	50-yr	4867	879.95	4.50	2591.30	498.65
Surface	9407	100-yr	6214	880.66	5.16	2959.97	540.50
Surface	9407	250-yr	8065	881.56	5.90	3460.18	560.55
Surface	9407	500-yr	9937	882.34	6.58	3895.50	563.53
Surface	9288	1-yr	5	869.75	0.81	6.15	26.62
Surface	9288	2-yr	366	873.05	1.92	226.31	145.47
Surface	9288	5-yr	1312	875.66	3.10	713.84	207.44
Surface	9288	10-yr	2242	876.98	4.11	1011.58	274.30
Surface	9288	25-yr	3662	878.54	5.06	1597.29	435.13
Surface	9288	50-yr	4867	879.76	5.30	2151.96	483.34
Surface	9288	100-yr	6214	880.44	6.01	2492.89	518.81
Surface	9288	250-yr	8065	881.32	6.75	2961.24	536.07
Surface	9288	500-yr	9937	882.08	7.43	3369.50	539.43
Surface	9210	1-yr	5	869.25	2.12	2.36	10.19
Surface	9210	2-yr	366	871.77	7.80	46.92	25.17
Surface	9210	5-yr	1312	874.41	8.53	219.77	108.67
Surface	9210	10-yr	2242	875.29	10.31	332.83	149.93
Surface	9210	25-yr	3662	876.36	12.18	515.57	203.56
Surface	9210	50-yr	4867	877.33	13.04	739.55	265.14
Surface	9210	100-yr	6214	878.64	12.18	1173.78	357.19
Surface	9210	250-yr	8065	879.33	13.35	1428.52	404.64
Surface	9210	500-yr	9937	879.97	14.26	1698.96	439.15
Surface	9116	1-yr	5	868.77	0.87	5.74	21.90
Surface	9116	2-yr	366	871.01	5.06	72.37	37.59
Surface	9116	5-yr	1312	873.14	5.58	298.91	235.38
Surface	9116	10-yr	2242	873.83	6.70	475.06	274.91
Surface	9116	25-yr	3662	874.93	7.04	815.44	339.68
Surface	9116	50-yr	4867	875.64	7.43	1066.67	374.41
Surface	9116	100-yr	6214	876.26	7.94	1310.73	406.65
Surface	9116	250-yr	8065	876.96	8.60	1607.82	437.75
Surface	9116	500-yr	9937	877.59	9.18	1889.04	462.92
Surface	9052	1-yr	5	868.37	0.44	11.45	32.07
Surface	9052	2-yr	366	870.67	3.56	102.92	47.67
Surface	9052	5-yr	1312	872.02	7.36	181.86	114.68
Surface	9052	10-yr	2242	872.91	8.78	330.35	222.18
Surface	9052	25-yr	3662	873.96	9.63	618.19	314.40
Surface	9052	50-yr	4867	874.57	10.45	821.04	356.00
Surface	9052	100-yr	6214	875.10	11.31	1019.24	390.42
Surface	9052	250-yr	8065	875.79	12.05	1301.66	424.35
Surface	9052	500-yr	9937	876.32	12.90	1531.53	442.50

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	8987	1-yr	5	868.36	0.26	19.10	45.92
Surface	8987	2-yr	366	870.62	2.18	170.96	89.14
Surface	8987	5-yr	1312	872.03	3.84	470.54	296.20
Surface	8987	10-yr	2242	872.78	4.84	699.80	318.16
Surface	8987	25-yr	3662	873.62	6.04	976.18	346.83
Surface	8987	50-yr	4867	874.10	7.04	1148.54	371.13
Surface	8987	100-yr	6214	874.47	8.18	1292.97	390.33
Surface	8987	250-yr	8065	875.17	9.01	1573.38	406.23
Surface	8987	500-yr	9937	875.88	9.53	1886.00	508.57
Surface	8835	1-yr	5	868.18	2.41	2.07	10.66
Surface	8835	2-yr	366	869.93	5.85	129.05	168.14
Surface	8835	5-yr	1312	870.88	9.06	317.66	238.55
Surface	8835	10-yr	2242	871.47	10.74	470.23	278.95
Surface	8835	25-yr	3662	872.11	12.68	660.96	312.78
Surface	8835	50-yr	4867	872.68	13.24	846.83	341.36
Surface	8835	100-yr	6214	873.43	12.88	1119.16	379.68
Surface	8835	250-yr	8065	874.36	12.90	1502.25	459.85
Surface	8835	500-yr	9937	875.20	12.83	1937.02	551.06
Surface	8697	1-yr	5	866.23	1.10	4.54	30.30
Surface	8697	2-yr	366	867.58	4.10	121.49	137.51
Surface	8697	5-yr	1312	869.26	5.33	449.05	244.10
Surface	8697	10-yr	2242	870.21	6.23	698.52	275.57
Surface	8697	25-yr	3662	871.33	7.19	1051.19	348.56
Surface	8697	50-yr	4867	872.10	7.78	1329.60	372.03
Surface	8697	100-yr	6214	872.90	8.17	1628.91	376.93
Surface	8697	250-yr	8065	873.85	8.72	1989.88	382.76
Surface	8697	500-yr	9937	874.69	9.26	2315.44	387.94
Surface	8629	1-yr	5	865.12	1.98	2.53	21.22
Surface	8629	2-yr	366	867.27	3.86	162.65	170.92
Surface	8629	5-yr	1312	869.04	5.45	532.02	263.34
Surface	8629	10-yr	2242	869.95	6.69	793.63	309.53
Surface	8629	25-yr	3662	871.07	7.78	1199.60	409.38
Surface	8629	50-yr	4867	871.85	8.39	1536.80	446.11
Surface	8629	100-yr	6214	872.70	8.63	1925.29	463.77
Surface	8629	250-yr	8065	873.68	9.03	2384.08	472.75
Surface	8629	500-yr	9937	874.54	9.45	2800.06	496.24
Surface	8525	1-yr	5	864.10	0.47	11.39	42.72
Surface	8525	2-yr	366	867.24	1.93	472.18	237.22
Surface	8525	5-yr	1312	868.98	3.67	960.51	308.39
Surface	8525	10-yr	2242	869.86	4.91	1255.25	371.18
Surface	8525	25-yr	3662	870.94	6.32	1693.26	430.95
Surface	8525	50-yr	4867	871.70	7.24	2038.97	480.00
Surface	8525	100-yr	6214	872.53	7.92	2462.55	535.62
Surface	8525	250-yr	8065	873.49	8.85	3009.53	619.78
Surface	8525	500-yr	9937	874.36	9.29	3578.75	665.87

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	8407	1-yr	5	863.97	1.22	4.10	8.94
Surface	8407	2-yr	366	866.91	3.98	134.16	130.80
Surface	8407	5-yr	1312	868.48	5.95	401.58	230.85
Surface	8407	10-yr	2242	869.33	6.85	634.58	315.82
Surface	8407	25-yr	3662	870.58	6.88	1060.00	360.98
Surface	8407	50-yr	4867	871.43	7.01	1379.16	390.36
Surface	8407	100-yr	6214	872.31	7.08	1738.41	421.48
Surface	8407	250-yr	8065	873.29	7.26	2166.52	448.75
Surface	8407	500-yr	9937	874.18	7.38	2573.41	465.22
Surface	8291	1-yr	5	863.40	2.00	2.50	8.41
Surface	8291	2-yr	366	866.51	3.94	118.15	118.90
Surface	8291	5-yr	1312	867.80	6.66	359.58	260.66
Surface	8291	10-yr	2242	868.95	6.56	757.09	428.11
Surface	8291	25-yr	3662	870.37	5.96	1409.27	484.39
Surface	8291	50-yr	4867	871.25	6.01	1846.77	504.74
Surface	8291	100-yr	6214	872.15	6.15	2314.60	530.74
Surface	8291	250-yr	8065	873.14	6.51	2849.82	559.16
Surface	8291	500-yr	9937	874.03	6.91	3381.34	622.73
Surface	8232	1-yr	5	863.27	0.74	6.76	17.43
Surface	8232	2-yr	366	866.43	2.77	157.15	138.20
Surface	8232	5-yr	1312	867.54	5.78	336.44	178.74
Surface	8232	10-yr	2242	868.48	6.88	539.42	241.48
Surface	8232	25-yr	3662	869.70	7.70	861.69	289.43
Surface	8232	50-yr	4867	870.49	8.36	1094.23	302.51
Surface	8232	100-yr	6214	871.25	9.19	1344.95	352.04
Surface	8232	250-yr	8065	872.23	9.63	1701.61	367.00
Surface	8232	500-yr	9937	873.13	10.00	2031.84	369.18
Surface	8173	1-yr	5	863.12	1.43	3.51	10.31
Surface	8173	2-yr	366	865.47	6.82	66.82	97.69
Surface	8173	5-yr	1312	867.10	7.76	460.51	280.67
Surface	8173	10-yr	2242	868.30	7.64	832.95	345.27
Surface	8173	25-yr	3662	869.55	8.53	1297.25	412.54
Surface	8173	50-yr	4867	870.38	8.84	1653.62	433.40
Surface	8173	100-yr	6214	871.18	9.23	2005.50	442.36
Surface	8173	250-yr	8065	872.18	9.70	2453.96	454.68
Surface	8173	500-yr	9937	873.09	10.16	2867.26	458.45
Surface	8085	1-yr	5	862.89	0.71	10.09	47.21
Surface	8085	2-yr	366	865.10	3.83	193.27	119.94
Surface	8085	5-yr	1312	866.77	6.59	465.28	196.38
Surface	8085	10-yr	2242	867.74	8.66	680.70	254.47
Surface	8085	25-yr	3662	868.94	9.96	1010.93	283.77
Surface	8085	50-yr	4867	869.64	10.95	1213.19	286.90
Surface	8085	100-yr	6214	870.32	11.96	1409.41	289.90
Surface	8085	250-yr	8065	871.19	13.07	1665.54	305.35
Surface	8085	500-yr	9937	871.98	14.04	1914.82	325.99

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	7939	1-yr	5	862.21	1.91	2.62	13.98
Surface	7939	2-yr	366	864.66	3.72	210.65	236.88
Surface	7939	5-yr	1312	866.41	4.90	732.99	364.69
Surface	7939	10-yr	2242	867.40	5.75	1122.59	426.46
Surface	7939	25-yr	3662	868.65	6.40	1716.90	505.55
Surface	7939	50-yr	4867	869.36	7.04	2086.85	539.51
Surface	7939	100-yr	6214	870.06	7.60	2467.61	553.65
Surface	7939	250-yr	8065	870.96	8.15	2976.54	571.47
Surface	7939	500-yr	9937	871.79	8.58	3453.71	578.38
Surface	7879	1-yr	5	861.81	1.09	4.59	16.20
Surface	7879	2-yr	427	864.19	5.16	153.06	159.45
Surface	7879	5-yr	1401	866.10	6.05	714.35	403.60
Surface	7879	10-yr	2359	867.20	6.36	1174.19	434.55
Surface	7879	25-yr	3824	868.49	6.96	1749.24	462.65
Surface	7879	50-yr	5067	869.16	7.81	2068.21	476.05
Surface	7879	100-yr	6452	869.83	8.56	2384.78	477.92
Surface	7879	250-yr	8360	870.70	9.35	2800.67	480.37
Surface	7879	500-yr	10285	871.48	10.06	3180.51	482.60
Surface	7767	1-yr	5	861.45	1.11	4.52	13.95
Surface	7767	2-yr	427	864.14	2.28	588.48	360.56
Surface	7767	5-yr	1401	866.05	3.33	1364.10	467.77
Surface	7767	10-yr	2359	867.14	3.95	1892.65	502.35
Surface	7767	25-yr	3824	868.41	4.65	2557.84	538.72
Surface	7767	50-yr	5067	869.08	5.37	2924.71	560.12
Surface	7767	100-yr	6452	869.73	6.09	3297.81	590.56
Surface	7767	250-yr	8360	870.60	6.85	3829.12	633.88
Surface	7767	500-yr	10285	871.39	7.42	4340.22	662.89
Surface	7669	1-yr	5	861.08	0.72	6.95	54.69
Surface	7669	2-yr	427	864.12	0.98	693.76	297.70
Surface	7669	5-yr	1401	866.02	1.85	1381.78	438.00
Surface	7669	10-yr	2359	867.09	2.39	1884.30	494.94
Surface	7669	25-yr	3824	868.36	2.97	2555.03	560.17
Surface	7669	50-yr	5067	869.02	3.48	2932.51	593.04
Surface	7669	100-yr	6452	869.66	3.97	3321.71	627.47
Surface	7669	250-yr	8360	870.51	4.47	3872.25	663.47
Surface	7669	500-yr	10285	871.29	4.89	4403.66	698.77
Surface	7551	1-yr	5	860.98	0.48	10.51	23.12
Surface	7551	2-yr	427	863.95	2.91	227.89	154.27
Surface	7551	5-yr	1401	865.70	4.59	611.46	253.89
Surface	7551	10-yr	2359	866.66	5.73	888.13	323.96
Surface	7551	25-yr	3824	867.89	6.48	1323.78	371.57
Surface	7551	50-yr	5067	868.43	7.49	1526.51	387.04
Surface	7551	100-yr	6452	868.94	8.47	1729.26	401.93
Surface	7551	250-yr	8360	869.70	9.34	2043.75	433.07
Surface	7551	500-yr	10285	870.44	9.92	2374.05	460.87

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	7443	1-yr	5	860.89	1.03	4.84	10.96
Surface	7443	2-yr	427	862.97	6.87	113.39	108.58
Surface	7443	5-yr	1401	864.42	9.48	323.28	186.26
Surface	7443	10-yr	2359	865.26	10.86	498.76	222.57
Surface	7443	25-yr	3824	866.34	12.33	762.45	299.52
Surface	7443	50-yr	5067	867.23	12.09	1065.66	361.23
Surface	7443	100-yr	6452	868.07	11.80	1378.82	383.39
Surface	7443	250-yr	8360	869.06	11.78	1772.12	409.53
Surface	7443	500-yr	10285	869.91	11.99	2134.51	450.22
Surface	7293	1-yr	5	860.65	0.50	12.46	80.94
Surface	7293	2-yr	427	862.95	1.46	499.97	310.76
Surface	7293	5-yr	1401	864.50	2.33	1158.40	452.06
Surface	7293	10-yr	2359	865.43	2.93	1605.59	511.51
Surface	7293	25-yr	3824	866.56	3.57	2206.23	554.50
Surface	7293	50-yr	5067	867.38	3.99	2671.90	601.49
Surface	7293	100-yr	6452	868.16	4.41	3171.56	675.01
Surface	7293	250-yr	8360	869.12	4.87	3848.61	738.17
Surface	7293	500-yr	10285	869.96	5.23	4490.21	785.36
Surface	7167	1-yr	5	860.62	0.30	19.85	43.57
Surface	7167	2-yr	427	862.54	4.67	235.94	238.97
Surface	7167	5-yr	1401	863.76	7.64	593.78	319.00
Surface	7167	10-yr	2359	864.54	9.07	849.79	340.98
Surface	7167	25-yr	3824	865.57	10.40	1217.57	391.43
Surface	7167	50-yr	5067	866.32	11.19	1531.95	440.01
Surface	7167	100-yr	6452	867.05	11.93	1883.42	515.28
Surface	7167	250-yr	8360	868.02	12.50	2411.08	574.63
Surface	7167	500-yr	10285	868.86	13.01	2909.92	612.29
Surface	7051	1-yr	5	860.57	0.74	6.72	36.47
Surface	7051	2-yr	427	862.07	4.25	237.37	279.83
Surface	7051	5-yr	1401	863.08	6.75	576.23	361.85
Surface	7051	10-yr	2359	863.85	7.89	870.07	404.61
Surface	7051	25-yr	3824	864.99	8.47	1381.75	494.86
Surface	7051	50-yr	5067	865.81	8.87	1834.77	588.80
Surface	7051	100-yr	6452	866.62	9.07	2341.56	690.69
Surface	7051	250-yr	8360	867.68	9.13	3113.75	754.86
Surface	7051	500-yr	10285	868.58	9.29	3802.46	787.15
Surface	6934	1-yr	5	859.31		2.26	14.65
Surface	6934	2-yr	427	860.64	6.92	164.16	221.54
Surface	6934	5-yr	1401	861.88	8.37	477.79	276.44
Surface	6934	10-yr	2359	862.83	9.26	758.10	320.85
Surface	6934	25-yr	3824	864.04	10.44	1189.53	409.19
Surface	6934	50-yr	5067	865.03	10.61	1655.53	501.33
Surface	6934	100-yr	6452	865.93	10.81	2131.85	570.20
Surface	6934	250-yr	8360	867.01	11.28	2827.57	717.09
Surface	6934	500-yr	10285	868.04	11.14	3601.11	779.82

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	6822	1-yr	5	858.51		66.18	80.50
Surface	6822	2-yr	427	860.20	1.92	341.91	201.66
Surface	6822	5-yr	1401	861.52	3.64	616.34	228.53
Surface	6822	10-yr	2359	862.49	4.58	873.60	284.15
Surface	6822	25-yr	3824	863.75	5.49	1237.50	290.00
Surface	6822	50-yr	5067	864.76	5.98	1532.95	290.00
Surface	6822	100-yr	6452	865.65	6.58	1830.64	404.60
Surface	6822	250-yr	8360	866.71	7.24	2307.80	469.19
Surface	6822	500-yr	10285	867.64	7.81	2758.09	508.44
Surface	6720	1-yr	5	858.50	0.61	16.98	97.83
Surface	6720	2-yr	427	859.93	3.44	364.14	285.10
Surface	6720	5-yr	1401	861.22	5.57	742.34	301.80
Surface	6720	10-yr	2359	862.19	6.79	1053.13	365.45
Surface	6720	25-yr	3824	863.49	7.75	1563.96	410.85
Surface	6720	50-yr	5067	864.57	8.06	2009.95	419.03
Surface	6720	100-yr	6452	865.48	8.59	2470.16	575.81
Surface	6720	250-yr	8360	866.58	9.13	3113.21	584.00
Surface	6720	500-yr	10285	867.53	9.65	3674.15	608.07
Surface	6620	1-yr	5	858.21	0.29	11.21	52.73
Surface	6620	2-yr	427	859.56	2.82	274.07	279.98
Surface	6620	5-yr	1401	860.95	3.67	710.78	344.86
Surface	6620	10-yr	2359	861.98	4.11	1081.37	379.72
Surface	6620	25-yr	3824	863.35	4.48	1639.02	423.02
Surface	6620	50-yr	5067	864.44	4.98	2126.83	538.49
Surface	6620	100-yr	6452	865.33	6.01	2717.33	794.89
Surface	6620	250-yr	8360	866.50	5.59	3687.26	863.00
Surface	6620	500-yr	10285	867.49	5.32	4541.68	863.00
Surface	6564	1-yr	5	858.21	0.07	77.52	111.17
Surface	6564	2-yr	427	859.46	2.20	264.24	185.78
Surface	6564	5-yr	1401	860.70	3.97	520.86	227.92
Surface	6564	10-yr	2359	861.66	4.87	761.36	276.10
Surface	6564	25-yr	3824	862.97	5.69	1177.13	389.02
Surface	6564	50-yr	5067	864.11	5.77	1725.74	561.76
Surface	6564	100-yr	6452	865.04	5.98	2400.05	847.23
Surface	6564	250-yr	8360	866.30	5.50	3592.17	1034.83
Surface	6564	500-yr	10285	867.35	5.25	4742.60	1165.42
Surface	6520	1-yr	198	858.07	2.34	107.98	130.70
Surface	6520	2-yr	829	859.11	4.58	268.70	175.98
Surface	6520	5-yr	1995	860.01	7.23	440.32	205.54
Surface	6520	10-yr	3139	860.72	8.82	595.95	231.25
Surface	6520	25-yr	4914	861.95	9.82	909.96	286.52
Surface	6520	50-yr	6421	862.91	10.66	1236.56	396.99
Surface	6520	100-yr	8082	864.05	10.36	1786.98	593.51
Surface	6520	250-yr	10365	865.52	9.75	2842.16	920.54
Surface	6520	500-yr	12650	866.97	8.08	4369.27	1141.58

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	6450	1-yr	198	857.66	3.95	80.35	143.08
Surface	6450	2-yr	829	858.63	6.12	257.26	238.91
Surface	6450	5-yr	1995	859.64	7.25	590.47	375.11
Surface	6450	10-yr	3139	860.54	7.13	953.80	435.27
Surface	6450	25-yr	4914	861.99	6.56	1660.01	531.69
Surface	6450	50-yr	6421	863.09	6.09	2255.22	559.76
Surface	6450	100-yr	8082	864.23	5.84	2921.94	595.92
Surface	6450	250-yr	10365	865.65	5.70	3787.84	618.97
Surface	6450	500-yr	12650	867.00	5.65	4635.60	642.67
Surface	6390	1-yr	198	857.27	2.95	92.71	140.45
Surface	6390	2-yr	829	858.35	4.22	371.13	340.76
Surface	6390	5-yr	1995	859.45	4.86	825.51	464.22
Surface	6390	10-yr	3139	860.42	4.83	1291.80	499.67
Surface	6390	25-yr	4914	861.92	4.62	2069.94	538.67
Surface	6390	50-yr	6421	863.03	4.63	2678.94	554.72
Surface	6390	100-yr	8082	864.18	4.67	3324.24	567.34
Surface	6390	250-yr	10365	865.61	4.77	4142.53	573.51
Surface	6390	500-yr	12650	866.96	4.88	4918.71	576.82
Surface	6275	1-yr	198	856.69	3.12	137.96	202.71
Surface	6275	2-yr	829	857.93	4.55	448.92	334.04
Surface	6275	5-yr	1995	859.13	5.35	875.44	378.00
Surface	6275	10-yr	3139	860.18	5.56	1285.90	403.39
Surface	6275	25-yr	4914	861.72	5.73	1960.16	466.63
Surface	6275	50-yr	6421	862.85	5.87	2500.40	491.10
Surface	6275	100-yr	8082	864.02	6.02	3089.12	521.28
Surface	6275	250-yr	10365	865.46	6.18	3856.04	534.73
Surface	6275	500-yr	12650	866.83	6.31	4588.69	542.03
Surface	6158	1-yr	198	856.15	3.21	139.96	157.03
Surface	6158	2-yr	829	857.40	5.05	423.59	307.28
Surface	6158	5-yr	1995	858.76	5.55	890.51	353.65
Surface	6158	10-yr	3139	859.91	5.70	1301.97	365.51
Surface	6158	25-yr	4914	861.50	6.12	1932.35	441.02
Surface	6158	50-yr	6421	862.66	6.21	2454.24	451.38
Surface	6158	100-yr	8082	863.85	6.34	2996.35	461.75
Surface	6158	250-yr	10365	865.31	6.59	3678.59	477.01
Surface	6158	500-yr	12650	866.67	6.84	4343.82	501.23
Surface	6039	1-yr	198	855.71	3.17	149.56	190.01
Surface	6039	2-yr	829	856.97	4.81	484.64	350.62
Surface	6039	5-yr	1995	858.51	4.94	1040.73	374.76
Surface	6039	10-yr	3139	859.71	5.26	1504.37	405.77
Surface	6039	25-yr	4914	861.34	5.55	2198.64	437.78
Surface	6039	50-yr	6421	862.53	5.83	2731.70	464.37
Surface	6039	100-yr	8082	863.73	6.06	3303.83	482.65
Surface	6039	250-yr	10365	865.20	6.36	4028.73	516.05
Surface	6039	500-yr	12650	866.58	6.62	4803.97	600.32

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	5925	1-yr	198	855.26	3.47	130.05	193.47
Surface	5925	2-yr	829	856.63	4.52	472.50	296.78
Surface	5925	5-yr	1995	858.28	4.96	1075.33	400.09
Surface	5925	10-yr	3139	859.53	5.15	1596.56	431.49
Surface	5925	25-yr	4914	861.21	5.42	2351.04	467.28
Surface	5925	50-yr	6421	862.41	5.66	2923.48	483.53
Surface	5925	100-yr	8082	863.60	6.23	3537.52	595.08
Surface	5925	250-yr	10365	865.10	6.39	4452.99	630.53
Surface	5925	500-yr	12650	866.48	6.69	5372.62	696.45
Surface	5821	1-yr	198	854.93	2.70	158.05	226.69
Surface	5821	2-yr	829	856.41	3.61	545.19	279.49
Surface	5821	5-yr	1995	858.12	4.43	1107.01	369.42
Surface	5821	10-yr	3139	859.40	4.86	1596.96	389.00
Surface	5821	25-yr	4914	861.10	5.32	2264.08	411.17
Surface	5821	50-yr	6421	862.30	5.70	2766.64	429.87
Surface	5821	100-yr	8082	863.50	6.06	3299.02	464.38
Surface	5821	250-yr	10365	864.99	6.48	4035.79	502.81
Surface	5821	500-yr	12650	866.37	6.83	4733.20	512.11
Surface	5718	1-yr	198	854.65	2.72	179.02	224.93
Surface	5718	2-yr	829	856.21	3.81	566.25	265.53
Surface	5718	5-yr	1995	857.95	4.80	1182.38	412.29
Surface	5718	10-yr	3139	859.26	5.19	1729.79	424.31
Surface	5718	25-yr	4914	860.98	5.66	2471.67	436.98
Surface	5718	50-yr	6421	862.19	6.08	3008.18	468.26
Surface	5718	100-yr	8082	863.40	6.48	3590.19	496.67
Surface	5718	250-yr	10365	864.90	6.91	4393.95	566.42
Surface	5718	500-yr	12650	866.28	7.26	5238.93	641.80
Surface	5605	1-yr	198	854.47	2.19	239.65	235.93
Surface	5605	2-yr	829	856.04	3.57	663.70	321.95
Surface	5605	5-yr	1995	857.79	4.57	1240.06	335.35
Surface	5605	10-yr	3139	859.10	5.28	1684.55	346.13
Surface	5605	25-yr	4914	860.80	6.10	2290.63	363.15
Surface	5605	50-yr	6421	862.00	6.66	2729.08	375.94
Surface	5605	100-yr	8082	863.19	7.18	3206.93	410.21
Surface	5605	250-yr	10365	864.67	7.79	3842.75	461.13
Surface	5605	500-yr	12650	866.04	8.24	4486.34	472.80
Surface	5469	1-yr	198	854.28	2.45	214.75	222.38
Surface	5469	2-yr	829	855.80	3.93	615.32	309.54
Surface	5469	5-yr	1995	857.58	4.88	1191.60	332.41
Surface	5469	10-yr	3139	858.89	5.56	1633.75	341.57
Surface	5469	25-yr	4914	860.60	6.36	2239.11	366.32
Surface	5469	50-yr	6421	861.79	6.97	2685.49	385.24
Surface	5469	100-yr	8082	862.99	7.50	3176.69	440.70
Surface	5469	250-yr	10365	864.49	8.01	3891.50	496.14
Surface	5469	500-yr	12650	865.87	8.40	4604.44	546.73

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	5343	1-yr	198	854.06	2.64	207.45	266.71
Surface	5343	2-yr	829	855.61	3.56	683.02	334.16
Surface	5343	5-yr	1995	857.42	4.34	1303.25	348.70
Surface	5343	10-yr	3139	858.75	4.97	1769.40	357.25
Surface	5343	25-yr	4914	860.46	5.71	2392.89	368.36
Surface	5343	50-yr	6421	861.66	6.30	2838.34	388.60
Surface	5343	100-yr	8082	862.84	7.09	3341.88	434.80
Surface	5343	250-yr	10365	864.35	7.57	4001.12	442.78
Surface	5343	500-yr	12650	865.74	7.99	4637.94	473.97
Surface	5215	1-yr	198	853.76	2.85	197.02	201.19
Surface	5215	2-yr	829	855.29	4.48	555.44	249.67
Surface	5215	5-yr	1995	857.05	6.04	1006.94	265.09
Surface	5215	10-yr	3139	858.30	7.19	1345.33	275.99
Surface	5215	25-yr	4914	859.89	8.71	1806.16	305.94
Surface	5215	50-yr	6421	861.00	9.69	2151.69	327.86
Surface	5215	100-yr	8082	862.15	10.45	2541.00	349.15
Surface	5215	250-yr	10365	863.61	11.25	3069.70	370.00
Surface	5215	500-yr	12650	864.97	11.84	3574.21	370.00
Surface	5066	1-yr	198	853.31	3.18	160.57	179.57
Surface	5066	2-yr	829	854.78	5.14	462.16	237.27
Surface	5066	5-yr	1995	856.53	6.74	903.18	268.84
Surface	5066	10-yr	3139	857.76	7.88	1246.14	289.18
Surface	5066	25-yr	4914	859.37	9.11	1734.17	314.78
Surface	5066	50-yr	6421	860.49	9.95	2094.89	327.11
Surface	5066	100-yr	8082	861.63	10.77	2482.07	350.74
Surface	5066	250-yr	10365	863.09	11.62	3016.72	391.01
Surface	5066	500-yr	12650	864.52	12.01	3583.45	396.00
Surface	4951	1-yr	198	853.10	2.27	141.15	151.73
Surface	4951	2-yr	829	854.55	3.75	401.43	219.74
Surface	4951	5-yr	1995	856.37	4.49	856.26	277.47
Surface	4951	10-yr	3139	857.62	5.18	1230.92	327.72
Surface	4951	25-yr	4914	859.30	5.53	1811.71	359.30
Surface	4951	50-yr	6421	860.46	5.82	2235.56	371.00
Surface	4951	100-yr	8082	861.63	6.05	2673.87	375.08
Surface	4951	250-yr	10365	863.12	6.35	3237.39	390.57
Surface	4951	500-yr	12650	864.57	6.55	3854.95	448.86
Surface	4847	1-yr	230	852.89	2.61	157.28	203.45
Surface	4847	2-yr	872	854.41	3.13	547.77	312.08
Surface	4847	5-yr	2061	856.30	3.37	1235.19	403.84
Surface	4847	10-yr	3227	857.57	3.61	1764.85	426.61
Surface	4847	25-yr	5040	859.27	3.91	2511.62	452.85
Surface	4847	50-yr	6580	860.43	4.26	3048.21	480.87
Surface	4847	100-yr	8279	861.61	4.58	3637.55	520.06
Surface	4847	250-yr	10611	863.10	5.13	4492.78	648.30
Surface	4847	500-yr	12939	864.56	5.19	5479.98	708.22

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	4737	1-yr	230	852.23	3.56	83.01	107.20
Surface	4737	2-yr	872	853.80	5.17	314.01	178.85
Surface	4737	5-yr	2061	855.57	6.69	711.35	285.15
Surface	4737	10-yr	3227	856.82	7.39	1105.80	370.34
Surface	4737	25-yr	5040	858.69	7.28	1857.26	436.13
Surface	4737	50-yr	6580	859.88	7.50	2401.98	475.21
Surface	4737	100-yr	8279	861.09	7.68	3003.19	521.29
Surface	4737	250-yr	10611	862.62	7.88	3851.80	581.20
Surface	4737	500-yr	12939	864.12	7.94	4781.66	661.55
Surface	4633	1-yr	230	851.79	3.30	88.22	116.11
Surface	4633	2-yr	872	853.52	4.55	353.74	173.49
Surface	4633	5-yr	2061	855.31	6.11	679.21	190.43
Surface	4633	10-yr	3227	856.44	7.42	900.37	220.88
Surface	4633	25-yr	5040	858.04	8.57	1399.51	364.72
Surface	4633	50-yr	6580	859.15	9.23	1834.82	425.95
Surface	4633	100-yr	8279	860.34	9.61	2385.32	486.71
Surface	4633	250-yr	10611	861.92	9.82	3182.01	523.55
Surface	4633	500-yr	12939	863.46	9.92	4062.33	595.83
Surface	4516	1-yr	230	851.30	3.70	92.26	84.95
Surface	4516	2-yr	872	853.20	5.07	414.73	197.67
Surface	4516	5-yr	2061	855.01	6.75	784.58	221.73
Surface	4516	10-yr	3227	856.11	8.18	1113.22	383.39
Surface	4516	25-yr	5040	857.79	8.90	1909.17	523.35
Surface	4516	50-yr	6580	858.96	9.10	2550.55	566.30
Surface	4516	100-yr	8279	860.21	9.20	3324.11	646.41
Surface	4516	250-yr	10611	861.85	9.11	4470.69	726.80
Surface	4516	500-yr	12939	863.43	8.84	5640.05	746.94
Surface	4384	1-yr	230	850.82	3.38	102.95	153.34
Surface	4384	2-yr	872	853.03	3.55	558.64	303.38
Surface	4384	5-yr	2061	854.94	4.03	1258.37	399.00
Surface	4384	10-yr	3227	856.09	4.47	1767.63	461.00
Surface	4384	25-yr	5040	857.81	4.71	2594.44	510.91
Surface	4384	50-yr	6580	858.98	4.96	3229.59	568.15
Surface	4384	100-yr	8279	860.23	5.10	3978.65	622.01
Surface	4384	250-yr	10611	861.87	5.20	5027.62	667.05
Surface	4384	500-yr	12939	863.45	5.22	6119.99	711.06
Surface	4264	1-yr	230	850.58	2.27	260.55	261.51
Surface	4264	2-yr	872	852.99	2.23	1058.61	395.85
Surface	4264	5-yr	2061	854.90	2.88	1974.17	523.65
Surface	4264	10-yr	3227	856.04	3.40	2585.79	540.44
Surface	4264	25-yr	5040	857.77	3.89	3543.97	625.88
Surface	4264	50-yr	6580	858.94	4.24	4318.19	689.69
Surface	4264	100-yr	8279	860.20	4.39	5209.39	715.13
Surface	4264	250-yr	10611	861.84	4.53	6404.04	747.90
Surface	4264	500-yr	12939	863.42	4.64	7630.91	794.41

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	4221	1-yr	230	850.54	1.69	270.46	269.36
Surface	4221	2-yr	872	852.98	1.48	1399.85	530.71
Surface	4221	5-yr	2061	854.89	1.91	2447.01	563.84
Surface	4221	10-yr	3227	856.04	2.31	3157.12	661.70
Surface	4221	25-yr	5040	857.77	2.63	4312.11	676.53
Surface	4221	50-yr	6580	858.94	2.88	5112.11	686.85
Surface	4221	100-yr	8279	860.20	3.08	5983.79	699.37
Surface	4221	250-yr	10611	861.83	3.31	7156.91	737.10
Surface	4221	500-yr	12939	863.42	3.46	8333.19	745.09
Surface	4127	1-yr	230	850.49	1.09	350.76	321.00
Surface	4127	2-yr	872	852.97	1.21	1195.07	382.68
Surface	4127	5-yr	2061	854.88	1.79	1969.03	429.51
Surface	4127	10-yr	3227	856.02	2.26	2538.76	543.94
Surface	4127	25-yr	5040	857.75	2.65	3501.03	567.80
Surface	4127	50-yr	6580	858.92	2.93	4174.52	580.13
Surface	4127	100-yr	8279	860.18	3.15	4910.67	587.83
Surface	4127	250-yr	10611	861.81	3.39	5875.07	590.89
Surface	4127	500-yr	12939	863.40	3.57	6812.95	594.25
Surface	3984	1-yr	230	850.41	1.30	257.30	272.71
Surface	3984	2-yr	872	852.94	1.35	1190.31	428.16
Surface	3984	5-yr	2061	854.84	1.91	2042.15	467.86
Surface	3984	10-yr	3227	855.97	2.41	2624.58	571.28
Surface	3984	25-yr	5040	857.68	2.82	3685.63	651.34
Surface	3984	50-yr	6580	858.85	3.11	4484.91	709.13
Surface	3984	100-yr	8279	860.11	3.34	5405.59	756.22
Surface	3984	250-yr	10611	861.74	3.59	6694.63	823.01
Surface	3984	500-yr	12939	863.33	3.79	8054.26	890.92
Surface	3885	1-yr	230	850.23	3.36	177.30	181.97
Surface	3885	2-yr	872	852.90	2.31	975.66	338.27
Surface	3885	5-yr	2061	854.79	3.12	1640.95	370.36
Surface	3885	10-yr	3227	855.90	4.04	2113.40	485.60
Surface	3885	25-yr	5040	857.61	4.60	3055.76	582.80
Surface	3885	50-yr	6580	858.78	4.88	3745.10	593.82
Surface	3885	100-yr	8279	860.04	5.09	4503.10	606.61
Surface	3885	250-yr	10611	861.69	5.28	5508.79	617.64
Surface	3885	500-yr	12939	863.28	5.42	6501.07	628.95
Surface	3775	1-yr	230	850.11	1.65	298.79	171.71
Surface	3775	2-yr	872	852.87	1.89	1087.13	333.19
Surface	3775	5-yr	2061	854.75	2.68	1930.04	509.37
Surface	3775	10-yr	3227	855.86	3.22	2501.92	528.73
Surface	3775	25-yr	5040	857.58	3.63	3438.42	561.60
Surface	3775	50-yr	6580	858.75	3.96	4109.44	583.97
Surface	3775	100-yr	8279	860.01	4.22	4862.43	607.96
Surface	3775	250-yr	10611	861.66	4.46	5878.24	625.40
Surface	3775	500-yr	12939	863.25	4.63	6883.47	637.29

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	3740	1-yr	236	850.10	1.44	457.73	263.23
Surface	3740	2-yr	881	852.87	1.73	1653.21	611.35
Surface	3740	5-yr	2077	854.75	2.20	2882.56	670.10
Surface	3740	10-yr	3250	855.85	2.65	3636.47	698.13
Surface	3740	25-yr	5073	857.57	2.99	4861.99	724.24
Surface	3740	50-yr	6626	858.75	3.27	5720.68	739.29
Surface	3740	100-yr	8340	860.01	3.50	6679.99	771.36
Surface	3740	250-yr	10687	861.66	3.70	7959.25	780.66
Surface	3740	500-yr	13026	863.25	3.84	9209.90	788.70
Surface	3646	1-yr	236	849.91	3.00	125.17	69.31
Surface	3646	2-yr	881	852.76	3.09	665.00	274.65
Surface	3646	5-yr	2077	854.60	4.11	1348.97	418.60
Surface	3646	10-yr	3250	855.66	4.96	1797.86	429.88
Surface	3646	25-yr	5073	857.36	5.57	2543.44	446.30
Surface	3646	50-yr	6626	858.51	6.08	3063.56	459.45
Surface	3646	100-yr	8340	859.76	6.48	3646.31	473.77
Surface	3646	250-yr	10687	861.39	6.89	4435.63	492.41
Surface	3646	500-yr	13026	862.98	7.18	5228.21	507.18
Surface	3540	1-yr	236	849.79	2.78	186.73	147.41
Surface	3540	2-yr	881	852.71	2.93	794.15	315.86
Surface	3540	5-yr	2077	854.54	3.93	1447.36	395.58
Surface	3540	10-yr	3250	855.59	4.71	1886.82	459.02
Surface	3540	25-yr	5073	857.30	5.14	2746.15	515.97
Surface	3540	50-yr	6626	858.45	5.52	3345.65	525.64
Surface	3540	100-yr	8340	859.70	5.79	4011.59	536.18
Surface	3540	250-yr	10687	861.34	6.06	4901.59	549.19
Surface	3540	500-yr	13026	862.94	6.26	5786.08	561.52
Surface	3466	1-yr	236	849.73	2.30	254.75	198.74
Surface	3466	2-yr	881	852.68	2.62	1045.15	413.00
Surface	3466	5-yr	2077	854.52	3.35	1886.93	487.66
Surface	3466	10-yr	3250	855.56	4.01	2408.07	511.45
Surface	3466	25-yr	5073	857.27	4.42	3311.74	544.73
Surface	3466	50-yr	6626	858.42	4.78	3951.68	567.24
Surface	3466	100-yr	8340	859.68	5.07	4685.63	613.53
Surface	3466	250-yr	10687	861.32	5.48	5772.23	722.53
Surface	3466	500-yr	13026	862.92	5.51	6933.12	727.99
Surface	3309	1-yr	236	849.25	4.23	66.77	76.44
Surface	3309	2-yr	881	852.47	3.92	495.33	189.66
Surface	3309	5-yr	2077	854.17	5.63	924.89	323.49
Surface	3309	10-yr	3250	855.09	6.92	1226.31	327.64
Surface	3309	25-yr	5073	856.81	7.50	1815.55	373.49
Surface	3309	50-yr	6626	857.94	8.05	2249.76	397.86
Surface	3309	100-yr	8340	859.19	8.39	2778.04	437.79
Surface	3309	250-yr	10687	860.86	8.65	3530.47	462.29
Surface	3309	500-yr	13026	862.47	8.83	4293.07	487.85

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	3252	1-yr	236	848.82	5.15	45.95	25.68
Surface	3252	2-yr	881	852.43	3.81	538.39	178.04
Surface	3252	5-yr	2077	854.09	5.71	900.86	291.60
Surface	3252	10-yr	3250	854.95	7.22	1159.70	305.65
Surface	3252	25-yr	5073	856.67	7.86	1715.23	358.60
Surface	3252	50-yr	6626	857.80	8.41	2164.16	418.14
Surface	3252	100-yr	8340	859.08	8.66	2706.21	425.21
Surface	3252	250-yr	10687	860.76	8.88	3424.75	430.03
Surface	3252	500-yr	13026	862.38	9.04	4125.70	434.89
Surface	3184	1-yr	236	848.71	3.42	68.94	21.68
Surface	3184	2-yr	881	852.32	3.96	531.58	233.95
Surface	3184	5-yr	2077	853.87	6.20	975.38	373.97
Surface	3184	10-yr	3250	854.72	7.52	1309.65	419.35
Surface	3184	25-yr	5073	856.57	7.38	2190.69	531.24
Surface	3184	50-yr	6626	857.73	7.44	2850.46	585.40
Surface	3184	100-yr	8340	859.04	7.27	3640.43	623.52
Surface	3184	250-yr	10687	860.75	7.08	4746.13	672.01
Surface	3184	500-yr	13026	862.39	6.94	5878.52	720.99
Surface	3134	1-yr	236	848.69	2.29	103.27	36.80
Surface	3134	2-yr	881	852.31	2.74	428.54	132.37
Surface	3134	5-yr	2077	853.83	4.65	680.84	251.09
Surface	3134	10-yr	3250	854.56	6.32	889.18	307.87
Surface	3134	25-yr	5073	856.26	6.96	1489.57	396.29
Surface	3134	50-yr	6626	857.34	7.44	1964.21	463.84
Surface	3134	100-yr	8340	858.66	7.49	2606.49	511.05
Surface	3134	250-yr	10687	860.40	7.45	3539.20	558.05
Surface	3134	500-yr	13026	862.06	7.44	4509.75	613.47
Surface	3078	1-yr	236	848.60	2.64	89.37	35.03
Surface	3078	2-yr	881	852.23	3.26	407.31	126.32
Surface	3078	5-yr	2077	853.64	5.55	712.29	376.26
Surface	3078	10-yr	3250	854.28	7.43	964.19	401.66
Surface	3078	25-yr	5073	856.03	8.03	1754.74	496.49
Surface	3078	50-yr	6626	857.26	8.04	2381.39	521.38
Surface	3078	100-yr	8340	858.61	7.87	3095.36	539.56
Surface	3078	250-yr	10687	860.37	7.71	4067.31	565.57
Surface	3078	500-yr	13026	862.04	7.65	5046.25	603.51
Surface	2919	1-yr	236	847.43	6.73	35.09	11.88
Surface	2919	2-yr	881	850.98	7.83	154.98	143.88
Surface	2919	5-yr	2077	852.60	8.56	592.91	429.40
Surface	2919	10-yr	3250	853.86	7.66	1185.26	499.85
Surface	2919	25-yr	5073	855.86	6.51	2225.24	540.23
Surface	2919	50-yr	6626	857.12	6.50	2930.97	589.82
Surface	2919	100-yr	8340	858.49	6.53	3779.37	653.37
Surface	2919	250-yr	10687	860.28	6.29	4996.48	699.01
Surface	2919	500-yr	13026	861.98	6.10	6206.46	721.33

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	2843	1-yr	236	847.59	2.02	117.07	31.67
Surface	2843	2-yr	881	851.13	3.35	491.64	310.25
Surface	2843	5-yr	2077	852.44	5.57	1023.29	505.29
Surface	2843	10-yr	3250	853.77	5.97	1834.50	660.46
Surface	2843	25-yr	5073	855.80	5.48	3219.94	704.84
Surface	2843	50-yr	6626	857.07	5.53	4133.34	728.68
Surface	2843	100-yr	8340	858.46	5.52	5159.42	759.82
Surface	2843	250-yr	10687	860.26	5.57	6596.91	830.74
Surface	2843	500-yr	13026	861.96	5.49	8048.86	870.11
Surface	2696	1-yr	236	846.76	6.06	38.94	12.41
Surface	2696	2-yr	881	850.27	6.82	214.50	215.56
Surface	2696	5-yr	2077	851.62	7.77	540.62	277.40
Surface	2696	10-yr	3250	853.37	6.60	1054.37	303.03
Surface	2696	25-yr	5073	855.37	6.63	1684.38	343.64
Surface	2696	50-yr	6626	856.62	6.91	2121.12	356.21
Surface	2696	100-yr	8340	858.00	7.07	2621.76	371.37
Surface	2696	250-yr	10687	859.80	7.20	3312.93	397.60
Surface	2696	500-yr	13026	861.51	7.27	4012.72	421.10
Surface	2531	1-yr	236	846.35	3.10	76.04	36.03
Surface	2531	2-yr	881	849.02	4.40	214.85	88.08
Surface	2531	5-yr	2077	851.11	6.01	468.73	135.48
Surface	2531	10-yr	3250	852.72	6.90	725.85	191.43
Surface	2531	25-yr	5073	854.77	7.40	1165.58	252.90
Surface	2531	50-yr	6626	855.97	7.99	1499.27	300.63
Surface	2531	100-yr	8340	857.42	8.11	1952.49	320.79
Surface	2531	250-yr	10687	859.29	8.25	2576.73	348.31
Surface	2531	500-yr	13026	861.05	8.33	3212.07	374.34
Surface	2409	1-yr	236	846.19	2.68	88.17	31.02
Surface	2409	2-yr	881	848.77	4.50	220.10	87.25
Surface	2409	5-yr	2077	850.79	6.28	451.27	132.81
Surface	2409	10-yr	3250	852.48	6.97	689.71	176.39
Surface	2409	25-yr	5073	854.43	7.88	1141.23	275.53
Surface	2409	50-yr	6626	855.60	8.57	1494.18	322.71
Surface	2409	100-yr	8340	857.15	8.52	2018.53	351.53
Surface	2409	250-yr	10687	859.13	8.40	2743.28	380.78
Surface	2409	500-yr	13026	860.92	8.43	3450.42	415.09
Surface	2293	1-yr	236	845.74	4.36	54.09	23.44
Surface	2293	2-yr	881	847.95	6.43	153.28	81.86
Surface	2293	5-yr	2077	849.14	9.96	253.24	86.38
Surface	2293	10-yr	3250	850.19	11.96	346.65	97.30
Surface	2293	25-yr	5073	851.82	13.33	531.07	128.49
Surface	2293	50-yr	6626	853.47	12.99	770.30	157.34
Surface	2293	100-yr	8340	855.22	12.79	1091.89	223.09
Surface	2293	250-yr	10687	858.22	10.65	1803.19	255.22
Surface	2293	500-yr	13026	860.22	10.24	2419.66	383.21

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	2186	1-yr	236	844.99	5.31	44.47	25.82
Surface	2186	2-yr	881	846.59	7.79	126.47	95.63
Surface	2186	5-yr	2077	848.20	9.57	320.62	129.00
Surface	2186	10-yr	3250	849.49	10.53	487.75	129.00
Surface	2186	25-yr	5073	851.39	11.40	732.42	129.00
Surface	2186	50-yr	6626	853.12	11.63	961.59	137.16
Surface	2186	100-yr	8340	854.89	11.94	1211.88	145.93
Surface	2186	250-yr	10687	857.08	12.43	1569.74	251.76
Surface	2186	500-yr	13026	858.79	12.93	2108.41	349.05
Surface	2091	1-yr	236	844.95	2.13	116.69	84.20
Surface	2091	2-yr	881	846.45	4.54	247.73	88.00
Surface	2091	5-yr	2077	847.87	7.53	372.88	88.00
Surface	2091	10-yr	3250	849.06	9.44	477.10	88.00
Surface	2091	25-yr	5073	850.51	11.86	604.60	88.00
Surface	2091	50-yr	6626	851.50	13.66	692.36	88.00
Surface	2091	100-yr	8340	852.49	15.41	781.63	98.65
Surface	2091	250-yr	10687	853.58	17.65	931.93	191.41
Surface	2091	500-yr	13026	855.01	18.54	1210.70	196.96
Surface	1959	1-yr	236	844.89	1.69	281.99	170.50
Surface	1959	2-yr	881	846.33	3.58	527.11	170.50
Surface	1959	5-yr	2077	847.70	5.94	761.39	170.50
Surface	1959	10-yr	3250	848.93	7.36	970.55	170.50
Surface	1959	25-yr	5073	850.47	9.11	1234.45	172.38
Surface	1959	50-yr	6626	851.58	10.33	1486.27	295.63
Surface	1959	100-yr	8340	852.75	11.22	1846.92	311.18
Surface	1959	250-yr	10687	854.13	12.24	2280.18	316.14
Surface	1959	500-yr	13026	855.36	13.12	2669.66	319.51
Surface	1845	1-yr	236	844.66	3.05	141.33	186.17
Surface	1845	2-yr	881	846.02	4.60	456.03	237.50
Surface	1845	5-yr	2077	847.37	6.43	776.47	240.09
Surface	1845	10-yr	3250	848.64	7.17	1096.41	276.58
Surface	1845	25-yr	5073	850.27	7.82	1733.78	468.02
Surface	1845	50-yr	6626	851.48	7.98	2302.95	471.35
Surface	1845	100-yr	8340	852.74	8.04	2899.90	474.67
Surface	1845	250-yr	10687	854.21	8.28	3598.07	478.53
Surface	1845	500-yr	13026	855.50	8.54	4218.82	481.93
Surface	1729	1-yr	236	843.58	5.67	54.53	76.32
Surface	1729	2-yr	881	845.05	7.08	314.83	302.68
Surface	1729	5-yr	2077	846.93	6.90	930.88	371.90
Surface	1729	10-yr	3250	848.32	7.12	1499.35	436.46
Surface	1729	25-yr	5073	850.04	7.41	2372.87	547.79
Surface	1729	50-yr	6626	851.27	7.75	3062.25	588.15
Surface	1729	100-yr	8340	852.56	7.96	3844.39	616.75
Surface	1729	250-yr	10687	854.05	8.14	4793.79	652.70
Surface	1729	500-yr	13026	855.36	8.40	5653.39	661.91

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	1573	1-yr	236	843.25	1.65	220.23	186.47
Surface	1573	2-yr	881	844.91	2.63	567.98	230.51
Surface	1573	5-yr	2077	846.76	3.68	1027.69	265.31
Surface	1573	10-yr	3250	848.14	4.35	1409.77	282.50
Surface	1573	25-yr	5073	849.84	5.13	1944.58	327.50
Surface	1573	50-yr	6626	851.05	5.70	2340.65	331.73
Surface	1573	100-yr	8340	852.25	6.23	2746.46	345.50
Surface	1573	250-yr	10687	853.62	6.95	3265.70	423.09
Surface	1573	500-yr	13026	854.81	7.57	3804.53	497.08
Surface	1419	1-yr	236	842.84	2.77	132.88	91.86
Surface	1419	2-yr	881	844.31	5.92	287.62	147.10
Surface	1419	5-yr	2077	845.82	8.57	548.83	179.51
Surface	1419	10-yr	3250	846.89	10.38	754.21	211.68
Surface	1419	25-yr	5073	848.08	12.78	1032.90	255.68
Surface	1419	50-yr	6626	848.95	14.27	1266.43	280.89
Surface	1419	100-yr	8340	850.03	15.13	1585.76	315.92
Surface	1419	250-yr	10687	850.98	16.85	1900.85	346.64
Surface	1419	500-yr	13026	851.88	18.17	2226.23	378.20
Surface	1284	1-yr	236	842.25	2.35	229.75	168.49
Surface	1284	2-yr	881	843.77	4.35	501.89	182.52
Surface	1284	5-yr	2077	845.24	6.75	775.82	196.98
Surface	1284	10-yr	3250	846.31	8.41	1003.15	226.83
Surface	1284	25-yr	5073	847.44	10.70	1275.34	253.86
Surface	1284	50-yr	6626	848.31	12.19	1503.35	274.46
Surface	1284	100-yr	8340	849.50	12.94	1845.19	298.30
Surface	1284	250-yr	10687	850.42	14.72	2127.10	313.07
Surface	1284	500-yr	13026	851.32	16.13	2414.58	327.73
Surface	1095	1-yr	236	840.46	5.99	53.56	69.39
Surface	1095	2-yr	881	841.78	8.29	215.20	187.30
Surface	1095	5-yr	2077	843.09	10.10	519.30	252.56
Surface	1095	10-yr	3250	843.84	11.91	710.58	257.15
Surface	1095	25-yr	5073	845.20	12.68	1066.43	264.92
Surface	1095	50-yr	6626	846.33	13.06	1368.90	273.23
Surface	1095	100-yr	8340	847.19	14.65	1634.21	325.19
Surface	1095	250-yr	10687	848.49	14.97	2063.44	331.61
Surface	1095	500-yr	13026	849.64	15.45	2447.51	337.25
Surface	947	1-yr	236	837.81	3.77	67.39	68.09
Surface	947	2-yr	881	838.94	6.46	148.31	74.46
Surface	947	5-yr	2077	840.13	9.59	240.00	80.79
Surface	947	10-yr	3250	841.05	11.57	316.82	88.25
Surface	947	25-yr	5073	842.70	12.57	535.22	182.52
Surface	947	50-yr	6626	843.80	13.28	756.52	215.87
Surface	947	100-yr	8340	844.90	13.99	1020.32	268.55
Surface	947	250-yr	10687	846.07	14.80	1356.60	300.88
Surface	947	500-yr	13026	846.96	15.79	1633.47	319.81

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	807	1-yr	236	836.20	5.33	97.55	122.23
Surface	807	2-yr	881	837.15	8.99	227.88	148.82
Surface	807	5-yr	2077	838.19	12.41	397.97	174.79
Surface	807	10-yr	3250	838.98	14.33	541.61	188.66
Surface	807	25-yr	5073	840.02	16.25	746.56	204.35
Surface	807	50-yr	6626	840.75	17.43	897.29	207.43
Surface	807	100-yr	8340	841.36	19.02	1023.48	208.69
Surface	807	250-yr	10687	842.22	20.47	1210.81	231.24
Surface	807	500-yr	13026	843.02	21.64	1402.50	251.82
Surface	654	1-yr	236	833.84	5.35	67.58	101.63
Surface	654	2-yr	881	834.98	7.81	258.71	220.77
Surface	654	5-yr	2077	835.96	9.70	490.97	253.77
Surface	654	10-yr	3250	836.71	10.81	686.14	266.78
Surface	654	25-yr	5073	837.44	12.94	884.10	269.18
Surface	654	50-yr	6626	837.96	14.49	1024.10	270.86
Surface	654	100-yr	8340	838.80	14.79	1253.00	273.59
Surface	654	250-yr	10687	839.07	17.87	1325.63	274.45
Surface	654	500-yr	13026	839.58	19.62	1466.79	276.12
Surface	571	1-yr	236	832.67	5.34	60.13	83.49
Surface	571	2-yr	881	834.08	6.97	279.11	260.48
Surface	571	5-yr	2077	834.89	9.49	505.16	297.59
Surface	571	10-yr	3250	835.48	11.13	690.36	345.75
Surface	571	25-yr	5073	836.18	12.90	942.88	371.12
Surface	571	50-yr	6626	836.66	14.26	1123.60	389.89
Surface	571	100-yr	8340	836.93	16.48	1232.81	405.54
Surface	571	250-yr	10687	837.86	16.33	1642.12	459.90
Surface	571	500-yr	13026	838.36	17.51	1876.03	468.81
Surface	480	1-yr	266	831.30	5.66	95.34	142.87
Surface	480	2-yr	922	832.19	8.44	248.95	227.07
Surface	480	5-yr	2139	833.27	9.34	590.78	371.20
Surface	480	10-yr	3332	833.73	11.00	761.32	373.30
Surface	480	25-yr	5190	834.31	12.92	978.52	375.96
Surface	480	50-yr	6774	834.71	14.34	1130.18	377.80
Surface	480	100-yr	8522	835.15	15.47	1295.95	379.81
Surface	480	250-yr	10914	835.67	16.86	1496.94	382.22
Surface	480	500-yr	13295	836.15	18.08	1679.76	384.41
Surface	405	1-yr	266	828.04	5.50	79.28	172.31
Surface	405	2-yr	922	828.71	8.59	209.06	217.95
Surface	405	5-yr	2139	829.50	9.61	464.59	396.05
Surface	405	10-yr	3332	830.00	10.50	678.03	440.28
Surface	405	25-yr	5190	830.55	12.02	926.44	469.61
Surface	405	50-yr	6774	830.96	12.78	1122.96	473.29
Surface	405	100-yr	8522	831.33	13.77	1296.18	475.54
Surface	405	250-yr	10914	831.76	15.05	1502.10	478.20
Surface	405	500-yr	13295	832.20	15.93	1713.16	480.91

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	298	1-yr	266	823.02	4.67	57.00	86.26
Surface	298	2-yr	922	823.87	6.41	155.75	150.28
Surface	298	5-yr	2139	824.82	8.31	321.87	198.58
Surface	298	10-yr	3332	825.56	9.46	483.88	241.16
Surface	298	25-yr	5190	826.53	10.63	744.98	294.93
Surface	298	50-yr	6774	827.15	11.69	957.12	390.71
Surface	298	100-yr	8522	828.27	11.30	1492.96	538.77
Surface	298	250-yr	10914	828.64	13.13	1694.33	550.16
Surface	298	500-yr	13295	829.90	12.03	2592.30	814.66
Surface	146	1-yr	266	808.00	1.12	237.62	49.49
Surface	146	2-yr	922	808.00	3.88	237.62	49.49
Surface	146	5-yr	2139	808.00	9.00	237.62	49.49
Surface	146	10-yr	3332	808.43	12.85	259.21	51.25
Surface	146	25-yr	5190	810.39	14.04	369.73	61.28
Surface	146	50-yr	6774	811.78	14.75	459.25	68.37
Surface	146	100-yr	8522	813.09	15.40	555.75	86.71
Surface	146	250-yr	10914	815.05	15.10	797.05	150.18
Surface	146	500-yr	13295	816.41	15.36	1068.16	224.47

Attachment 3 - Alternatives HEC-RAS Flow Load Points

Alternative 1		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	1031	2659	4328	6435	8421
J-11	11909.4	5	5	5	5	1186	2906	4689	6951	9098
J-10	9407.3	5	5	5	5	1120	2746	4452	6683	8848
J-09	7879.3	5	5	5	12	1172	2828	4570	6854	9074
J-04	6519.9	5	14	627	1194	2026	3397	5381	8041	10649
J-03	4847.2	5	127	792	1407	2314	3438	5440	8132	10784
J-02	3739.6	5	171	858	1492	2429	3406	5391	8068	10712
J-01	480.2	5	259	988	1663	2664	3550	5461	8169	10854

Alternative 2		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	1297	3174	5572	7819
J-11	11909.4	5	5	5	5	5	1464	3443	6000	8410
J-10	9407.3	5	5	5	5	78	1394	3252	5677	8023
J-09	7879.3	5	5	5	5	351	1452	3341	5812	8214
J-04	6519.9	5	5	511	1107	2006	2744	3959	6783	9562
J-03	4847.2	5	5	676	1320	2294	3095	4003	6851	9666
J-02	3739.6	5	5	742	1405	2409	3235	4164	6784	9581
J-01	480.2	5	61	872	1576	2644	3526	4514	6866	9695

Alternative 3		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	1881	4586	7111
J-11	11909.4	5	5	5	5	5	91	2075	4937	7621
J-10	9407.3	5	5	5	5	5	320	1906	4495	6984
J-09	7879.3	5	5	5	5	266	677	1972	4608	7143
J-04	6519.9	5	5	400	1004	1922	2711	3560	5370	8272
J-03	4847.2	5	5	565	1217	2210	3064	3975	5416	8344
J-02	3739.6	5	5	631	1302	2325	3203	4140	5438	8245
J-01	480.2	5	5	761	1472	2560	3493	4489	5870	8336

Attachment 3 - Alternatives HEC-RAS Flow Load Points

Alternative 4		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	202	2572	4957
J-11	11909.4	5	5	5	5	5	31	314	2804	5326
J-10	9407.3	5	5	5	5	5	260	584	2742	5159
J-09	7879.3	5	5	5	5	204	617	1046	2822	5280
J-04	6519.9	5	5	349	948	1860	2651	3533	4725	6149
J-03	4847.2	5	5	514	1161	2147	3003	3949	5236	6469
J-02	3739.6	5	5	580	1246	2262	3143	4114	5430	6686
J-01	480.2	5	5	710	1417	2497	3433	4463	5860	7203

Alternative 5		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	76	1491	3127	5317	9001
J-11	11909.4	5	5	5	5	180	1673	3403	5730	9017
J-10	9407.3	5	5	5	5	207	1684	3368	5661	8065
J-09	7879.3	5	5	5	5	248	1748	3463	5799	8270
J-04	6519.9	5	5	361	963	1827	2575	4142	6818	9691
J-03	4847.2	5	5	527	1177	2115	2926	4202	6905	9799
J-02	3739.6	5	5	592	1262	2230	3067	4192	6882	9706
J-01	480.2	5	5	722	1432	2465	3357	4356	6973	9828

Alternative 6		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	593	2220	4531	7782
J-11	11909.4	5	5	5	5	5	724	2439	4884	7684
J-10	9407.3	5	5	5	5	5	747	2422	4800	7112
J-09	7879.3	5	5	5	5	162	798	2498	4918	7284
J-04	6519.9	5	5	318	914	1817	2571	3412	5780	8511
J-03	4847.2	5	5	483	1127	2105	2922	3830	5854	8612
J-02	3739.6	5	5	549	1212	2220	3062	3997	5826	8562
J-01	480.2	5	5	679	1383	2455	3352	4347	5904	8670

Attachment 3 - Alternatives HEC-RAS Flow Load Points

Alternative 7		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	295	2302	4459
J-11	11909.4	5	5	5	5	5	5	412	2522	4801
J-10	9407.3	5	5	5	5	5	121	448	2545	4790
J-09	7879.3	5	5	5	5	70	477	881	2625	4906
J-04	6519.9	5	5	236	824	1726	2512	3369	4557	5764
J-03	4847.2	5	5	402	1037	2014	2864	3786	5068	6305
J-02	3739.6	5	5	467	1122	2129	3004	3951	5261	6522
J-01	480.2	5	5	597	1293	2364	3294	4300	5692	7039

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
146	813.1	810.6	810.6	809.7	809.7	809.6	809.6	809.6
298	828.3	826.7	826.7	826.2	826.2	826.1	826.1	826.1
405	831.3	830.7	830.7	830.4	830.4	830.3	830.3	830.3
480	835.2	834.4	834.4	834.1	834.1	834.1	834.1	834.0
571	836.9	836.3	836.3	835.8	835.8	835.8	835.8	835.8
654	838.8	837.6	837.6	837.1	837.1	837.2	837.1	837.0
807	841.4	840.2	840.2	839.5	839.5	839.5	839.4	839.4
947	844.9	842.9	842.9	841.9	841.9	841.9	841.8	841.7
1095	847.2	845.5	845.5	844.4	844.3	844.4	844.2	844.2
1284	849.5	847.6	847.6	847.0	847.0	847.0	846.9	846.9
1419	850.0	848.3	848.3	847.6	847.5	847.6	847.5	847.4
1573	852.3	850.1	850.1	849.0	849.0	849.1	848.9	848.9
1729	852.6	850.3	850.3	849.2	849.2	849.3	849.1	849.0
1845	852.7	850.5	850.5	849.5	849.5	849.5	849.4	849.3
1959	852.8	850.7	850.7	849.7	849.7	849.8	849.6	849.6
2091	852.5	850.7	850.7	849.8	849.8	849.9	849.7	849.7
2186	854.9	851.8	851.8	850.3	850.3	850.4	850.2	850.2
2293	855.2	852.2	852.2	851.0	851.0	851.1	850.9	850.8
2409	857.2	854.7	854.7	853.5	853.5	853.6	853.4	853.3
2531	857.4	855.1	855.1	853.8	853.8	853.9	853.7	853.6
2696	858.0	855.7	855.7	854.4	854.4	854.5	854.3	854.2
2843	858.5	856.1	856.1	854.8	854.8	854.9	854.7	854.6
2919	858.5	856.2	856.2	854.9	854.9	855.0	854.8	854.7
3078	858.6	856.3	856.3	855.2	855.1	855.2	855.0	855.0
3134	858.7	856.5	856.5	855.4	855.4	855.5	855.3	855.2
3184	859.0	856.8	856.8	855.7	855.7	855.8	855.5	855.5
3252	859.1	856.9	856.9	855.8	855.8	855.9	855.7	855.6
3309	859.2	857.1	857.1	856.0	855.9	856.0	855.8	855.8
3466	859.7	857.5	857.5	856.4	856.4	856.5	856.3	856.2
3540	859.7	857.6	857.6	856.5	856.4	856.5	856.3	856.3
3646	859.8	857.6	857.6	856.5	856.5	856.6	856.4	856.3
3740	860.0	857.8	857.8	856.7	856.7	856.8	856.6	856.5
3775	860.0	857.8	857.8	856.7	856.7	856.8	856.6	856.5
3885	860.0	857.9	857.9	856.8	856.7	856.8	856.6	856.6
3984	860.1	858.0	858.0	856.8	856.8	856.9	856.7	856.6
4127	860.2	858.0	858.0	856.9	856.9	857.0	856.8	856.7
4221	860.2	858.0	858.0	856.9	856.9	857.0	856.8	856.7
4264	860.2	858.0	858.0	856.9	856.9	857.0	856.8	856.7
4384	860.2	858.1	858.1	857.0	856.9	857.0	856.8	856.8
4516	860.2	858.1	858.1	856.9	856.9	857.0	856.8	856.8
4633	860.3	858.3	858.3	857.2	857.2	857.3	857.1	857.1
4737	861.1	859.0	859.0	857.8	857.7	857.9	857.6	857.6
4847	861.6	859.6	859.6	858.4	858.4	858.5	858.2	858.2
4951	861.6	859.6	859.6	858.4	858.4	858.6	858.3	858.2
5066	861.6	859.7	859.7	858.5	858.5	858.7	858.4	858.3
5215	862.2	860.2	860.2	859.0	858.9	859.2	858.8	858.8

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
5343	862.8	860.8	860.8	859.4	859.3	859.7	859.2	859.2
5469	863.0	861.0	861.0	859.5	859.5	859.9	859.4	859.3
5605	863.2	861.2	861.2	859.7	859.7	860.1	859.5	859.5
5718	863.4	861.3	861.3	859.8	859.8	860.3	859.7	859.6
5821	863.5	861.5	861.5	860.0	859.9	860.4	859.8	859.8
5925	863.6	861.6	861.6	860.1	860.1	860.5	859.9	859.9
6039	863.7	861.7	861.7	860.2	860.2	860.7	860.1	860.0
6158	863.9	861.9	861.9	860.4	860.4	860.8	860.3	860.2
6275	864.0	862.1	862.1	860.6	860.6	861.1	860.5	860.5
6390	864.2	862.3	862.3	860.8	860.8	861.3	860.7	860.7
6450	864.2	862.3	862.3	860.9	860.9	861.4	860.8	860.8
6520	864.1	862.2	862.2	861.0	861.0	861.4	860.9	860.9
6564	865.0	863.2	863.2	862.1	862.2	862.4	861.9	862.1
6620	865.3	863.7	863.7	862.3	862.3	862.8	862.2	862.1
6720	865.5	863.9	863.9	862.4	862.3	863.0	862.4	862.1
6822	865.7	864.1	864.1	862.6	862.3	863.3	862.7	862.2
6934	865.9	864.4	864.4	862.8	862.4	863.6	863.0	862.3
7051	866.6	865.5	865.5	863.6	862.9	864.7	864.0	862.7
7167	867.1	866.0	866.0	864.3	863.4	865.3	864.7	863.2
7293	868.2	867.1	867.1	865.1	864.1	866.3	865.5	863.8
7443	868.1	866.9	866.9	865.0	864.0	866.1	865.4	863.7
7551	868.9	868.3	868.3	866.3	865.2	867.5	866.8	864.9
7669	869.7	868.8	868.8	866.7	865.5	868.0	867.2	865.2
7767	869.7	868.9	868.9	866.7	865.5	868.0	867.3	865.2
7879	869.8	868.9	868.9	866.8	865.6	868.1	867.3	865.2
7939	870.1	869.1	869.1	867.0	866.0	868.3	867.5	865.8
8085	870.3	869.4	869.4	867.4	866.2	868.6	867.9	865.9
8173	871.2	870.1	870.1	867.8	866.2	869.3	868.5	865.9
8232	871.3	870.2	870.2	868.1	866.8	869.5	868.7	866.6
8291	872.2	871.0	871.0	868.5	866.9	870.1	869.2	866.7
8407	872.3	871.1	871.1	869.0	867.4	870.3	869.5	867.1
8525	872.5	871.4	871.4	869.6	867.8	870.7	870.0	867.5
8629	872.7	871.6	871.6	869.7	867.8	870.9	870.1	867.5
8697	872.9	871.9	871.9	869.9	868.1	871.1	870.4	867.8
8835	873.4	872.4	872.4	871.3	870.2	872.0	871.6	870.0
8987	874.5	874.0	874.0	872.5	871.1	873.5	872.9	870.8
9052	875.1	874.4	874.4	872.5	871.2	873.8	873.1	870.9
9116	876.3	875.4	875.4	873.6	871.8	874.7	874.0	871.3
9210	878.6	876.7	876.7	875.0	872.5	876.2	875.5	872.1
9288	880.4	879.4	879.4	876.6	874.1	878.2	877.2	873.5
9407	880.7	879.6	879.6	876.7	874.1	878.4	877.4	873.5
9580	881.0	879.8	879.8	876.9	874.2	878.7	877.6	873.6
9696	881.0	879.9	879.9	876.9	874.2	878.7	877.6	873.7
9769	881.2	880.0	880.0	877.0	874.3	878.8	877.7	873.8
9868	881.1	880.0	880.0	877.0	874.2	878.8	877.7	873.8
9967	881.5	880.3	880.3	877.5	874.5	879.1	878.1	874.5

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
10072	881.5	880.3	880.3	877.5	874.9	879.2	878.1	875.0
10175	881.6	880.4	880.4	877.8	876.0	879.3	878.3	876.2
10290	881.7	880.6	880.6	878.3	876.5	879.5	878.6	876.7
10376	881.8	880.8	880.8	878.9	877.1	879.8	879.1	877.3
10499	882.8	881.9	881.9	880.2	877.9	881.1	880.5	878.2
10603	883.1	882.3	882.3	880.5	878.2	881.5	880.8	878.4
10707	883.6	882.7	882.7	880.8	878.3	881.8	881.1	878.6
10815	883.8	882.9	882.9	881.0	878.4	882.0	881.3	878.7
10888	884.0	883.1	883.1	881.1	878.5	882.2	881.4	878.8
10934	884.1	883.2	883.2	881.2	878.6	882.3	881.5	878.9
11039	884.2	883.4	883.4	881.4	878.8	882.5	881.7	879.1
11148	884.0	883.2	883.2	881.5	878.9	882.4	881.8	879.2
11260	885.6	884.6	884.6	881.9	879.0	883.4	882.3	879.3
11370	885.7	884.7	884.7	882.2	879.1	883.7	882.7	879.5
11473	887.7	886.5	886.5	883.3	879.3	885.1	883.8	879.7
11577	887.8	886.6	886.6	883.3	879.4	885.2	883.9	879.8
11693	888.0	886.7	886.7	883.6	880.2	885.4	884.1	880.6
11744	888.3	887.1	887.1	883.9	880.4	885.7	884.4	880.8
11799	888.3	887.1	887.1	883.9	880.5	885.7	884.4	880.8
11853	888.5	887.2	887.2	884.0	880.6	885.8	884.5	880.9
11909	888.5	887.3	887.3	884.0	880.7	885.8	884.5	881.0
12010	888.5	887.2	887.2	884.0	881.3	885.7	884.5	881.5
12124	888.8	887.7	887.7	885.1	881.9	886.6	885.5	882.2
12219	888.7	887.6	887.6	885.2	882.4	886.6	885.6	882.8
12329	890.0	889.2	889.2	886.9	883.4	888.3	887.3	883.8
12440	890.1	889.3	889.3	887.0	883.7	888.4	887.5	884.1
12539	890.1	889.3	889.3	887.1	883.9	888.4	887.5	884.3
12649	890.1	889.4	889.4	887.1	884.1	888.4	887.5	884.5
12745	890.3	889.5	889.5	887.3	884.3	888.6	887.7	884.6
12873	889.7	889.1	889.1	887.3	885.1	888.3	887.6	885.2
12955	891.2	890.8	890.8	889.2	886.6	890.1	889.5	887.0
13069	892.8	892.2	892.2	890.5	887.9	891.5	890.8	888.2
13217	893.3	893.0	893.0	891.5	889.7	892.3	891.7	889.9
13295	894.7	894.3	894.3	893.1	891.4	893.8	893.3	891.5
13358	897.2	896.8	896.8	895.5	893.4	896.2	895.7	893.6
13384	898.2	897.8	897.8	896.5	893.9	897.3	896.8	894.2
13467	899.2	898.6	898.6	896.9	894.0	897.9	897.2	894.4
13526	899.3	898.6	898.6	897.0	894.1	897.9	897.2	894.5
13642	899.3	898.7	898.7	897.0	894.1	898.0	897.3	894.5
13763	899.4	898.8	898.8	897.0	894.2	898.0	897.3	894.5
13866	899.4	898.7	898.7	897.0	893.7	898.0	897.3	894.2
13970	899.4	898.7	898.7	897.0	894.0	898.0	897.3	894.4
14089	899.4	898.8	898.8	897.0	894.4	898.0	897.3	894.7
14199	899.4	898.8	898.8	897.1	894.5	898.0	897.4	894.8
14304	899.4	898.8	898.8	897.1	894.5	898.0	897.4	894.8
14408	899.4	898.8	898.8	897.2	894.8	898.1	897.4	895.1

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
14527	899.5	898.9	898.9	897.3	895.3	898.2	897.6	895.5
14610	899.5	898.9	898.9	897.3	895.4	898.2	897.6	895.6
14729	899.5	898.9	898.9	897.4	895.6	898.2	897.6	895.7
14829	899.5	898.9	898.9	897.2	895.2	898.1	897.5	895.4
14939	899.5	898.9	898.9	897.3	895.4	898.2	897.6	895.6
15054	899.5	898.9	898.9	897.4	896.0	898.2	897.7	896.1
15159	899.7	899.1	899.1	897.9	896.8	898.5	898.1	896.9
15261	899.7	899.2	899.2	898.0	897.0	898.6	898.2	897.1
15365	899.8	899.3	899.3	898.1	897.3	898.7	898.3	897.4

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
146	15.4	14.2	14.2	13.6	13.6	13.6	13.6	13.5
298	11.3	10.8	10.8	10.3	10.3	10.2	10.2	10.2
405	13.8	11.9	11.9	11.5	11.5	11.4	11.4	11.3
480	15.5	13.2	13.2	12.3	12.3	12.2	12.1	12.1
571	16.5	13.2	13.2	12.1	12.1	12.2	12.0	11.9
654	14.8	13.3	13.3	11.8	11.8	11.8	11.6	11.6
807	19.0	16.3	16.3	15.4	15.4	15.4	15.2	15.2
947	14.0	12.7	12.7	12.2	12.2	12.2	12.1	12.1
1095	14.7	12.7	12.7	12.8	12.9	13.0	12.9	12.9
1284	12.9	11.1	11.1	9.5	9.4	9.5	9.3	9.2
1419	15.1	13.1	13.1	11.6	11.5	11.6	11.3	11.3
1573	6.2	5.3	5.3	4.8	4.7	4.8	4.7	4.7
1729	8.0	7.5	7.5	7.3	7.3	7.3	7.3	7.2
1845	8.0	7.9	7.9	7.6	7.5	7.6	7.5	7.5
1959	11.2	9.4	9.4	8.3	8.2	8.3	8.1	8.1
2091	15.4	12.3	12.3	10.7	10.6	10.7	10.5	10.4
2186	11.9	11.4	11.4	11.2	11.2	11.3	11.1	11.1
2293	12.8	13.4	13.4	12.8	12.8	12.8	12.7	12.7
2409	8.5	8.0	8.0	7.5	7.5	7.5	7.4	7.4
2531	8.1	7.5	7.5	7.1	7.1	7.1	7.1	7.1
2696	7.1	6.7	6.7	6.5	6.5	6.5	6.5	6.5
2843	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7
2919	6.5	6.5	6.5	6.9	6.9	6.8	6.9	7.0
3078	7.9	8.0	8.0	7.8	7.8	7.9	7.7	7.7
3134	7.5	7.1	7.1	6.7	6.7	6.7	6.7	6.7
3184	7.3	7.4	7.4	7.4	7.4	7.4	7.5	7.5
3252	8.7	8.0	8.0	7.6	7.6	7.6	7.6	7.6
3309	8.4	7.6	7.6	7.2	7.2	7.3	7.2	7.2
3466	5.1	4.5	4.5	4.2	4.2	4.2	4.2	4.2
3540	5.8	5.2	5.2	5.0	5.0	5.0	4.9	4.9
3646	6.5	5.7	5.7	5.3	5.3	5.3	5.3	5.2
3740	3.5	3.1	3.1	2.8	2.8	2.8	2.8	2.8
3775	4.2	3.8	3.8	3.3	3.3	3.5	3.3	3.3
3885	5.1	4.7	4.7	4.3	4.3	4.5	4.3	4.2
3984	3.3	2.9	2.9	2.6	2.5	2.7	2.5	2.5
4127	3.2	2.8	2.8	2.4	2.4	2.5	2.4	2.4
4221	3.1	2.7	2.7	2.4	2.4	2.5	2.4	2.4
4264	4.4	4.1	4.1	3.5	3.5	3.7	3.5	3.5
4384	5.1	4.8	4.8	4.5	4.5	4.6	4.4	4.4
4516	9.2	9.1	9.1	8.5	8.5	8.8	8.4	8.4
4633	9.6	8.8	8.8	7.9	7.9	8.2	7.8	7.8
4737	7.7	7.4	7.4	7.1	7.1	7.3	7.1	7.1
4847	4.6	4.0	4.0	3.7	3.7	3.8	3.7	3.7
4951	6.1	5.7	5.7	4.9	4.8	5.5	4.8	4.8
5066	10.8	9.5	9.5	7.7	7.7	8.7	7.6	7.5
5215	10.5	9.1	9.1	7.2	7.2	8.0	7.1	7.1

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
5343	7.1	5.9	5.9	5.0	5.0	5.4	4.9	4.9
5469	7.5	6.6	6.6	5.6	5.6	6.1	5.5	5.5
5605	7.2	6.3	6.3	5.4	5.3	5.8	5.3	5.3
5718	6.5	5.8	5.8	5.2	5.1	5.5	5.1	5.1
5821	6.1	5.5	5.5	4.8	4.8	5.2	4.8	4.8
5925	6.2	5.5	5.5	5.1	5.1	5.3	5.0	5.0
6039	6.1	5.7	5.7	5.2	5.2	5.5	5.2	5.2
6158	6.3	6.2	6.2	5.6	5.6	6.0	5.6	5.6
6275	6.0	5.8	5.8	5.5	5.5	5.7	5.5	5.5
6390	4.7	4.6	4.6	4.7	4.7	4.7	4.7	4.7
6450	5.8	6.4	6.4	6.9	6.9	6.8	6.9	6.9
6520	10.4	10.1	10.1	9.1	9.1	9.5	9.0	8.9
6564	6.0	6.5	6.5	3.6	1.9	5.9	4.8	1.6
6620	6.0	4.9	4.9	3.1	1.7	4.8	4.1	1.5
6720	8.6	8.5	8.5	5.4	3.0	8.0	6.9	2.6
6822	6.6	6.1	6.1	3.7	2.1	5.5	4.6	1.9
6934	10.8	11.2	11.2	7.8	4.8	10.4	9.2	4.4
7051	9.1	8.8	8.8	7.3	5.7	8.5	8.0	5.5
7167	11.9	11.0	11.0	8.5	6.7	10.2	9.2	6.3
7293	4.4	3.8	3.8	2.7	2.1	3.4	3.0	2.0
7443	11.8	12.3	12.3	10.2	8.8	11.6	11.0	8.5
7551	8.5	7.0	7.0	5.4	4.1	6.6	5.9	3.9
7669	4.0	3.3	3.3	2.2	1.6	2.9	2.5	1.5
7767	6.1	5.1	5.1	3.7	3.0	4.6	4.0	2.7
7879	8.6	7.5	7.5	6.2	5.9	7.0	6.4	6.0
7939	7.6	6.9	6.9	5.6	2.6	6.6	6.0	2.2
8085	12.0	10.7	10.7	8.2	3.7	10.1	9.0	3.2
8173	9.2	8.8	8.8	7.8	6.2	8.6	7.7	6.2
8232	9.2	8.2	8.2	6.8	3.6	7.6	7.0	3.1
8291	6.2	6.0	6.0	6.8	4.9	6.0	6.4	4.3
8407	7.1	7.0	7.0	6.7	4.5	6.9	6.9	4.2
8525	7.9	7.0	7.0	4.5	2.5	6.1	5.2	2.1
8629	8.6	8.3	8.3	6.3	4.2	7.6	6.9	4.0
8697	8.2	7.6	7.6	5.9	4.5	7.0	6.4	4.3
8835	12.9	13.3	13.3	10.3	7.0	12.3	11.1	6.3
8987	8.2	6.7	6.7	4.5	2.7	5.8	5.0	2.5
9052	11.3	10.3	10.3	8.7	4.5	9.5	8.9	4.0
9116	7.9	7.3	7.3	6.5	5.7	6.9	6.8	5.4
9210	12.2	13.6	13.6	9.9	8.6	11.6	10.6	8.2
9288	6.0	5.2	5.2	3.7	2.2	5.0	4.3	2.0
9407	5.2	4.4	4.4	3.3	1.8	4.1	3.7	1.7
9580	4.1	3.8	3.8	3.1	1.3	3.4	3.1	2.3
9696	4.9	4.6	4.6	4.0	1.6	4.2	3.8	2.6
9769	3.3	3.0	3.0	2.5	1.1	2.7	2.5	1.7
9868	6.1	5.8	5.8	5.8	3.1	5.4	5.3	5.3
9967	2.9	2.7	2.7	2.3	1.3	2.4	2.3	1.6

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
10072	4.1	4.1	4.1	4.4	5.1	4.0	4.0	5.7
10175	5.0	4.8	4.8	5.0	2.6	4.7	4.7	2.9
10290	7.1	7.2	7.2	7.8	4.3	7.3	7.5	4.8
10376	11.7	11.5	11.5	9.9	5.3	11.2	10.4	5.7
10499	8.3	7.7	7.7	5.7	3.0	6.8	6.0	3.3
10603	8.3	7.6	7.6	5.7	3.0	6.8	6.0	3.2
10707	6.9	6.4	6.4	4.8	2.2	5.7	5.0	2.4
10815	7.0	6.7	6.7	5.4	2.6	6.1	5.6	2.9
10888	7.1	6.7	6.7	5.8	2.9	6.3	6.0	3.4
10934	7.4	7.0	7.0	6.0	3.2	6.6	6.2	3.6
11039	7.8	7.2	7.2	5.3	2.4	6.5	5.7	2.6
11148	12.5	11.4	11.4	7.7	2.6	9.9	8.5	3.0
11260	9.5	8.8	8.8	7.6	2.6	8.4	7.9	3.0
11370	12.1	10.9	10.9	7.7	2.9	9.6	8.3	3.3
11473	6.6	6.0	6.0	4.4	2.4	5.4	4.7	2.6
11577	7.5	6.9	6.9	5.8	5.1	6.5	6.0	5.4
11693	7.1	6.7	6.7	5.4	3.3	6.3	5.6	3.4
11744	5.1	4.8	4.8	3.7	2.0	4.4	3.9	2.2
11799	5.0	4.6	4.6	3.7	2.4	4.3	3.9	2.6
11853	4.1	3.9	3.9	3.5	2.7	3.7	3.5	2.8
11909	4.2	4.1	4.1	4.3	3.4	4.0	4.2	3.6
12010	6.7	7.2	7.2	7.8	3.5	7.8	7.8	4.2
12124	7.0	6.8	6.8	5.8	3.2	6.1	5.9	3.8
12219	10.9	11.5	11.5	10.3	6.0	11.1	10.6	6.1
12329	4.9	4.4	4.4	4.0	3.4	4.1	4.0	3.6
12440	4.4	4.1	4.1	3.2	2.3	3.6	3.3	2.6
12539	4.2	3.9	3.9	3.3	2.5	3.6	3.3	2.7
12649	5.2	5.0	5.0	4.5	2.0	4.7	4.7	2.3
12745	5.3	5.1	5.1	4.5	1.9	5.0	4.6	2.2
12873	10.3	9.5	9.5	7.4	4.2	8.5	7.7	4.8
12955	11.9	11.1	11.1	8.9	5.8	10.3	9.4	6.2
13069	7.2	6.7	6.7	5.5	2.7	6.1	5.7	2.9
13217	11.4	10.6	10.6	9.1	4.6	10.3	9.5	5.1
13295	10.1	9.3	9.3	7.6	4.1	8.5	7.7	4.6
13358	11.9	10.9	10.9	8.2	5.6	9.7	8.7	6.3
13384	8.5	7.6	7.6	4.9	2.6	6.4	5.4	2.9
13467	4.2	3.9	3.9	3.2	1.8	3.6	3.3	2.1
13526	3.4	3.2	3.2	2.4	1.2	2.8	2.5	1.4
13642	2.5	2.3	2.3	1.6	0.9	2.0	1.7	1.0
13763	1.7	1.5	1.5	0.9	0.2	1.2	1.0	0.2
13866	2.2	2.4	2.4	3.4	7.4	2.8	3.2	6.8
13970	2.4	2.8	2.8	3.8	7.3	3.2	3.6	6.6
14089	2.6	2.8	2.8	3.6	5.6	3.2	3.6	5.3
14199	2.5	2.8	2.8	3.8	5.9	3.2	3.6	5.6
14304	2.7	3.1	3.1	4.3	7.3	3.5	4.1	7.0
14408	2.7	3.0	3.0	4.2	6.7	3.5	4.0	6.4

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
14527	2.1	2.4	2.4	3.1	4.4	2.7	3.0	4.3
14610	2.2	2.4	2.4	3.2	4.6	2.8	3.1	4.5
14729	2.8	3.0	3.0	3.7	4.6	3.4	3.6	4.5
14829	4.1	4.5	4.5	5.9	8.2	5.1	5.7	8.0
14939	4.3	4.8	4.8	6.6	9.9	5.6	6.3	9.5
15054	5.0	5.6	5.6	7.4	9.3	6.3	7.1	9.3
15159	4.3	4.7	4.7	6.0	7.4	5.2	5.7	7.4
15261	4.5	4.9	4.9	6.4	8.0	5.6	6.1	8.0
15365	4.4	4.8	4.8	6.0	7.0	5.3	5.8	6.9

Attachment 5 - Alternatives HEC-RAS Flow Load Points Including Outlet B

Alternative 1		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	842	2468	4136	6241	8227
J-11	11909.4	5	5	5	5	996	2715	4496	6757	8904
J-10	9407.3	5	5	5	5	930	2555	4260	6489	8654
J-09	7879.3	5	5	5	12	983	2637	4378	6661	8879
J-04	6519.9	5	14	441	1008	1837	3206	5189	7847	10454
J-03	4847.2	5	127	607	1222	2125	3247	5248	7938	10590
J-02	3739.6	5	171	672	1306	2240	3215	5199	7875	10517
J-01	480.2	5	259	802	1477	2475	3359	5268	7975	10659

Alternative 2		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	1107	2983	5379	7625
J-11	11909.4	5	5	5	5	5	1274	3251	5807	8216
J-10	9407.3	5	5	5	5	5	1204	3061	5483	7829
J-09	7879.3	5	5	5	5	165	1262	3149	5619	8019
J-04	6519.9	5	5	325	921	1821	2555	3768	6590	9367
J-03	4847.2	5	5	491	1134	2109	2906	3812	6658	9471
J-02	3739.6	5	5	556	1219	2224	3046	3972	6591	9386
J-01	480.2	5	5	686	1390	2459	3336	4323	6673	9500

Alternative 3		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	1691	4394	6917
J-11	11909.4	5	5	5	5	5	4	1885	4744	7427
J-10	9407.3	5	5	5	5	5	135	1715	4303	6790
J-09	7879.3	5	5	5	5	5	491	1782	4416	6949
J-04	6519.9	5	5	214	818	1736	2526	3369	5178	8078
J-03	4847.2	5	5	380	1031	2024	2878	3784	5224	8150
J-02	3739.6	5	5	445	1116	2139	3018	3950	5246	8051
J-01	480.2	5	5	575	1287	2374	3308	4298	5678	8142

Attachment 5 - Alternatives HEC-RAS Flow Load Points Including Outlet B

Alternative 4		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	5	2381	4764
J-11	11909.4	5	5	5	5	5	5	5	2613	5133
J-10	9407.3	5	5	5	5	5	5	397	2551	4966
J-09	7879.3	5	5	5	5	5	431	859	2631	5087
J-04	6519.9	5	5	163	763	1674	2465	3345	4534	5956
J-03	4847.2	5	5	329	976	1962	2818	3761	5045	6276
J-02	3739.6	5	5	394	1061	2077	2957	3926	5239	6493
J-01	480.2	5	5	524	1231	2312	3248	4275	5669	7011

Alternative 5		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	1301	2935	5124	8806
J-11	11909.4	5	5	5	5	5	1483	3211	5537	8822
J-10	9407.3	5	5	5	5	5	1494	3177	5468	7870
J-09	7879.3	5	5	5	5	5	1558	3271	5606	8075
J-04	6519.9	5	5	176	778	1641	2386	3951	6625	9496
J-03	4847.2	5	5	341	991	1929	2736	4010	6712	9604
J-02	3739.6	5	5	407	1076	2044	2877	4001	6689	9511
J-01	480.2	5	5	537	1247	2279	3167	4165	6780	9633

Alternative 6		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	2030	4338	7588
J-11	11909.4	5	5	5	5	5	5	2248	4692	7490
J-10	9407.3	5	5	5	5	5	5	2231	4608	6918
J-09	7879.3	5	5	5	5	5	610	2307	4726	7090
J-04	6519.9	5	5	132	729	1632	2382	3222	5588	8317
J-03	4847.2	5	5	298	942	1920	2733	3639	5662	8418
J-02	3739.6	5	5	363	1027	2035	2873	3806	5633	8368
J-01	480.2	5	5	493	1197	2270	3163	4156	5712	8476

Attachment 5 - Alternatives HEC-RAS Flow Load Points Including Outlet B

Alternative 7		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	5	2111	4267
J-11	11909.4	5	5	5	5	5	5	5	2332	4608
J-10	9407.3	5	5	5	5	5	5	261	2354	4598
J-09	7879.3	5	5	5	5	5	292	693	2434	4714
J-04	6519.9	5	5	5	638	1541	2326	3182	4366	5572
J-03	4847.2	5	5	216	852	1828	2679	3598	4877	6112
J-02	3739.6	5	5	282	937	1943	2818	3763	5071	6330
J-01	480.2	5	5	412	1107	2178	3108	4112	5501	6847

The USACE Engineering Circular (EC) 2014-10 recommends consideration of meteorological projections developed by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the World Climate Research Programme's (WCRP's) Working Group on Coupled Modeling (WGCM). This study acknowledges the roles of these modeling groups in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy. 132 modeled results, which are part of the WCRP's Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset were retrieved in July 2015 and evaluated to consider 50-year projections of precipitation and temperature. The archive of these Bias Corrected and Downscaled WCRP CMIP3 Climate Projections is available at http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/.

The 132 modeled projections of daily maximum temperature and daily precipitation between years 1950-2099 were summarized as annual maximum daily data (Figure 1, Figure 5). The 132 modeled projections of daily minimum temperature between years 1950-2099 were summarized as annual minimum daily data (Figure 3). For each variable, the median, 25th and 75th percentiles were computed for each year to support data visualization.

Visual inspection of the data indicates a warming trend is projected throughout the 50-year planning window although significant variation exists. The projected temperature and precipitation changes between years 2017-2067 of the 132 models are summarized with histograms (Figure 2, Figure 4, and Figure 6) to explain their distributions and ranges of uncertainty. Table 1 summarizes the conclusions of the analysis.

Table 1: Pertinent Information for 132 WCRP CMIP3 Climate Projections in St. Joseph, MO

Variable	Average 50-year Projection	Maximum Range of Projected Change	Supporting Figures	Inferred conclusions that can be made
Annual Maximum Daily Temperature	3.3°F	-10.8°F to 13.3°F	Figure 1, Figure 2	Clear trend exists, large uncertainty
Annual Minimum Daily Temperature	5.2°F	-17.2°F to 32°F	Figure 3, Figure 4	Clear trend exists, large uncertainty
Annual Maximum Daily Rainfall	0.1 inch	-2.2 to 3.6 inches	Figure 5, Figure 6	Weak trend exists, large uncertainty

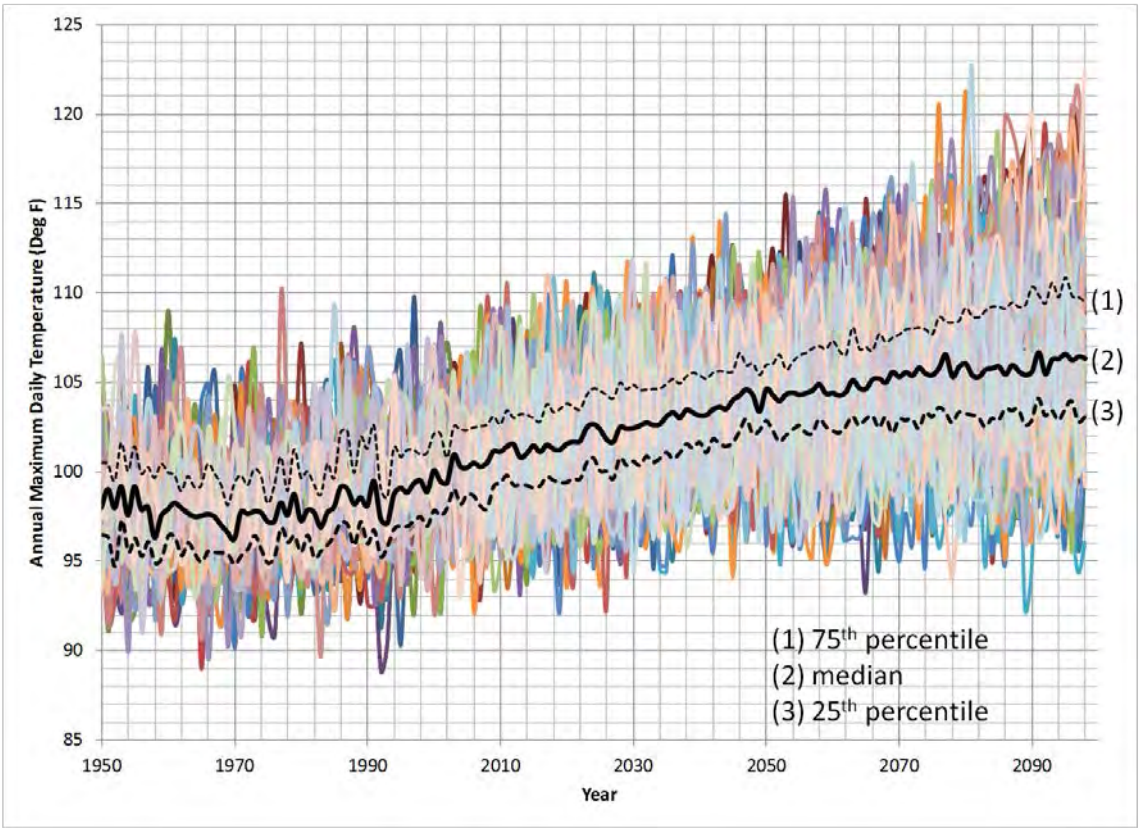
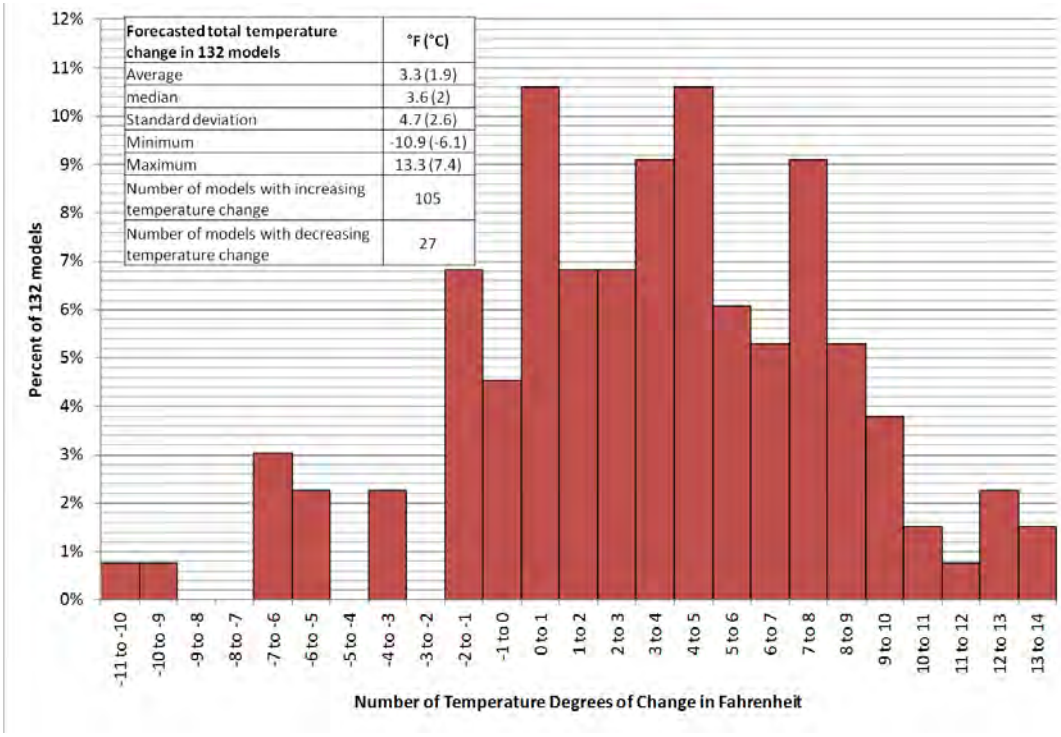


Figure 1: Annual maximum daily temperature projections of 132 models



Forecasted total temperature change in 132 models	°F (°C)
Average	3.3 (1.9)
median	3.6 (2)
Standard deviation	4.7 (2.6)
Minimum	-10.9 (-6.1)
Maximum	13.3 (7.4)
Number of models with increasing temperature change	105
Number of models with decreasing temperature change	27

Figure 2: Distribution of 132 projected changes in maximum daily temperature between 2017-2067

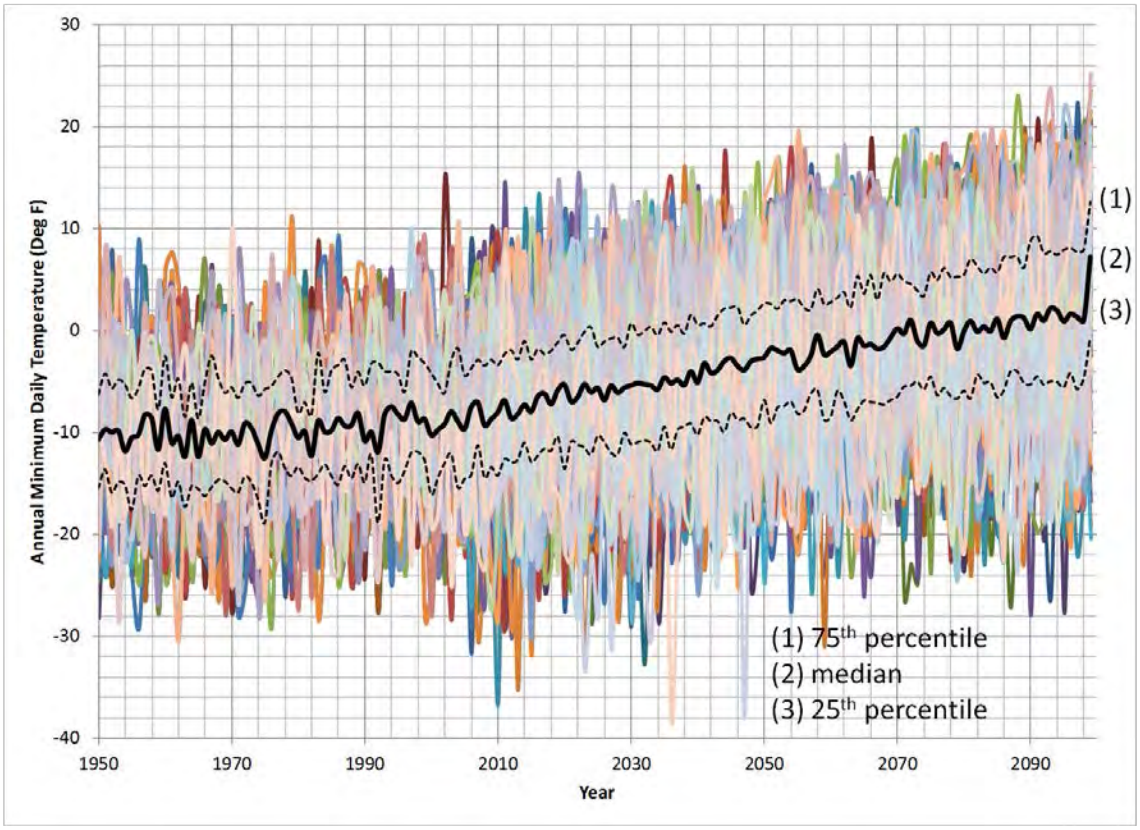
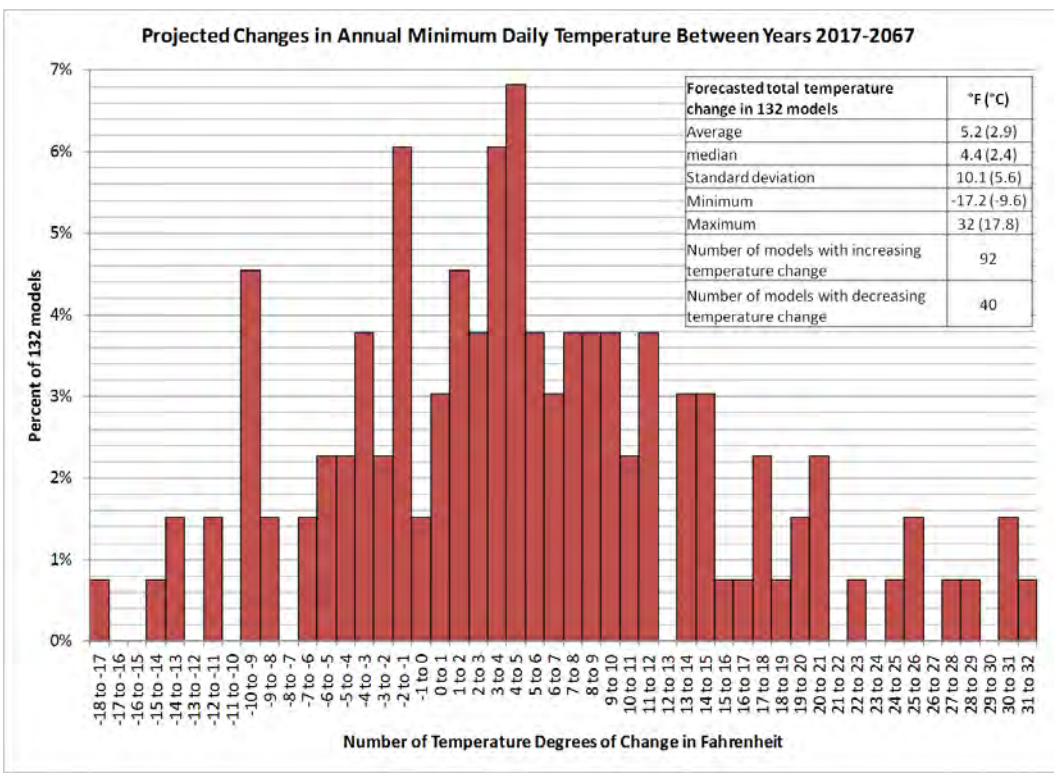


Figure 3: Annual minimum daily temperature projections of 132 models



Forecasted total temperature change in 132 models	°F (°C)
Average	5.2 (2.9)
median	4.4 (2.4)
Standard deviation	10.1 (5.6)
Minimum	-17.2 (-9.6)
Maximum	32 (17.8)
Number of models with increasing temperature change	92
Number of models with decreasing temperature change	40

Figure 4: Distribution of 132 projected changes in minimum daily temperature between 2017-2067

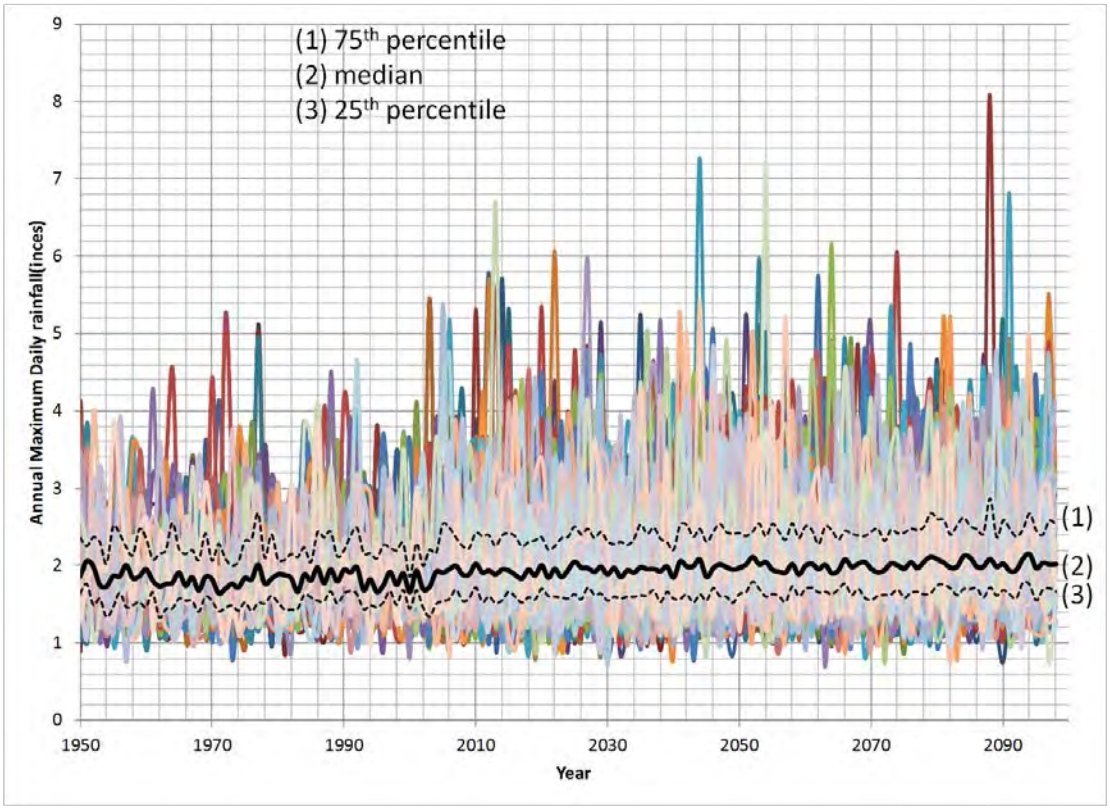
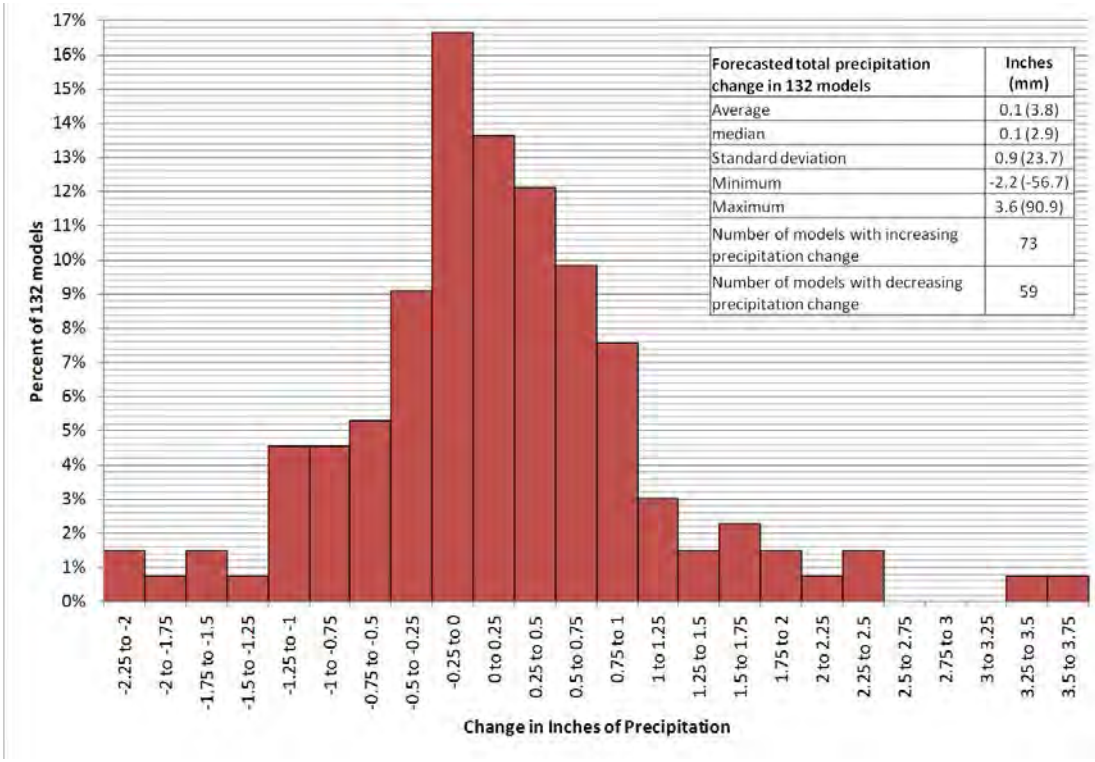


Figure 5: Annual maximum daily precipitation projections of 132 models



Forecasted total precipitation change in 132 models	Inches (mm)
Average	0.1 (3.8)
median	0.1 (2.9)
Standard deviation	0.9 (23.7)
Minimum	-2.2 (-56.7)
Maximum	3.6 (90.9)
Number of models with increasing precipitation change	73
Number of models with decreasing precipitation change	59

Figure 6: Distribution of 132 projected changes in maximum daily precipitation between 2017-2067