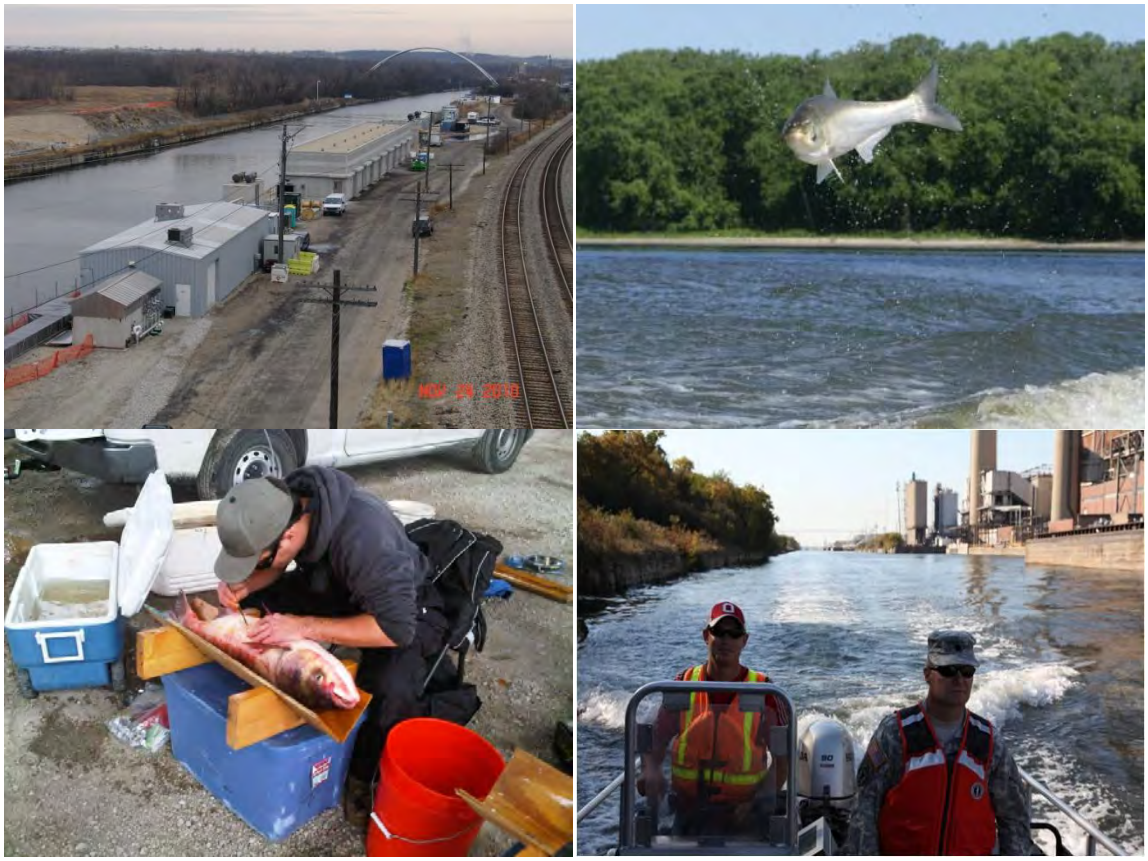
Dispersal Barrier Efficacy Study

Comprehensive Efficacy Study, Chicago Sanitary and Ship Canal Dispersal Barriers Risk Reduction Study and Integrated Environmental Assessment

Appendix A, Hydrology & Hydraulics



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OBJECTIVE

The purpose of this analysis is to find the locations where the Des Plaines River may overflow into the Chicago Sanitary and Ship Canal (CSSC), creating a pathway to bypass the fish barrier. Hydraulic models of the Des Plaines River were used to examine the locations and magnitudes of overflow at various flood frequencies. The analysis consisted of four parts: compare FIS profiles to the available HEC-2 model; use the hydraulic model to assess the impact of debris at Romeoville Road on Des Plaines River flood stages; incorporate overflow potential into the hydraulic model; and determine the impact a levee that prevents overflow would have on Des Plaines River flood stages.

PROJECT AREA DESCRIPTION

The Des Plaines River is located in northeast Illinois. It originates in Racine County in southern Wisconsin and flows in a general southerly direction to its confluence with Salt Creek in Riverside, Illinois. It then flows southwesterly to its confluence with the CSSC near Lockport, Illinois. The present analysis is concerned with a portion of this reach that flows to the southwest because in this area the Des Plaines River flows parallel and adjacent to the CSSC, and the two waterways are separated by a strip of land only a few hundred feet across. The drainage area of the Des Plaines River upstream of Lockport is 705 square miles. The watershed is aligned primarily along a north-south axis with a length of 82 miles and an average width of about 9 miles. Between Lockport and Riverside, the reach of the Des Plaines River modeled in this analysis, the average slope of the river is 1.9 ft/mi (USACE 1999). There are two USGS gages located near the study area: one just downstream of Hoffman Dam in Riverside and the other at Romeoville Road. The gage at Riverside has been operating since 1943 and the gage at Romeoville has been in operation since 2008.

The strip of land between the Des Plaines River and CSSC accommodates industrial plants, navigation facilities and recreational bike trails. It can be accessed through small access roads. There were two large spoil banks, mostly consisting of the debris left from the canal construction, which existed on this strip of land near Romeoville. These spoil banks functioned as a levee that prevented the Des Plaines River water from overflowing to the CSSC. The spoil banks were removed in the 1990s, and overflows into the CSSC have been observed several times since then, most recently in May 2008. The water surface elevation on the CSSC is mainly controlled by the Lockport Lock and Dam. The stage on the Des Plaines River can significantly rise during flood events, but the stage on the CSSC will rise by a much lesser degree due to canal operations. Canal drawdown at the Lockport Lock and Dam and Controlling works allows more flood water to pass through the canal.

DATA

Flood Insurance Studies

Water surface profiles were obtained from the Flood Insurance Studies (FIS) for Cook and Will Counties. The profiles were based on hydraulic modeling performed in 1976 and 1977 using

HEC-2. In Cook County, the peak discharges were based on discharge-drainage area-frequency plots for USGS gages in the region. The hydraulic model contained 12 surveyed cross sections, labeled from "A" to "L." In Will County, the peak discharges were based on a Log-Pearson (III) flow frequency analysis at a USGS gage in Lockport, IL with 7 years of record. The hydraulic model contained 16 surveyed cross sections, labeled from "BG" to BV."

Hydraulic Model

An HEC-2 model for the lower Des Plaines River was obtained from the Illinois State Water Survey (ISWS). This model was created in 1991 using the FIS model, and cross sections were extended and added. The peak discharges were adjusted as well. The model extends from River Mile 17.84, which is about two miles downstream of 9th Street, to River Mile 44.49, which is the crest of Hoffman Dam. It contains flows for 8 storm events. Comparing the magnitude of the peak flows to the flows in a hydraulic model for the Upper Des Plaines River, the storm events were confirmed to represent the 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods.

Comments in the HEC-2 input file note that the FIS cross sections for Will County are included in the updated model, and some of them have been extended. Other comments note that 1980 land use was figured into the peak discharges and that new cross sections were obtained from "the Pittsburg model." More recent comments from the ISWS noted that since the HEC-2 model was completed in 1991, a portion of the model near Romeoville Road is no longer applicable because it was superseded by a 1995 CLOMR. The Chicago District requested hydraulic models relating to the CLOMR from FEMA, but they were unavailable.

Topography

LIDAR data was available for Cook, DuPage, and Will Counties. A digital elevation model (DEM) was created for the project area in order to obtain elevation data for the overbank areas. A survey was performed for the Chicago District in October 2009 in order to obtain new cross sections. Points were also taken at structures that were to be included in the hydraulic model.

Gage Measurements

There are two USGS streamflow gages on the Des Plaines River in the study area, at Riverside and Romeoville. The Riverside gage (05532500) is located at River Mile 44.3, just downstream of Hoffman Dam. It records both flow and stage, and it has been recording data since 1943. The contributing drainage area at Riverside is 630 mi^2. The Romeoville gage (05534000) is located at River Mile 23.4, on the downstream face of Romeoville Rd. It records stage only, and it has been recording data since 2008. The contributing drainage area at Romeoville is 696 mi^2. The locations of the two streamflow gages are marked on Plate A-1.

Three precipitation gages are located in the study area and are shown on Plate A-1. Two of the raingages are from the 25-gage network used for Lake Michigan Diversion Accounting

(Westcott 2007) and are called Gage 11 and Gage 15. The third raingage is a NOAA station in Romeoville. Gage 11 is located in La Grange and Gage 15 is located in Lemont at St. Mary's Seminary. The entire 25-raingage grid is shown on Plate A-2. This gage network has been collecting data since 1989. The Romeoville raingage (COOP ID 117457) is located at the Lewis University Airport, and it has been collecting data since 1997.

HYDROLOGIC MODEL DEVELOPMENT

A hydrologic model of the Des Plaines River watershed between Riverside and Romeoville was developed using HEC-HMS. This program is a product of the USACE Hydrologic Engineering Center, and it simulates the surface-runoff response of a watershed to precipitation.

An HEC-HMS model has three parts – basin model, meteorology, and control specifications. The basin model includes parameters for subbasin delineation, curve numbers, unit hydrograph descriptors time of concentration and storage coefficient, base flow, and parameters for routing calculations. The meteorology portion includes time-series data of measured precipitation at rain gages or synthetic storms. The control specifications define the duration of the simulation as well as the date and time for the models that include measured rainfall. The derivation of the basin model and meteorological parameters are summarized in the following paragraphs. This section also includes discussion on calibration and simulation of synthetic precipitation.

Basin Model

Basin Delineation

The subbasin delineation was determined based on topographic data obtained from LiDAR. The larger basin was cut based on USGS delineations, with a buffer added. The subbasins were delineated using ArcHydro Tools version 1.4 (Beta) in ArcMap version 9.3. Both Plate A-1 and Plate A-3 shows the subbasin delineation of the project area; Plate A-3 is a detailed HEC-HMS schematic that shows other features of the basin model such as routing reaches. The drainage areas are included in Table 1, located after the Baseflow section of this report. The subbasin sizes ranged from 0.28 mi^2 to 6.32 mi^2.

Curve Numbers

Losses due to infiltration were represented with curve numbers, computed in GIS using the method described in TR-55 (NRCS 1986). The curve number method was developed to represent the effects of soil type, land use, and antecedent moisture conditions on a basin's capacity for infiltration. Land use data came from the Northeastern Illinois Planning Commission (NIPC), and was from the year 2005. The soil types were obtained from the NRCS STATSGO database. The soil moisture conditions were assumed to be AMC II. The curve numbers computed for each subbasin are included in Table 1; they ranged from 77.7 to 86.9.

Unit Hydrograph

The unit hydrograph is a method used to transform excess rainfall into a runoff hydrograph. This project utilized the Clark unit hydrograph (Clark 1943), which is based on models of watershed storage. The parameters used in HEC-HMS to describe the Clark unit hydrograph for each subbasin are the time of concentration, T_c, and a storage coefficient, R. The method described in USGS WRI-00-4184 (Straub et al. 2000) was used to compute these parameters as a function of flowpath length and slope. The time of concentration and storage coefficient computed for each subbasin are included in Table 1.

Baseflow

Baseflow is the discharge in a stream during non-rainy periods. Baseflow parameters were estimated through analysis of streamflow gage records for the Upper Des Plaines Flood Damage Reduction Study (USACE 1999). The baseflow parameters were taken from the HEC-1 model developed in that study and applied in HEC-HMS to the corresponding locations in the watershed. The baseflow parameters are included in Table 1.

Table 1. HEC-HMS Basin Model Summary.

Stream	Basin	Area (mi^2)	CN	Clark UH		Baseflow	
				Tc (hr)	R (hr)	Initial Q (cfs/mi^2)	Recession (ratio-to-peak)
Des Plaines	DP1	1.67	84.9	4.78	15.09	0.2	0.78
	DP2	4.36	86.9	4.37	3.13	0.2	0.78
	DP3	5.09	82.1	7.08	6.85	0.2	0.78
Flag Creek	FL1	6.32	82.8	5.39	3.31	0.92	0.78
	FL2	5.42	82.3	2.31	2.19	0.92	0.78
	FL3	4.34	82.9	3.33	2.37	0.92	0.78
	FL4	3.26	82.3	2.76	1.77	0.92	0.78
	FL5	1.20	80.0	1.68	1.21	0.92	0.78
Des Plaines	DP4	1.55	82.0	1.83	1.06	0.92	0.78
	DP5	1.91	78.9	2.18	1.39	0.92	0.78
Sawmill Creek	WARD	4.65	82.0	3.58	2.43	1.4	0.44
	SM1	5.20	84.2	2.24	2.54	1.4	0.44
	SM2	2.19	84.0	2.10	1.48	1.4	0.44
	SM3	0.28	79.9	0.94	0.49	1.4	0.44
Des Plaines	DP6	1.33	77.7	1.17	0.64	1.4	0.44
	DP7	1.62	78.8	2.43	1.16	1.4	0.44
Black Partridge	BLP	3.62	81.6	2.60	1.54	1.4	0.44
Des Plaines	DP8	5.91	81.7	5.07	2.53	1.4	0.44
	DP9	3.63	82.8	2.05	2.29	1.4	0.44
	DP10	4.58	78.6	4.76	2.98	1.4	0.44
	DP11	0.65	82.4	1.96	1.27	1.4	0.44

Routing

The HEC-HMS model was paired with an unsteady-state HEC-RAS model. This means that the flow routing for the Des Plaines River was performed by HEC-RAS. Routing reaches on the tributaries to the Lower Des Plaines River included in this study, Flag Creek and Sawmill Creek, were taken from an HEC-1 model developed for the Upper Des Plaines Flood Damage Reduction Study (USACE 1999). The Muskingum-Cunge method was used, and the parameters are summarized in Table 2.

Table 2. Muskingum-Cunge Routing Parameters for Flag and Sawmill Creeks.

Stream	Reach	Length (ft)	Manning's n			Slope	Invert Elev (ft)
			LOB	Channel	ROB		
Flag	RF1	12,800	0.09	0.055	0.09	0.002	608
	RF2	11,600	0.09	0.055	0.09	0.002	598
	RF3	1,300	0.09	0.055	0.09	0.002	598
Sawmill	RS1	7,800	0.08	0.055	0.08	0.008	646.5
	RS2	6,700	0.09	0.055	0.09	0.005	593.5

The energy slope, Manning's n, and 8-point cross sections were taken from the HEC-1 model. Channel lengths were adjusted to conform to the new subbasin delineation using GIS.

Other Discharges

The flow at the Riverside gage was added as a source at the upstream end of the model.

Combined sewer overflows (CSOs) located near the head of the study area were simulated for both synthetic and actual events using TNET, a program that simulates the Chicago Tunnel and Reservoir Plan's (TARP) deep tunnel network. The TNET model was run for the period of record that contained the selected calibration events, which occurred in Water Years 2008 and 2009. The TNET model is calibrated every year, but sufficient data for calibration to 2008 values was not available at the time of analysis. The 2007 calibration was used.

The HEC-1 model developed in USACE (1999) included diversions from Flag Creek and the Des Plaines River to TARP. These diversions were also included in the HEC-HMS model at the same approximate locations in the model. The diversion was computed by HEC-HMS as a function of inflow.

These other discharges and diversions are shown in Plate A-3.

Meteorology

The meteorology model used raingage measurements during calibration runs and synthetic storm events during the simulation runs. For the calibration runs, Thiessen polygons were constructed

by hand for the three raingages. Gage weights were determined based on the area of each subbasin contained within each Thiessen polygon. More information on the synthetic events is included in the Simulation of Synthetic Events paragraph below.

Calibration

In order to calibrate the models, several storm events were selected from the period of record from the precipitation gages. Initially, events were selected based upon their relatively large peak intensity and relative isolation from other events. These events were finally narrowed down to five events – three amongst the largest peaks and two more moderate – based upon temporal consistency between the data sets of the two precipitation gages. The selected events are summarized in Table 3. Some of the events had small gaps in the data sets. These were filled by using the equation for a best-fit polynomial fit to the data adjacent to the gap. This allowed for a reasonably smooth and continuous data set.

Table 3. Storm Events Selected for Calibration.

Date	Rainfall Depth (in)		
	Gage 11	Gage 15	Romeoville
September 4, 2008	2.7	3.0	2.7
September 12-14, 2008	5.5	6.4	6.1
December 8-9, 2008	1.0	1.0	1.1
December 26-27, 2008	1.6	2.1	1.8
July 24, 2010	4.6	3.6	0.55

The HEC-HMS and unsteady HEC-RAS models were calibrated simultaneously. Parameters in the hydrologic model were not adjusted during calibration. It was found that adjusting only the Manning's n values in the hydraulic model sufficiently calibrated the model based on flow and stage. The hydraulic model calibration is discussed further in the Hydraulic Model Development section.

Simulation of Synthetic Events

Rainfall amounts and storm distributions for synthetic events were taken from USACE (1999). Eight events were analyzed: 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods. A 10-day duration storm event was used; the earlier study determined it to be the critical duration for the Upper Des Plaines River for all analyzed frequency events in terms of peak flows and volumes. Rainfall amounts were obtained from the isohyetals in Bulletin 70 (Huff 1989), and distributions were derived from Circular 173 (Huff 1990). Point precipitation values were initially adjusted to areal mean values using data in Bulletion 70 and Circular 176 (Huff 1993). Further adjustments were made to the synthetic precipitation during final calibration of the modeling developed for USACE (1999). The point rainfall depths for the eight synthetic storms used in this analysis are listed in Table 4.

Table 4. Point Precipitation Amounts for Synthetic Storm Events.

Return Period (yr)	1	2	5	10	25	50	100	500
Point Precip (in)	3.26	4.15	4.85	5.51	6.84	7.50	8.82	12.50

Discharge hydrographs at CSOs were modeled using a version of TNET developed for Lake Michigan Diversion Accounting. The hydrographs were developed using CSO data from the Downtown Flooding Study (AECOM 2010). The Downtown Flooding study had developed discharges using the TNET model for 20-, 50-, 100-, and 500-year events, but discharges for the 1-, 2-, 5-, and 10-year events were also required. The 20- through 500-year events were plotted on probability paper and used to extrapolate the peak discharges for the smaller events. The forms of the previously developed hydrographs were compared and, once their consistency had been confirmed, scaled as necessary to develop a distribution for the smaller return period events.

HYDRAULIC MODEL DEVELOPMENT

The hydraulic analysis of the Lower Des Plaines River was performed using HEC-RAS. HEC-RAS is an application developed by the USACE Hydrologic Engineering Center (HEC) to perform one-dimensional hydraulic analysis. A steady-state model was developed first using existing cross-section geometry and topographic data, and then new survey data was used to create an unsteady-state model. This section describes the development of both the steady and unsteady HEC-RAS models.

HEC-RAS require three categories of input data: physical characteristics of the stream, discharge data, and boundary conditions. The physical characteristics include the geometry of cross sections and structures, reach lengths, and surface roughness. The discharge data used in this study were peak flows computed by HEC-1 or HEC-HMS at various locations in the watershed. Steady-state models require boundary conditions at the downstream end, and the upstream end if supercritical flow occurs. Unsteady-state models require boundary conditions and initial conditions. The physical characteristics and boundary conditions are described further in the following paragraphs.

Steady Model Development

Geometry

The cross sectional geometry was obtained from the 1991 HEC-2 model. Each scenario in the steady-state hydraulic analysis added information to the geometric data. The HEC-2 Import scenario took the geometry as-is from HEC-2, making the minor adjustments to the bridge data necessary for successful simulation in HEC-RAS. For the Modified Existing scenario, LIDAR data was used to extend some cross sections in order to fully contain the flow on the right overbank. A lateral weir was added to the left overbank to allow the Des Plaines River to overflow. The elevation of the lateral weir was pulled from the LIDAR data, along the alignment of the proposed barrier project.

Channel Roughness

Channel roughness, represented by Manning's n, was taken from the 1991 HEC-2 model. The assigned roughness values ranged from 0.035 to 0.05 in the channel and from 0.06 to 0.12 in overbank areas.

Flows

The 1991 HEC-2 model contained flows for 8 storm events. They are not identical to the flows in the 1976 FIS. Comparing the magnitude of the peak flows to the flows in a hydraulic model for the Upper Des Plaines River, the storm events were confirmed to represent the 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods.

Table 5 below shows the difference in modeled discharges between the FIS and the HEC-2 Import scenario. The flows in the more recent HEC-2 model are higher than the FIS. The flows in the HEC-2 Import model were developed at least 15 years later than the FIS, and the increased period of record makes the recent discharges more reliable.

Table 5. Comparison of Peak Flows, HEC-2 Import to FIS.

River Mile	Location	Peak Discharge (cfs)				Source
		10-yr	50-yr	100-yr	500-yr	
44.49		6,292	8,415	9,079	10,821	HEC-2
43.25	Ogden Ave	5,923	7,363	7,895	8,990	Cook FIS
42.11	47th St	5,930	7,370	7,900	9,000	Cook FIS
41.98		6,254	8,394	9,063	10,793	HEC-2
40.80	I-55	6,000	7,500	8,400	9,300	Cook FIS
30.25		6,382	8,781	9,534	11,179	HEC-2
26.80	Will-Cook Co. Line	6,060	7,800	9,000	10,000	Will FIS

Boundary Conditions

The downstream boundary condition was a rating curve taken directly from the FIS model. It represented normal pool at Brandon Dam, at River Mile 17.84. The model was run assuming subcritical flow throughout, so no upstream boundary condition was required.

Calibration

The steady-state hydraulic model runs were not calibrated. The HEC-RAS model results were compared to the published FIS; this model run constitutes the HEC-2 Import scenario described in the Hydraulic Analysis section of this report.

Unsteady Model Development

Geometry

Cross sections were developed using data from both the field and LiDAR surveys. Overbank areas of the cross sections were cut from a TIN developed from the LiDAR data. Where available, points from the field survey were used to define the channel of each cross section. When this was not possible, channel data was interpolated from the nearest bounding surveyed channel points.

Data for the structures was extracted from the original HEC-2 model, survey field notes, LiDAR data and photos. Bridges with low chords sufficiently high to not conceivably interfere with flow were not included in the model.

Along the length where flow exchange between the Des Plaines River and CSSC were considered, the high point of the land separating the two was assumed to be the point of overflow. The left overbank of each cross section was extended or truncated so that the 0.0 station of each cross section corresponded to the high point. This collection of high points was modeled as a lateral weir.

Flows

Flow information was entered into the unsteady HEC-RAS model using a combination of data from the HEC-2 model and the recently developed HEC-HMS output. HEC-2 data was used at the top of the Lower Des Plaines reach to account for the flows from the upstream portion of the river. Lateral inflows for the study area were taken from the HEC-HMS model. Inflows from tributaries, combined sewer overflow and point discharges were entered as lateral inflow hydrographs; subbasin runoff was distributed to multiple cross sections using uniform lateral inflows.

Boundary Conditions

The downstream boundary condition was a rating curve. It was developed by iteration: the rating curve was set and HEC-RAS was run. The model results at Romeoville Rd were compared to the USGS rating curve, and the downstream boundary condition was adjusted until the computed rating curve converged with the USGS curve. The upstream boundary condition accounts for flows at Riverside downstream of Huffman Dam. The upstream boundary condition was taken from the HEC-1 hydrology associated with the “Upper Des Plaines River Flood Damage Reduction Study” created in June 1999.

Calibration

Model calibration was performed in reference to the five previously mentioned storm events. Due to limited gage data throughout the project area, calibration was performed by comparing observed stage data at the Riverside and Romeoville gages to the calculated stages produced by the HEC-RAS unsteady model. Peak stage calibration was within 0.4 feet for moderate storm events and within 0.27 feet for severe events. In general, the hydrograph shapes and peak flows compared well to the observed data, however peak timings were off by up to 14 hours. See Plates A5-A9 for hydrograph comparisons. Table 6 below shows a summary of stage comparisons for each calibration event.

Table 6: Peak of Stage Comparsion of Calibration Events

Storm	Gage @ Riverside Peak (feet)	Model @ Riverside (feet)	Gage @ Romeoville (feet)	Model @ Romeoville (feet)	Riverside Difference (gage – model)	Romeoville Difference (gage – model)
Sept 4, 2008	600.00	599.70	583.23	583.60	+0.3	-0.37
Sept 12-14, 2008	604.27	604.54	585.12	585.30	-0.27	-0.18
Dec 8-9, 2008	599.31	598.99	582.66	583.06	0.32	-0.4
Dec 26-27, 2008	602.33	602.41	584.55	584.66	-0.08	-0.11
July 24, 2010	603.63	603.76	584.86	585.07	-0.13	-0.21

HYDRAULIC ANALYSIS

Steady State Analysis

Five scenarios were simulated in HEC-RAS. The HEC-2 Import scenario was used to compare the 1991 HEC-2 model to the FIS data that used the 1976 model. The Debris at Romeoville scenario incorporated debris at two of the bridge's openings. The Modified Existing scenario extended cross sections further into overbank areas and included the path as a lateral weir to allow for overflow from the Des Plaines to the CSSC. The Proposed Berm scenario raised the path such that no water was allowed to overflow it. The Fence-Barricade Combination scenario represented the recommended plan to use a combination of concrete barricades and chain-link fence to allow some overflow while blocking fish.

HEC-2 Import Scenario

The purpose of the HEC-2 Import scenario was to compare results from the available hydraulic model to the regulatory flood profiles. First, the HEC-2 model was imported into HEC-RAS. Minor adjustments were made to the bridge widths to make the data compatible with HEC-RAS.

This scenario used the peak discharges in the HEC-2 model, although it was noted that they did not match the published FIS flows.

Debris at Romeoville Road Scenario

The purpose of the Debris at Romeoville Road scenario was to assess whether debris blockages at this bridge would have a significant impact to the water surface profile. Romeoville Road, also called East 135th Street, goes over (from west to east) the Des Plaines River, the CSSC, and the I&M Canal. At this bridge, the Des Plaines River is split into four distinct channels by islands, including Isle A La Cache. At least two of the channels have had some degree of blockage by trees and vegetation. Based on recent observations, the eastern-most channel (Opening 1) is completely closed off by a debris jam, and the third channel from the east (Opening 3) has a significant blockage.

The debris jam was modeled by two methods in HEC-RAS: 1) floating debris caught on bridge piers, and 2) blocked obstructions in the channel. Floating debris is a better representation of a debris jam, while the blocked obstruction is a worst-case scenario. It was assumed that Opening 1 was 100% blocked and that Opening 3 was 30% blocked. This was modeled in the floating debris method by setting the height of the debris pile in Openings 1 and 3 to be equal to 100% and 30% of the bridge opening height, respectively. The blocked obstruction method set the blockage equal to that depth.

Modified Existing Scenario

The purpose of the Modified Existing scenario was to incorporate the potential for the Des Plaines River to overflow its left bank. The cross sections in the HEC-2 model generally did not extend far past the left bank station, and the modeled water surface profiles were higher than the highest left overbank station. HEC-2 and HEC-RAS both deal with missing overbank data by extending the cross section vertically at the last station to the elevation of the computed water surface. Also, the HEC-2 model does not model lateral outflows.

First the cross sections in the HEC-2 Import geometry file were extended. Cross sections were cut through the DEM for the overbank areas using ArcMap. Since LIDAR does not capture bathymetry, the points from the HEC-2 model were used to represent the stream channel. Then, a lateral weir was added to the left overbank to allow for overflow. A path runs close to the left bank of the Des Plaines River, and this was selected as the location of the proposed berm project. The lateral weir was located along this path, and the elevation of the weir was obtained from the DEM. The Des Plaines River is the focus of this analysis, so the lateral weir was configured such that overflows simply left the system. A weir coefficient of 1.0 was used, lowered from the default value of 2.6 to account for vegetation along the left bank that could impede flow.

Solid Wall Scenario

The purpose of the Solid Wall scenario was to model the impact to the Des Plaines River if the path on the left overbank were raised such that overflows were no longer possible. This was accomplished by raising the height of the lateral weir on the left overbank high enough to prevent overflows during all floods, including the 500-year event.

Fence-Barricade Combination Scenario

The purpose of the Fence-Barricade scenario was to model a combination of concrete barriers and chain-link fence on the left overbank of the Des Plaines River. The selected chain-link fence opening was 0.25 inches. This scenario allows for some overflow of water while preventing fish passage. This alternative was modeled in HEC-RAS by estimating the average head loss through the chain-link fence based on the length and depth of overflow as well as a loss coefficient for trash-rack losses from USBR (1987). The estimated head loss was computed to be 0.16 ft, and it was applied to the lateral weir as added height, to slightly impede the flow.

Lockport Prairie Impacts

The purpose of the Lockport Prairie scenario was to model the impacts of the existing fence-barrier combination vs. the solid wall scenario on the Lockport Prairie. The prairie is located along the west bank of the Des Plaines River between W. 9th street and the Lockport Powerhouse and is considered an environmentally sensitive area. The modeling was accomplished by creating a steady state model for the prairie area using Will County LIDAR and field survey data for cross section development. Due to the area being just downstream of the end of the HEC-RAS unsteady model, flows from the unsteady model were input at the upstream boundary condition in the steady state model. Generally, water surface elevations in the prairie were raised approximately 1.0 ft with the solid wall scenario. See Plate A-4 for flooding impacts.

<u>Unsteady State Analysis</u>

Three scenarios were modeled using the unsteady flow feature in HEC-RAS: Existing conditions, Fence-Barrier combination, and Solid wall. The existing conditions scenario depicts the water surface elevations in the Lower Des Plaines River with no restrictions in place to prevent flow into the Chicago Sanitary and Ship Canal. The Fence-Barricade scenario models a combination of Jersey barrier and one-quarter inch mesh fence along potential overflow areas between LDPR and the CSSC, and the Solid Wall scenario models water surface profiles in a hypothetical situation where all overflow areas are completely blocked by an impermeable wall.

Existing Conditions Scenario

The existing conditions scenario was necessary to model the Lower Des Plaines River in its current condition with no flow impediments along the overflow area. This scenario used the lateral weir option in HEC-RAS to simulate the overflow in the CSSC. The elevations of the

lateral weir were taken from a combination of LiDAR data and field survey along the bike path (highest ground elevation) adjacent to the east bank of the Lower Des Plaines river.

Solid Wall Scenario

The purpose of the Solid Wall scenario was to model the impact to the Des Plaines River if the path on the left overbank were raised such that overflows were no longer possible. This was accomplished by raising the height of the lateral weir on the left overbank high enough to prevent overflows during all floods, including the 500-year event.
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Fence-Barricade Combination Scenario

The purpose of the Fence-Barricade scenario was to model a combination of concrete barriers and chain-link fence on the left overbank of the Des Plaines River. The selected chain-link fence opening was 0.25 inches. This scenario allows for some overflow of water while preventing fish passage. This alternative was modeled in HEC-RAS by estimating the average head loss through the chain-link fence based on the length and depth of overflow as well as a loss coefficient for trash-rack losses from USBR (1987). The estimated head loss was computed to be 0.16 ft, and it was applied to the lateral weir as added height, to slightly impede the flow.

RESULTS

Steady State Analysis

HEC-2 Import Scenario

Figure 1 compares the Cook and Will County FIS flood profiles for the 100-year event to the HEC-2 model imported into HEC-RAS. In Will County, the FIS profile is about 0.5 ft higher than the HEC-RAS results. In Cook County, the FIS profile is about 1 ft lower than the HEC-RAS results. There is some uncertainty in the stationing of the FIS data in Cook County: for example, LaGrange Road was located at River Mile 35.05 in the FIS data set while the HEC-RAS model places it at River Mile 37.25. The difference may be due to the fact that the FIS data were plucked from a paper map and tables. Future work includes confirmation and possible adjustment of the stationing of the FIS data for better comparison with the HEC-RAS modeling.

Table 5 in the Steady Model Development section above showed the difference in modeled discharges between the FIS and the HEC-2 Import scenario. Given that the HEC-2 Import uses higher peak discharges, it makes sense that the flood stages were higher in Cook County.

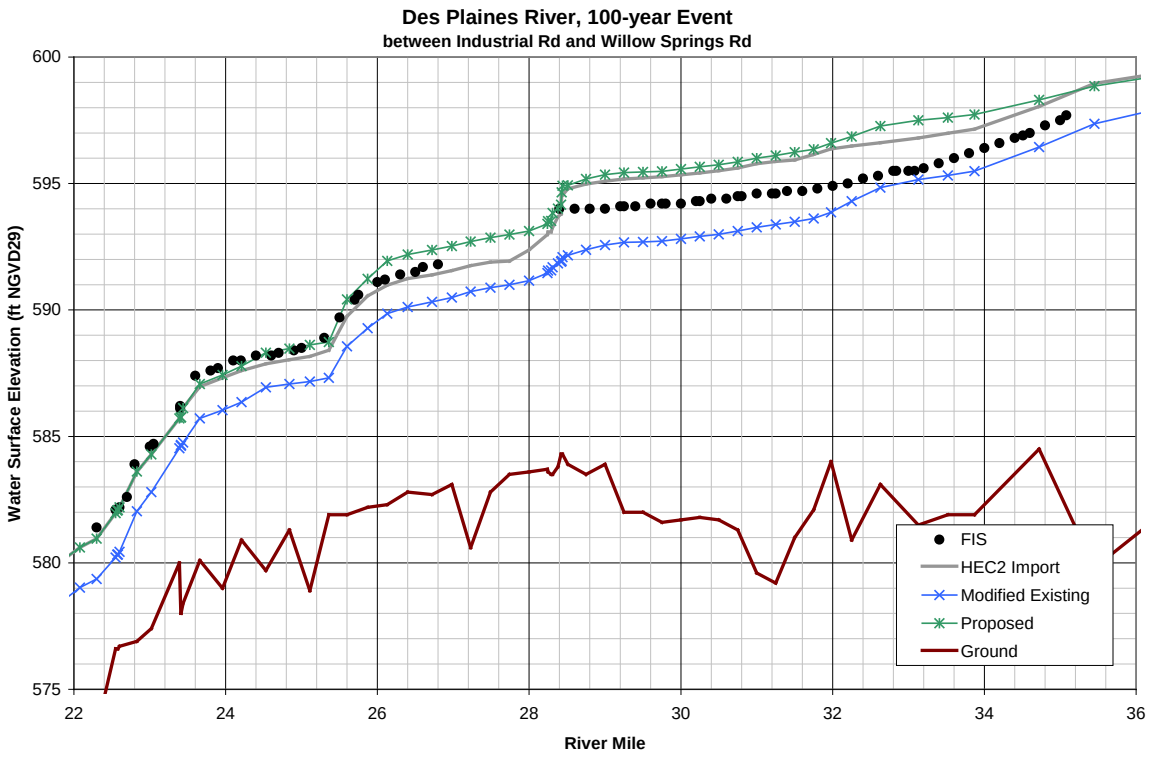

Figure 1 - Comparison of Cook and Will County FIS flood profiles for the 100-year event to the HEC-2 model imported into HEC-RAS

Debris at Romeoville Road Scenario

Figure 2 shows the computed stage increases upstream of Romeoville Road for the floating-debris method, and Figure 3 displays the results from the blocked-obstruction method.

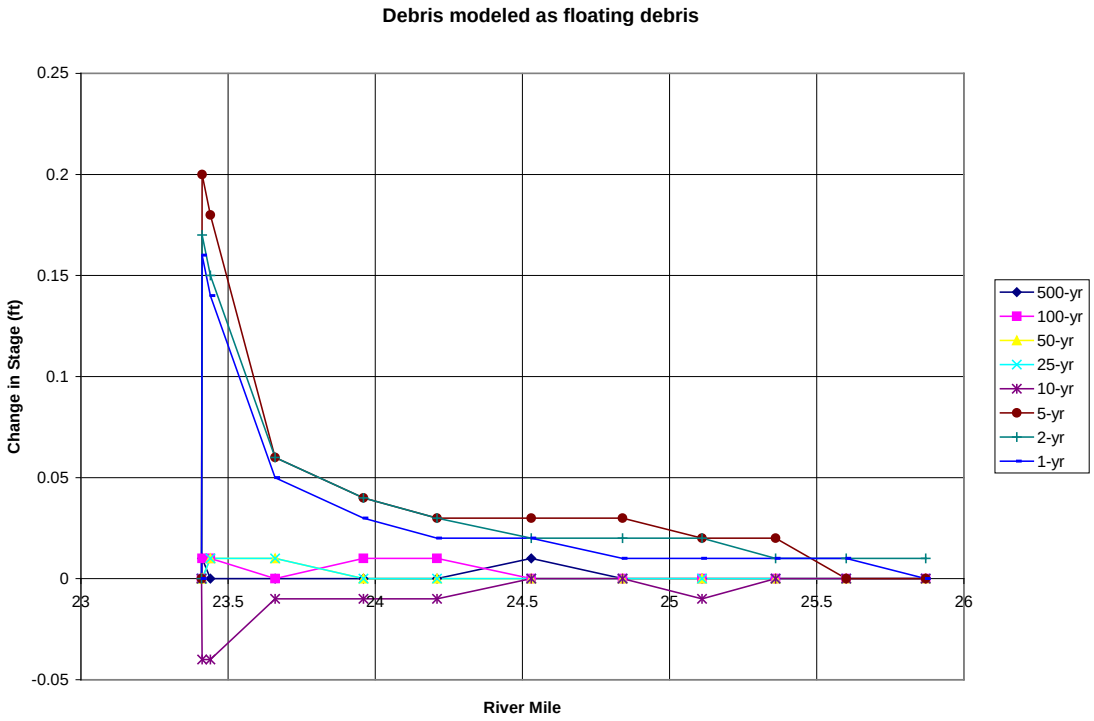

Figure 2 - Stage Increases Upstream of Romeoville Road Due to Debris Jam (Modeled as Floating Debris in HEC-RAS)

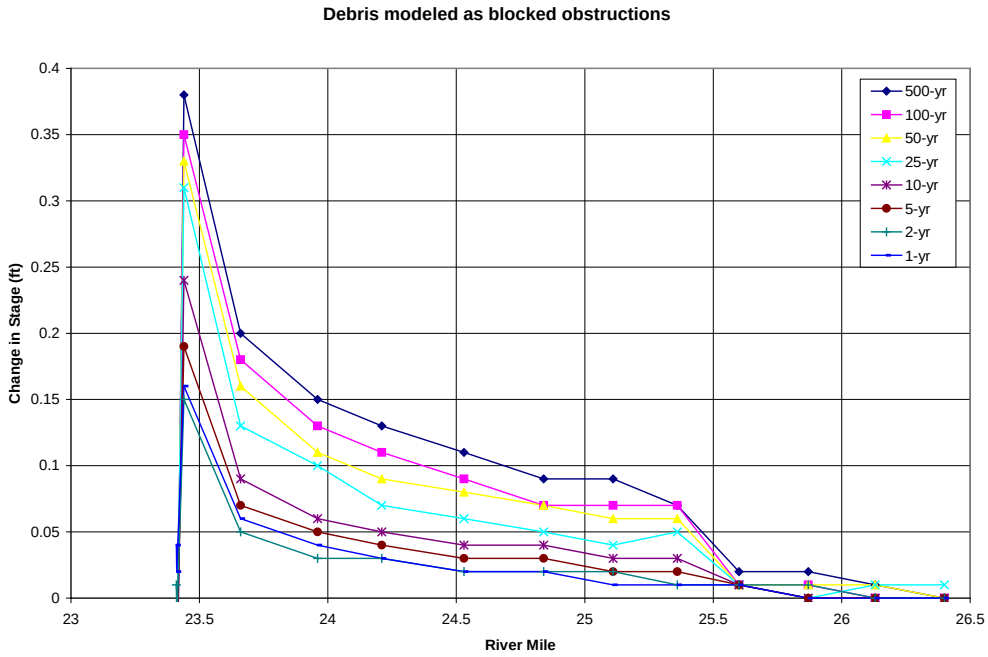

Figure 3 - Stage Increases Upstream of Romeoville Road Due to Debris Jam (Modeled as Blocked Obstructions in HEC-RAS)

Using the floating debris method, the without-debris and with-debris profiles converged about 2.5 miles upstream of the bridge. The 1-, 2-, and 5-year profiles are affected the most, but the stage increase fell below 0.05 ft within a half-mile of the bridge.

Using the blocked obstruction method had a greater impact on the water surface profiles, as expected. The larger storm events were affected more than smaller events. For the 100-year storm, the water surface was 0.35 ft higher just upstream of the bridge, and the stage increase went below 0.05 ft after about 2 miles. For all storms, the without-debris and with-debris profiles converged about 3 miles upstream of the bridge.

Modified Existing Scenario

Figure 4 is a plot of the left-bank path modeled as a lateral weir along with four water-surface profiles: the 1-, 5-, 25-, and 100-year events. This shows that there are two locations where overflows occur during smaller events: just upstream of IL-83 and about halfway between IL-83 and Willow Springs Road. There is another low spot between Lemont Road and IL-83 at which overflows occur during larger events.

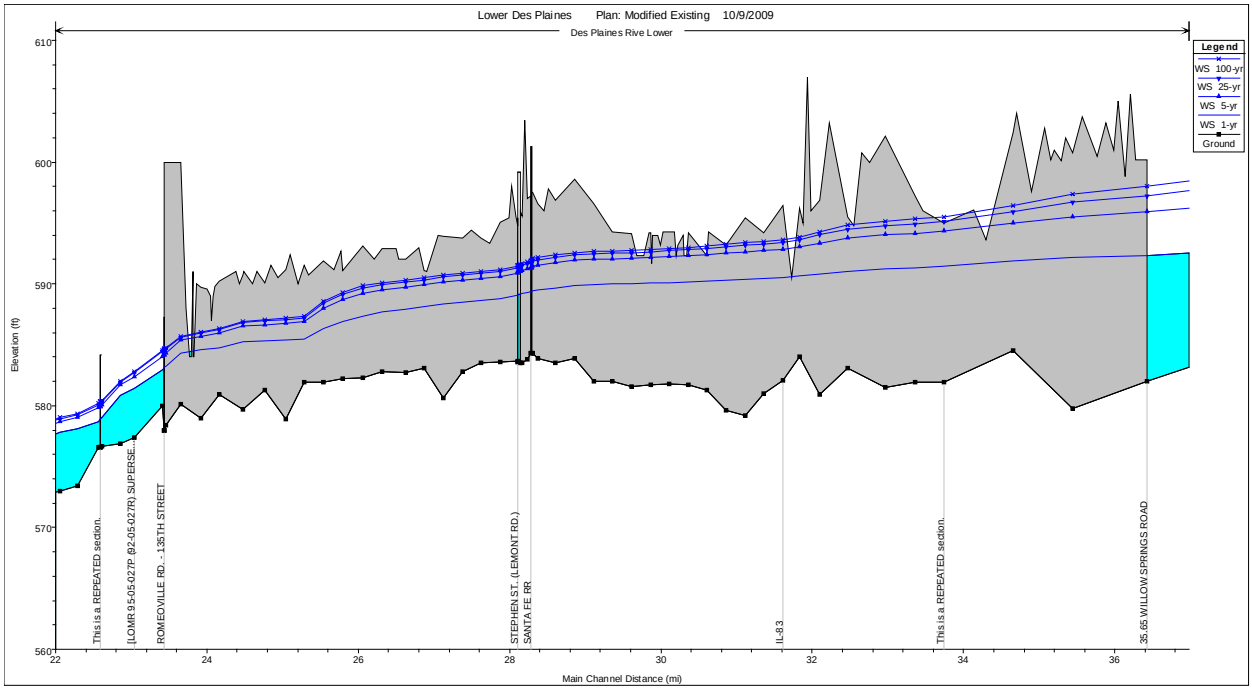

Figure 4 - Water Surface Profiles of the Modified Existing Model along with the Topo of a Left Bank Path

Figures 5 through 9 show the flow in the river under two conditions, with and without overflow. Where the lower line drops off is where overflows occur. These figures illustrate that overflows occur during storms as frequent as the 2-year event, and that nearly half of the flow during a 100-year event leaves the Des Plaines by flowing over the path. With that much water leaving the system, the water surface profiles in the Modified Existing scenario were lower than the HEC-2 Import scenario, with a maximum difference of about 2.5 ft in the 100-year storm.

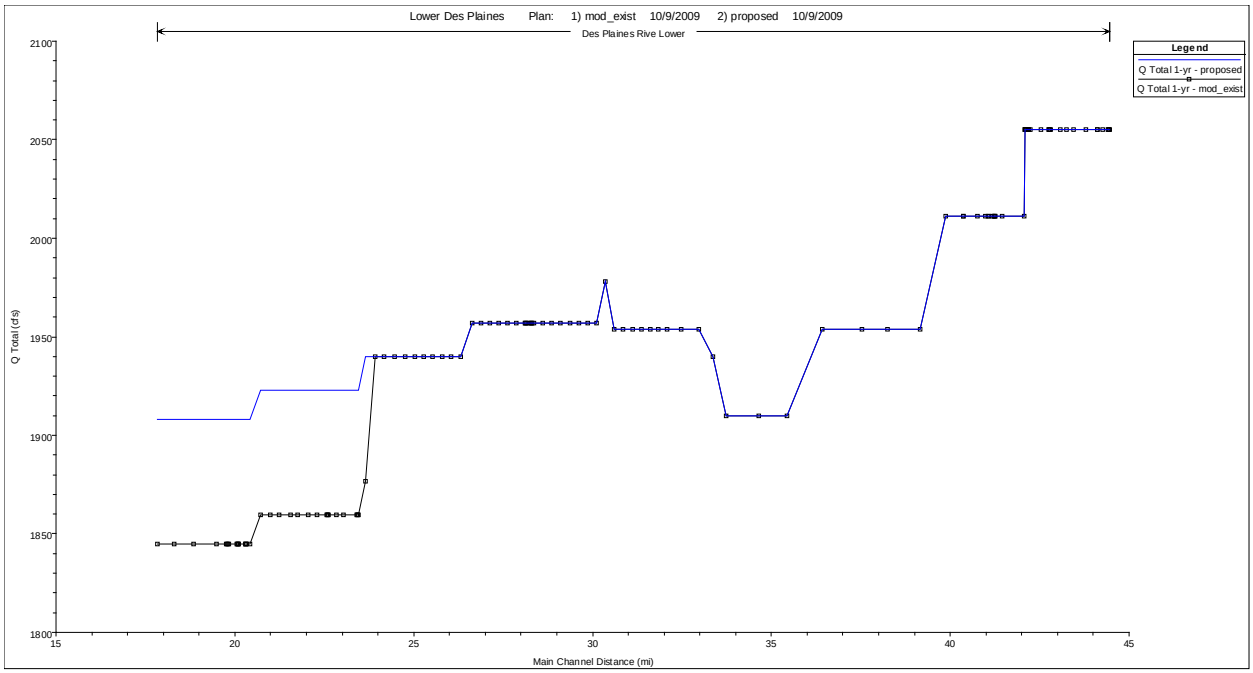

Figure 5 – Comparison of Total Flows with and without Proposed Berm for the 1-year Event

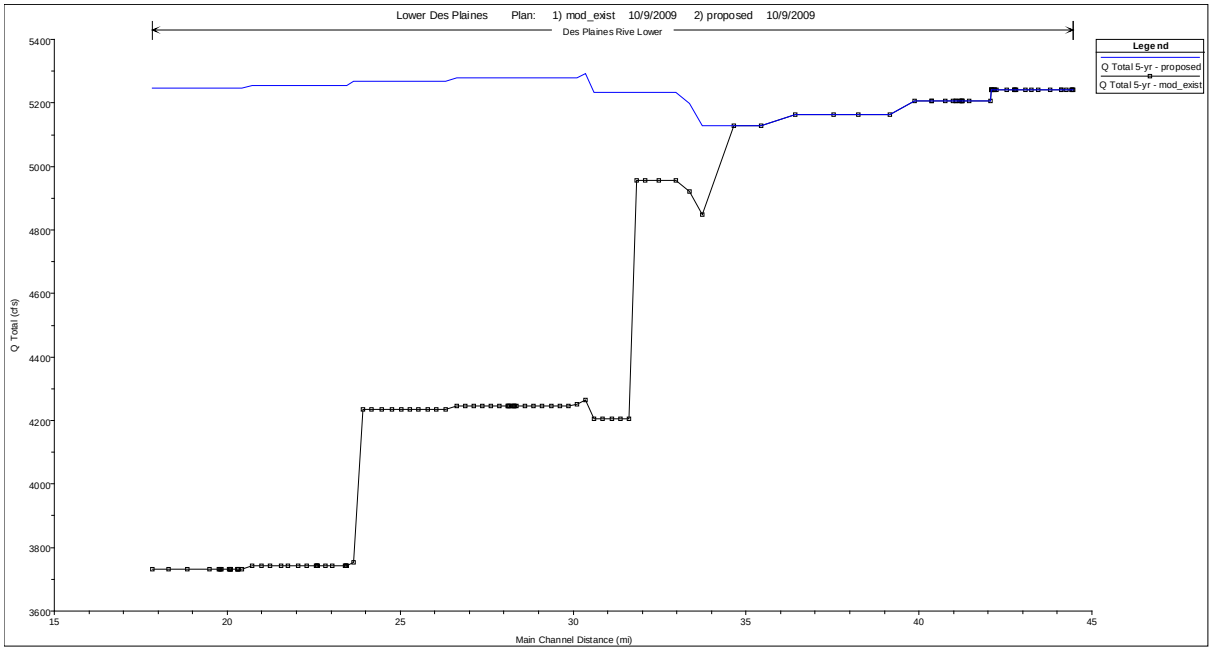

Figure 6 - Comparison of Total Flows with and without Proposed Berm for the 5-year Event.

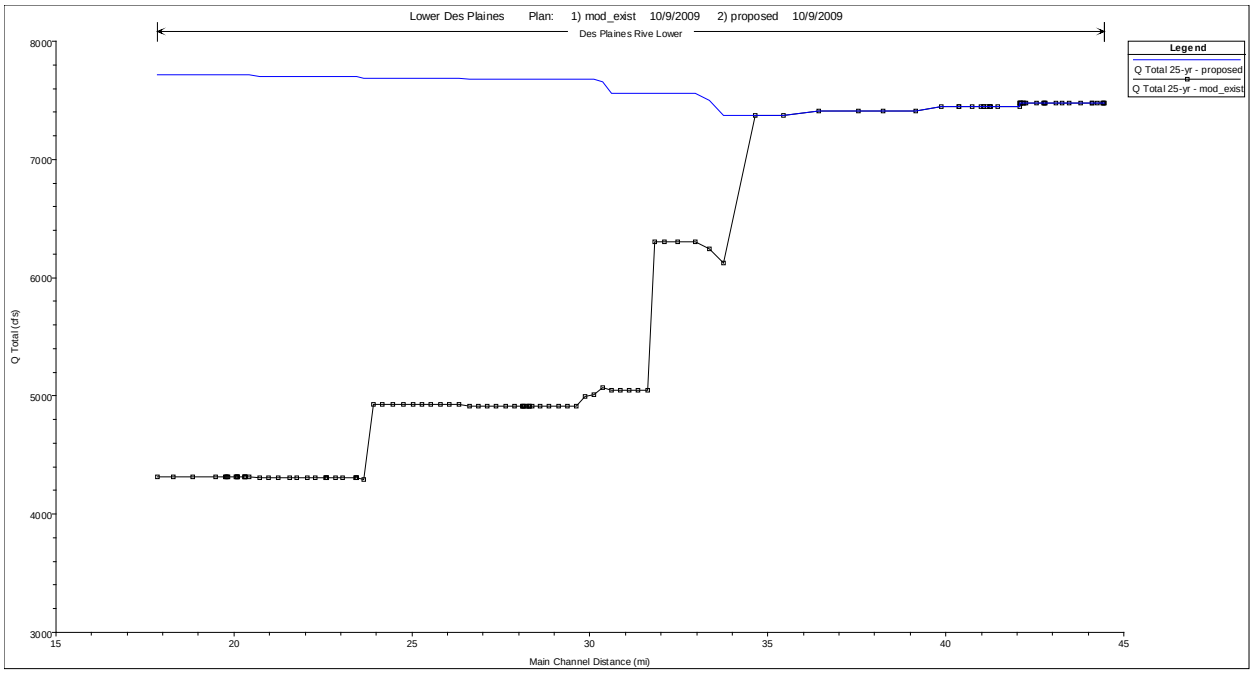

Figure 7 - Comparison of Total Flows with and without Proposed Berm for the 25-year

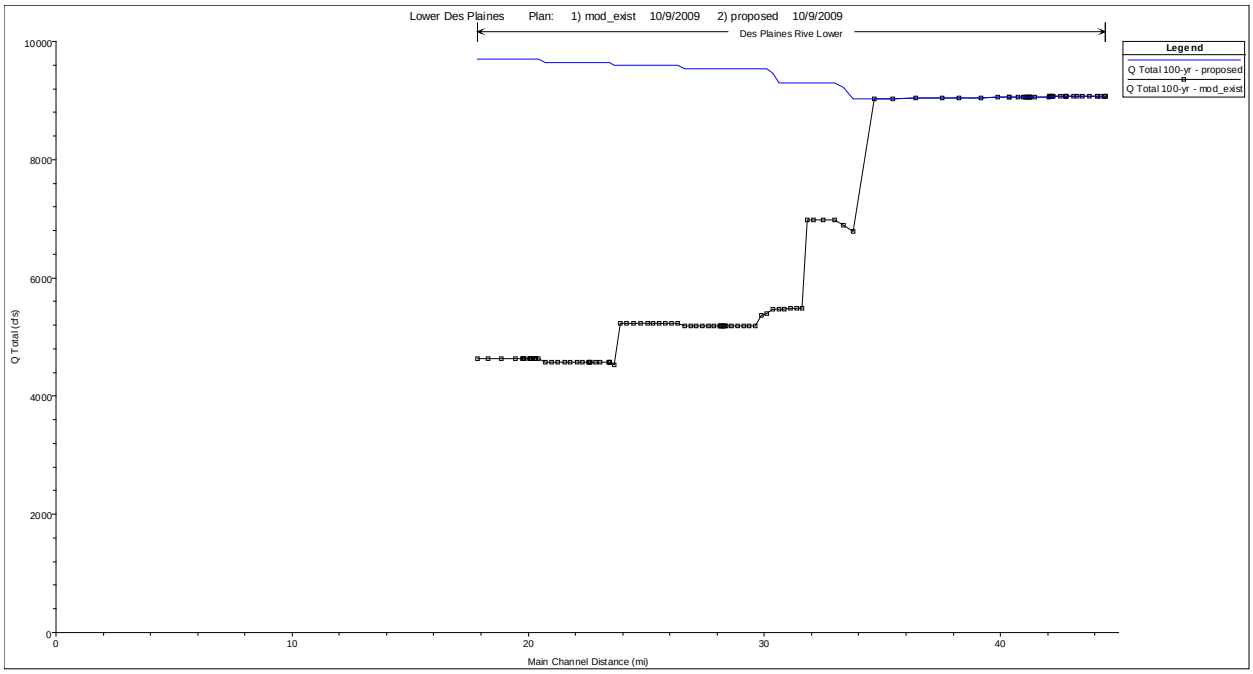

Figure 8 - Comparison of Total Flows with and without Proposed Berm for the 100-year Event

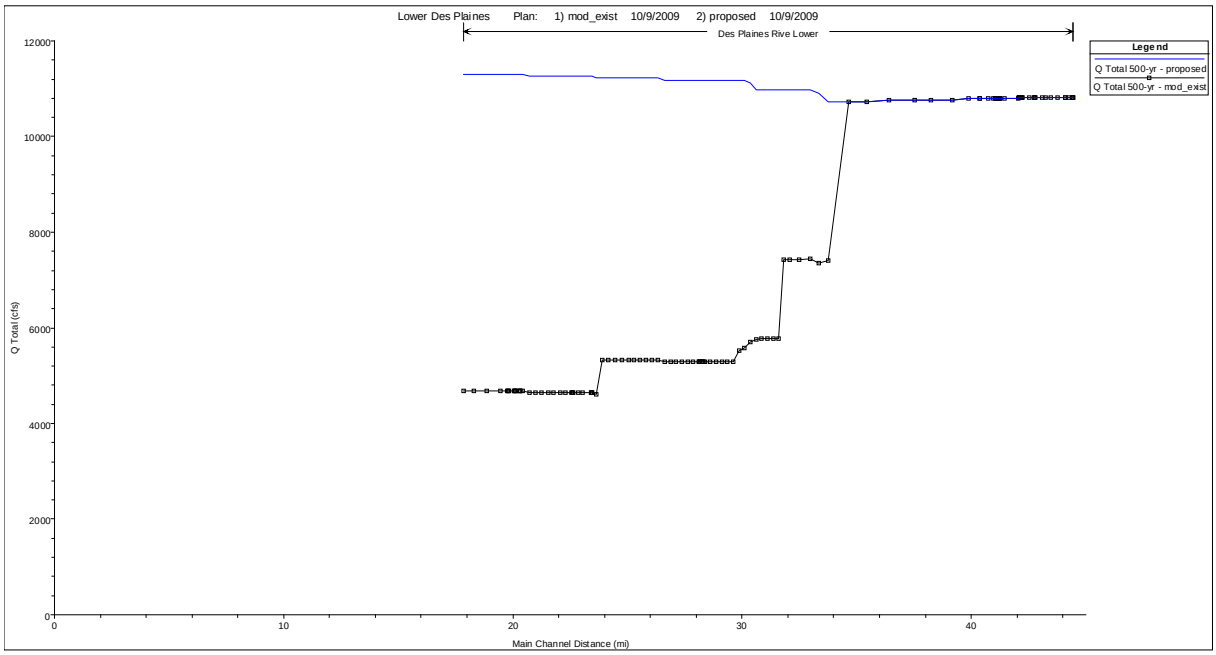

Figure 9 - Comparison of Total Flows with and without Proposed Berm for the 500-year Event

Solid Wall Scenario

Figure 10 is a plot of the left bank modeled as a lateral weir raised to prevent overflows, along with four water surface profiles: the 1-, 5-, 25-, and 100-year events. The final weir elevation was set as 3 ft higher than the Solid Wall scenario's 100-year profile. Because the higher lateral structure prevents overflow, the water-surface profiles in the Solid Wall scenario are higher than the Modified Existing scenario. The Solid Wall profiles are much closer to the HEC-2 Import scenario, and in some reaches they are identical.

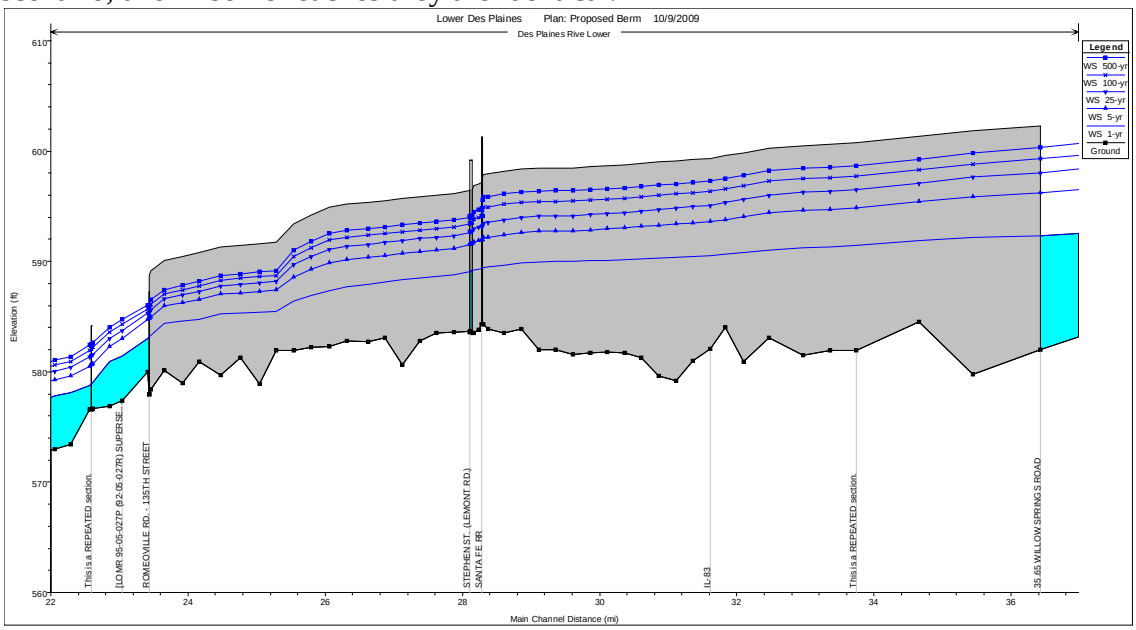

Figure 10 - Water Surface Profiles with Berms Raised to Prevent Overflows

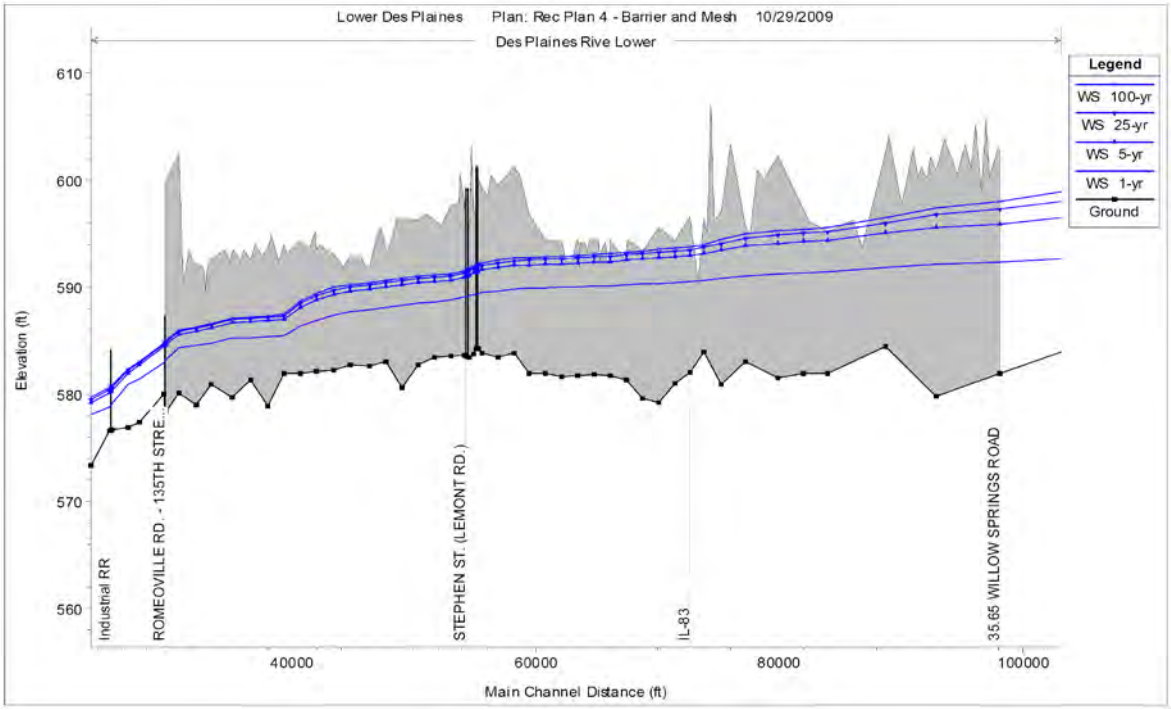

Figure 11 - Water Surface Profiles with Fence-Barricade Combination.

Fence-Barricade Combination Scenario

Figure 11 is a plot of the left bank modeled as the fence-barrier combination, along with four water surface profiles: the 1-, 5-, 25-, and 100-year events. The final weir elevation was set to 2.5 ft higher than the existing elevations in the reaches where a barricade was specified, and the weir elevation was raised by 0.16 ft in the reaches where fence was specified to simulate the head loss through a chain-link fence with 0.25-in openings. Because the fenced reaches allow overflow, the water-surface profiles in the Fence-Barricade Combination scenario are close to the Modified Existing scenario.

Discussion

Figure 12 and Table 7 below display the 100-year flood profiles of three scenarios: the FIS, Proposed Berm, and the Fence-Barricade Combination. The FIS case assumed no overflow from the Des Plaines into the CSSC because the spoil piles used when the model was created were removed in the 1990s. Because the fence-barricade combination still allows water overflows while blocking fish, the flood stage is lower than both the FIS and solid wall simulations.

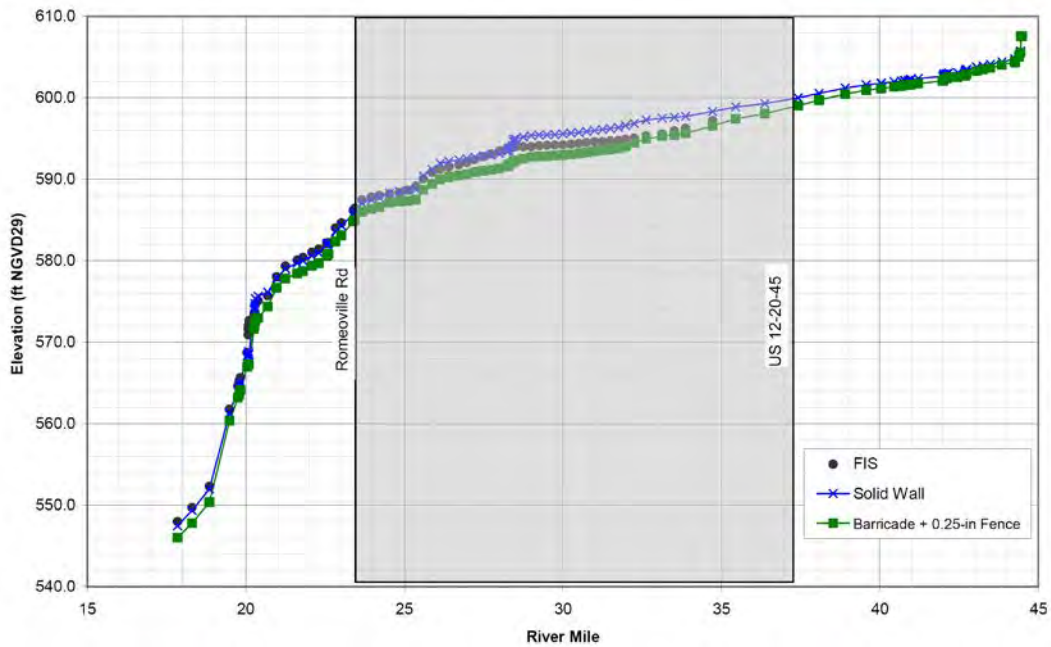

Figure 12 - 100 -year flood stage comparision, solid wall to fence-barricade combination.

Table 7. 100-year Flood Stage Comparison at Selected Landmarks.

Location	River Mile	100-year Water Surface Elevation		
		FIS	Solid Wall	Fence-Barricade
Lockport Prairie	18.3	549.7	549.3	547.8
	19.8	564.6	564.7	563.6
Romeoville Rd	23.41	586.3	585.8	584.9
Black Partridge Woods	26.25	591.3	592.0	590.1
	28.25	593.8	593.5	591.7
Lemont Rd	28.25	593.8	593.5	591.7
Waterfall Glen	28.25	593.8	593.5	591.7
	31.75	594.8	596.4	593.8
IL-83 / Kingery Rd	31.75	594.8	596.4	593.8

The fence-barricade combination produced lower flood stages than the solid wall or the FIS. The solid wall option would raise the water surface elevation in sensitive areas highlighted in the table. At Lockport Prairie, a solid wall would induce 100-year flood stages 0.1 ft higher than the FIS and over 1 ft higher than the fence-barricade combination. At Black Partridge Woods, the solid wall would induce flood stages up to 0.7 ft higher than the FIS and nearly 2 ft higher than the fence-barricade combination. At Waterfall Glen, a solid wall would induce flood stages 1.6 ft higher than the FIS and 2.6 ft higher than the fence-barricade combination. Attachment A-1 is a summary of the HEC-RAS results for the 100-year storm.

Unsteady State Analysis

Existing Conditions Scenario

The existing conditions analysis identifies areas along the east bank of the Des Plaines River in which overflow into the CSSC is possible. Generally flows greater than the 5 year event will cause overflows into the CSSC. Overflows occur around the area of Willow Springs Road, approximately 1.5 miles downstream of Willow Springs Road, approximately 2 miles upstream of Old Lemont Rd., and approximately 3,000 miles upstream of I-355.

Fence-Barricade Combination Scenario

The fence-barricade analysis shows water surface level increases less than 0.07 for all frequency events when compared to the Existing Conditions analysis. The final weir elevation was set to 2.5 ft higher than the existing elevations in the reaches where a barricade was specified, and the weir elevation was raised by 0.16 ft in the reaches where fence was specified to simulate the head loss through a chain-link fence with 0.25-in openings. Because the fenced reaches allow overflow, the water-surface profiles in the Fence-Barricade Combination scenario are close to the Existing Conditions analysis.

Solid Wall Scenario

The solid wall scenario completely blocks all overflow into the CSSC. The results of the solid wall modeling show water surface elevations increasing up to 1.5 feet during the 100 year event and up to 5.3 feet during the 500 year profile when compared to the Existing Conditions scenario.

Discussion

The modeling results of the three scenarios modeled in HEC-RAS unsteady indicate the solution of the fence and Jersey barrier combination will have the least impact on the Des Plaines River water surface profiles; however, issues with maintenance of the chain link fence to maintain its permeability still need to be addressed.

SUMMARY

A hydraulic model of the lower Des Plaines River was obtained and updating with current topographic data to investigate possible overflows to the Chicago Sanitary and Ship Canal. The modeling showed that overflows can occur during the range of events modeled, return periods ranging from one to five hundred years. Including overflows in the model lowered flood stages compared to the regulatory profiles. Constructing a berm to block overflows would increase stages significantly, and they would approach the regulatory levels. Constructing a barrier of concrete barricades and fencing would block fish passage but increase stages only slightly. Debris at the bridge piers of Romeoville Road does not have a significant impact to the water-surface profiles.

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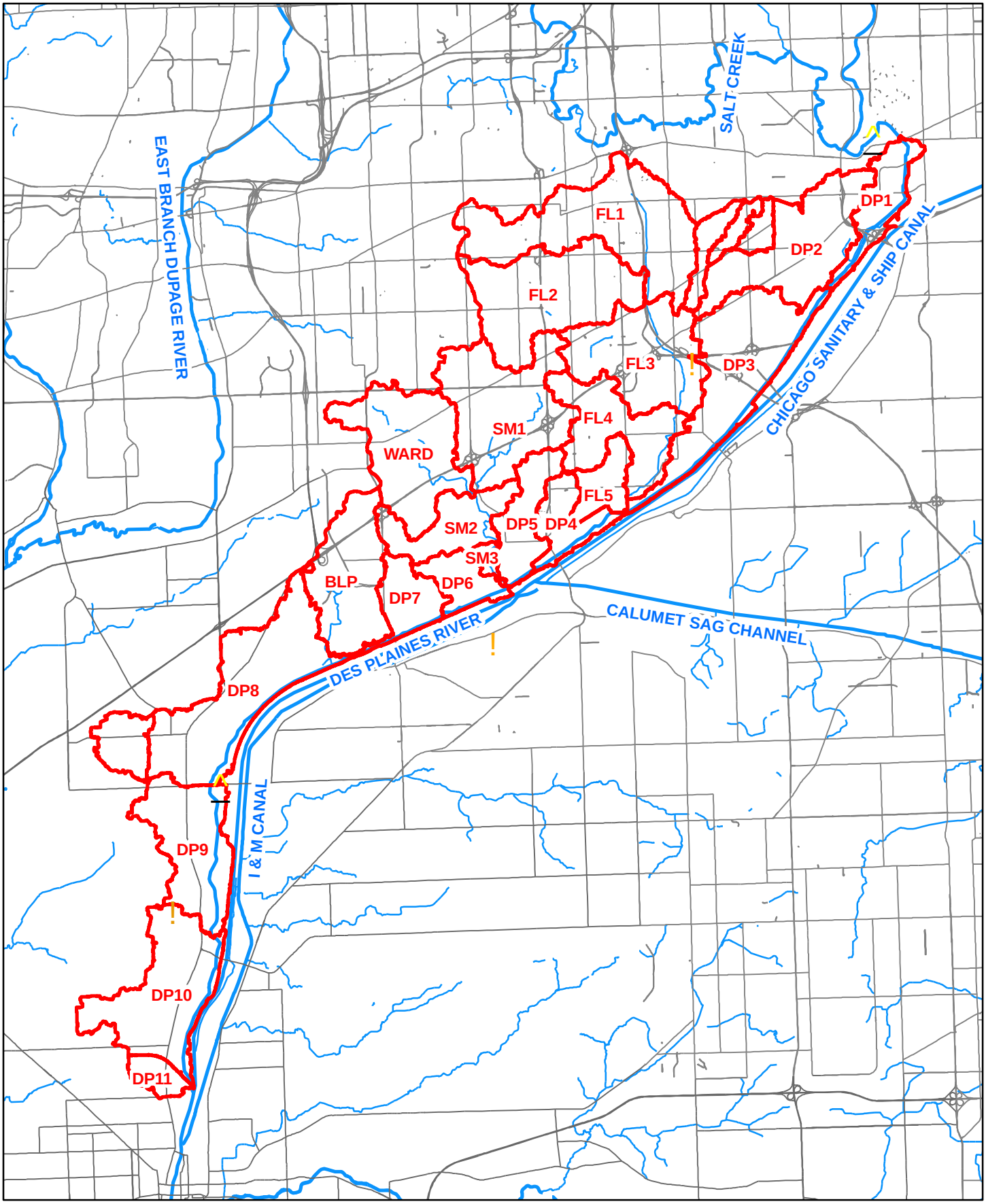


Legend

- Subwatershed
- Major Roads - Cook
- Major Roads - Will
- Major Rivers
- Streams
- ! Rain Gage
- USGS Streamflow

0 1 2 Miles

US Army Corps of Engineers
Chicago District

Fish Barrier Efficacy Study Appendix A - Hydrology and Hydraulics	
Lower Des Plaines Subbasin Map	
Chicago District, U.S. Army Corps of Engineers	
September 2010	Plate A-1

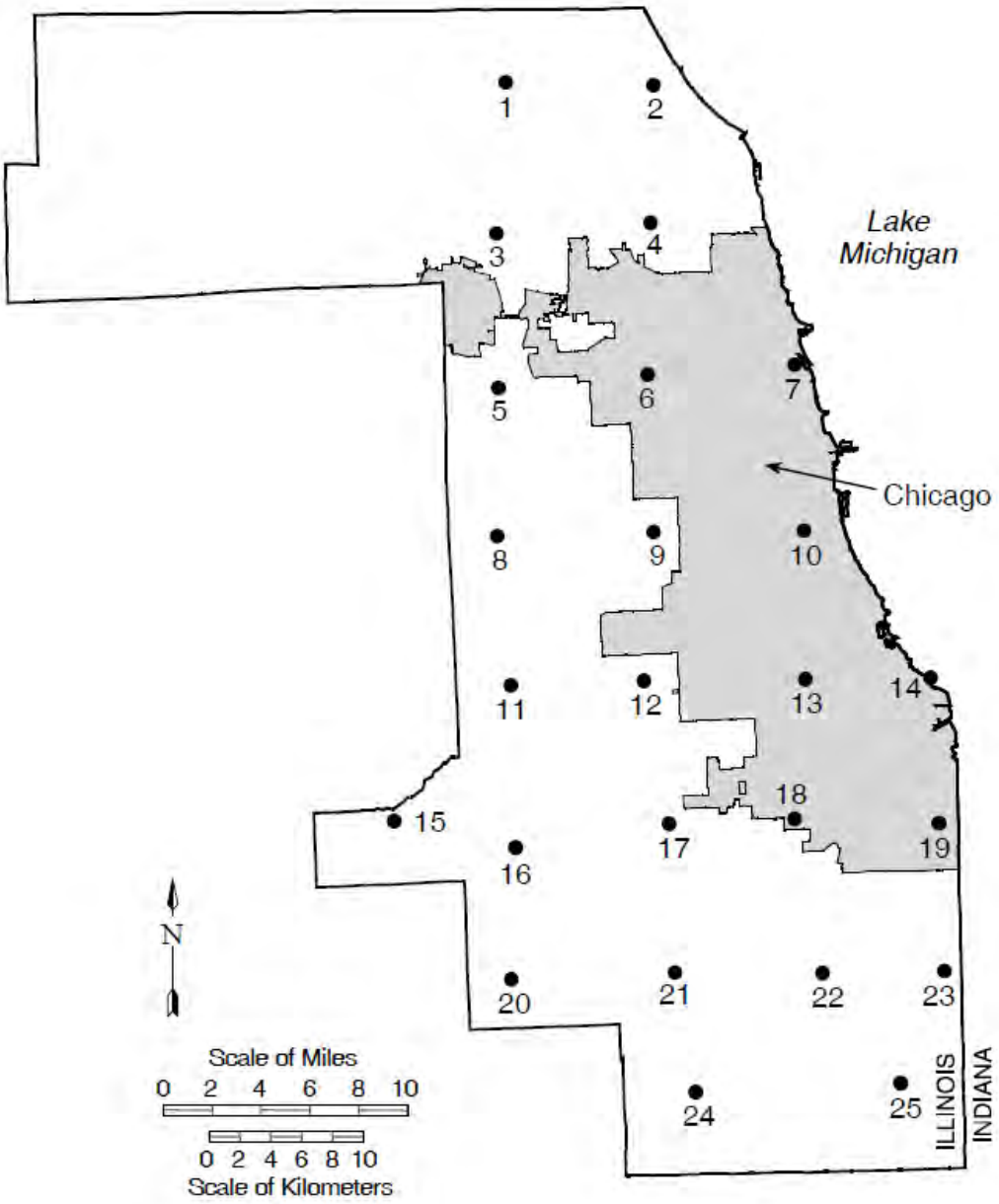
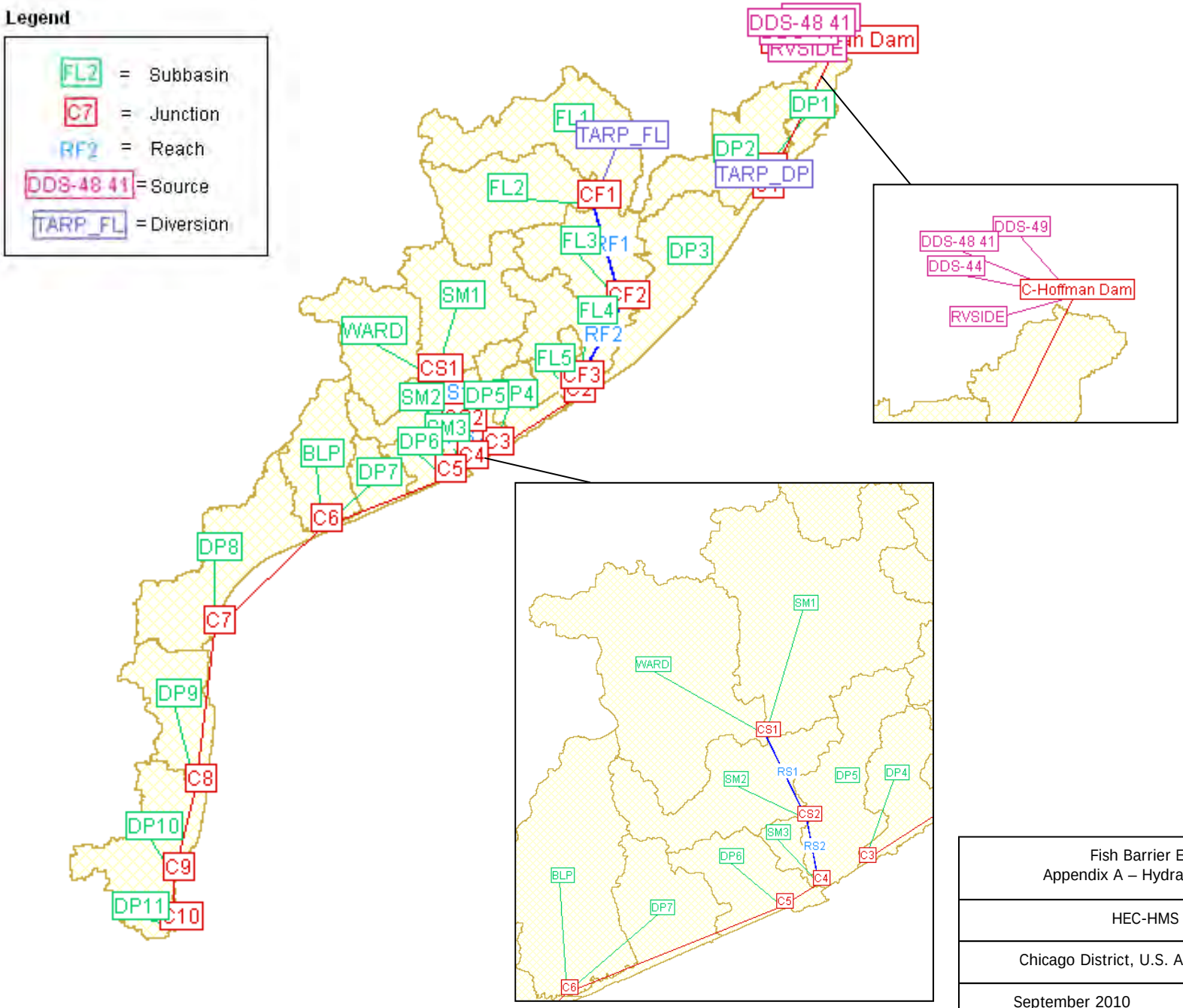


Figure 2. The Cook County 25-site raingage network for Water Years 1990-2006.

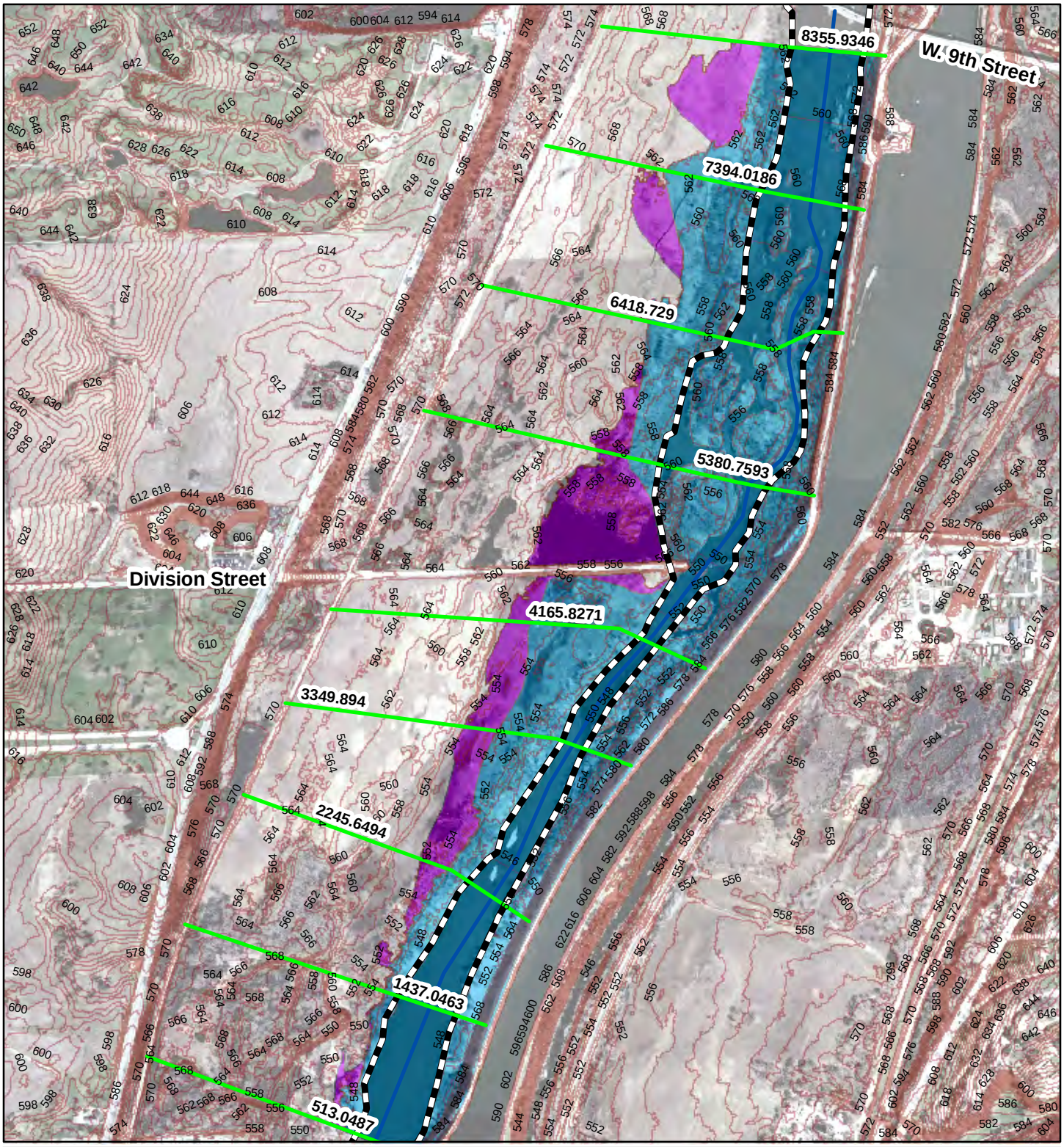
Source: Westcott, 2007.

Fish Barrier Efficacy Study Appendix A – Hydraulics and Hydrology	
Cook County 25-Site Raingage Network	
Chicago District, U.S. Army Corps of Engineers	
September 2010	Plate A-2



Fish Barrier Efficacy Study Appendix A – Hydraulics and Hydrology	
HEC-HMS Schematic	
Chicago District, U.S. Army Corps of Engineers	
September 2010	Plate A-3

Lockport Prairie Potential Impacts



Legend

- Lockport Prairie Cross Sections
- Lower Des Plaines River
- Existing Conditions Flood
- Proposed Solid Wall Flood
- River Banks

N
W E
S

PLATE A-4

0 225 450 900
Feet

DISCLAIMER - While the United States Army Corps of Engineers, (hereinafter referred to USACE) has made a reasonable effort to insure the accuracy of the maps and associated data, its should be explicitly noted that USACE makes no warranty, representation or guaranty, either express or implied, as to the content, sequence, accuracy, timeliness or completeness of any of the data provided herein. The USACE, its officers, agents, employees, or servants shall assume no liability of any nature for any errors, omissions, or inaccuracies in the information provided regardless of how caused. The USACE, its officers, agents, employees or servants shall assume no liability for any decisions made or actions taken or not taken by the user of the maps and associated data in reliance upon any information or data furnished here. By using these maps and associated data the user does so entirely at their own risk and explicitly acknowledges that he/she is aware of and agrees to be bound by this disclaimer and agrees not to present any claim or demand of any nature against the USACE, its officers, agents, employees or servants in any forum whatsoever for any damages of any nature whatsoever that may result from or may be caused in any way by the use of the maps and associated data.

PLATE A-5 CALIBRATION HYDROGRAPHS SEPTEMBER 12-21, 2008

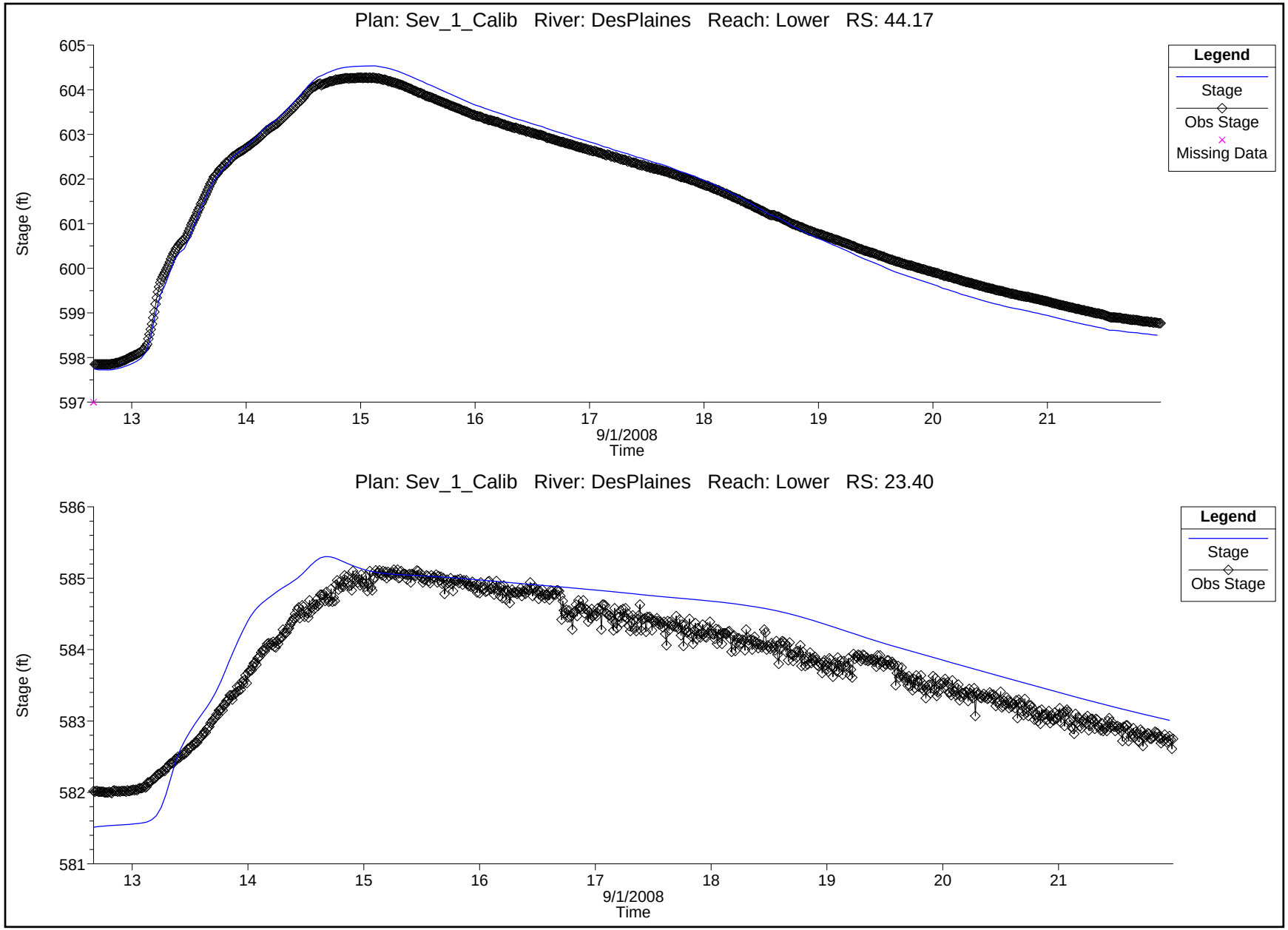


PLATE A-6 CALIBRATION HYDROGRAPHS DECEMBER 25-31, 2008

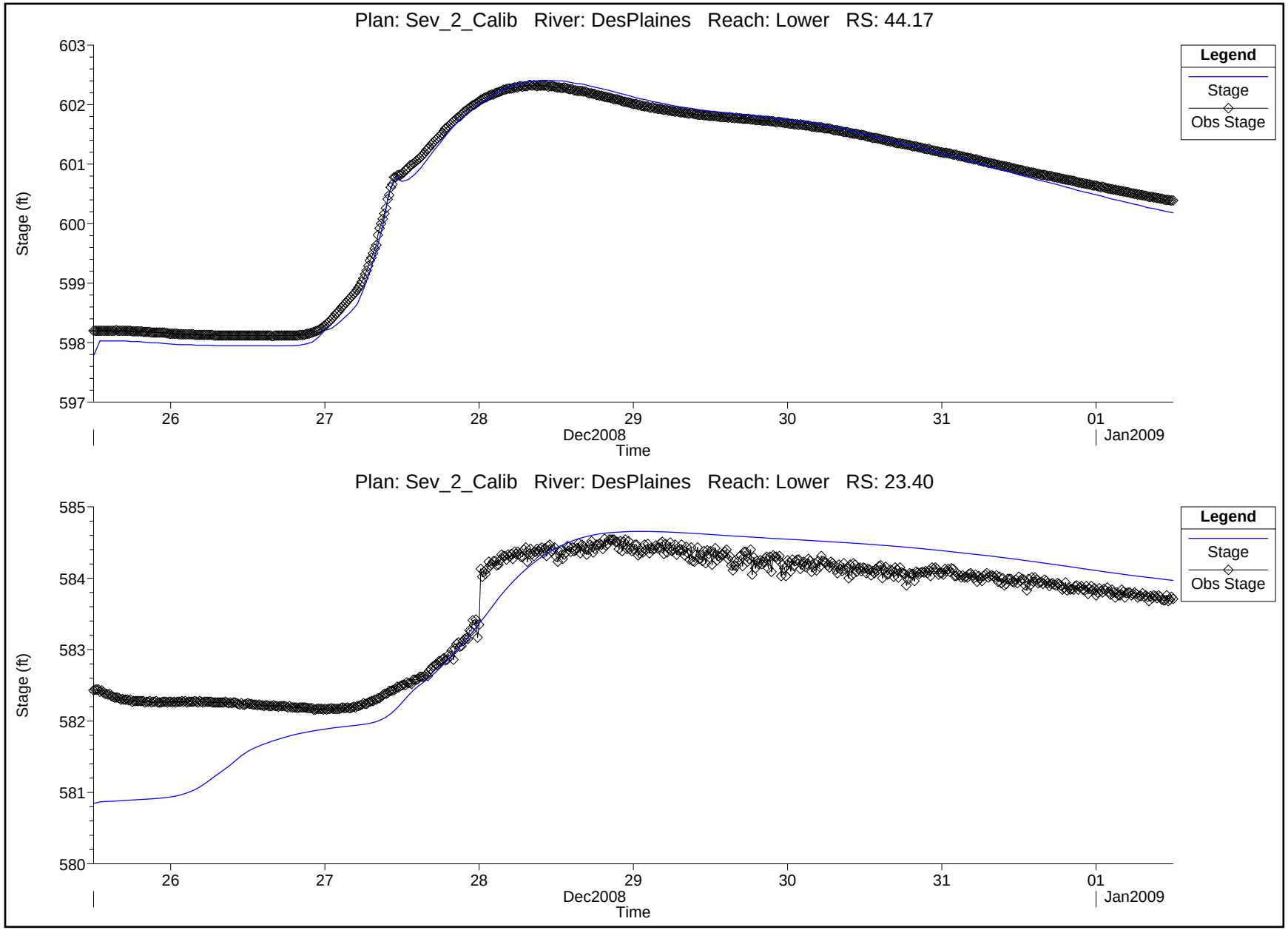


PLATE A-7 CALIBRATION HYDROGRAPHS JULY 22-27, 2010

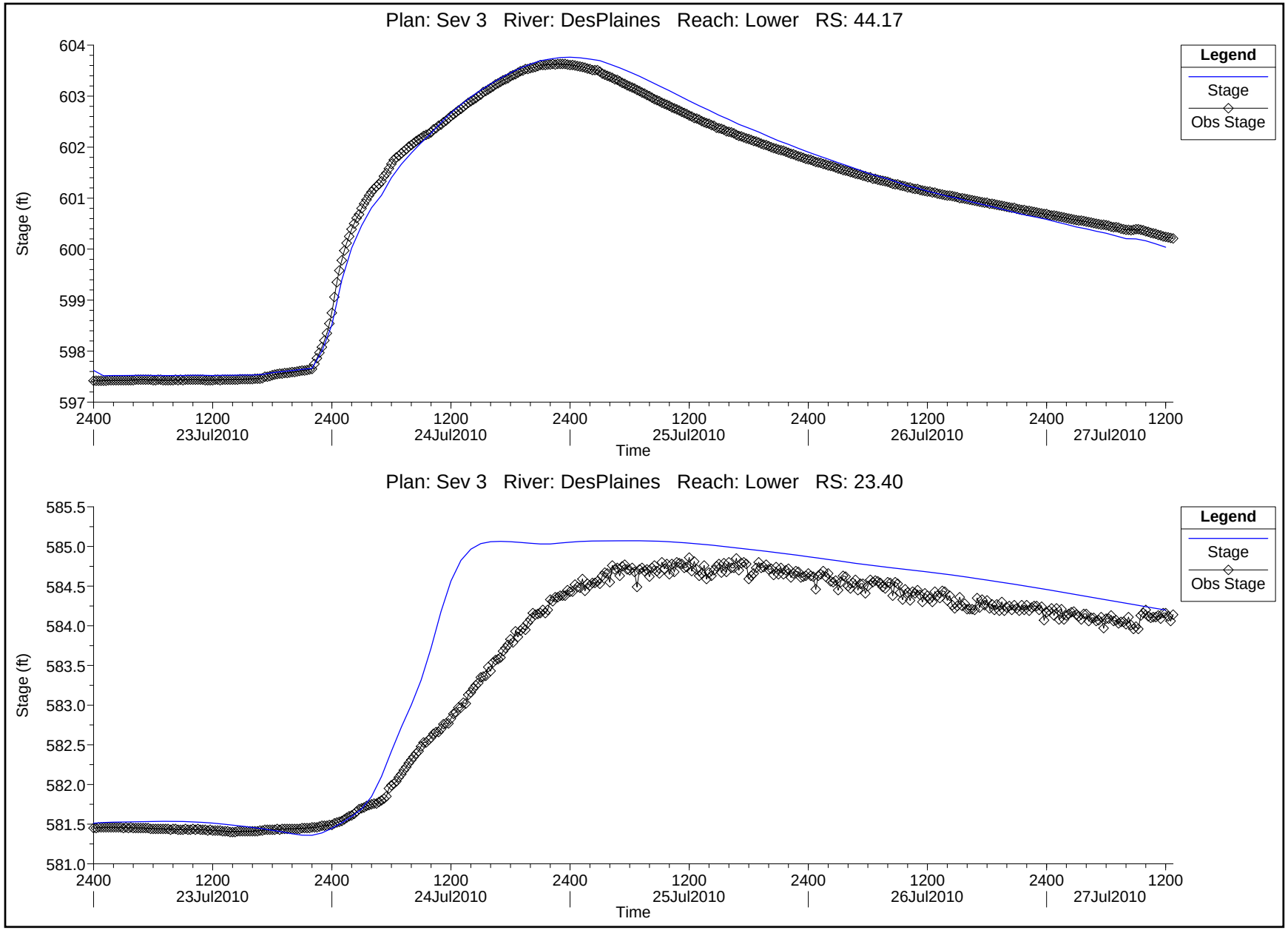


PLATE A-8 CALIBRATION HYDROGRAPHS DECEMBER 07-20, 2008

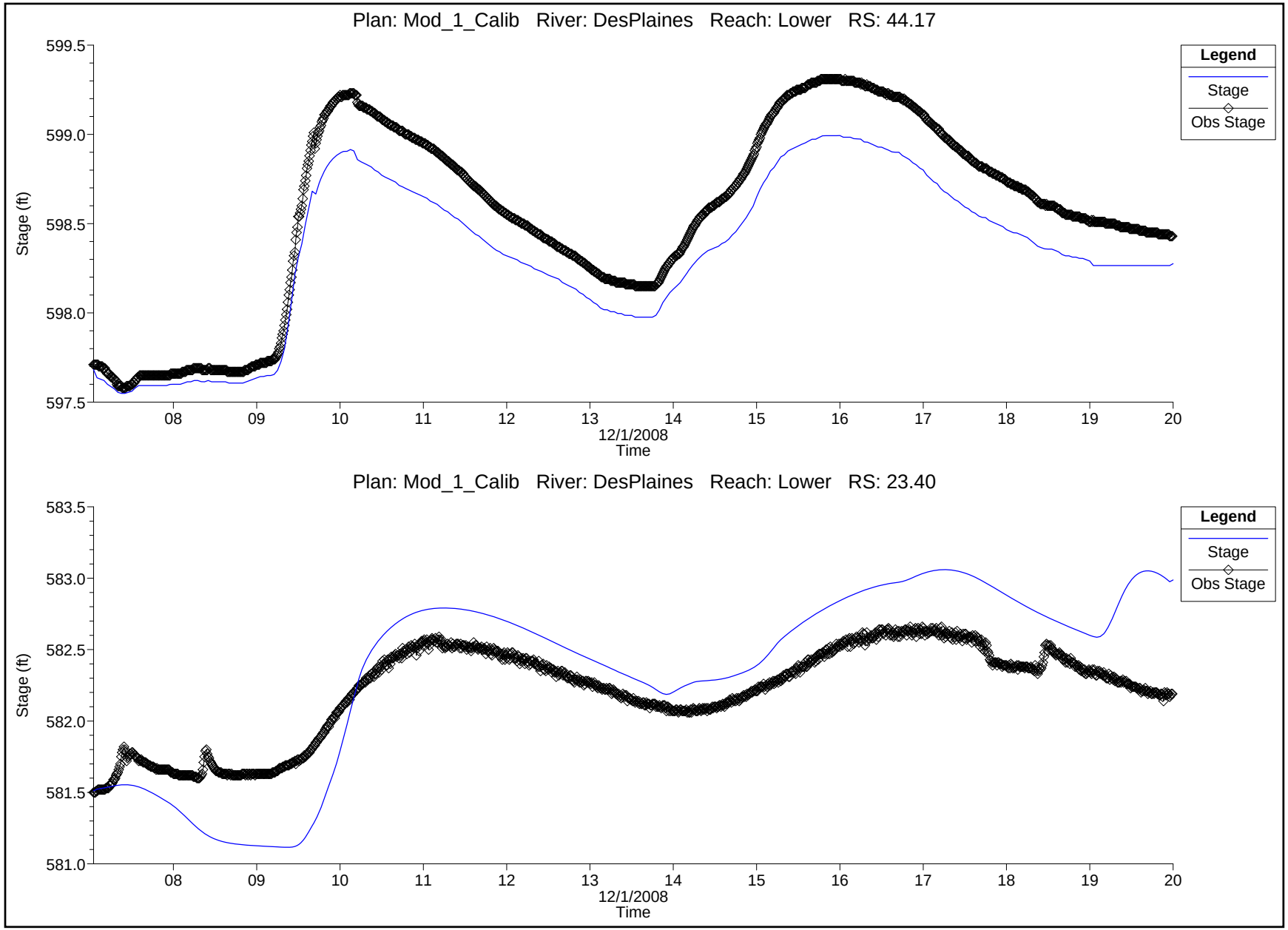
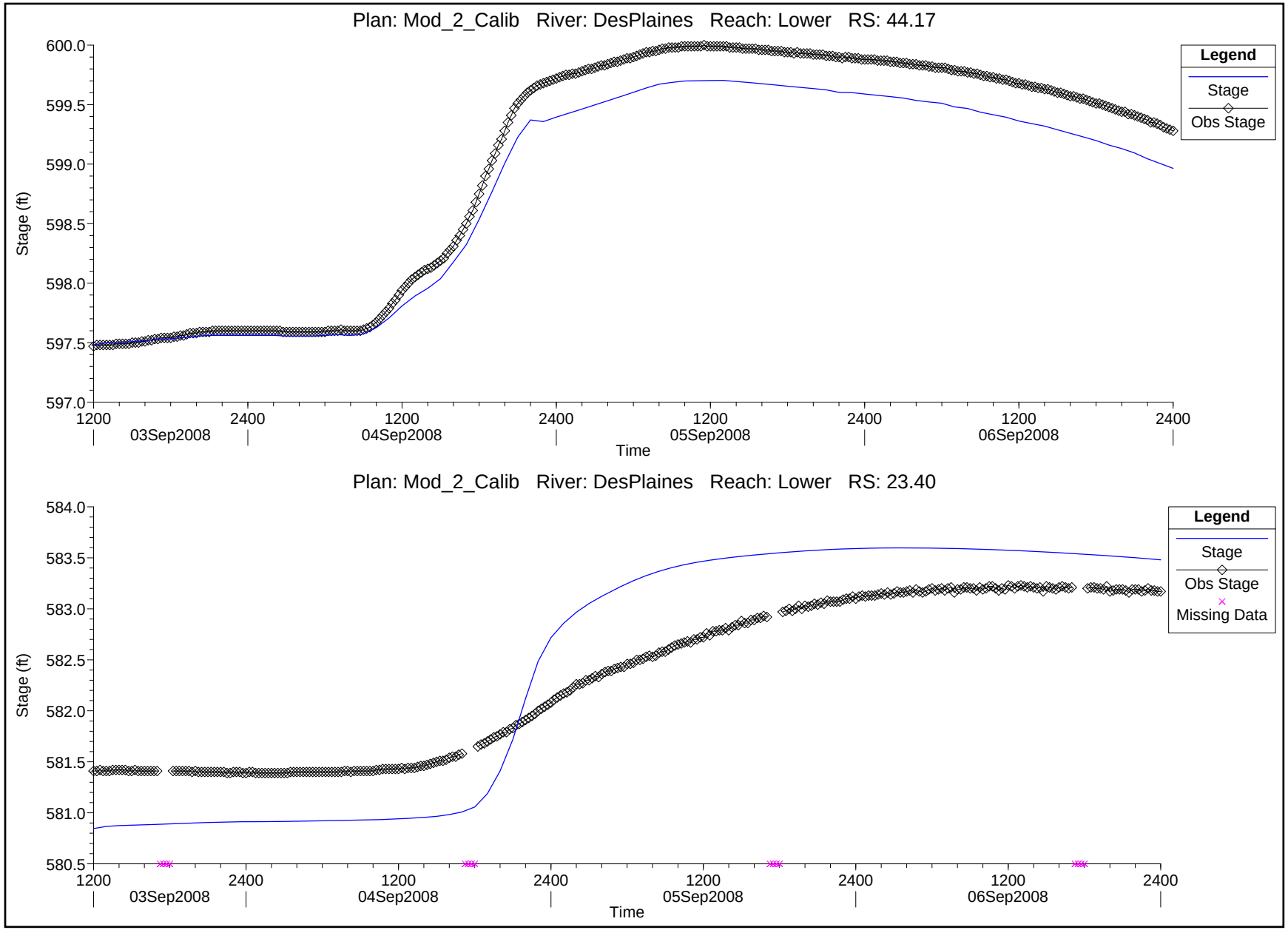


PLATE A-9 CALIBRATION HYDROGRAPHS SEPTEMBER 03-20, 2008



Attachment 1 – Des Plaines River 100-yr Flood Profiles

Des Plaines River HEC-RAS Results, 100-year Storm

River Mile	Min Chan El	FIS	Modified Existing		Barrier + 1-in Fence			Barrier + 0.25-in Fence			Solid Barrier		
		Z	Q	Z	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)
44.49	598.4		9079	607.52	9079	607.52	0	9079	607.52		9079	607.6	
44.452	593.5		9079	607.54	9079	607.54	0	9079	607.54		9079	607.62	
44.451	593.5		9079	607.53	9079	607.53	0	9079	607.54		9079	607.62	
44.44	593.5		9079	605.52	9079	605.52	0	9079	605.52		9079	605.75	
44.39	594		9079	605.01	9079	605.01	0	9079	605.02		9079	605.28	
44.27	593.7		9079	604.32	9079	604.32	0	9079	604.33		9079	604.68	
44.26	591		9079	604.42	9079	604.43	0.01	9079	604.44		9079	604.78	
43.85	590.1		9079	604.01	9079	604.01	0	9079	604.02		9079	604.43	
43.49	588.3		9079	603.63	9079	603.63	0	9079	603.65		9079	604.11	
43.25	587.8		9079	603.42	9079	603.42	0	9079	603.44		9079	603.94	
43.05	587.8		9079	603.24	9079	603.24	0	9079	603.26		9079	603.79	
42.74	588.2		9079	602.87	9079	602.87	0	9079	602.89		9079	603.49	
42.71	587.9		9079	602.78	9079	602.78	0	9079	602.8		9079	603.41	
42.7	587.5		9079	602.64	9079	602.64	0	9079	602.66		9079	603.25	
42.69	587.5		9079	602.65	9079	602.65	0	9079	602.67		9079	603.19	
42.46	587		9079	602.5	9079	602.5	0	9079	602.52		9079	603.06	
42.17	583.7		9079	602.47	9079	602.47	0	9079	602.49		9079	603.05	
42.12	586.2		9079	602.33	9079	602.33	0	9079	602.35		9079	602.93	
42.11	584		9079	602.33	9079	602.33	0	9079	602.35		9079	602.92	
42.1	584		9079	602.35	9079	602.35	0	9079	602.37		9079	602.94	
42.03	581.2		9079	602.33	9079	602.34	0.01	9079	602.36		9079	602.93	
42.022	585		9079	602.28	9079	602.29	0.01	9079	602.31		9079	602.88	
42.021	585		9079	602.16	9079	602.16	0	9079	602.18		9079	602.75	
42.01	585.2		9079	602.14	9079	602.15	0.01	9079	602.17		9079	602.74	
42	585.2		9079	602.02	9079	602.02	0	9079	602.04		9079	602.61	
41.98	585		9063	602.02	9063	602.03	0.01	9063	602.05		9063	602.62	
41.21	585.5		9063	601.72	9063	601.73	0.01	9063	601.75		9063	602.36	
40.98	585.8		9063	601.59	9063	601.59	0	9063	601.61		9063	602.24	
40.97	586.4		9063	601.57	9063	601.57	0	9063	601.59		9063	602.22	
40.96	586.4		9063	601.56	9063	601.56	0	9063	601.58		9063	602.16	
40.95	586.4		9063	601.56	9063	601.56	0	9063	601.59		9063	602.16	
40.89	584.2		9063	601.51	9063	601.51	0	9063	601.54		9063	602.12	
40.79	584		9063	601.52	9063	601.52	0	9063	601.54		9063	602.13	
40.77	584		9063	601.51	9063	601.52	0.01	9063	601.54		9063	602.13	
40.69	583.48		9063	601.43	9063	601.44	0.01	9063	601.46		9063	602.05	
40.45	583.24		9063	601.31	9063	601.32	0.01	9063	601.34		9063	601.95	
40.05	583		9063	601.12	9063	601.12	0	9063	601.15		9063	601.78	
40.04	583		9063	601.11	9063	601.12	0.01	9063	601.14		9063	601.78	

Des Plaines River HEC-RAS Results, 100-year Storm

River Mile	Min Chan El	FIS	Modified Existing		Barrier + 1-in Fence			Barrier + 0.25-in Fence			Solid Barrier		
		Z	Q	Z	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)
39.57	583.3		9063	600.9	9063	600.91	0.01	9063	600.93		9063	601.59	
38.91	581.9		9042	600.43	9042	600.43	0	9042	600.46		9042	601.17	
38.08	583.2		9042	599.68	9042	599.68	0	9042	599.72		9042	600.54	
37.42	584.3		9042	598.97	9042	598.98	0.01	9042	599.02		9042	600	
36.37	582		9042	598	9042	598.01	0.01	9042	598.06		9042	599.29	
35.45	579.8		9026	597.36	9026	597.36	0	9026	597.43		9026	598.85	
34.72	584.5	597.2	9026	596.44	9026	596.45	0.01	9026	596.54	-0.64	9026	598.31	1.13
33.87	581.9	596.3	6781.37	595.49	6798.41	595.5	0.01	6926.81	595.61	-0.66	9026	597.73	1.46
33.52	581.9	595.9	6881.1	595.31	6894.25	595.32	0.01	7047.26	595.44	-0.48	9216	597.61	1.69
33.13	581.5	595.5	6968.1	595.15	6981.25	595.17	0.02	7134.26	595.29	-0.251667	9303	597.5	1.96
32.63	583.1	595.3	6967.58	594.83	6980.49	594.85	0.02	7134.17	594.97	-0.36	9303	597.27	1.94
32.25	580.9	595.1	6967.58	594.3	6980.49	594.31	0.01	7134.17	594.44	-0.61	9303	596.86	1.81
31.98	584	594.9	6967.58	593.85	6980.49	593.87	0.02	7134.17	594.01	-0.88	9303	596.6	1.71
31.75	582.1	594.8	5467.92	593.61	5495.93	593.63	0.02	5645.7	593.77	-1.005	9303	596.35	1.58
31.5	581	594.7	5467.92	593.49	5495.93	593.51	0.02	5645.7	593.64	-1.06	9303	596.24	1.54
31.25	579.2	594.6	5467.92	593.37	5495.93	593.39	0.02	5645.7	593.53	-1.07	9303	596.11	1.51
31	579.6	594.6	5467.69	593.26	5495.6	593.28	0.02	5645.69	593.41	-1.19	9303	596	1.40
30.75	581.3	594.5	5458.5	593.11	5486.23	593.13	0.02	5637.83	593.27	-1.23	9303	595.86	1.36
30.5	581.7	594.4	5464.76	592.99	5492.21	593.01	0.02	5661.75	593.14	-1.26	9466	595.74	1.34
30.25	581.8	594.3	5386.66	592.9	5414.77	592.92	0.02	5598.18	593.05	-1.25	9534	595.66	1.36
30	581.7	594.2	5351.7	592.8	5380.15	592.82	0.02	5566.23	592.96	-1.24	9534	595.57	1.37
29.75	581.6	594.2	5165.03	592.71	5194.18	592.73	0.02	5406.3	592.87	-1.33	9534	595.48	1.28
29.5	582	594.2	5165.03	592.68	5194.18	592.7	0.02	5406.3	592.84	-1.31	9534	595.46	1.31
29.25	582	594.1	5165.03	592.66	5194.18	592.68	0.02	5406.3	592.81	-1.29	9534	595.43	1.33
29	583.9	594.0	5165.03	592.57	5194.18	592.58	0.01	5406.3	592.72	-1.28	9534	595.35	1.35
28.75	583.5	594.0	5165.03	592.37	5194.18	592.39	0.02	5406.3	592.52	-1.48	9534	595.18	1.18
28.51	583.9	594.0	5165.03	592.15	5194.18	592.17	0.02	5406.3	592.3	-1.7	9534	594.93	0.93
28.44	584.3	594.0	5165.03	592.09	5194.18	592.11	0.02	5406.3	592.24	-1.76	9534	594.91	0.91
28.43	584.3	594.0	5165.03	591.93	5194.18	591.95	0.02	5406.3	592.07	-1.93	9534	594.65	0.65
28.42	584.3	594.0	5165.03	591.9	5194.18	591.92	0.02	5406.3	592.04	-1.96	9534	594.16	0.16
28.38	583.8	594.0	5165.03	591.83	5194.18	591.85	0.02	5406.3	591.97	-2.0025	9534	594.01	0.04
28.31	583.5	593.9	5165.03	591.68	5194.18	591.7	0.02	5406.3	591.82	-2.05625	9534	593.84	-0.04
28.29	583.5	593.8	5165.03	591.56	5194.18	591.58	0.02	5406.3	591.69	-2.15875	9534	593.52	-0.33
28.25	583.6	593.8	5165.03	591.56	5194.18	591.57	0.01	5406.3	591.69	-2.10375	9534	593.51	-0.28
28.24	583.7	593.8	5165.03	591.45	5194.18	591.47	0.02	5406.3	591.58	-2.2	9534	593.41	-0.37
28	583.6	593.5	5165.03	591.15	5194.18	591.17	0.02	5406.3	591.29	-2.16	9534	593.12	-0.33
27.74	583.5	593.1	5165.03	591	5194.18	591.01	0.01	5406.3	591.13	-1.9625	9534	592.98	-0.11
27.49	582.8	592.7	5165.03	590.88	5194.18	590.89	0.01	5406.3	591.01	-1.73875	9534	592.86	0.11

Des Plaines River HEC-RAS Results, 100-year Storm

River Mile	Min Chan El	FIS	Modified Existing		Barrier + 1-in Fence			Barrier + 0.25-in Fence			Solid Barrier		
		Z	Q	Z	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)
27.23	580.6	592.4	5165.03	590.72	5194.18	590.74	0.02	5406.3	590.86	-1.53125	9534	592.71	0.32
26.98	583.1	592.0	5165.03	590.49	5194.18	590.5	0.01	5406.3	590.63	-1.4175	9534	592.53	0.48
26.72	582.7	591.8	5165.03	590.31	5194.18	590.33	0.02	5406.3	590.46	-1.3	9534	592.37	0.61
26.4	582.8	591.5	5220.03	590.12	5249.18	590.14	0.02	5461.3	590.27	-1.18	9589	592.19	0.74
26.13	582.3	591.2	5220.03	589.86	5249.18	589.87	0.01	5461.3	590	-1.23	9589	591.94	0.71
25.87	582.2	590.8	5220.03	589.29	5249.18	589.31	0.02	5461.3	589.42	-1.42	9589	591.23	0.39
25.6	581.9	590.1	5220.03	588.58	5249.18	588.6	0.02	5461.3	588.7	-1.35	9589	590.42	0.37
25.36	581.9	589.1	5220.03	587.38	5249.18	587.39	0.01	5461.3	587.48	-1.66	9589	588.73	-0.41
25.11	578.9	588.6	5220.03	587.24	5249.18	587.25	0.01	5461.3	587.33	-1.316667	9589	588.62	-0.03
24.84	581.3	588.4	5220.03	587.14	5249.18	587.15	0.01	5461.3	587.23	-1.14	9589	588.47	0.10
24.53	579.7	588.2	5220.03	587.02	5249.18	587.03	0.01	5461.3	587.11	-1.09	9589	588.31	0.11
24.21	580.9	588.0	5220.03	586.52	5249.18	586.53	0.01	5461.3	586.61	-1.4	9589	587.78	-0.23
23.96	579	587.8	5220.03	586.25	5249.18	586.26	0.01	5461.3	586.34	-1.45	9589	587.43	-0.36
23.66	580.1	587.5	5220.03	585.94	5249.18	585.95	0.01	5461.3	586.02	-1.44	9589	587.07	-0.39
23.44	578.4	586.4	5274.03	584.98	5303.18	584.98	0	5515.3	585.04	-1.4	9643	586.12	-0.32
23.412	578	586.3	5274.03	584.86	5303.18	584.87	0.01	5515.3	584.92	-1.352	9643	585.75	-0.52
23.41	578	586.3	5274.03	584.83	5303.18	584.83	0	5515.3	584.88	-1.38	9643	585.75	-0.51
23.39	580	586.2	5274.03	584.72	5303.18	584.73	0.01	5515.3	584.78	-1.377143	9643	585.71	-0.45
23.02	577.4	584.6	5274.03	583.03	5303.18	583.03	0	5515.3	583.1	-1.54	9643	584.29	-0.35
22.83	576.9	584.0	5274.03	582.28	5303.18	582.29	0.01	5515.3	582.36	-1.645	9643	583.61	-0.39
22.6	576.7	582.2	5274.03	580.73	5303.18	580.74	0.01	5515.3	580.82	-1.38	9643	582.2	0.00
22.58	576.6	582.2	5274.03	580.62	5303.18	580.63	0.01	5515.3	580.72	-1.44	9643	582.09	-0.07
22.57	576.6	582.2	5274.03	580.61	5303.18	580.62	0.01	5515.3	580.7	-1.456	9643	582.07	-0.09
22.55	576.6	582.1	5274.03	580.5	5303.18	580.51	0.01	5515.3	580.6	-1.5	9643	581.97	-0.13
22.3	573.4	581.4	5274.03	579.62	5303.18	579.63	0.01	5515.3	579.71	-1.69	9643	580.96	-0.44
22.08	573	581.0	5274.03	579.28	5303.18	579.29	0.01	5515.3	579.37	-1.658763	9643	580.61	-0.42
21.8	572.6	580.4	5274.03	578.64	5303.18	578.65	0.01	5515.3	578.72	-1.664886	9643	580	-0.38
21.62	572.6	580.1	5274.03	578.34	5303.18	578.35	0.01	5515.3	578.43	-1.64236	9643	579.7	-0.37
21.25	572.3	579.3	5274.03	577.74	5303.18	577.75	0.01	5515.3	577.82	-1.514067	9643	579.03	-0.30
20.97	571	578.0	5274.03	576.58	5303.18	576.59	0.01	5515.3	576.67	-1.365636	9643	577.89	-0.15
20.69	569.2	575.7	5274.03	574.31	5303.18	574.32	0.01	5515.3	574.37	-1.315203	9643	576.14	0.45
20.39	567.8	575.1	5326.03	572.81	5355.18	572.83	0.02	5567.3	572.98	-2.08272	9695	575.63	0.57
20.3	564.2	574.7	5326.03	572.44	5355.18	572.46	0.02	5567.3	572.63	-2.032769	9695	575.34	0.68
20.282	563.6	573.7	5326.03	572.07	5355.18	572.09	0.02	5567.3	572.24	-1.45592	9695	574.73	1.03
20.281	563.6	573.7	5326.03	571.86	5355.18	571.88	0.02	5567.3	572.02	-1.63896	9695	574.32	0.66
20.26	564.9	573.3	5326.03	571.45	5355.18	571.46	0.01	5567.3	571.61	-1.645617	9695	574.02	0.76
20.1	561.6	572.6	5326.03	567.13	5355.18	567.14	0.01	5567.3	567.23	-5.396511	9695	568.52	-4.11
20.085	559.4	572.0	5326.03	567.22	5355.18	567.23	0.01	5567.3	567.32	-4.677294	9695	568.83	-3.17

Des Plaines River HEC-RAS Results, 100-year Storm

River Mile	Min Chan El	FIS	Modified Existing		Barrier + 1-in Fence			Barrier + 0.25-in Fence			Solid Barrier		
		Z	Q	Z	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)	Q	Z	DZ (FIS)
20.08	559.4	571.6	5326.03	567.09	5355.18	567.1	0.01	5567.3	567.18	-4.452353	9695	568.55	-3.08
20.07	559.4	570.9	5326.03	567.04	5355.18	567.06	0.02	5567.3	567.14	-3.762471	9695	568.43	-2.47
20.04	561.4	568.7	5326.03	566.86	5355.18	566.87	0.01	5567.3	566.95	-1.762824	9695	568.3	-0.41
19.83	561	565.6	5326.03	564.02	5355.18	564.03	0.01	5567.3	564.09	-1.535	9695	565.13	-0.50
19.801	559.7	565.3	5326.03	563.49	5355.18	563.5	0.01	5567.3	563.57	-1.72324	9695	564.67	-0.62
19.8	559.7	565.3	5326.03	563.47	5355.18	563.48	0.01	5567.3	563.55	-1.729	9695	564.65	-0.63
19.75	558.3	564.6	5326.03	563.09	5355.18	563.1	0.01	5567.3	563.16	-1.459	9695	564.2	-0.42
19.48	556.8	561.8	5326.03	560.26	5355.18	560.27	0.01	5567.3	560.33	-1.428462	9695	561.3	-0.46
18.85	543.4	552.3	5326.03	550.25	5355.18	550.27	0.02	5567.3	550.36	-1.930919	9695	551.97	-0.32
18.3	542.5	549.7	5326.03	547.66	5355.18	547.68	0.02	5567.3	547.78	-1.924372	9695	549.33	-0.37
17.84	540.3	548.0	5326.03	545.87	5355.18	545.88	0.01	5567.3	545.99	-1.982817	9695	547.46	-0.51