HUNTING BAYOU FLOOD RISK MANAGEMENT, HARRIS COUNTY, TEXAS

DRAFT GENERAL REEVALUATION REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDIX 2
HYDROLOGY & HYDRAULICS

June 2014

HARRIS COUNTY FLOOD CONTROL DISTRICT

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Acronyms

AEP	Annual Exceedance Probability
cfs	Cubic Feet per Second
COH	City of Houston
DA	Drainage Area
DCI	Percent Channel Improvement
DLU	Percent Urban Development
DTM	Digital Terrain Model
EA	Environmental Assessment
ERRY	Englewood Railroad Yard
FEMA	Federal Emergency Management Agency
FRM	Flood Risk Management
GRR	General Reevaluation Report
H&H	Hydrologic and Hydraulic
HB&T	Houston Belt and Terminal
HCFCD	Harris County Flood Control District
HCOEM	Harris County Office of Emergency Management
IDs	Identifications
IH	Interstate Highway
IMP	Impervious
L	Sub-watershed length
L_{CA}	Length to Sub-watershed Centroid
NED	National Economic Development
NGVD	National Geodetic Vertical Datum
R	Storage Coefficient
RCB	Reinforced Concrete Box
RTIMP	Percent of Sub-basin which is impervious
S	Channel Slope
S_o	Watershed Slope
SSP	Statistical Software Package
STRTL	Initial Rainfall Loss Value
TC	Time of Concentration
TSP	Tentatively Selected Plan
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
US	U.S. Highway
WOP	Without Project
WSELs	Water Surface Elevations
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

The following document has been prepared as *Appendix 2 – Hydrology and Hydraulics* for the Hunting Bayou Flood Risk Management (FRM), *Draft General Reevaluation Report (GRR) and Integrated Environmental Assessment (EA)* for FRM on Hunting Bayou in Texas. This appendix presents the hydrologic and hydraulic (H&H) modeling results for developing the Without Project (WOP) (baseline) conditions for the study area and the results from the component and alternative identification analysis to support the GRR/EA. This study's scope spans more than 14 years; during that time, events occurred that changed the path of the H&H analysis and affected the component and alternative analysis. To make this appendix concise and easier to follow, only some of these events are described. Other major changes are described to guide the reader through the various analyses associated with the GRR/EA.

1.1 Purpose and Scope

This appendix is intended to provide sufficient detail so the reader can understand engineering judgments and assumptions made to derive the final opinion relating to the H&H characteristics for Hunting Bayou, Harris County, Texas. The scope for H&H investigations is to evaluate the flooding extent within the study area for the WOP conditions and for the With Project flood reduction components and alternatives. The flooding extent, evaluated in terms of water surface elevations (WSELs) and peak discharges, is to be analyzed for eight annual exceedance probabilities (AEPs): the 50 percent, 20 percent, 10 percent, 4 percent, 2 percent, 1 percent, 0.4 percent and 0.2 percent events. The H&H analysis results are used as input for the economic model, which calculates damages from flooding. Also included in the scope is developing H&H risk and uncertainty parameters for use in the economic analysis.

1.2 Assumptions

The following assumptions were made in developing WOP conditions and all the plan alternatives.

- The analysis period for comparing costs and benefits following project implementation begins in the year 2022 and extends 50 years to 2072. The 2022 base year (existing conditions) was selected since it is the year in which the project is anticipated to be completed and benefits are expected to begin to accrue.

- Structural flood control alternatives involve Hunting Bayou's main stem, from the downstream limit of the culvert under the US 59 crossing to its confluence with the Houston Ship Channel.

- Flood control modifications to tributary channels will not be considered unless such modifications directly affect the feasibility of a flood control plan on the main stem. The project will result in increased outlet capacity for each tributary channel. Adverse impacts are not expected due to the lowered tailwater in the main channel.

1.3 Hydrologic and Hydraulic (H&H) Modeling Software

The Hunting Bayou GRR/EA was started in July 1998. Initially, the hydrologic modeling was completed using the HEC-1 software package and the hydraulic modeling was completed using the HEC-RAS 3.1.1 software package. At the time, HEC-1 was the locally approved modeling software (Ref. 14) and since HEC-HMS had just recently released, it did not have the necessary modeling functionality as HEC-1. Due to updated local H&H modeling standards and expansion of modeling capabilities, H&H modeling for Hunting Bayou has been completed using HEC-HMS 3.4.0 and HEC-RAS 4.1.0. Some references in this appendix refer back to analyses completed using the HEC-1 and HEC-RAS 3.1.1 models. *Section 3.1* also discusses the conversion from the legacy HEC models to the NexGen version of the HEC models.

2.0 WATERSHED DESCRIPTION

The Hunting Bayou watershed, shown on the map in *Exhibit A2-1*, comprises approximately 30 square miles in Harris County, Texas. Located about five miles northeast of downtown in the city of Houston (COH), the watershed is highly developed as mixed residential, commercial and industrial land use. The watershed resides in three municipal jurisdictions: COH corporate and extraterritorial limits, Jacinto City and Galena Park.

Hunting Bayou's main stem consists of an earthen channel section and extends approximately 15 miles from its headwaters west of U.S. Highway (US) 59 to its confluence with the Houston Ship Channel. Except for isolated improvements and maintenance activities, Hunting Bayou was constructed with its current capacity sometime during the 1940s. Many residential subdivisions in the watershed's upstream portion date back to that time period.

Hunting Bayou has a relatively flat slope of approximately 0.0007 ft/ft with extensive floodplain area in the watershed's upper half (see *Exhibit A2-29*). The existing flood protection level along Hunting Bayou is between the 50- and 20-percent AEP events (see *Section 5.10.1*) with structural flooding occurring for events greater than the 50-percent AEP. During an intense rainfall event, Hunting Bayou's existing conditions do not provide adequate flood protection, nor does the bayou serve as an adequate outfall source for the local drainage system.

In the upper portion of the watershed, the right overbank is largely confined at its outer limits to the UPRR railroad embankment. Several sections extend beyond the embankment to capture potential storage volume within the UPRR storage facility located between Lockwood Drive and Wayne Street. There are no major drainage ways directly south of the UPRR. As such overflow into the Buffalo Bayou watershed is considered negligible as backwater from a coincident event would limit flow interaction between these two watersheds in this area.

Hot summers and mild winters characterize the climate of the area. The average annual temperature for Harris County for years 1947 through 2003 was 70.9 degrees Fahrenheit (°F). Over the same period, the average annual rainfall was 51.5 inches (Ref. 26).

2.1 Survey Datum and Land Subsidence

The horizontal datum and vertical datum used in this report are:

Horizontal Datum:	Texas State Plane Coordinates SC Zone. North American Datum (NAD) of 1983
Vertical Datum:	National Geodetic Vertical Datum (NGVD) of 1929 1973 subsidence adjustment

The source of the survey is through field reconnaissance, which is discussed further in *Section 5.1*. Topography of the watershed is relatively flat and featureless, typical of the Gulf Coast in this area. Natural ground elevations range from five feet near the mouth of Hunting Bayou up to 48 feet near US 59. Since 1906, land subsidence in the Houston area due to groundwater withdrawals has resulted in reductions in ground surface elevations along Hunting Bayou, ranging from seven (8.5) feet at the mouth to two (6.5) feet near US 59. It is recognized that inland riverine flooding is not altered by land subsidence when it is relatively uniform in magnitude and areal extent. It is known subsidence has continued to occur through certain portions of the project area after 2000. Since the subsidence is not uniform along the bayou, the potential for differential changes in the channel slope and adjacent topography exists. However, the differential subsidence and change in channel slope from 2001 to 2011 would be very minor [All elevations referenced in this paragraph are 1929 NGVD, 1973 adjustment].

A previous study (Ref. 25) concluded even with the most unusual amount of differential subsidence considered to be possible, flood levels would typically only change by approximately one-tenth of the related differential subsidence. Even if the differential subsidence was one foot, a tenth of a foot of change in flood level would not be significant. This amount of change is not considered to be significant. Also as the COH and Harris County continue to convert from groundwater to surface water supplies, based on mandates from the Harris-Galveston Subsidence District, excessive groundwater pumpage has been mostly halted, and the rate and overall amount of subsidence have declined dramatically. Within the watershed area subsidence is not expected to increase significantly over the study evaluation period. The effect of subsidence with respect to boundary conditions is discussed further in *Section 5.7.2*.

ER 1110-2-8160 requires that all projects be referenced to a consistent nationwide vertical datum. The current orthometric vertical reference datum in the continental United States is the North American Vertical Datum (NAVD) of 1988. At the time the re-study was initiated in 1998, the Hunting Bayou hydrologic models adopted by FEMA and in use for management of floodplain regulations in Harris County were based on 1929 NGVD, with a 1973 adjustment for subsidence. All of the hydraulic and hydrologic models as well as the HEC-FDA models were compiled and essentially completed prior to the date of adoption of the 1988 NAVD standard. These 1929 NGVD models were verified by extensive field surveys that tied all of the pertinent criteria relating to channel geometry, bridges, culverts, and structure elevations to one consistent datum. Use of 1988 NAVD was not brought into practice by HFCFCD until after Tropical Storm Allison in 2004. Therefore, all elevation information shown in the GRR/EA is tied to the 1929 NGVD datum, with a 1973 adjustment for subsidence. Converting to the 1988 NAVD datum would not significantly alter the identification of the NED Plan and LPP as the application of a consistent datum in the economic analysis produced a relative measure of damages and damages prevented that is indifferent to the base reference. Furthermore, slight variations which may exist between the two datums are taken into account in the stochastic HEC-FDA model with expressions of uncertainty in flood stage, ground elevation of damageable structures, and uncertainty associated with the depth-damage relationship. To ensure ultimate compliance with ER 1110-2-8160, all final design and construction documents will be tied to the 1988 NAVD datum.

3.0 HYDROLOGIC AND HYDRAULIC (H&H) ANALYSIS PROCEDURE

The H&H analysis began in July 1998. The Harris County Federal Emergency Management Agency (FEMA) effective flood insurance study models at that time were provided in HEC-1 and HEC-2 formats. During the 2005 GRR/EA update, the HEC-2 model was updated to HEC-RAS 3.1.1. Numerous and extensive flood damage modeling and analyses were performed with these models. Since this study is being used to determine federal interest for a FRM project and so much work had been completed using the previous H&H model set, the HEC-1 and HEC-RAS 3.1.1 models used for the GRR/EA were maintained for completing the study.

In 2010, a comprehensive update from the HEC-1 and HEC-RAS 3.1.1 models to the more recent HEC-HMS 3.4.0 and HEC-RAS 4.1.0 software package was completed to be consistent with local practices. The Hydrologic Engineering Center and FEMA also no longer support using HEC-1. HEC-HMS is the successor and replacement for the HEC-1 program as documented in the HEC-HMS Technical Reference Manual. The analysis, results and comparisons for the conversion process are described in *Section 3.1*. The model conversions were completed using standard practice, and results were checked for consistency with previous model results. HEC-HMS and HEC-RAS are considered Community of Practice Preferred Models.

Since the bulk of the H&H analyses were completed in 2005, the discussion that follows applies to the work completed at that time. Flooding associated with Hunting Bayou's main stem was computed using the HEC-1 and HEC-RAS computer models. HEC-1 was used to compute runoff hydrographs and peak flows for hypothetical events. HEC-RAS 3.1.1 was used to compute the corresponding water surface profiles for WOP conditions, Component Optimization and Alternative Evaluation. The procedure used to develop the WOP conditions hydrology is listed below.

1. Obtain starting HEC-1 and HEC-2 models from the non-federal sponsor, Harris County Flood Control District (HCFCD).

2. Review HEC-1 and HEC-2 models and make necessary adjustments.

    a. Change loss rate methodology in HEC-1 from Exponential Loss Rate to Uniform Loss Rate to provide for better calibration against the gauge frequency curve and historical storm events. This process is detailed in *Section 4.2*.

    b. Field-verify channel roughness conditions and bridge and pipeline crossings and make appropriate modifications to the HEC-2 model.

    d. Convert HEC-2 model to HEC-RAS, Version 3.1.1, and replace original overbank sections with new overbank sections.

3. Compute storage-outflow relationships using HEC-RAS. Insert relationships into HEC-1 models.

4. Calibrate and verify using HEC-1 and HEC-RAS models.

    a. Compute gauge frequency curve using Log Pearson Type III analysis.

    b. Compare HEC-1 results for eight frequencies to gauge frequency curve.

c. Compare HEC-1 results to five historical storm events.

d. Compare HEC-RAS results to observed high water marks for one historical storm event.

5. Compute peak flows using HEC-1 for eight frequencies for existing watershed conditions.

6. Compute water surface profiles using HEC-RAS for eight frequencies for existing watershed conditions.

7. Insert computed peak flows and WSELs into economics models to determine WOP conditions damages.

3.1 Hydrologic and Hydraulic (H&H) Model Updates For Without Project (WOP) Conditions

A critical need was identified to update the older HEC-1 and HEC-RAS 3.1.1 models used in the previous WOP analyses to more current HEC software package releases. The analysis, results and comparisons for these conversions are discussed in the following sections.

3.1.1 Without Project (WOP) Hydrologic and Hydraulic (H&H) Model Conversion

The WOP Conditions model was converted from HEC-1 and HEC-RAS 3.1.1 to HEC-HMS 3.4.0 and HEC-RAS 4.1.0, respectively. The conversion was necessary to facilitate current and future modeling for Hunting Bayou. Due to differing loss rates for the various storm events, multiple HEC-1 models were required to perform complete hydrologic analyses. Converting HEC-1 to HEC-HMS 3.4.0 allowed for a single hydrologic model, thereby improving the measures for quality assurance and quality control, model cohesiveness and maintenance. Additionally, HEC-RAS 4.1.0 was much improved from HEC-RAS 3.1.1 including improved storage volume calculations. Results from the conversion process were compared in detail. The following summarizes the differences in the peak flow rate and WSELs resulting from the model conversions. Economic damage computations using HEC-FDA were performed on the model updates to quantify damage cost impacts associated with updating the models. Details on this damage analysis are deferred to *Attachment A – WOP Conversion Memo*.

3.2 Hydrologic and Hydraulic (H&H) Model 2013 Updates

In response to 2013 DQA and ATR comments, the rainfall used in HEC-HMS was converted from TP-40 to USGS rainfall (further described in *Section 4.1*), while the HEC-RAS models were updated to include the new boundary conditions (further described in *Sections 5.7* through *5.7.2*). WOP conditions and alternative plan results reference these updated models. All other analysis results reference the models before these changes were made.

4.0 HYDROLOGIC MODELING (WITHOUT PROJECT [WOP] CONDITIONS)

The non-federal sponsor, HCFCD, provided the study's starting HEC-1 model for WOP conditions in 1998. This model included the FEMA regulatory model with updates to reflect constructed improvements described in the Binkley and Barfield reports in 1991 (Ref. 3). The following subsections discuss the determination of hydrologic model parameters, model calibration, peak flow results and the model conversion from HEC-1 to HEC-HMS 4.3.0.

4.1 Hypothetical Rainfall Events

The National Weather Service Technical Paper 40: *Rainfall Frequency Atlas of the United States (TP-40)* was used to develop the hypothetical precipitation for the 50, 20, 10, 4, 2 and 1 percent AEPs (Ref. 4). Precipitation for the 0.4 and 0.2 percent AEPs was obtained by extrapolating the values obtained from TP-40 on log-normal paper.

The rainfall depths obtained from TP-40 are based on partial duration series. Partial duration series rainfall includes all independent events above a base value, and can include more than one rainfall event per year. For this study, the partial duration series rainfall was converted to annual series rainfall, which is based on the largest event for each year. The conversion factors for the 50, 20 and 10 percent events are 0.88, 0.96 and 0.99, respectively (Ref. 5). No conversion factor is required for the 4, 2 and 1 percent events.

Table A2-1 shows the annual series rainfall depths for the various events and durations for Harris County Region 2, the same region where Hunting Bayou is located (Ref. 6).

Table A2-1:
Annual Series Rainfall – TP-40

AEP (%)	Rainfall Depth (inches) for Given Duration						
	30-min	60-min	2-hour	3-hour	6-hour	12-hour	24-hour
50	1.5	2.0	2.5	2.7	3.3	3.8	4.4
20	2.0	2.7	3.5	3.9	4.7	5.7	6.6
10	2.3	3.2	4.3	4.8	5.8	6.8	8.3
4	2.7	3.7	4.9	5.5	6.7	8.4	9.7
2	3.0	4.1	5.5	6.2	7.6	9.4	11.0
1	3.3	4.6	6.1	6.9	8.6	10.6	12.6
0.4	3.7	5.2	7.0	7.9	9.8	12.2	14.5
0.2	4.0	5.6	7.6	8.6	10.7	13.4	15.9

Other studies conducted in the Harris County area have used rainfall data from the Depth-Duration Frequency of Precipitation for Texas (USGS Water Resource Investigations 98-4044) document. The earlier Hunting Bayou study models used the TP-40 rainfall data since this is what was prescribed by local practice when the study began; however, since the project start, the local practice has updated from the TP-40 levels to the USGS levels. As part of the 2013 update, the rainfall data used in this H&H analysis was updated to the USGS data. *Table A2-2* shows the annual series rainfall depths for the various events and durations for USGS data.

Table A2-2:
Annual Series Rainfall – USGS

AEP (%)	Rainfall Depth (inches) for Given Duration						
	15-min	60-min	2-hour	3-hour	6-hour	12-hour	24-hour
50	0.7	2.0	2.3	2.6	3.1	3.7	4.4
20	1.4	2.5	3.1	3.5	4.3	5.1	6.2
10	1.5	2.9	3.6	4.1	5.1	6.2	7.6
4	1.7	3.4	4.3	5.0	6.4	7.8	9.6
2	1.9	3.8	5.0	5.8	7.6	9.2	11.3
1	2.1	4.3	5.7	6.7	8.9	10.8	13.2
0.4	2.4	4.9	6.7	8.0	10.9	13.3	16.2
0.2	2.6	5.5	7.6	9.2	12.8	15.5	18.9

A comparison with the USGS rainfall data was completed and revealed that runoff volumes increased by approximately 5 percent when using the USGS data. The 5 percent increase did not change the peak flows or WSELs in the hydraulic model by more than a tenth of a foot when comparing 1 percent AEP without project conditions. Thus, the rainfall data used in the H&H calibration and model verification remains as the TP-40 data.

4.1.1 Rainfall Distribution

The hypothetical 24-hour precipitation was used for all eight AEPs modeled in HEC-1. The rainfall distribution for a particular AEP was developed using the standard 24-hour hyetograph for Harris County (Ref. 6). A uniform areal distribution of rainfall over the entire watershed was used. A 24-hour rainfall duration was used with the peak intensity occurring at a 67 percent rainfall duration position. *Table A2-3* lists the point rainfall distribution used for each AEP.

Table A2-3:
Point Rainfall Distribution (Harris County 24-Hour Hyetograph)

Time (hours)	AEP (%)							
	50	20	10	4	2	1	0.4	0.2
0.0	0.02	0.04	0.06	0.05	0.07	0.08	0.09	0.10
0.5	0.02	0.04	0.06	0.05	0.07	0.08	0.09	0.10
1.0	0.02	0.04	0.06	0.05	0.07	0.08	0.09	0.10
1.5	0.02	0.04	0.06	0.05	0.07	0.08	0.09	0.10
2.0	0.03	0.04	0.06	0.05	0.07	0.08	0.09	0.10
2.5	0.03	0.04	0.06	0.06	0.07	0.08	0.10	0.10
3.0	0.03	0.04	0.06	0.06	0.07	0.08	0.10	0.10
3.5	0.03	0.04	0.06	0.06	0.07	0.08	0.10	0.11
4.0	0.03	0.04	0.06	0.06	0.07	0.09	0.10	0.11
4.5	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.11
5.0	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.11
5.5	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.11

Time (hours)	AEP (%)							
	50	**20**	**10**	**4**	**2**	**1**	**0.4**	**0.2**
6.0	0.03	0.08	0.08	0.13	0.14	0.16	0.20	0.22
6.5	0.03	0.08	0.08	0.13	0.14	0.16	0.20	0.22
7.0	0.03	0.08	0.08	0.13	0.14	0.16	0.20	0.22
7.5	0.03	0.08	0.08	0.13	0.14	0.17	0.20	0.22
8.0	0.04	0.08	0.08	0.13	0.14	0.17	0.20	0.22
8.5	0.04	0.08	0.08	0.14	0.14	0.17	0.20	0.22
9.0	0.04	0.08	0.08	0.14	0.14	0.17	0.20	0.23
9.5	0.04	0.08	0.09	0.14	0.15	0.17	0.20	0.23
10.0	0.04	0.08	0.09	0.14	0.15	0.17	0.20	0.23
10.5	0.04	0.08	0.09	0.14	0.15	0.17	0.20	0.23
11.0	0.04	0.08	0.09	0.14	0.15	0.17	0.20	0.23
11.5	0.04	0.09	0.09	0.14	0.15	0.17	0.20	0.23
12.0	0.10	0.13	0.16	0.20	0.23	0.28	0.31	0.35
12.5	0.10	0.13	0.17	0.21	0.24	0.28	0.32	0.35
13.0	0.10	0.13	0.17	0.21	0.24	0.29	0.32	0.35
13.5	0.11	0.13	0.17	0.21	0.24	0.29	0.32	0.35
14.0	0.22	0.40	0.55	0.59	0.68	0.75	0.90	1.00
14.5	0.22	0.40	0.56	0.59	0.68	0.75	0.90	1.00
15.0	1.53	1.99	2.30	2.69	2.97	3.25	3.70	4.00
15.5	0.49	0.71	0.85	1.03	1.17	1.30	1.50	1.60
16.0	0.14	0.20	0.26	0.31	0.36	0.40	0.45	0.50
16.5	0.13	0.20	0.25	0.30	0.35	0.40	0.45	0.50
17.0	0.10	0.13	0.17	0.20	0.24	0.29	0.32	0.35
17.5	0.10	0.13	0.17	0.20	0.24	0.29	0.31	0.35
18.0	0.03	0.05	0.07	0.06	0.07	0.09	0.10	0.11
18.5	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.11
19.0	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.11
19.5	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.11
20.0	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.11
20.5	0.03	0.04	0.07	0.06	0.07	0.09	0.10	0.10
21.0	0.02	0.04	0.06	0.05	0.07	0.08	0.10	0.10
21.5	0.02	0.04	0.06	0.05	0.06	0.08	0.09	0.10
22.0	0.02	0.04	0.06	0.05	0.06	0.08	0.09	0.10
22.5	0.02	0.04	0.06	0.05	0.06	0.08	0.09	0.10
23.0	0.02	0.04	0.06	0.05	0.06	0.08	0.09	0.10
23.5	0.02	0.04	0.06	0.05	0.06	0.08	0.09	0.10
Total	**4.40**	**6.62**	**8.32**	**9.70**	**11.00**	**12.60**	**14.50**	**15.90**

Using this rainfall distribution, the peak incremental rainfall occurs in hour 15.5 during a 24-hour duration storm event. The 24-hour hyetograph is set up so the rainfall amounts for a given duration are nested. For example, the 1 percent AEP 30-minute rainfall duration is equal to the peak 30-minute interval within the 24-hour hyetograph. Similarly, the 60-minute rainfall duration is equal to the sum of the two highest 30-minute intervals in the 24-hour hyetograph, and so on. This is illustrated in *Exhibit A2-2*, which shows the rainfall pattern for the 1 percent AEP along with the cumulative totals.

4.1.2 Depth Area Adjustment

The average rainfall depth occurring over a drainage area (DA) will decrease with increasing DA for a particular storm and duration. The values presented in *Table A2-1* are point rainfall depths for a maximum 24-hour duration. TP-40 contains a relationship between DA and point rainfall reduction. However, for DAs larger than a few square miles, consideration must also be given to the entire DA. Since Hunting Bayou's total DA is about 30 square miles, the depth area curve listed as Figure 15 in TP-40 was used to define the point rainfall percent for four DAs: 0.01 (point), 10, 25 and 50 square miles. *Table A2-4* contains the point rainfall percent or adjustment factors for the four DAs and corresponding 24-hour rainfall depths for each AEP.

The adjusted 24-hour rainfall amounts for the four DAs were distributed in the same manner described in sections above and put into the HEC-1 models. Index hydrographs are computed in HEC-1 for the four rainfall distributions at each analysis point, and a final hydrograph is interpolated based on the total contributing DA.

Table A2-4:
Rainfall Depth-Area Relationship for Study Area

DA (mi^2)	Area Adjustment (%)	Rainfall Depth* (inches) for Given AEP							
		50	20	10	4	2	1	0.4	0.2
0.01	100	4.40	6.62	8.32	9.70	11.00	12.60	14.50	15.90
10.0	98.2	4.32	6.50	8.17	9.52	10.80	12.37	14.23	15.61
25.0	96.8	4.26	6.41	8.05	9.39	10.65	12.20	14.04	15.39
50.0	95.0	4.18	6.29	7.91	9.22	10.45	11.98	13.78	15.11

**Depths listed are for a 24-hour duration.*

4.2 Rainfall Losses

The non-federal sponsor, HCFCD, provided HEC-1 model used the exponential loss rate method for computing rainfall losses. For this study, the initial and constant loss rate method was used. The loss rate method was changed because the initial and constant loss rate method provided a better calibration against the gauge frequency curve and historical storm events. The required inputs in HEC-1 for the constant loss rate method are described below.

STRTL – initial rainfall loss, in inches

CNSTL – constant rainfall loss rate, in inches per hour, to be applied after initial loss value (STRTL) is completely satisfied

RTIMP – percent of sub-basin which is impervious (no losses computed for this portion of the sub-basin)

The STRTL value for all eight exceedance probability events was set at 0.5 inch, which is typically used by non-federal sponsor, HCFCD, for clay soils in urban areas (Ref. 5). *Table A2-5* lists the constant rainfall loss used for each event, along with the average rainfall loss over the storm duration and the corresponding percent runoff.

Table A2-5:
Constant Loss Rates and Percent Runoff

AEP (%)	Constant Loss Rate (inch per hour)	Average Rainfall Loss* (inches)	Approximate Runoff** (%)
50	0.30	1.66	62
20	0.13	1.66	75
10	0.10	1.63	81
4	0.10	1.60	84
2	0.10	1.67	85
1	0.10	1.69	87
0.4	0.10	1.72	88
0.2	0.10	1.74	89

* *Computed at U.S. Geological Survey (USGS) Stream Gauge Location, rainfall losses are for a 24-hour duration storm.*
** *Computed at USGS Stream Gauge Location.*

The 0.10 inch per hour loss rate assigned to the 4, 2, 1, 0.4 and 0.2 percent AEPs falls within the value range used by non-federal sponsor, HCFCD, in urban areas (Ref. 5). The loss rates used for the 50 and 20 percent AEPs (0.30 inch per hour and 0.13 inch per hour, respectively) are slightly higher than the standard loss rates used in Harris County. All loss rates were determined through the calibration efforts as discussed in *Section 4.6*. As can be seen from *Table A2-5*, the average rainfall loss over the 24-hour storm duration is approximately the same for all storm frequencies. Considering Hunting Bayou is a highly developed watershed, much of the rainfall loss can be attributed to runoff's inability to get to a drainage channel. This can be due in part to local depression storage and inadequate secondary drainage systems. Once the depression storage is overcome and the secondary systems are surcharged, additional rainfall will contribute to runoff at nearly 100 percent. Thus, it would seem reasonable the average rainfall loss on a sub-watershed would be similar regardless of the total rainfall amount.

The RTIMP value varies for each sub-watershed depending on the amount and type of development. The percent imperviousness calculations are described in *Section 4.3*.

4.3 Sub-watershed Unit Hydrograph Methodology

Exhibit A2-3 has a map showing Hunting Bayou's sub-watersheds. Twenty-four sub-watersheds were delineated based on lateral drainage patterns and COH-provided documentation for storm drainage systems. Land use was identified using aerial photography from March 1998 in combination with field reconnaissance.

Sub-watershed unit hydrographs were computed for Hunting Bayou using the Clark Method. This method requires a time of concentration (TC) and a storage coefficient (R) to compute a unit hydrograph. Using the equations shown below (Ref. 6), TC and R values were calculated for WOP conditions for each of the 24 sub-watersheds.

$$TC + R = 7.25(L/\sqrt{S})^{0.706} \text{ if DLU} < 18\%$$

$$TC + R = 4295 DLU^{-0.678} DCC^{-0.967} (L/\sqrt{S})^{0.706} \text{ if DLU} > 18\%$$

$$TC = D(1 - 0.0062)(0.7DCI + 0.3DLU)(L_{CA}/\sqrt{S})^{1.06}$$

Where:

TC	=	Time of concentration (hours)
R	=	Storage coefficient
L	=	Sub-watershed length (miles)
S	=	Channel slope (feet per mile)
DLU	=	Percent urban development
DCC	=	Percent channel conveyance

(other variables provided in *Table A2-6*)

DCI	=	Percent channel improvement
L_{CA}	=	Length to sub-watershed centroid (miles)
S_o	=	Watershed slope (feet per mile)
DA	=	Drainage area (square miles)
D	=	2.46 (if $S_o < 20$ feet per mile)
		3.79 (if $20 < S_o < 40$ feet per mile)
		5.12 (if $S_o > 40$ feet per mile)

Table A2-6:
WOP Conditions Unit Hydrograph Parameters

Sub-Area Name	DA (mi^2)	L (mi)	LCA (mi)	*S* (feet/mi)	So (feet/mi)	DLU (%)	DCI (%)	DCC (%)	% IMP	D	TC+R	TC (hours)	R
H100A	1.46	1.94	1.25	10.8	10	93	100	50	33	2.46	3.12	0.35	2.77
H100B	1.36	2.02	0.91	4.2	10	98	100	50	34	2.46	4.32	0.40	3.92
H100C	1.31	2.06	0.86	4.1	10	95	100	50	33	2.46	4.51	0.39	4.13
H100D	1.51	2.60	1.46	7.5	10	77	100	50	27	2.46	4.96	0.53	4.42
H100E	0.57	1.95	1.42	6.2	10	75	100	50	45	2.46	4.40	0.58	3.83
H100F	0.97	1.90	0.80	5.8	10	99	100	50	59	2.46	3.67	0.29	3.38
H100G	1.50	2.60	1.97	4.7	10	67	100	50	23	2.46	6.42	0.98	5.44
H100H	0.58	1.91	1.16	3.9	10	85	100	50	30	2.46	4.70	0.57	4.12
H100I	0.87	2.80	1.86	4.6	10	73	70	50	26	2.46	6.43	1.19	5.25
H100J	0.84	1.78	1.52	4.9	10	58	70	50	20	2.46	5.34	0.97	4.37
H100K	1.13	1.27	0.53	5.5	10	37	70	50	13	2.46	5.48	0.32	5.16
H100L	0.74	1.58	1.14	3.4	10	49	60	50	17	2.46	6.26	0.96	5.30
H100M	0.88	1.54	0.98	7.3	10	82	30	50	29	2.46	3.31	0.60	2.71
H100N	1.73	3.53	2.73	10.6	10	73	10	30	26	2.46	9.25	1.68	7.57
H100O	1.10	3.01	1.63	4.8	10	19	10	30	7	2.46	27.23	1.66	25.57
H102A	1.13	2.12	1.55	0.5	10	0	0	100	0	2.46	15.74	5.65	10.09
H102B	2.16	3.53	1.97	8.3	10	89	60	90	31	2.46	3.05	0.94	2.10
H103A	1.28	2.56	1.17	3.7	10	79	100	20	47	2.46	14.99	0.61	14.39
H103B	1.84	2.27	1.14	11.0	10	73	100	60	26	2.46	3.42	0.34	3.08
H112A	1.19	2.15	0.93	3.8	10	98	100	50	34	2.46	4.68	0.43	4.25
H118A	1.58	3.10	2.27	4.1	10	92	60	10	32	2.46	29.18	1.58	27.60
H118B	1.66	1.85	1.40	8.7	10	93	100	10	33	2.46	15.43	0.44	14.99
H118C	1.54	2.75	1.97	10.6	10	88	40	10	31	2.46	19.76	0.96	18.81
H125A	1.19	2.51	1.21	3.1	10	39	100	100	14	2.46	5.36	0.82	4.54
Total	**30.12**												

The non-federal sponsor, HCFCD, established these equations, and they are used countywide. *Table A2-6* lists the Clark unit hydrograph parameters for the WOP conditions. Because Hunting Bayou is almost a fully developed watershed, it is reasonable to assume the Future WOP sub-watershed parameters will not change significantly from WOP conditions.

For the nine tributary sub-watersheds listed in *Table A2-6* (H102A, H102B, H103A, H103B, H118C, H112A, H118A, H118B and H125A), the DCI factors were those used to compute TC and R in the starting HEC-1 models obtained from the non-federal sponsor, HCFCD. For the remaining sub-watersheds on Hunting Bayou's main stem, DCI was measured from aerial photographs.

The same approach was taken to determine the 2011 DCC for the sub-watersheds. For all the tributary sub-watersheds (except H112A), the values were those used to compute TC and R in starting HEC-1 models obtained from the non-federal sponsor, HCFCD. For sub-watersheds H100A through H100M (and including H112A), DCC was measured to be 50 percent on average. For sub-watersheds H100N and H100O, the average DCC factor was 30 percent. The percent impervious (IMP) column in *Table A2-6* has the impervious percentage for each sub-watershed. This value corresponds to the RTIMP parameter needed to calculate the constant loss rate described in *Section 4.2*. The impervious percentage was determined by multiplying the DLU by the average impervious percent for each sub-watershed. An average 35 percent imperviousness, which the non-federal sponsor, HCFCD, typically uses for developed residential areas (Ref. 6), was assigned to all but three sub-watersheds. H100E, H100F and H103A were assigned a 60 percent impervious average due to large amounts of commercial and industrial developments within these sub-watersheds.

4.4 Hydrograph Routing

The Hunting Bayou HEC-1 models use the Modified Puls routing method to simulate attenuating a flood hydrograph as it moves downstream. Storage-outflow relationships for the HEC-1 routing reaches were developed using the Hunting Bayou HEC-RAS 3.1.1 model. Nine water surface profiles were computed with flows varying along the stream's length. These profiles covered the eight AEPs needed for HEC-1 computations. The ninth profile included the 0.2 percent AEP multiplied by 1.25, which was necessary to create an additional point beyond the 0.2 percent AEP event on the storage-outflow curves used in Modified Puls routing. The 1.25 x 0.2 percent AEP event approximates a straight line fit to the existing storage-outflow relationship. *Exhibit A2-4* is a schematic diagram for the WOP conditions HEC-1 model.

Part of the required input for the Modified Puls routing method is the number of routing steps. The number of routing steps affects attenuation where one routing step gives the maximum attenuation and increasing the number of steps reduces the attenuation. The number of routing steps for each reach in this study was generally selected based on the average travel time in the reach divided by the 15-minute HEC-1 computation interval. If the average reach velocity was less than one foot per second, a routing step of one was selected to treat the reach as a level pool routing. The storage for each reach was calculated by subtracting the volume for a profile at the downstream cross-section from the volume at the upstream cross-section.

4.4.1 Tributary Routing

The major tributaries (shown in *Exhibit A2-5*) are H112-00-00, H110-00-00, H118-00-00, H125-00-00, H103-00-00 and H102-00-00. *Table A2-7* shows information for each of these tributaries including sub-watersheds, DA and HEC-1 nodes.

**Table A2-7:
Hunting Bayou Tributaries Modeled in HEC-1**

Tributary	HEC-1 Sub-watershed(s)	DA (mi^2)	HEC-1 Node
H112-00-00	H112A	1.19	H100#1
H110-00-00	H100C	1.31	H100#3
H118-00-00	H118A, H118B, H118C	4.78	H100#3
H125-00-00	H125A	1.19	H100#10
H103-00-00	H103A, H103B	3.12	H100#12
H102-00-00	H102A, H102B	3.29	H100#14

Of the six major tributaries, H118-00-00 and H103-00-00 are routed prior to their confluence with Hunting Bayou. Storage-outflow relationships for these two tributaries were obtained from the non-federal sponsor, HCFCD, HEC-1 models for the tributaries. Both tributaries are modeled in HEC-1 using one routing reach.

4.5 Base Flow

Base flow for a stream can be defined as flow originating from the subsurface. Since the Hunting Bayou watershed contains mostly clay soils and has a high level of impervious cover, there is little base flow from the subsurface. Some wastewater treatment plant (WWTP) effluent is discharged into Hunting Bayou; however, this flow is negligible when compared to the computed flood discharges. As a result, base flow was not considered in this study.

4.6 HEC-1 Model Calibration

Calibration for the runoff parameters (unit hydrograph coefficients and loss rates) comprised the Log Pearson frequency analysis, using the USGS stream gauge on Hunting Bayou at interstate highway (IH) 610, and verifying peak flow and stages for five storm events. The five historic storm events studied were the June 1989, January 1991, October 1993, October 1994 and September 1998 (Tropical Storm Frances) events.

Due to the lack of high water marks throughout the watershed prior to 1998, only HEC-1 verification was performed on the 1989, 1991, 1993 and 1994 storm events. Several high water marks along Hunting Bayou were identified and surveyed after the September 1998 event, which provided the opportunity to verify the HEC-1 and HEC-RAS 3.1.1 models for this event. The gauge frequency analysis and verification to historical storm events are described in the following sections.

4.6.1 Gauge Frequency Analysis

Hunting Bayou's stream gauge at IH 610 (USGS Stream Gauge 08075770) was installed in 1964. USGS reports a 16.1 square mile Hunting Bayou watershed DA is upstream from the gauge location. In this study, a 15 square mile DA was computed at the gauge location, which is within 5 percent of the USGS reported DA. *Exhibit A2-6* shows the USGS stream gauge location within the Hunting Bayou watershed. All other stream gauges in the Hunting Bayou watershed were not used due to the period recorded being too short for analysis.

USGS has published 49 years of recorded annual peak flows at the stream gauge. *Table A2-8* lists the annual peak discharges at the gauge.

Table A2-8:
Annual Peak Discharges
USGS Stream Gauge 08075770

Water Year	Date	Observed Peak Discharge cubic feet per second (cfs)
1964	04/17/64	166
1965	12/10/64	355
1966	04/14/66	1,150
1967	10/05/66	920
1968	05/10/68	1,460
1969	02/21/69	1,050
1970	05/15/70	880
1971	10/23/70	2,260
1972	02/20/72	3,130
1973	06/13/73	3,380
1974	05/10/74	830
1975	08/04/75	890
1976	06/15/76	2,520
1977	09/10/77	790
1978	06/07/78	1,370
1979	09/20/79	2,470
1980	10/22/80	1,710
1981	06/05/81	2,600
1982	05/17/82	2,500
1983	08/18/83	3,440
1984	01/09/84	785
1985	10/25/84	2,500
1986	06/16/86	1,660
1987	07/09/87	2,610
1988	03/17/88	542
1989	06/26/89	3,470
1990	04/26/90	850
1991	01/15/91	1,900
1992	03/04/92	2,800
1993	03/22/93	2,900
1994	10/20/93	1,970
1995	10/18/94	3,430
1996	09/19/96	1,460
1997	05/24/97	2,580
1998	09/11/98	3,130
1999	05/12/99	1,610
2000	05/20/00	1,340
2001	06/09/01	3,230
2002	04/08/02	1,420
2003	10/29/02	1,160
2004	06/25/04	2,070
2005	11/02/04	1,120
2006	06/19/06	3,100
2007	08/16/07	3,430
2008	09/13/08	4,390
2009	04/18/09	1,380
2010	07/02/10	3,380
2011	12/29/10	688
2012	01/09/12	1,530

The watershed conditions upstream from the gauge have remained relatively the same. Major road crossings, including the IH 610 crossing where the gauge is located, were constructed in the 1970s. *Exhibit A2-7* is a plot with the annual peak discharges along with a 5-year moving average for the annual peaks. *Exhibit A2-7* shows the 5-year moving average has a slight upward trend until about 1982, where the flows level off. This reflects development in the watershed leveling off and the policies of the non-Federal sponsor which require new development to include measures to ensure "no adverse impact" to the surrounding area's water surface profiles. (Ref. 22) Because of these requirements, developers must either retain increased runoff associated with changes in land use onsite or purchase storage volume in regional detention facilities which retain runoff over the pre-development levels. Therefore, flows prior to 1982 were excluded from the gauge frequency analysis. In addition, the high outlier threshold was set to 3,300 cfs, since the annual peak flows for USGS Stream Gauge 08075770 historically did not accurately capture flows above this level.

The gauge frequency analysis was performed in accordance with the procedures described in *Guidelines for Determining Flood Flow Frequency, USGS Bulletin 17B*, 1981 (Ref. 9). The program HEC-SSP; Version 2.0, was used to perform the Log Pearson Type III analysis on the gauge data (Ref. 10). A -0.3 skew factor with a 0.302 Mean-Square Error, which are the published regional values, were used in the analysis. One low outlier shown in *Table A2-8* was identified by HEC-SSP in the analysis.

Table A2-9 shows the Log Pearson Type III analysis results. According to the frequency analysis shown in *Exhibit A2-8* and *Exhibit A2-9*, the 50 percent event was equaled or exceeded 25 times (or once every 2 years); the 20 percent event 10 times (or once every 4.9 years); and the 10 percent event five times (or once every 9.8 years). The record flood on Hunting Bayou (4,390 cfs in September 2008) is approximately equivalent to a 2 percent AEP.

Table A2-9:
Log Pearson Type III Analysis – USGS Stream Gauge 08075770

Exceedance Probability (%)	Computed Probability (cfs)	Confidence Limits (cfs)	
		5%	95%
99.0	382	495.7	268.5
95.0	664.8	808	515.2
90.0	871.3	1030.6	704.8
80.0	1182	1366.1	995.8
50.0	1981.6	2277	1730.4
20.0	3057.5	3643.6	2639.9
10.0	3718	4546.6	3164.2
5.0	4303.8	5378.4	3614.5
2.0	4994.8	6391.7	4132.2
1.0	5467.4	7102.2	4479.3
0.5	5903.8	7769.5	4795.5
0.2	6432.2	8591.3	5173.5

The HEC-1 model was then executed for the eight hypothetical AEPs using the WOP conditions unit hydrograph parameters calculated in *Section 4.3*. The initial loss for each sub-watershed was set at

0.50 inch, which is the value the non-federal sponsor, HCFCD, typically uses for clay soils in urban areas (Ref. 5). The constant loss rate was assumed to be 0.10 inch per hour for each sub-watershed, which also falls within the range the non-federal sponsor, HCFCD, typically uses. The computed discharges for HEC-1 Node H100#7 (USGS stream gauge location) were then compared to the SSP discharges. This comparison is shown in *Table A2-10* and *Exhibit A2-8*.

Table A2-10:
HEC-1 Model Versus SSP
(Same Loss Rates for All Events) – USGS Stream Gauge 08075770

AEP (%)	HEC-SSP Computed Probability (cfs)	HEC-1 Computed Discharge (cfs)	Difference	
			(cfs)	(%)
50.0	1,982	2,715	733	37
20.0	3,058	3,708	651	21
10.0	3,718	4,143	425	11
4.0	3,962	4,469	507	13
2.0	4,995	4,761	-234	-5
1.0	5,467	5,127	-340	-6
0.4	5,904	5,426	-478	-8
0.2	6,432	5,634	-798	-12

** Interpolated from Exhibit A2-8.*

Exhibit A2-8 shows the HEC-1 discharges at the USGS stream gauge for the 50 and 20 percent AEPs are outside the frequency curve's upper confidence limit. *Table A2-10* also shows the 50 percent discharge computed by HEC-1 is greater than the 20 percent discharge by the frequency analysis. It was determined some modification was required for the 50 and 20 percent loss rates to make the discharges at the USGS stream gauge more reasonable.

The average rainfall loss upstream from the USGS stream gauge was computed for the eight AEPs. For the 10, 4, 2, 1, 0.4 and 0.2 percent AEPs, the average rainfall loss was 1.6 to 1.7 inches. For the 50 and 20 percent AEPs, it was 1.1 inches and 1.4 inches, respectively.

As discussed in *Section 2.0*, the Hunting Bayou Watershed is highly developed. Regardless of the total rainfall amount, during a storm event, the rainfall is unable to get to Hunting Bayou until it overcomes local depression storage and inadequate secondary drainage systems, which would be approximately the same for each event.

The loss rates for the 50 and 20 percent AEPs were then modified so the average loss upstream from the USGS stream gauge was between 1.6 and 1.7 inches. This resulted in a 0.30 inch per hour loss rate for the 50 percent event and a 0.13 inch per hour rate for the 20 percent event. *Table A2-5* compares the average rainfall loss and percent runoff for the eight AEPs.

The HEC-1 model was re-executed for the 50 and 20 percent AEPs using the modified loss rates. The computed HEC-1 discharges are compared to the SSP in *Table A2-11* and *Exhibit A2-9*.

Table A2-11:
HEC-1 Model versus SSP
(Higher Loss Rates for 50% and 20% Events) – USGS Stream Gauge 08075770

AEP (%)	HEC-SSP Computed Probability (cfs)	HEC-1 Computed Discharge (cfs)	Difference	
			(cfs)	(%)
50.0	1,982	2,321	339	17
20.0	3,058	3,640	583	19
10.0	3,718	4,155	437	12
4.0	3,962	4,502	540	14
2.0	4,995	4,808	-187	-4
1.0	5,467	5,180	-287	-5
0.4	5,904	5,483	-421	-7
0.2	6,432	5,724	-708	-11

** Interpolated from Exhibit A2-9*.

Exhibit A2-9 shows the HEC-1 discharges for the 50 and 20 percent AEPs are still outside the frequency curve's confidence limits. However, flooding in the upper portion of the Hunting Bayou watershed typically occurs between the 10 percent and 4 percent AEP storm events, which make the 50 percent and 20 percent storm events less critical for FRM analyses.

The 0.10 inch per hour constant loss rate used for the 10, 4, 2, 1, 0.4 and 0.2 percent AEPs is consistent with the values typically used in Harris County. For the 50 and 20 percent events, the constant loss rates (0.30 inch per hour and 0.13 inch per hour) are slightly higher than values typically used. However, as previously discussed, the total rainfall loss for each hypothetical event is similar, which seems reasonable based on the watershed's development and drainage conditions.

The results presented in *Table A2-11* and *Exhibit A2-9* also indicate the unit hydrograph coefficients (TC and R) developed for WOP conditions (*Section 4.3*) are reasonable. The equations used to compute TC and R are geared toward a 1 percent AEP event. Namely, the equation parameter DCC (percent channel conveyance) is computed based on the 1 percent event. In *Table A2-11*, the 1 percent discharge for HEC-1 at the gauge is within 5 percent of the HEC-SSP computed discharge.

Based on the results presented in this section, it can be concluded the HEC-1 models for the eight hypothetical events are reasonable and can be considered calibrated to the frequency analysis at the USGS stream gauge.

4.6.2 Verifying HEC-1 Models to Historic Storm Events

The calibrated HEC-1 models were then applied against each historical storm event to verify the accuracy for the loss rates and unit hydrograph parameters. Observed hydrographs for each storm event were obtained either directly from USGS or by converting observed stage data to discharges using the rating curve for the stream gauge. Rainfall data was obtained from the Harris County Office of Emergency Management (HCOEM) website. Five HCOEM rain gauges were used in the verification efforts, three of which are within the Hunting Bayou watershed. The locations for these rain gauges are shown in *Exhibit A2-10.*

Comparisons were made between runoff volume, peak flow and time to peak for each historic storm event and each HEC-1 model. The following describes the verification efforts for each of the five historic events analyzed.

4.6.2.1 June 1989 Storm Event

This event produced the flood of record (3,470 cfs) at the USGS stream gauge, which corresponds to approximately a 9 percent AEP according to the frequency analysis. The storm began on the morning of June 24 and lasted through June 27, with the peak rainfall rates occurring during the afternoon on June 26. *Table A2-12* shows the point rainfall depths and associated frequencies for various durations recorded at the HCOEM rain gauges upstream from the USGS stream gauge. *Exhibit A2-11* is a cumulative rainfall plot for the same rain gauges.

Table A2-12:
Point Rainfall Data and Associated Frequencies
June 1989 Storm Event

Duration	Point Rainfall Depth (inches)			Approximate AEP (%)		
	HCOEM Gauge 0560	HCOEM Gauge 1680	HCOEM Gauge 0830	HCOEM Gauge 0560	HCOEM Gauge 1680	HCOEM Gauge 0830
1-hour	1.77	1.69	2.05	59	67	50
2-hour	3.19	2.80	3.50	26	56	20
3-hour	3.70	3.39	4.41	24	30	14
6-hour	6.11	6.58	7.56	7	5	2
12-hour	6.62	7.48	8.43	11	7	4
24-hour	7.28	8.43	9.25	14	9	6
Total	**8.54**	**10.04**	**10.83**	**N/A**	**N/A**	**N/A**

Table A2-12 shows the greatest rainfall intensity amounts occurred in the 6-hour duration, with totals ranging from a 7 percent AEP in the watershed's upper portion to a 2 percent AEP at the USGS stream gauge location.

The rainfall data shown in *Table A2-12* was inserted into the HEC-1 model. For each sub-watershed upstream from the USGS stream gauge, the rainfall pattern from a particular recording rain gauge was used along with the total rainfall. The rain gauge weightings for this storm event verification are shown in *Table A2-13* (refer to *Exhibit A2-10* for rain gauge locations).

Table A2-13:
Gauge Weighting Information for HEC-1 Model
June 1989 Storm Event

Sub-watershed	Recording Gauge (rainfall pattern)	Gauge Weighting (total rainfall)
H100A	0560	100% - 0560
H112A	0560	100% - 0560
H100B	0560	100% - 0560
H100C	0560	100% - 0560
H118A	1680	100% - 1680
H118B	1680	100% - 1680
H118C	1680	100% - 1680
H100D	0830	100% - 1680
H100E	0830	100% - 0560
H100F	0830	100% - 0830
H100G	0830	100% - 0830
H100H	0830	100% - 0830

The constant loss rate was set at 0.10 inch per hour, since the peak rainfall rates were greater than a 10 percent AEP. The initial loss was adjusted by trial and error until the computed hydrograph's initial rising limb was similar to the observed hydrograph. The adopted initial loss for this storm event was one inch.

Exhibit A2-12 shows a comparison between the computed and observed hydrographs. The computed hydrograph's rising limb is close to the observed hydrograph, but the peak discharge is 24 percent higher than observed, and the receding limb drops off quicker than the observed hydrograph. The computed runoff volume is within 2 percent of the observed runoff volume, and the computed hydrograph's peak is 4.75 hours after the observed hydrograph peak.

The observed discharges above 2,570 cfs (see *Table A2-8*) were determined based on extrapolating the rating curve at the USGS stream gauge. This could explain the difference between computed and observed peak discharges. In addition, the rating curve assumes the same relationship for the flood hydrograph's rising and falling portions. This may not be an accurate estimate for an out-of-bank flood, considering Hunting Bayou has a flat streambed (generally less than 3 feet per mile downstream from the USGS stream gauge) and any tailwater conditions downstream from the gauge would cause a looped relationship in the rating curve. This tailwater condition would be unique for each storm event and cannot be replicated in the HEC-1 model. [All elevations referenced in this paragraph are 1929 NGVD, 1973 adjustment].

4.6.2.2 January 1991 Storm Event

This event was the smallest event analyzed, and the observed 1,903 cfs peak discharge corresponds to approximately a 44 percent AEP according to the frequency analysis. The storm began on the morning of January 14 and lasted until the early hours on January 15. The point rainfall depths and associated frequencies for various durations recorded at the HCOEM rain gauges upstream from the

USGS stream gauge are shown in *Table A2-14*. The cumulative rainfall plot for these same rain gauges is shown in *Exhibit A2-13*.

Table A2-14:
Point Rainfall Data and Associated Frequencies
January 1991 Storm Event

Duration	Point Rainfall Depth (inches)			Approximate AEP (%)		
	HCOEM Gauge 0560	**HCOEM Gauge 1680**	**HCOEM Gauge 0830**	**HCOEM Gauge 0560**	**HCOEM Gauge 1680**	**HCOEM Gauge 0830**
1-hour	1.14	0.90	1.46	91	99	77
2-hour	1.61	1.10	1.69	83	99	83
3-hour	2.12	1.45	2.56	71	91	56
6-hour	2.52	1.65	2.95	71	91	59
Total	**2.72**	**1.81**	**3.03**	**N/A**	**N/A**	**N/A**

Table A2-14 shows the peak rainfall rates occurred in the 3-hour and 6-hour durations, with totals being less than a 50 percent AEP in all cases.

The rainfall data shown in *Table A2-14* was inserted into the HEC-1 model. *Table A2-15* presents the rain gauge weightings used for this storm event verification. These weightings are very similar to those used in the 1989 storm event.

Table A2-15:
Gauge Weighting Information for HEC-1 Model
January 1991 Storm Event

Sub-watershed	Recording Gauge (rainfall pattern)	Gauge Weighting (total rainfall)
H100A	0560	100% - 0560
H112A	0560	100% - 0560
H100B	0560	100% - 0560
H100C	0830	100% - 0560
H118A	1680	100% - 1680
H118B	1680	100% - 1680
H118C	1680	100% - 1680
H100D	0830	50% - 0830, 50% - 1680
H100E	0830	50% - 0830, 50% - 0560
H100F	0830	100% - 0830
H100G	0830	100% - 0830
H100H	0830	100% - 0830

Since the peak rainfall rates were less than a 50 percent AEP, the constant loss rate was initially set at 0.30 inch per hour. However, this caused the computed peak discharge and runoff volume to be lower than observed by 15 percent and 26 percent, respectively. The loss rate was then adjusted to 0.13 inch per hour (corresponding to a 20 percent event by the frequency analysis), which resulted in a better correlation with the peak discharge and runoff volume. The initial loss adopted for this storm event was 0.00 inches.

A comparison between the computed and observed hydrographs for the January 1991 storm event is shown in *Exhibit A2-14*. The shape and timing for the computed hydrograph match well with the observed hydrograph, with the computed peak discharge being slightly higher (10 percent) and the computed runoff volume being slightly lower (-11 percent) than observed.

The observed peak discharge is well below the highest field-measured discharge of 2,570 cfs at the time. This storm event was also contained within Hunting Bayou's banks, which would make using the rating curve at the USGS stream gauge more applicable to this event than the June 1989 storm event.

4.6.2.3 October 1993 Storm Event

The October 1993 storm event began around midday on October 20 and lasted until the early hours on October 21. The observed 1,981 cfs peak discharge translates to approximately a 41 percent AEP per the frequency analysis at the USGS stream gauge. *Table A2-16* is a cumulative rainfall plot for the HCOEM rain gauges located upstream from the USGS stream gauge. The rainfall pattern for HCOEM rain gauge 0560 indicates possible errors in the recording equipment during this event. *Table A2-16* lists the point rainfall depths and associated frequencies for the HCOEM rain gauges. Information on HCOEM gauge 0560 was not included due to the possible recording errors.

Table A2-16:
Point Rainfall Data and Associated Frequencies
October 1993 Storm Event

Duration	Point Rainfall Depth (inches)			Approximate AEP (%)		
	HCOEM Gauge 0560	HCOEM Gauge 1680	HCOEM Gauge 0830	HCOEM Gauge 0560	HCOEM Gauge 1680	HCOEM Gauge 0830
1-hour	N/A	1.02	2.92	N/A	99	14
2-hour	N/A	1.14	3.86	N/A	99	14
3-hour	N/A	1.46	4.49	N/A	83	14
6-hour	N/A	2.44	5.32	N/A	83	14
12-hour	N/A	3.27	5.98	N/A	63	17
24-hour	N/A	3.35	6.06	N/A	71	25
Total	**N/A**	**3.35**	**6.06**	**N/A**	**N/A**	**N/A**

Table A2-16 shows the rainfall rates varied from less than a 50 percent AEP in the watershed's upper portion to generally greater than a 20 percent AEP near the USGS stream gauge.

Table A2-17 lists the rain gauge weightings used in the HEC-1 model for this event. The gauge weightings are the same as those used in the January 1991 storm event verification; however, only HCOEM rain gauges 1680 and 0830 were used for rainfall patterns due to the possible recording errors associated with gauge 0560.

**Table A2-17:
Gauge Weighting Information for HEC-1 Model
October 1993 Storm Event**

Sub-watershed	Recording Gauge (rainfall pattern)	Gauge Weighting (total rainfall)
H100A	1680	100% - 0560
H112A	1680	100% - 0560
H100B	1680	100% - 0560
H100C	0830	100% - 0560
H118A	1680	100% - 1680
H118B	1680	100% - 1680
H118C	1680	100% - 1680
H100D	0830	50% - 0830, 50% - 1680
H100E	0830	50% - 0830, 50% - 0560
H100F	0830	100% - 0830
H100G	0830	100% - 0830
H100H	0830	100% - 0830

The constant loss rate was set equal to 0.13 inch per hour, since the peak rainfall rates at the USGS stream gauge were near a 20 percent AEP. An initial 1-inch loss was used in the HEC-1 model.

Exhibit A2-16 provides a comparison between the computed and observed hydrographs for the October 1993 storm event. There is a good correlation between the computed and observed hydrograph shapes and timing, with the computed peak discharge and runoff volume being slightly above observed. As with the January 1991 storm event, the observed peak discharge for the October 1993 event is below the highest field-measured discharge at the time and was an in-bank flood.

4.6.2.4 October 1994 Storm Event

The observed peak discharge for the October 1994 storm event (3,451 cfs) was the second highest recorded at the USGS stream gauge. Like the June 1989 flood, this event also corresponds to approximately a 9 percent AEP according to the frequency analysis. This storm began on the morning of October 15 and lasted until the evening on October 18, or about 3½ days. *Table A2-18* presents the point rainfall depths and frequencies for various durations recorded at the HCOEM rain gauges located upstream from the USGS stream gauge. A cumulative rainfall plot for the same rain gauges is shown in *Exhibit A2-17.*

Table A2-18:
Point Rainfall Depth and Associated Frequencies
October 1994 Storm Event

Duration	Point Rainfall Depth (inches) HCOEM Gauge			Approximate Annual Exceedance Probability (%) HCOEM Gauge		
	0560	1680	0830	0560	1680	0830
1-hour	1.46	1.10	1.30	83	91	91
2-hour	2.44	1.57	2.13	53	91	67
3-hour	2.83	2.01	2.84	45	77	45
6-hour	3.89	2.64	4.68	33	71	20
12-hour	4.69	3.23	5.94	33	63	17
24-hour	6.69	4.76	8.39	19	43	9
Total	**10.24**	**8.58**	**14.13**	**N/A**	**N/A**	**N/A**

Table A2-18 shows the peak rainfall amounts occurred in the 24-hour duration. In the upper watershed, totals were approximately between a 20 percent and 50 percent event, while near the USGS stream gauge they were near a 10 percent event.

Since the peak rainfall amounts near the USGS stream gauge were near a 10 percent AEP, the constant loss rate was set at 0.10 inch per hour. The initial loss was set at 2 inches, which provided the best match against the observed hydrograph's rising limb.

Initially, the rain gauge weighting used in the June 1989 storm event was applied to the HEC-1 model for this event, since the flood magnitudes were approximately the same. However, this resulted in a 7 percent lower peak discharge than observed and a 44 percent less runoff volume than observed. The rainfall pattern and total amount at HCOEM gauge 0830 was then used for all sub-watersheds upstream from the USGS stream gauge. This is shown in *Table A2-19*.

Table A2-19:
Gauge Weighting Information for HEC-1 Model
October 1994 Storm Event

Sub-watershed	Recording Gauge (rainfall pattern)	Gauge Weighting (total rainfall)
H100A	0830	100% - 0830
H112A	0830	100% - 0830
H100B	0830	100% - 0830
H100C	0830	100% - 0830
H118A	0830	100% - 0830
H118B	0830	100% - 0830
H118C	0830	100% - 0830
H100D	0830	100% - 0830
H100E	0830	100% - 0830
H100F	0830	100% - 0830
H100G	0830	100% - 0830
H100H	0830	100% - 0830

The computed and observed hydrographs are shown in *Table A2-19*. The computed hydrograph's rising limb correlates well with the observed hydrograph, and the computed peak discharge is within 10 percent of the observed peak discharge. The computed hydrograph's receding limb drops off quicker than the observed hydrograph, which causes the computed runoff volume to be 8 percent less than the observed runoff volume.

The October 1994 storm event also required extrapolating the rating curve since the observed discharges exceeded the highest field-measured discharge at the time. In addition, this event was an out-of-bank flood, which may have caused a looped relationship in the rating curve.

The observed runoff volume at the USGS stream gauge was calculated to be about 10 inches. Over the same period, the following rainfall amounts were recorded: 9.4 inches at HCOEM gauge 0830, 7.6 inches at HCOEM gauge 0560 and 5.6 inches at HCOEM gauge 1680. This indicates an error occurred either in the total rainfall recorded or in the observed discharges on the hydrograph's receding limb since they are based solely on the recorded stage. Finally, the observed hydrograph for this event has a flat peak, which implies the stream gauge may have hung up, thus affecting the measurements' accuracy.

4.6.2.5 September 1998 Storm Event

The September 1998 storm event occurred as a result of Tropical Storm Frances. This event was the only one of the five verified which had high water marks identified and surveyed along Hunting Bayou. The observed peak discharge was 3,070 cfs, approximately a 14 percent AEP according to the frequency analysis at the USGS stream gauge. Rainfall began on the afternoon of September 9 and lasted until the morning on September 13. The point rainfall depths and frequencies recorded at the HCOEM rain gauges located upstream from the USGS stream gauge are shown in *Table A2-20*. *Exhibit A2-19* is a cumulative rainfall plot for the same gauges along with HCOEM gauge 0820, which is at IH 10 on Hunting Bayou in the watershed's lower portion. Note also HCOEM gauge 0840 (Hunting Bayou at Lockwood) was included, since it was installed in 1995.

Table A2-20:
Point Rainfall Data and Associated Frequencies
September 1998 Storm Event

Duration	Point Rainfall Depth (inches) HCOEM Gauge No.				Approximate Exceedance Probability (%) HCOEM Gauge No.			
	0560	0840	1680	0830	0560	0840	1680	0830
1-hour	1.85	1.77	1.00	1.33	59	63	99	83
2-hour	2.64	2.87	1.76	2.25	42	34	77	59
3-hour	3.12	3.82	2.28	2.76	38	21	67	45
6-hour	4.48	6.30	3.75	4.79	24	6	38	19
12-hour	6.30	8.58	4.98	6.70	14	3	28	11
24-hour	7.20	10.08	5.94	7.97	14	3	27	11
Total	**8.11**	**11.54**	**6.92**	**9.33**	**N/A**	**N/A**	**N/A**	**N/A**

Table A2-20 shows the peak rainfall rates for this event occurred in the 24-hour duration. In the watershed's upper portion, the totals were between a 3 percent and 27 percent event, while at the USGS stream gauge they were equivalent to about an 11 percent event.

The constant loss rate was set at 0.10 inch per hour in the HEC-1 model, since the rainfall totals were near a 10 percent AEP at the USGS stream gauge. A 0.50 inch value was adopted for the initial loss through trial and error.

Initially, HCOEM gauge 0840 was used as the recording gauge for the sub-watersheds in the overall watershed's upper portion, since this gauge was not in place for the other four storm events verified. However, this caused the computed peak discharge and runoff volume to be 41 percent and 48 percent higher, respectively, than the observed values. A rain gauge weighting similar to the June 1989 storm event was then adopted. Because gauge 0840 had no prior data from the other storm event verification efforts, the accuracy for the recorded amounts for this gauge was questionable. In the watershed's lower portion, HCOEM gauge 0820 was used as the recording rain gauge. *Table A2-21* shows the rain gauge weightings used in the HEC-1 model.

Table A2-21:
Gauge Weighting Information for HEC-1 Model
September 1998 Storm Event

Sub-watershed	Recording Gauge (Rainfall Pattern)	Gauge Weighting (Total Rainfall)
H100A	0830	100% - 0560
H112A	0830	100% - 0560
H100B	0830	100% - 0560
H100C	0830	100% - 0560
H118A	0830	100% - 1680
H118B	0830	100% - 1680
H118C	0830	100% - 1680
H100D	0830	100% - 0560
H100E	0830	100% - 1680
H100F	0830	100% - 0830
H100G	0830	100% - 0830
H100H	0830	100% - 0830
H100I	0830	100% - 0830
H100J	0830	100% - 0830
H100K	0830	100% - 0830
H125A	0830	100% - 0830
H100L	0820	100% - 0820
H103A	0830	100% - 0830
H103B	0820	100% - 0820
H100M	0820	100% - 0820
H102A	0820	100% - 0820
H102B	0820	100% - 0820
H100N	0820	100% - 0820
H100O	0820	100% - 0820

Exhibit A2-20 compares the computed and observed hydrographs for the September 1998 storm event. It shows the computed hydrograph's rising limb compares well against the observed hydrograph. The computed peak discharge is within 10 percent of the observed peak discharge, and the runoff volume is within 1 percent. As with the June 1989 and October 1994 events, the computed hydrograph's receding limb drops off quicker than the observed hydrograph.

The rating curve at the USGS stream gauge again required extrapolation for this event. For the most part, this flood was at bank-full with some isolated overbank flooding areas mostly downstream from the USGS stream gauge. This may have caused a tailwater condition which affected the rating curve's accuracy for the flood hydrograph's falling portion. As discussed later in *Section 5.8*, discharges from the HEC-1 model were inserted into the HEC-RAS model for Hunting Bayou. The resulting peak WSELs compared favorably with observed high water marks.

4.6.2.6 HEC-1 Verification Results

Table A2-22 summarizes the results from verifying the calibrated HEC-1 model against the five historic storm events. Included in this table is a comparison between computed and observed peak discharge, runoff volume and time to peak.

All of the historical storms described above were also modeled in the updated HEC-HMS model, which further described in the next section. Each of the historical storm events matched very closely with the results from the HEC-1 calibration runs. *Exhibit A2-11* through *Exhibit A2-20* displays the rainfall data used and hydrograph comparison between the two models and observed data. The peak discharges from the HEC-HMS model runs are listed in *Table A2-22.*

Table A2-22:
Summary for Computed Versus Observed Hydrograph Data
Historic Storm Events

Parameter	Storm Event	Observed	Computed	Difference
Peak Discharge (cfs)	Jun 1989	3,470	4,312	24%
	Jan 1991	1,903	2,089	4%
	Oct 1993	1,981	2,112	1%
	Oct 1994	3,451	3,802	10%
	Sep 1998	3,070	3,373	10%
Runoff Volume (inches)	Jun 1989	7.43	7.76	4%
	Jan 1991	2.24	1.99	-11%
	Oct 1993	2.58	2.61	1%
	Oct 1994	11.18	10.35	-8%
	Sep 1998	6.37	6.43	1%
Time To Peak	Jun 1989	06/26/89 8:00 PM	06/27/89 12:45 AM	4.75 hr
	Jan 1991	01/15/91 1:30 AM	01/15/91 1:30 AM	0.0 hr
	Oct 1993	10/20/93 6:00 PM	10/20/93 5:30 PM	-0.50 hr
	Oct 1994	10/18/94 2:30 AM	10/18/94 2:45 AM	0.25 hr
	Sep 1998	09/11/98 11:00 AM	09/11/98 10:00 AM	-1.00 hr

Table A2-22 shows the computed peak flow is within 10 percent of the observed peak flow for all storm events except June 1989. The computed runoff volume is also within 10 percent of the observed runoff volume for all storm events except October 1994. Finally, the computed peak time is within 1 hour of the observed peak time in all cases except June 1989. Any differences greater than 10 percent can be attributed to possible errors in the rating curve when it is extrapolated beyond the field-measured values.

For all five storm events, the computed hydrograph's rising portion correlated well with the observed hydrograph. The January 1991 and October 1993 computed hydrographs had the best overall shape when compared to the observed hydrographs. Both events were in-bank floods. For the other three storm events analyzed, the computed hydrographs' falling limb dropped off quicker than the observed hydrographs. These three events were all out-of-bank events, which may have caused a tailwater condition downstream, thereby creating a looped stage-discharge relationship. Consequently, the rating curve at the USGS stream gauge would not be accurate for this situation.

Since the HEC-1 models were calibrated to a frequency analysis at the USGS stream gauge and subsequently verified against five historic storm events, the loss rates and unit hydrograph parameters developed in these efforts can be used to define the WOP conditions hydrology for Hunting Bayou.

4.6.2.7 September 2008 Storm Event

The September 2008 storm event occurred as a result of Hurricane Ike. The observed peak discharge was 4,390 cfs, approximately a 4 percent AEP according to the frequency analysis at the USGS stream gauge. Rainfall began on the afternoon of September 12 and lasted until midday on September 13. Rainfall data were based on NEXRAD Radar from the National Climatic Data Center and gauge data information from the Harris County FWS website in and surrounding the watershed. After reviewing the gauge data for about 15 rain gauges, several gauges were excluded from the analysis due to clear problems with the gauge data collection, leaving 9 gauges for the analysis. These gauges were used to 'ground truth' the radar by the radar processing tool within PCSWMM software. The software compares the observed rainfall rate with the radar-predicted rainfall rate and creates a single 'bias' number customized for the storm and the set of gauges used, and uses this bias factor to adjust the entire radar field. Radar to rainfall processing was done using the Tropical Z-R relationship (Ref. 27 and Ref. 28), which is the equation that converts the radar reflectivity (R) to a rainfall rate (Z) for tropical storms. The point rainfall depths and frequencies recorded at the HCOEM rain gauges used for this analysis are shown in *Table A2-23* and *Table A2-24*. Gauge rainfall hyetographs are shown in *Exhibit A2-21*.

Table A2-23:
Point Rainfall Data -September 2008 Storm Event

	Point Rainfall Depth (inches)								
Duration	**HCOEM Gauge 0530**	**HCOEM Gauge 0830**	**HCOEM Gauge 0940**	**HCOEM Gauge 1420**	**HCOEM Gauge 1440**	**HCOEM Gauge 1620**	**HCOEM Gauge 1675**	**HCOEM Gauge 1680**	**HCOEM Gauge 2210**
1-hour	0.28	0.39	0.2	0.12	0.27	0.12	0.2	0.28	0.24
2-hour	0.51	0.75	0.67	0.48	0.9	0.55	0.63	0.51	0.67
3-hour	1.1	1.22	1.22	1.18	1.45	1.02	1.02	0.79	1.54
6-hour	5.94	4.68	4.02	3.59	3.5	3.86	5.59	3.97	6.35
12-hour	9.29	9.45	7.83	6.86	7.12	7.68	9.92	6.81	11.7
24-hour	9.45	9.64	7.87	6.98	7.32	7.96	10.28	6.96	11.82
Total	**17.51**	**10.98**	**8.02**	**7.06**	**8.38**	**9.53**	**13.31**	**10.98**	**12.84**

Table A2-24:
Associated AEP Events for Point Rainfall Data - September 2008 Storm Event

Duration	Approximate AEP (%)								
	HCOEM Gauge 0530	HCOEM Gauge 0830	HCOEM Gauge 0940	HCOEM Gauge 1420	HCOEM Gauge 1440	HCOEM Gauge 1620	HCOEM Gauge 1675	HCOEM Gauge 1680	HCOEM Gauge 2210
1-hour	98.1	97.4	98.5	98.8	98.1	98.8	98.5	98.1	98.3
2-hour	95.3	93.0	93.8	95.5	91.1	95.0	94.2	95.3	93.8
3-hour	86.9	85.0	85.0	85.7	81.0	88.1	88.1	91.0	79.2
6-hour	8.8	20.3	33.3	43.1	45.2	36.8	11.6	34.4	5.8
12-hour	2.2	1.9	5.7	9.7	8.5	6.2	1.5	9.9	0.5
24-hour	4.8	4.2	12.1	17.4	15.2	11.6	3.0	17.5	1.4

Table A2-23 shows the peak rainfall rates for this event occurred within the 24-hour duration. *Table A2-24* shows the associate AEP events for each rainfall gauge analyzed. *Table A2-25* shows the total rainfall for each sub-watershed in a 24-hour period used in the HEC-HMS model. After the NEXRAD rainfall was processed into one time series per HEC-HMS sub-watershed, those rainfall values were entered into the HEC-HMS model as individual rain gages, and assigned to their matching sub-watersheds. The 24-hour rainfall totals for each of the sub-watersheds are shown in *Table A2-25.*

Table A2-25:
24-hr Rainfall Totals for Sub-watersheds- September 2008 Storm Event

Sub-watershed	24-hr Rainfall Total (in)
H100A	10.15
H112A	10.15
H100B	9.83
H100C	9.68
H118A	9.47
H118B	9.58
H118C	9.22
H100D	8.58
H100E	9.55
H100F	9.44
H100G	8.33
H100H	8.57
H100I	7.91
H100J	7.89
H100K	7.84
H125A	8.06
H100L	7.31
H103A	8.59
H103B	7.94
H100M	7.02
H102A	7.83
H102B	8.16
H100N	7.33
H100O	8.03

The constant loss rate was set at 0.10 inch per hour in the HEC-HMS model, since the observed peak flow was less frequent than a 10 percent AEP at the USGS stream gauge, and a 0.5 inch value was adopted for the initial loss, which is in accordance with modeling procedures utilized in the plan analysis. The HEC-HMS model was executed and the resulting peak flow, volume, and time to peak were compared against the observed gage data, as shown in *Exhibit A2-22*.

Exhibit A2-22 shows the computed hydrograph's rising limb compares well against the observed hydrograph, while the computed hydrograph's receding limb drops off quicker than the observed hydrograph. In the exhibit, the observed hydrograph is drawn out for an extended period of time, which leads to the conclusion that there is a backwater effect for the storm. This backwater condition would result in a looped rating curve, so the modeled falling limb is ignored since HEC-HMS can only model single-point rating curves. The computed peak discharge is within 6 percent of the observed peak discharge, indicating that the model results matched closely with observed records.

4.6.2.8 HEC-HMS Verification Results

Table A2-26 summarizes the results from verifying the calibrated HEC-HMS model against the six historic storm events. Included in this table is a comparison between computed and observed peak discharge, runoff volume and time to peak.

Table A2-26:
Summary for HEC-HMS Versus Observed Hydrograph Data
Historic Storm Events

Parameter	Storm Event	Observed	Computed	Difference
Peak Discharge (cfs)	Jun-89	3,470	4,338	25%
	Jan-91	1,903	2,023	6%
	Oct-93	1,981	2,116	7%
	Oct-94	3,451	3,854	12%
	Sep-98	3,070	3,369	10%
	Sep-08	4,390	4,635	6%
Runoff Volume (inches)	Jun-89	7.43	9.13	23%
	Jan-91	2.24	1.99	-11%
	Oct-93	2.58	2.71	6%
	Oct-94	11.18	10.33	-8%
	Sep-98	6.37	6.69	5%
	Sep-08	7.46	7.44	0%
Time To Peak	Jun-89	06/26/1989 20:00	06/26/1989 12:00	4.0 hr
	Jan-91	01/15/1991 1:30	01/15/1991 2:00	0.5 hr
	Oct-93	10/20/1993 18:00	10/20/1993 17:00	1 hr
	Oct-94	10/18/1994 2:30	10/18/1994 2:15	-0.25 hr
	Sep-98	09/11/1998 11:00	09/11/1998 7:45	-3.25 hr
	Sep-08	09/13/2008 13:15	09/13/2008 15:00	1.75 hr

For the storm events previously modeled in HEC-1, the HEC-HMS hydrographs correlated well with the observed hydrographs and the HEC-1 hydrographs, so the HEC-1 calibrated parameters were maintained. Exhibit A2-11 through Exhibit A2-22 displays the rainfall data used and hydrograph comparison between the two models and observed data.HEC-1 Conversion to HEC-HMS 3.4.0

The HEC-1 models were imported into the original HEC-HMS model using the HEC-HMS import tool. Three separate basin files were required for all eight AEP events due to different loss rate parameters associated with each storm event.

Hypothetical rainfall distribution data and unit hydrograph methods remained identical to those used for the HEC-1 model development explained in *Section 5.0*. HEC-HMS model verifications were based on percent differences in peak flow comparisons with the HEC-1 model. When importing HEC-1 precipitation data into HEC-HMS, individual gauge data was created for each event and each sub-basin based on areal reduction factors. This required each sub-basin to have individually named gauge data for each storm frequency. To simplify the conversion process, precipitation data was entered into HEC-HMS as a frequency event. The point rainfalls used were based on the HEC-1 model rainfall intensities for a 0.01 square mile storm area with a 67 percent peak intensity position.

The Modified Puls routing data was not modified from those used in the HEC-1 model for the first conversion comparison. This allowed a direct comparison for the peak flows based solely on the software differences combined with the change in applied precipitation. *Table A2-27* compares the HEC-1 and HEC-HMS maximum decrease and increase in flow rates.

Table A2-27:
HEC-1 Versus HEC-HMS 3.4 (with Original Routing):
Maximum Increase and Decrease in Computed Flows

	Cross Section	% Change	Flow Change (cfs)	AEP Storm Event
Maximum % Decrease	66605	- 11.1	122	50%
Maximum % Increase	54950	+ 6.8	186	0.4%
Average Change		+1%		

Because the HEC-1 alternative models did not update the storage-outflow curves for the entire Hunting Bayou mainstem, a second HEC-HMS model was created to incorporate a change in Modified Puls routing parameters (storage-outflow rate). Updated Modified Puls routing parameters were calculated using the HEC-HMS model and the updated HEC-RAS 4.1.0 model. Rating curves for storage versus discharge were updated for all Hunting Bayou reaches.

Table A2-28 repeats *Table A2-27*, but with the implemented updated routing parameters.

Table A2-28:
HEC-1 Versus HEC-HMS 3.4 (with Updated Routing):
Maximum Increase and Decrease in Computed Flows

	Cross Section	% Change	Flow Change (cfs)	AEP Storm Event
Maximum % Decrease	22389	- 13.7	369	50%
Maximum % Increase	54950	+ 7.3	394	2%
Average Change		+1%		

The results show on average a 1 percent increase in computed flow across the mainstem. The maximum percent increase and decrease computed occurred at lower flow events. Overall, the hydrologic changes were insignificant, which allowed more efficient modeling techniques to be implemented that linked HEC-DSS files with the HEC-RAS 4.1.0 model. This linking was necessary to accommodate improved modeling for the proposed offline basin. Due to the large backwater conditions existing in Hunting Bayou, a looped rating curve existed at the control structure receiving and delivering flow to and from the offline basin. Due to this looped rating curve and HEC-HMS not having the capability to adequately model the flow interaction between Hunting Bayou and the basin, an unsteady state HEC-RAS model was required. A truncated HEC-RAS model was created for the reach just upstream and sufficiently downstream from the basin control structure.

Flow hydrographs from HEC-HMS were assigned to the HEC-RAS model, and the unsteady state model was executed. The resulting hydrograph computed across the control structure was inserted as a source element into HEC-HMS, and the HEC-HMS model was re-computed. Storage outflow curves were re-computed, and the process was repeated until the storage outflows converged. It is worth noting the HEC-1 to HEC-HMS model conversion process resulted in creating additional node identifications (IDs) for the HEC-HMS model as a consequence of improving storage routing techniques within the reach. *Exhibit A2-38* has a geometric schematic for the updated basin model. The schematic identifies the basin, junction and reach IDs used in the HEC-HMS model. *Table A2-29* is a revised version of *Table A2-7* following the conversion process, which relates the HEC-HMS From Node and To Node junctions to the HEC-RAS station locations.

Table A2-29:
Updated Node IDs Following HEC-1 to HEC-HMS 3.4 Model Conversion

HEC-HMS		HEC-RAS	
From Node	**To Node**	**From Station**	**To Station**
H100#1	J-1	76752	71037
J-1	J-2	71037	66605
J-2	J-4	66605	64090
J-4	J-5	64090	62067
J-5	J-6	62067	60280
J-6	J-7	60280	57533
J-7	J-8	57533	54950
J-8	J-9	54950	49831
J-9	J-10	49831	46183
J-10	J-12	46183	41700
J-12	J-13	41700	32049
J-13	J-14	32049	30749
J-14	J-16	30749	25706
J-16	J-17	25706	24429
J-17	J-18	24429	16284
J-18	J-20	16284	9888

Exhibit A2-39 through *Exhibit A2-41* tabulate the HEC-HMS peak discharges and volumes for all eight AEPs for WOP Conditions, B50-A25 and B60-A75 (the Tentatively Selected Plan [TSP]).

4.7 Without Project (WOP) Conditions Results

The results from the calibrated model for WOP conditions are presented in *Table A2-30*. The discharges in rows with a HEC-HMS computation point are directly from the HEC-HMS output. The corresponding HEC-RAS station is listed for each discharge.

Additional discharges were computed between some of the computation points (between HEC-RAS stations 98+88 and 257+06) using a logarithmic relationship between the HEC-HMS discharge and the channel reach length. The discharge upstream from US 59 was computed as 60 percent of the discharge at HEC-1 node H100A. The additional discharges are indicated by italics in *Table A2-30*. *Exhibit A2-23* is a station-discharge plot used to define the WSELs for WOP conditions.

Table A2-30:
WOP Conditions Discharges

Location Description	HEC-HMS Node	DA (mi^2)	HEC-RAS Station	Discharge (cfs) for Given AEP (%)							
				50	20	10	4	2	1	0.4	0.2
Mouth	-	-	21+40	2,454	5,099	6,418	7,596	8,404	9,272	10,629	11,582
COH Water Plant	-	-	57+41	2,454	5,099	6,418	7,596	8,404	9,272	10,629	11,582
PTRA Railroad	Junction-20	30.12	98+88	2,454	5,099	6,418	7,596	8,404	9,272	10,629	11,582
	Interpolated Junction-18 & 19	-	121+70	2,497	5,055	6,354	7,540	8,396	9,274	10,556	11,479
	Junction-18	27.29	162+84	2,577	4,975	6,242	7,440	8,383	9,277	10,425	11,296
	Interpolated Junction-17 & 18	-	171+39	2,573	4,960	6,201	7,376	8,298	9,174	10,294	11,136
Missouri Pacific Railroad	-	-	221+70	2,549	4,870	5,953	6,995	7,794	8,562	9,524	10,201
Market Street	-	-	223+55	2,549	4,870	5,953	6,995	7,794	8,562	9,524	10,201
	Junction-17	24	223+89	2,549	4,870	5,953	6,995	7,794	8,562	9,524	10,201
	Interpolated Junction-16 & 17	-	244+29	2,525	4,802	5,829	6,793	7,527	8,256	9,232	9,943
IH 10	-	-	255+19	2,510	4,761	5,752	6,669	7,364	8,069	9,053	9,785
	Junction-16	23.12	257+06	2,510	4,761	5,752	6,669	7,364	8,069	9,053	9,785
	Junction-14	20	307+49	2,304	4,329	5,089	5,693	6,174	6,677	7,571	8,525
	Junction-13	19.26	320+49	2,265	4,218	4,913	5,452	5,946	6,526	7,345	8,108
Wallisville Road	-	-	371+23	2,193	4,022	4,610	5,114	5,506	5,935	6,611	7,212
	Junction-12	18.07	417+00	2,193	4,022	4,610	5,114	5,506	5,935	6,611	7,212
Manitou Road	-	-	461+36	2,061	3,706	4,239	4,716	4,958	5,257	5,565	5,771
	Junction-10	16.1	461+83	2,061	3,706	4,239	4,716	4,958	5,257	5,565	5,771
IH 610 (1st Crossing)	-	-	480+40	1,989	3,541	4,071	4,563	4,730	5,164	5,346	5,472
McCarty Road	-	-	497+81	1,989	3,541	4,071	4,563	4,730	5,164	5,346	5,472
	Junction-9	15.23	498+31	1,989	3,541	4,071	4,563	4,730	5,164	5,346	5,472
Oil Tank Farm Road	-	-	538+36	1,934	3,449	4,037	4,580	4,974	5,380	5,934	6,407
	Junction-8	14.65	549+50	1,934	3,449	4,037	4,580	4,974	5,380	5,934	6,407
Houston Belt and Terminal (HB&T) Railroad	-	-	561+85	1,778	3,140	3,710	4,264	4,629	4,886	5,263	5,587
Liberty Road	-	-	572+61	1,778	3,140	3,710	4,264	4,629	4,886	5,263	5,587
	Junction-7	13.15	575+33	1,778	3,140	3,710	4,264	4,629	4,886	5,263	5,587
IH 610 (2nd Crossing)	-	-	599+60	1,622	2,905	3,530	4,066	4,391	4,619	4,900	5,106
	Junction-6	12.18	602+80	1,622	2,905	3,530	4,066	4,391	4,619	4,900	5,106
	Junction-5	11.61	620+67	1,518	2,729	3,326	3,865	4,189	4,432	4,713	4,976

Location Description	HEC-HMS Node	DA (mi^2)	HEC-RAS Station	Discharge (cfs) for Given AEP (%)							
				50	20	10	4	2	1	0.4	0.2
Homestead Road	-	-	636+05	1,313	2,329	2,893	3,615	4,177	4,570	5,197	5,808
	Junction-4	10.1	640+90	1,313	2,329	2,893	3,615	4,177	4,570	5,197	5,808
Kelley Road (Westbound)	-	-	649+07	1,030	1,796	2,184	2,693	3,088	3,389	3,707	4,029
IH 610 (3rd Crossing)	-	-	659+19	1,030	1,796	2,184	2,693	3,088	3,389	3,707	4,029
	Junction-2	5.32	666+05	1,030	1,796	2,184	2,693	3,088	3,389	3,707	4,029
Lockwood Road	-	-	686+73	880	1,470	1,760	2,145	2,439	2,664	2,964	3,249
Wipprecht Street	-	-	704+62	880	1,470	1,760	2,145	2,439	2,664	2,964	3,249
	Junction-1	4.01	710+37	880	1,470	1,760	2,145	2,439	2,664	2,964	3,249
Wayne Street	-	-	716+63	734	1,245	1,564	1,938	2,254	2,611	3,133	3,611
Falls Street	-	-	732+65	734	1,245	1,564	1,938	2,254	2,611	3,133	3,611
	H100#1	2.65	733+19	734	1,245	1,564	1,938	2,254	2,611	3,133	3,611
US 59	-	-	760+33	464	785	981	1,211	1,406	1,625	1,937	2,225
	H100A	1.46	761+53	464	785	981	1,211	1,406	1,625	1,937	2,225
Neches Street	-	-	762+02	279	471	589	727	844	975	1,162	1,335
	0.6 * H100A	-	767+52	279	471	589	727	844	975	1,162	1,335

5.0 HYDRAULIC MODELING FOR WITHOUT PROJECT (WOP)

Water surface profiles for Hunting Bayou were calculated using the HEC-RAS program (Ref. 11), Version 3.1.1 (later updated to Version 4.1.0, see *Section 5.9*). HEC-RAS computes steady state, gradually varied flow profiles using input flow rates. Discussions about the input parameters and modifications to the original model are contained in *Section 5.9*.

5.1 Field Reconnaissance

Field reconnaissance activities occurred from May 1998 to March 1999. Photographic documentation for all bridges, obvious pipeline crossings and other channel conveyance obstructions were obtained. Field reconnaissance was used to verify estimates for channel roughness and overbank roughness and to determine where additional field surveys were needed at bridge locations to provide accurate modeling. Subsequent field visits conducted in December 2002 for updating and verifying utility crossings corroborated the information collected in 1989-1999. Updated aerial photos reviews conducted to verify bridge construction items during coordination for TxDOT IH 610 improvements in 2009 and for cost estimate updates in 2010 verified the previous existing bridge information.

5.2 Cross Section Geometry

The starting hydraulic models provided for use in this study were HEC-2 models developed under previous agreement with the non-federal sponsor, HCFCD, as referenced in the Binkley and Barfield Report of 1991, which were updated based on field reconnaissance, additional field surveys and reviewing current design documents (Ref. 3). The starting models are actually an update of the original FEMA models established in the early 1980s. Geometric information for these models is based on field surveys conducted in the late 1970s by the U.S. Army Corps of Engineers (USACE) – Galveston District, under contract with FEMA for establishing flood insurance studies in Harris County. The datum for these field surveys is 1929 NGVD, 1973 adjustment.

Upon receiving the models, cross-section information was compared to mapping to determine geometry adequacy and accuracy for replicating the model for the cross-section locations. Stream stationing was revised based on the available aerial photographs. These changes in stationing were reflected in the channel and overbank distances in the HEC-2 model.

A review of the geometry in the original HEC-2 model showed a large number of extended cross-sections, particularly in the watershed's upper portion. Thus, the HEC-2 model did not sufficiently model the available floodplain storage. As a result, a new HEC-RAS 3.1.1 model was developed for this study. This model used the channel sections from the starting HEC-2 model, which were supplemented with new overbank sections. The overbank sections were obtained from the Digital Terrain Model (DTM) created for this study. A brief description for the DTM follows.

5.2.1 Digital Terrain Model (DTM)

Within COH's corporate limits, a geographic data set referred to as monumentation mapping was available in hard-copy form. This data set, developed from 1973 to 1978, included 2-foot contour intervals and spot elevations. The maps were converted into digital form and transposed into a DTM. Some of the older monumentation maps did not contain contours. In these areas the elevation data were supplemented with information from the USGS National Elevation Dataset.

For those areas where monumentation mapping was not available, new topographic mapping was developed using photogrammetric techniques dated 1998-1999. This mapping conformed to National Map Accuracy Standards for 1-foot contour intervals. A portion of this mapping included establishing ground control throughout the entire watershed, including those portions covered by the monumentation mapping. The cross section data used 1) the original HEC-2 model geometry, verified against the COH monumentation topographical data, 2) supplemental geometry using the DTM developed from the monumentation data, and 3) photogrammetry performed for this study during the 1998-1999 which included establishing ground control throughout the whole watershed. These data were the best available large area topography when the hydraulic model was being established. The elevations of structures in the study area were verified by an extensive field survey conducted in 1998. As the study progressed over the years, based on the level of effort expended on surveys and modeling effort, the decision was made by the non-federal sponsor, HCFCD to maintain the use of the original topographic information. The topography in the watershed has not changed substantially due to the watershed being almost fully developed when the study was initiated. This is further illustrated in the 1995 and 2012 aerials as shown in *Exhibit A2-1*. In addition, as discussed in *Section 5.7.2*, land subsidence in the vicinity of the TSP has virtually stopped since 1995. Since the topography in the watershed has not changed substantially due to the watershed being almost fully developed and the diminished subsidence rates when the study was initiated, initial modeling conditions have remain consistent with current levels.

The photogrammetric mapping was provided in digital form and converted to a DTM. The data was combined with the DTM developed from the monumentation maps to create a complete elevation coverage for the entire watershed. All data was converted to the 1929 NGVD, 1973 adjustment, to develop a consistent DTM throughout the watershed. This is discussed in *Section 5.8* and shown in *Table A2-33* and *Table A2-35*.

5.3 Bridges

Supplemental field surveys for bridge sections were required based on field reconnaissance efforts. These surveys were necessary due to apparent modifications made to the bridges since the HEC-2 model was developed.

The starting HEC-2 model from the non-federal sponsor, HCFCD, had 20 bridges modeled using the Special Bridge routine. In this study, all bridges in Hunting Bayou were modeled using the Normal Bridge calculation method (energy equation). The bridges were converted to the Normal Bridge method because unreasonably high head losses were calculated using the Special Bridge method. *Table A2-31* lists all the bridge and pipeline crossings modeled in HEC-RAS for this study. A total of 45 bridge and pipeline crossings were modeled along Hunting Bayou.

Table A2-31:
HEC-RAS Bridge and Pipeline Crossings

Crossing	Type	Stream Station
Neches Street	Bridge	761+97
US 59	Culvert	760+28
Pedestrian Bridge @ W. Hunting	Bridge	738+78
Falls Street	Bridge	732+40
Leffingwell Street	Bridge	729+15
COH Waterline	Pipeline	725+04
Hirsch Street	Bridge	724+92
Wayne Street	Bridge	716+58
Wipprecht Street	Bridge	704+37
Pickfair Walkway	Bridge	693+06
Lockwood Road	Bridge	686+66
Pedestrian Bridge @ Hutcheson Park	Bridge	673+44
Pedestrian Bridge @ Hutcheson Park	Bridge	661+56
IH 610 - 3rd Crossing	Bridge	659+14
Kelley Street (Eastbound)	Bridge	653+78
Kelley Street (Westbound)	Bridge	649+02
COH Waterline	Pipeline	647+74
Utility Crossing	Bridge	636+19
Homestead Road	Bridge	636+00
Utility Crossing	Bridge	600+32
IH 610 - 2nd Crossing	Bridge	597+51
Liberty Road	Bridge	572+38
Southern Pacific Railroad #4 Englewood Railroad Yard (ERRY)	Bridge	571+48
Southern Pacific Railroad #3 (ERRY)	Bridge	568+34
Southern Pacific Railroad #2 (ERRY)	Bridge	567+16
Southern Pacific Railroad #1 (ERRY)	Bridge	566+11
Wayside Drive	Bridge	563+15
HB&T Railroad	Bridge	561+66
Oil Tank Farm Road	Bridge	538+21
McCarty Road	Bridge	497+52
IH 610 - 1st Crossing	Bridge	478+71
COH Waterline	Pipeline	476+35
Manitou Road	Bridge	461+19
Wallisville Road	Bridge	370+77
Utility Crossing	Pipeline	256+46
COH Waterline	Pipeline	255+85
IH 10	Bridge	253+34
Market Street	Bridge	223+16
Missouri Pacific Railroad	Bridge	221+60
PTRA Railroad	Bridge	98+57
Abandoned Railroad	Bridge	60+65
COH Water Plant	Bridge	57+19
Abandoned Timber Bridge	Bridge	56+81
COH Waterline	Pipeline	31+14
Federal Road	Bridge	30+16

5.4 Manning's n-Values

Manning's n-values from the original non-federal sponsor, HCFCD, HEC-2 model were verified and adjusted as needed based on field reconnaissance. For clarification, Manning's n-values were not adjusted during the calibration procedure from the field conditions estimate. As documented in *Section 5.8*, the difference between computed WSELs and high water marks were less than 1 foot, the general accuracy for hydraulic model calibration to high water mark measurements as discussed USACE guidance cited in *Section 8.1.3*. The roughness coefficients used for the overbanks and channel are described in more detail in the next sections.

5.4.1 Overbank n-Values

Overbank roughness coefficients for the calibrated model range from 0.07 to 0.12. The lower roughness coefficients are generally used from the mouth to about a mile upstream, where there is more undeveloped land with sparse tree cover. For the remaining portion of Hunting Bayou, overbank n-values of 0.1 to 0.15 are typically used to reflect limited conveyance.

5.4.2 Channel n-Values

Hunting Bayou is an earthen channel for its entire length, except for a concrete lining through ERRY. Channel roughness coefficients for the earthen sections range from 0.035 to 0.06. As with the overbank n-values, the lower channel n-values (0.035 to 0.04) are used in Hunting Bayou's lower reaches (from HEC-RAS station 21+40 to station 83+75). The rest of Hunting Bayou has channel n-values of 0.05 to 0.06. A 0.05 Manning n-value was assigned to portions of Hunting Bayou where the channel was fairly well maintained. For Hunting Bayou's remaining reaches, where the existing channel was more overgrown, a 0.06 n-value was used.

Finally, through the ERRY (HEC-RAS station 565+55 to station 568+83), the existing channel is concrete-lined. A 0.015 Manning n-value was assigned to the channel for these cross-sections. This n-value is typically used by the non-federal sponsor, HCFCD, for concrete-lined channels (Ref. 14).

Exhibit A2-24 is an overall watershed map showing the limits for each Manning's n-value used for the channel. *Exhibit A2-25* shows pictures with typical sections for each Manning's n-value used for the channel.

5.5 Ineffective Flow Areas

In the watershed's upper portion (above ERRY), it was determined the large majority of overbank flooding was ineffective for conveyance. Early model iterations attempted to replicate this with a higher n-value. Even with the higher n-value and low overbank velocities, it was determined the models were showing excessive flow in the right overbank. This is due to the significant area the floodplain occupies in the right overbank. To maintain channel flow for flooding events at or near bank-full capacity, a large majority of the overbanks are defined as ineffective flow. The watershed's middle and lower reaches have much more confined floodplains and were determined to be adequately modeled with higher n-values.

5.6 Contraction and Expansion Losses

The HEC-RAS Hydraulic Reference Manual lists typical values for contraction and expansion coefficients, as shown below (Ref. 12).

	Contraction	Expansion
No transition loss computed	0.0	0.0
Gradual transitions	0.1	0.3
Typical bridge sections	0.3	0.5
Abrupt transitions	0.6	0.8

For this study, the gradual transition values above are used for all cross-sections not located near a bridge or pipeline. The typical bridge values are used for all bridge and pipeline crossings except for the Liberty Road bridge and the four Southern Pacific ERRY bridges immediately downstream. The abrupt transition values are used for these five bridges. There is a significant amount of head loss at these locations due to the constriction caused by the bridges and the concrete section through ERRY.

5.7 Starting Water Surface Elevation (WSEL)

The HEC-RAS model for this study uses the slope-area method, with a slope of 0.000758 feet/feet. Although the lower six miles of Hunting Bayou is influenced by tides in the Houston Ship Channel, it was determined that the slope-area method was still appropriate to use because the TSP is located at the upper portion of the watershed, several miles upstream of the limit of tidal influence.

Based on guidance in EM 1110-2-1416, Section 6-8(f), the HEC-RAS models for Hunting Bayou were re-executed taking into account the fact that the mouth of Hunting Bayou can be affected by both riverine and coastal flooding. These areas are considered to have a combined probability and WSELs taken from the effective Harris County Flood Insurance Study were adjusted to the project datum and the HEC-RAS model was re-executed. Again, the effect of tidal influences in the model ends near the Wallisville Road crossing, approximately six miles upstream of the mouth of Hunting Bayou and more than three miles downstream from the project site.

5.7.1 Sea Level Rise Consideration

In consideration of the requirements in EC 1165-2-212, *Sea-Level Change Considerations for Civil Works Programs*, the effects of sea level rise on project performance were evaluated. Local tidal gauges were checked for the mean higher high water value. The maximum mean higher high water value was 1.7 feet, well below the starting WSEL for the HEC-RAS model. To investigate the influence from tidal effects and sea level rise, a sensitivity analysis was conducted on the HEC-RAS model. The analysis involved increasing the starting WSEL at the downstream boundary condition by 1.0, 2.0, 3.0 and 4.66 feet. The WSEL increases were developed from equation 3 in EC 1165-2-212, which took into account regional sea level changes (1.7 mm/yr, Ref 19), local sea level changes (6.39 mm/yr, Ref 23) and local subsidence (8.57 mm/yr, Ref 24). Analysis results showed the influence from higher starting tailwater stages end at Wallisville Road. The project area is located upstream from Wallisville Road and is thus beyond the tidal effects influence area. Therefore, using the slope-area method was determined appropriate for this study. [All elevations referenced in this paragraph are 1929 NGVD, 1973 adjustment].

Climate change is anticipated in this region by climate change scientists, which in addition to sea level rise, could potentially include changes in precipitation. However, reports by the Gulf Coast

Regional Climate Change Council, the Intergovernmental Panel on Climate Change, and the U.S. Department of Transportation differ on whether precipitation will increase or decrease in this region and describe significant uncertainty in forecasting regional precipitation change in the next 50 to 100 years. Therefore, it is concluded that the Hunting Bayou watershed is not anticipated to incur the significant impacts due to climate change, associated with either sea level rise or changes in precipitation, within the anticipated 50 year period of analysis. Further discussions of the potential impacts of climate change are discussed in Section 6.1.4 of the Main Report and Appendix 1 – Attachment D in Section 6.0. To ensure full compliance with ECB 2014-10, a qualitative analysis of climate change impacts will be conducted during the PED phase. The qualitative analysis is not required during the feasibility phase, as the TSP milestone had already been reached prior to the publication date of the referenced ECB.

5.7.2 Subsidence Considerations

Following the link provided in Reference 24 provides a plot of subsidence observations from NETP Extensometer from 1981 to 2012. This extensometer is located just south of the TSP location. *Figure A2-1* and *Figure A2-2* show the information associated with the extensometer. The plot shows subsidence rate in the project area has stopped since 1995. Subsidence is not expected to continue in the region due to the implementing the local Groundwater Reduction Plan which will reduce groundwater withdrawals by 80 percent countywide by 2030.

Figure A2-1:
North East Extensometer Location

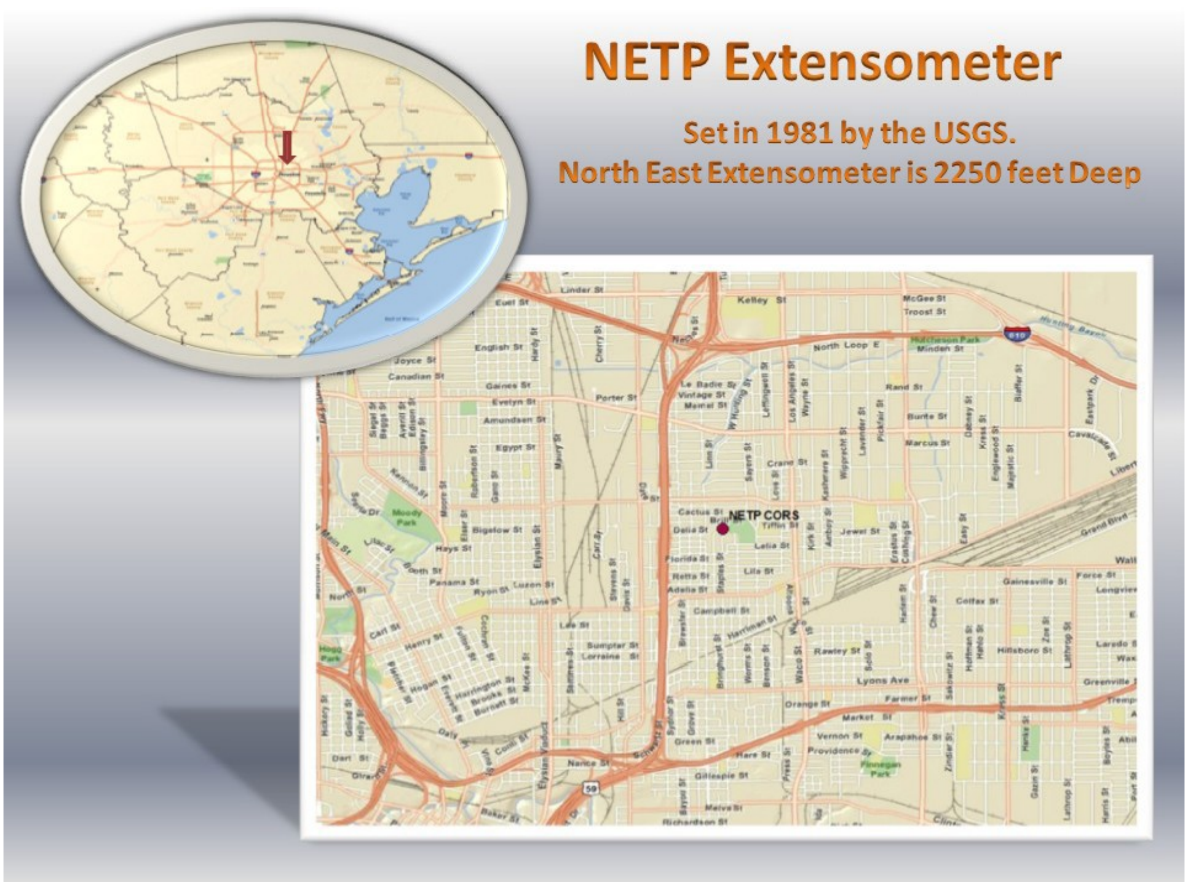
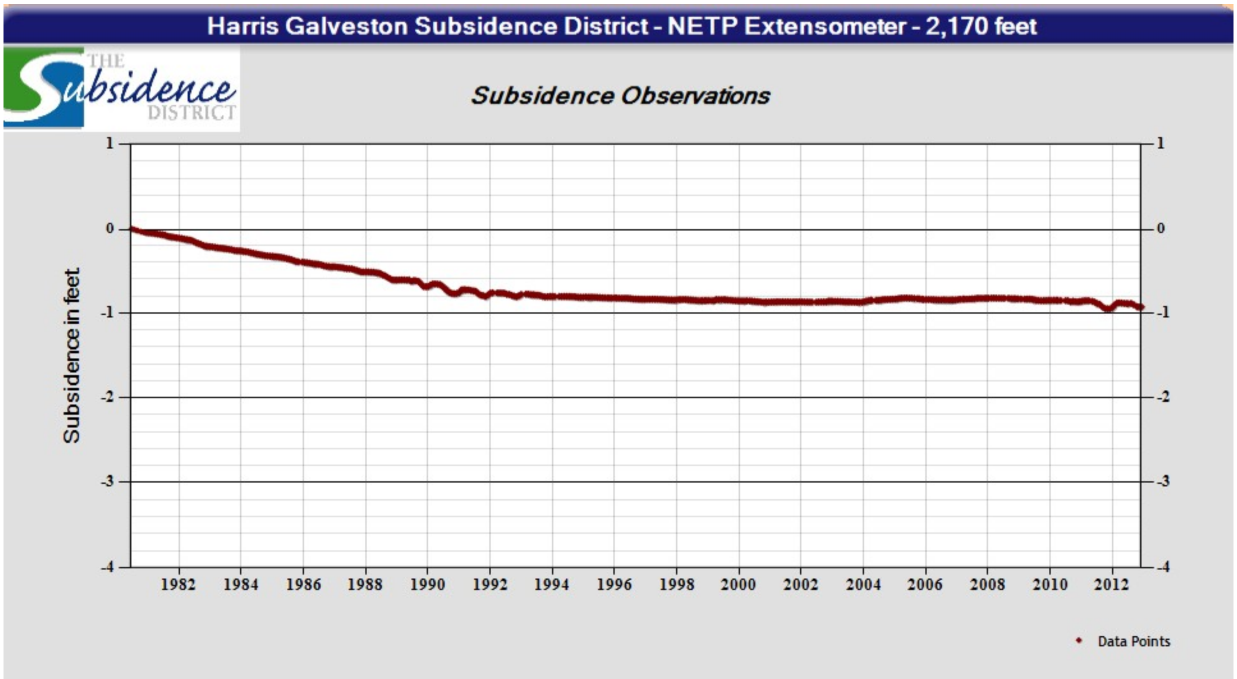


Figure A2-2:
North East Extensometer Data



5.8 HEC-RAS Verification for September 1998 Storm Event

As previously discussed, the HEC-1 models were verified against five historic storm events. Of these, only the September 1998 event had observed high water marks to verify the HEC-RAS model. The accuracy for the high water marks surveyed after the September 1998 event is not known, but in general they are accurate within ±1 foot.

The starting WSEL at the mouth was taken as 8.4 feet, which was recorded near the mouth at Federal Road. The flows computed using the HEC-1 model for the September 1998 storm event were put into the HEC-RAS 3.1.1 model, assuming the peak WSEL occurred at the peak discharge [All elevations referenced in this paragraph are 1929 NGVD, 1973 adjustment].

Table A2-32 lists the computed HEC-1 discharges, corresponding HEC-RAS stations and time to peak discharge. A logarithmic station-discharge relationship was used to define discharges between HEC-1 computation points, and is denoted in italics in *Table A2-32*. *Exhibit A2-26* is a plot for the station-discharge relationship used in HEC-RAS.

Table A2-32:
September 1998 Storm Event Discharges

Location Description	HEC-1 Node	HEC-RAS Station	HEC-1 Peak Discharge (cfs)	Time to Peak (hours)
Mouth of Hunting Bayou	H100#15	98+88	6,011	42.25
		121+70	5,900	
Downstream H102-00-00	H100#14	162+84	5,705	41.25
		171+39	5,650	
Market Street	H100#13	223+89	5,321	41.00
		244+29	5,230	
IH 10	H100#12	257+06	5,174	41.25
Confluence H100L	H100#11	307+49	4,635	41.25
Downstream H125-00-00	H100#10	320+49	4,521	41.00
Wallisville Road	H100#9	417+00	4,182	40.75
Confluence H100I	H100#8	461+83	3,625	40.75
IH 610 – 1st Crossing (USGS Stream Gauge)	H100#7	498+31	3,373	40.50
Confluence H100G	H100#6	549+50	3,231	38.00
Wayside Drive	H100#5	575+33	2,851	37.75
IH 610 – 2nd Crossing	H100#4	602+80	2,575	37.00
Downstream H118-00-00 (Homestead Road)	H100#3	640+90	2,134	36.25
Upstream H118-00-00	H100#3	666+05	1,679	36.00
Lockwood Road (Upstream H110-00-00)	H100#2	710+37	1,349	35.75
Downstream H112-00-00 (Falls Street)	H100#1	733+19	963	35.50
Upstream H112-00-00	H100A	761+58	573	35.50
Upstream US 59		767+52	340	

Table A2-33 shows a comparison between the computed and observed WSELs in Hunting Bayou for the September 1998 storm event. The observed high water marks were surveyed based on the 1978 datum, so the computed WSELs were adjusted from the 1973 datum to the 1978 datum to allow for comparison. The survey adjustment from 1973 to 1978 ranges from -0.9 foot to -0.8 foot. On average, the computed WSELs are 0.3 foot higher than the observed high water marks.

Table A2-33:
HEC-RAS Model Versus September 1998 Storm High Water Marks
(Peak on Peak Assumption)

Location	HEC-RAS Station Number	HEC-RAS CWSEL (1973 Datum)	1973 to 1978 Datum Adjustment	HEC-RAS CWSEL (1978 Datum)	Observed High Water Mark (1978 Datum)	CWSEL Difference (feet)
Federal Road	31+05	8.6	-0.9	7.7	7.5	0.2
Market Street	223+55	17.7	-0.8	16.9	N/A	
IH 10	255+19	21.8	-0.8	21.0	21.2	-0.2
Wallisville Road	371+23	30.2	-0.8	29.4	30.7	-1.3
IH 610	480+40	36.7	-0.8	35.9	35.5	0.4
McCarty Road	497+81	37.4	-0.8	36.6	35.7	0.9
Liberty Road	572+61	40.6	-0.8	39.8	40.8	-1.0
Homestead Road	636+05	42.7	-0.8	41.9	39.8	2.1
Lockwood Road	686+73	44.1	-0.8	43.3	42.5	0.8
Wipprecht Street	704+62	44.5	-0.8	43.7	43.0	0.7
Hirsch Road	724+92	45.0	-0.8	44.2	44.8	-0.6
US 59	760+33	45.8	-0.8	45.0	43.7	1.3
Average						**0.3**

Table A2-34 shows the peak discharge at the USGS stream gauge (HEC-1 Node H100#7) occurs at 40.50 hours. Downstream from the gauge, the time to peak is similar; however, upstream from the gauge the time to peak occurs up to 5½ hours before the peak at the gauge.

Table A2-34:
September 1998 Storm Event Discharges
(Coincidental Peaks Upstream from USGS Stream Gauge)

Location Description	HEC-1 Node	HEC-RAS Station	HEC-1 Peak Discharge (cfs)	Time to Peak (hours)
Mouth of Hunting Bayou	H100#15	98+88	6,011	42.25
		121+70	5,900	
Downstream H102-00-00	H100#14	162+84	5,705	41.25
		171+39	5,650	
Market Street	H100#13	223+89	5,321	41.00
		244+29	5,230	
IH 10	H100#12	257+06	5,174	41.25
Confluence H100L	H100#11	307+49	4,635	41.25
Downstream H125-00-00	H100#10	320+49	4,521	41.00
Wallisville Road	H100#9	417+00	4,182	40.75
Confluence H100I	H100#8	461+83	3,625	40.75
IH 610 – 1st Crossing (USGS Stream Gauge)	H100#7	498+31	3,373	40.50
Confluence H100G	H100#6	549+50	3,163	40.50
Wayside Drive	H100#5	575+33	2,717	40.50
IH 610 – 2nd Crossing	H100#4	602+80	2,379	40.50
Downstream H118-00-00 (Homestead Road)	H100#3	640+90	1,910	40.50
Upstream H118-00-00	H100#3	666+05	1,382	40.50
Lockwood Road (Upstream H110-00-00)	H100#2	710+37	1,056	40.50
Downstream H112-00-00 (Falls Street)	H100#1	733+19	744	40.50
Upstream H112-00-00	H100A	761+58	419	40.50
Upstream US 59		767+52	250	

Stage data from HCOEM gauge 0839 (Hunting Bayou at Lockwood – HEC-1 Node H100#2) was reviewed for the September 1998 event. The data showed the peak stage actually occurred at the same time as the peak stage at the USGS stream gauge. As a result, the discharges used in the HEC-RAS 3.1.1 model upstream from the USGS stream gauge were modified to reflect the discharge at 40.50 hours as obtained from the HEC-1 model.

Table A2-34 shows the modified discharges used in the HEC-RAS 3.1.1 model, assuming the peak WSELs upstream from the USGS stream gauge occurred at the same time as the peak at the gauge. The station-discharge plot for these discharges is shown in *Exhibit A2-27*.

The comparison for the computed and observed WSELs assuming coincidental peaks upstream from the USGS stream gauge are shown in *Table A2-35*. On average, the computed WSELs are 0.1 foot lower than the observed high water marks. By using the coincidental peak assumption, all computed WSELs are within 2 feet of the observed high water marks, and seven out of the 11 measurements are within 1 foot. At IH 10 and Lockwood Road where the floodwaters were out of banks, the measurements were within 0.2 foot and 0.1 foot, respectively.

Table A2-35:
HEC-RAS Model Versus September 1998 Storm High Water Marks
(Coincidental Peaks Upstream from USGS Stream Gauge)

Location	HEC-RAS Station Number	HEC-RAS CWSEL (1973 Datum)	1973 to 1978 Datum Adjustment	HEC-RAS CWSEL (1978 Datum)	Observed High Water Mark (1978 Datum)	CWSEL Difference (feet)
Federal Road	31+05	8.6	-0.9	7.7	7.5	0.2
Market Street	223+55	17.7	-0.8	16.9	N/A	
IH 10	255+19	21.8	-0.8	21.0	21.2	-0.2
Wallisville Road	371+23	30.2	-0.8	29.4	30.7	-1.3
IH 610	480+40	36.7	-0.8	35.9	35.5	0.4
McCarty Road	497+81	37.4	-0.8	36.6	35.7	0.9
Liberty Road	572+61	40.4	-0.8	39.6	40.8	-1.2
Homestead Road	636+05	42.3	-0.8	41.5	39.8	1.7
Lockwood Road	686+73	43.4	-0.8	42.6	42.5	0.1
Wipprecht Street	704+62	43.7	-0.8	42.9	43.0	-0.1
Hirsch Road	724+92	44.1	-0.8	43.3	44.8	-1.5
US 59	760+33	44.8	-0.8	44.0	43.7	0.3
Average						**-0.1**

These results verify the WOP conditions HEC-RAS 3.1.1 model for Hunting Bayou is accurately predicting WSELs.

5.9 HEC-RAS 3.1.1 Conversion to HEC-RAS 4.1.0

No changes were made to the HEC-RAS 3.1.1 model geometry, boundary conditions or computation parameters in the conversion to HEC-RAS 4.1.0. The HEC-RAS 4.1.0 model was run under three different flow scenarios.

Scenario 1: Flow rates from the HEC-1 model

Scenario 2: Flow rates from the HEC-HMS model with the original routing data

Scenario 3: Flow rates from the HEC-HMS model with the updated routing data

Table A2-36 compares WSELs between HEC-RAS 3.1.1 and HEC-RAS 4.1.0 for Scenario 1. The peak flow rates used in both hydraulic models are from the HEC-1 model. This provides a direct comparison for the hydraulic calculation differences in the models. *Table A2-36* only shows cross-sections where WSEL differences were noted as a result of the HEC-RAS 4.1.0 conversion. The maximum observed increase was 0.13 foot, and the maximum observed WSEL decrease was -0.01 foot. The average change was a 0.05-foot increase. Elevations are shown in 1929 NGVD, 1973 adjustment.

Table A2-36:
HEC-RAS 3.1.1 Versus HEC-RAS 4.1.0 (Scenario 1):
Cross-Sections with Different WSELs

Station	Exceedance Probability	HEC-1 Flows (cfs)	WSEL (feet)*		Difference (feet)
			RAS 3.1.1	RAS 4.0	
59540	0.02	4,702	44.48	44.49	0.01
53836	0.1	4,293	40.15	40.16	0.01
46183	0.01	5,309	37.75	37.76	0.01
37807	0.1	4,758	32.36	32.37	0.01
37123	0.01	5,707	32.81	32.82	0.01
37029	0.01	5,707	32.26	32.27	0.01
34658	0.01	5,707	30.18	30.20	0.02
32049	0.01	6,229	28.51	28.53	0.02
30749	0.01	6,558	27.84	27.87	0.03
28512	0.01	6,558	26.79	26.86	0.07
25706	0.01	7,842	25.41	25.52	0.11
25647	0.01	7,842	25.42	25.54	0.12
25643	0.01	7,842	25.37	25.48	0.11
25591	0.04	6,603	23.78	23.77	-0.01
25591	0.01	7,842	25.35	25.46	0.11
25591	0.004	8,533	26.61	26.60	-0.01
25577	0.5	3,015	18.53	18.54	0.01
25577	0.01	7,842	25.26	25.37	0.11
25577	0.004	8,533	26.52	26.51	-0.01
25519	0.01	7,842	25.22	25.33	0.11
25152	0.01	7,842	24.42	24.54	0.12
25105	0.01	7,842	24.38	24.51	0.13
25105	0.004	8,533	25.23	25.22	-0.01
24429	0.01	8,030	24.00	24.10	0.10
24429	0.004	8,780	24.86	24.85	-0.01

*Elevations are shown in 1929 NGVD, 1973 adjustment

Table A2-37 compares WSELs between HEC-RAS 3.1.1 with peak flow rates from HEC-1 and HEC-RAS 4.1.0 and peak flows from HEC-HMS using the original reach routing data representing Scenario 2. This compares the original model with the updated hydraulic model and updated hydrologic model. *Table A2-37* presents differences noted for all eight storm events and for selected upstream cross-sections near bridge crossings. When evaluated across all the cross-sections, the maximum WSEL increase was 0.6 foot upstream from IH-10 for the 0.01 exceedance probability; the maximum WSEL decrease was 0.59 foot upstream from Wayside Drive for the 0.5 exceedance probability; and the average WSEL change was a 0.08-foot increase surveyed across all cross-sections and exceedance probabilities. Elevations are shown in 1929 NGVD, 1973 adjustment.

Table A2-37:
HEC-RAS 3.1.1 Versus HEC-RAS 4.0 (Scenario 2):
Difference in WSEL for Selected Upstream Bridge Cross-Sections

Description	Station	Exceedance Probability	HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1 routings / RAS 4.1.0		Difference (feet)
			Flow (cfs)	WSEL* (feet)	Flow (cfs)	WSEL* (feet)	
Upstream from Wayside Drive	56555	0.5	2,044	36.63	1,865	36.04	**-0.59**
	56555	0.2	3,337	40.66	3,332	40.69	0.03
	56555	0.1	3,929	41.72	4,029	41.79	0.07
	56555	0.04	4,429	42.03	4,548	42.13	0.10
	56555	0.02	4,778	42.28	4,934	42.41	0.13
	56555	0.01	5,182	42.54	5,356	42.68	0.14
	56555	0.004	5,639	42.82	5,790	42.98	0.16
	56555	0.002	5,917	43.02	6,077	43.18	0.16
Upstream from IH-10	25577	0.5	3,015	18.53	2,818	18.16	-0.37
	25577	0.2	4,815	21.34	4,890	21.43	0.09
	25577	0.1	5,821	22.68	6,010	22.91	0.23
	25577	0.04	6,603	23.72	6,806	23.93	0.21
	25577	0.02	7,182	24.39	7,379	24.56	0.17
	25577	0.01	7,842	25.26	8,009	25.86	**0.60**
	25577	0.004	8,533	26.52	8,642	26.64	0.12
	25577	0.002	8,886	26.99	9,002	27.09	0.10

*Elevations are shown in 1929 NGVD, 1973 adjustment

Table A2-38 compares WSELs between HEC-RAS 3.1.1 with peak flow rates from HEC-1 and HEC-RAS 4.1.0 and peak flows from HEC-HMS using the updated reach routing data representing Scenario 3. This compares the original models with the proposed H&H model updates. The revised storage vs. discharge curves were developed using automated scripts allowing the models to be iterated until flow rates converged within 1 percent (or less) of the previous iteration. *Table A2-38* shows differences noted for all eight storm events and for selected upstream cross-sections near bridge crossings. When evaluated across all the cross-sections, the maximum WSEL increase was 0.57 foot just upstream from the second downstream crossing at IH Loop 610 for the 0.01 exceedance probability. The maximum WSEL decrease was 0.78 foot upstream from Wallisville Road for the 0.5 exceedance probability. The average WSEL change was a 0.07-foot increase surveyed across all cross-sections and exceedance probabilities. Elevations are shown in 1929 NGVD, 1973 adjustment.

Table A2-38:
HEC-RAS 3.1.1 Versus HEC-RAS 4.1.0 (Scenario 3):
Difference in WSEL for Selected Upstream Bridge Cross-Sections

Description	Station	Exceedance Probability	HEC-1 / RAS 3.1.1		HEC-HMS with updated routings / RAS 4.0		Difference (feet)
			Flow (cfs)	WSEL (feet)*	Flow (cfs)	WSEL (feet)*	
Upstream from IH Loop 610 – 2nd downstream crossing	59960	0.5	1,854	39.28	1,679	38.68	-0.60
	59960	0.2	3,187	42.95	3,076	42.97	0.02
	59960	0.1	3,888	44.42	3,911	44.56	0.14
	59960	0.04	4,399	45.14	4,350	45.58	0.44
	59960	0.02	4,702	46.05	4,720	46.30	0.25
	59960	0.01	5,071	46.76	5,146	47.33	**0.57**
	59960	0.004	5,555	47.75	5,590	47.89	0.14
	59960	0.002	5,856	48.09	5,870	48.21	0.12
Upstream from Wallisville Road	41700	0.5	2,599	29.82	2,316	29.04	**-0.78**
	41700	0.2	4,063	33.52	4,274	33.88	0.36
	41700	0.1	4,758	34.67	4,923	34.82	0.15
	41700	0.04	5,118	35.00	5,293	35.14	0.14
	41700	0.02	5,395	35.22	5,564	35.34	0.12
	41700	0.01	5,707	35.44	5,962	35.59	0.15
	41700	0.004	6,114	35.70	6,339	35.82	0.12
	41700	0.002	6,428	35.88	6,629	35.99	0.11

*Elevations are shown in 1929 NGVD, 1973 adjustment

5.9.1 Calibration

As stated in *Section 4.6*, hydrologic model calibration data was available for five storms; and one storm high water mark was available to verify the HEC-RAS 3.1.1 model. The HEC-RAS 3.1.1 model verification described in *Table A2-38* indicates computed WSELs varied from -1.3 feet to +2.1 feet from measured high water marks with an average +.03 foot difference. The computed WSEL comparison in *Table A2-38* indicates variations in the water surface profiles fall within the tolerances used in the original model verification work. As described in a previous section, the variance in computed WSELs between the updated HEC-RAS 4.1.0 model and the HEC-RAS 3.1.1 is less than 1.0 foot, and the overall average is +0.07 foot. EM 1110-2-1416 (Ref 21) and EM 1110-2-1417 (Ref 20) discuss the general accuracy for hydraulic model calibration to high water marks is ±1 foot.

5.10 Without Project (WOP) Conditions HEC-RAS Results

HEC-RAS 4.1.0 model run results for WOP conditions are presented in the next two sections.

5.10.1 Without Project (WOP) Conditions HEC-RAS Results

Flows from the WOP conditions HEC-HMS models were put into the updated HEC-RAS 4.1.0 model to compute WSELs for the eight AEPs. *Table A2-39* shows the computed WSELs at selected locations along Hunting Bayou. Profiles for the eight frequencies are shown in *Exhibit A2-28* along with the existing flow line, critical elevation and major crossings. The critical elevation is the minimum flood elevation at which structural damages are incurred at a particular location along Hunting Bayou. Elevations are shown in 1929 NGVD, 1973 adjustment.

Table A2-39:
WOP Conditions Calculated WSELs

Location	HEC-RAS Station	Calculated WSEL* (feet) for Given AEP (%)							
		50	20	10	4	2	1	0.4	0.2
Mouth	21+40	9.10	11.30	12.80	14.60	16.30	17.90	19.70	21.20
Federal Road	31+05	9.13	11.38	12.87	14.65	16.34	17.94	19.73	21.23
COH Water Plant	57+41	9.26	11.66	13.16	14.92	16.57	18.13	19.90	21.38
PTRA Railroad	98+88	9.73	12.34	13.78	15.43	17.01	18.54	20.53	21.99
Missouri Pacific Railroad	221+70	13.86	16.79	17.92	19.03	20.03	21.14	22.57	23.77
Market Street	223+55	14.19	17.32	18.53	19.68	20.71	22.08	24.37	25.12
IH 10	255+19	17.58	21.25	22.63	23.87	24.91	26.38	27.40	27.75
Wallisville Road	371+23	25.54	29.80	31.30	32.28	32.64	33.00	33.47	33.87
Manitou Road	461+36	30.68	35.44	36.64	37.23	37.51	37.80	38.20	38.52
IH 610 (1st Crossing)	480+40	32.14	36.63	37.86	38.77	39.09	39.53	39.91	40.19
McCarty Road	497+81	33.04	37.42	38.62	39.50	39.75	40.15	40.42	40.62
Oil Tank Farm Road	538+36	34.34	38.73	39.91	40.54	40.80	41.12	41.36	41.55
HB&T Railroad	561+85	35.42	39.74	40.88	41.46	41.77	42.11	42.43	42.68
Wayside Drive	563+94	35.58	40.34	41.49	42.00	42.26	42.52	42.82	43.07
So. Pacific RR #1 (ERRY)	566+30	35.84	40.45	41.58	42.10	42.36	42.62	42.92	43.17
So. Pacific RR #2 (ERRY)	567+30	36.02	40.50	41.64	42.16	42.43	42.69	43.00	43.25
So. Pacific RR #3 (ERRY)	568+48	36.18	40.59	41.73	42.26	42.55	42.81	43.13	43.39
So. Pacific RR #4 (ERRY)	571+99	36.67	40.92	42.22	42.94	43.37	43.74	44.22	44.65
Liberty Road	572+61	36.73	40.98	42.29	43.01	43.43	43.80	44.29	44.79
IH 610 (2nd Crossing)	599+60	38.46	42.52	43.84	44.91	45.81	46.32	47.27	47.68
Homestead Road	636+05	39.45	43.31	44.63	45.67	46.49	46.92	47.77	48.17
Kelley Road (Westbound)	649+07	39.84	43.63	44.98	46.10	46.99	47.39	48.05	48.41
Kelley Road (Eastbound)	653+78	39.98	43.76	45.10	46.21	47.09	47.49	48.14	48.50
IH 610 (3rd Crossing)	659+19	40.17	43.92	45.40	46.62	47.55	47.99	48.62	49.00
Lockwood Road	686+73	41.06	44.70	46.10	47.13	47.94	48.35	48.93	49.31
Wipprecht Street	704+62	41.53	45.07	46.34	47.32	48.10	48.51	49.08	49.46
Wayne Street	716+63	41.87	45.32	46.54	47.49	48.23	48.62	49.19	49.57
Hirsch Road	724+92	42.17	45.63	46.83	47.69	48.38	48.77	49.34	49.72
Leffingwell Street	729+40	42.42	45.80	46.98	47.81	48.49	48.88	49.44	49.83
Falls Street	732+65	42.62	46.03	47.25	47.98	48.62	49.01	49.57	49.96
US 59	760+33	43.67	46.76	47.93	48.29	48.81	49.19	49.73	50.02
Neches Street	762+02	43.68	46.81	47.97	48.34	48.86	49.25	49.80	50.07

** All data on 1929 Datum, 1973 Datum Adjustment*

As shown in *Exhibit A2-28*, Hunting Bayou provides protection from the 20 percent AEP from its mouth to IH 10 and from the ERRY to IH 610 (third crossing). Between IH 10 and the ERRY, and upstream from IH 610 (third crossing), the protection level is between a 50 percent and 20 percent

AEP. The flood profiles for WOP conditions indicate structural flooding occurs along Hunting Bayou at least once every 5 years, and in some cases even more frequently. This is consistent with the historical flooding data for Hunting Bayou.

5.11 Without Project (WOP) Conditions Floodplains

Floodplain mapping associated with the 10, 1 and 0.2 percent AEPs is shown in *Exhibit A2-29* for WOP conditions. This mapping was accomplished by comparing the DTM elevations and the WSELs determined by HEC-RAS 3.1.1. The DTM has a 50-foot by 50-foot pixel resolution. Each pixel was assigned to the nearest HEC-RAS cross-section. A definition for each floodplain was accomplished by assigning those pixels whose elevation is lower than the HEC-RAS elevation to that hazard zone. The inundated areas corresponding to the floodplains shown in *Exhibit A2-29* are as follows:

- 10 percent flood – approximately 2,550 acres (4.0 square miles)
- 1 percent flood – approximately 5,600 acres (8.8 square miles)
- 0.2 percent flood – approximately 6,750 acres (10.5 square miles)

Table A2-40 summarizes the number of structures flooded for each of the eight AEPs under WOP conditions.

Table A2-40:
Number of Structures Damaged – WOP Conditions, 2013

AEP (%)	Number of Structures Damaged				Percent Distribution		
	Residential	Commercial	Public	Total	Residential	Commercial	Public
50	0	0	0	0	0.0%	0.0%	0.0%
20	203	25	2	230	88.3%	10.9%	0.9%
10	1,091	112	13	1,216	89.7%	9.2%	1.1%
4	2,265	251	33	2,549	88.9%	9.8%	1.3%
2	3,564	352	52	3,968	89.8%	8.9%	1.3%
1	4,614	438	58	5,110	90.3%	8.6%	1.1%
0.4	5,759	542	67	6,368	90.4%	8.5%	1.1%
0.2	6,616	643	70	7,329	90.3%	8.8%	1.0%

These tables show a significant number of structures are damaged beginning at the 20 percent AEP. Greater than 90 percent of the structures damaged are residential at the 1 percent through the 0.2 percent AEP floodplains. The 1 percent AEP event affects 5,110 structures under WOP conditions.

Referring to *Exhibit A2-29*, the floodplain appears to show significant depth near the Upper Reach. The floodplain is essentially one large basin upstream from ERRY; therefore, routing steps were reduced to one – treating the routing as a level pool. The overbanks are largely confined at their outer limits to the Settegast railroad yard and ERRY embankments. Several sections extend beyond the embankment to capture potential storage volume within the railroad yard storage facility between Lockwood and Wayne Streets. There are no major drainage ways directly south of ERRY. As such, overflow concerns into the adjacent Buffalo Bayou watershed are considered negligible since backwater from a coincident event would limit flow interaction between these two watersheds in this area.

5.12 Without Project (WOP) Conditions Risk Distribution

Risk-based computations with uncertainty were carried out for WOP conditions and all With Project conditions. *Table A2-41* presents the AEP, long-term risk and conditional non-exceedance probability for the WOP conditions by damage reach for existing project conditions. Target Stage, shown on the tables, is defined as the stage typically associated with starting significant damage for the WOP conditions. To ensure consistency with various damage reaches, the stage is determined as the stage associated with the percent of residual damage for a specific exceedance probability event.

Table A2-41 shows the expected AEP along Hunting Bayou varies considerably from reach to reach, but, in general, the existing stream channel provides less than a 10-year level of protection (10 percent AEP).

5.12.1 Economic Impacts for Model Revision

To evaluate the economic impacts from converting the WOP HEC-1 and HEC-RAS 3.1.1 models to the more current HEC-HMS 3.4 and HEC-RAS 4.1.0 models, a HEC-FDA model was prepared and evaluated. A detailed discussion about this analysis is in *Attachment A – WOP Conversion Memo*.

In summary, the change in peak flows caused a change in the computed water surface profiles, which resulted in changes to the HEC-FDA damage output. However, the distribution for WOP damages was virtually the same between the models, never varying more than 2.5 percent. Therefore, the FRM alternatives which performed best when using HEC-1 and HEC-RAS 3.1.1 results will continue to do so when using HEC-HMS and HEC-RAS 4.1.0 results. The changes in the computed water surface profiles were also a magnitude which would not invalidate the model verification procedures described in this appendix for the HEC-1 and HEC-RAS 3.1.1 models. Lastly, by converting from HEC-1 to HEC-HMS and updating the HEC-RAS model version, refined modeling for the off-line basin can be performed to better account for the basin's impact on flooding risk and mitigation of induced impacts due to upstream channel improvements.

Table A2-41:
AEP and Long-Term Risk – WOP Conditions

Economic Damage Reach	Damage Reach Description	Expected Annual Damage (1) (x $1,000)	Target Stage* (feet)	Target Stage AEP		Long-Term Risk			Conditional Non-Exceedance Probability by Events					
				Median	Expected	10-yrs	30-yrs	50-yrs	10%	4%	2%	1%	0.4%	0.2%
D	Sta. 2140 to 6110	0.85	2.07	0.7683	0.7615	1.0000	1.0000	1.0000	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
H	Sta. 6111 to 9930	0.06	8.20	0.5666	0.5618	0.997	1.0000	1.0000	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
L	Sta. 9931 to 13551	3.53	16.07	0.0527	0.0770	0.5515	0.8653	0.9818	0.6765	0.4245	0.2754	0.1790	0.1026	0.0680
M	Sta. 13552 to 17139	67.48	14.70	0.1504	0.1578	0.8204	0.9863	0.9998	0.3203	0.1456	0.0774	0.0431	0.0210	0.0126
O	Sta. 17140 to 18385	5	16.68	0.0627	0.0914	0.6165	0.9089	0.9917	0.6125	0.3939	0.2694	0.1838	0.1147	0.0831
P	Sta. 18386 to 22389	5.35	18.09	0.0354	0.0672	0.5014	0.8244	0.9692	0.7284	0.5157	0.0001	0.0001	0.1789	0.1338
R-Right	Sta. 22390 to 25706 - Right	334.35	23.33	0.1290	0.0950	0.6316	0.9176	0.9932	0.5974	0.3928	0.2753	0.1899	0.1130	0.0773
R-Left	Sta. 22390 to 25706 - Left	445.15	22.66	0.1039	0.1220	0.7279	0.9614	0.9985	0.4817	0.2918	0.1943	0.1279	0.0723	0.0478
T-Left	Sta. 25707 to 28512 - Right	254.94	22.66	0.1117	0.1291	0.7489	0.9684	0.999	0.4568	0.3065	0.2169	0.1513	0.0788	0.0411
T-Right	Sta. 25707 to 28512 - Left	989.47	24.21	0.2240	0.2131	0.9089	0.9975	1.0000	0.2030	0.1153	0.0729	0.0463	0.0210	0.0098
U-Left	Sta. 28513 to 32049 - Right	11.99	25.24	0.0746	0.1059	0.6736	0.9391	0.9963	0.5499	0.3902	0.2897	0.2087	0.1164	0.0628
U-Right	Sta. 28513 to 32049 - Left	182.83	26.10	0.1397	0.1482	0.7989	0.9819	0.9997	0.3918	0.2520	0.1750	0.1199	0.0605	0.0306
V	Sta. 32050 to 37029	10.29	29.10	0.0461	0.0841	0.5844	0.8887	0.9876	0.6474	0.4704	0.3521	0.2492	0.1388	0.0818
X	Sta. 37030 to 41700	198.12	31.48	0.2900	0.2847	0.9649	0.9998	1.0000	0.0634	0.0273	0.0138	0.0069	0.0024	0.0010
Z	Sta. 41701 to 46183	309.03	34.02	0.2133	0.1948	0.8855	0.9956	1.0000	0.2300	0.1181	0.0826	0.0542	0.0370	0.0265
AE	Sta. 46184 to 49831	2356.58	35.76	0.2465	0.2386	0.9345	0.9989	1.0000	0.1263	0.0524	0.0392	0.0185	0.0143	0.0116
AF	Sta. 49832 to 53772	1031.96	37.25	0.2431	0.2363	0.9325	0.9988	1.0000	0.1137	0.0417	0.0200	0.0095	0.0034	0.0017
AG	Sta. 53773 to 56554	183.35	39.16	0.2000	0.1815	0.8651	0.9933	1.0000	0.2467	0.1117	0.0610	0.0327	0.0143	0.0075
AH	Sta. 56555 to 59445	51.65	41.99	0.1476	0.1535	0.8111	0.9845	0.9998	0.3588	0.2018	0.1408	0.1092	0.0800	0.0638
AI	Sta. 59446 to 62067	876.48	43.63	0.1249	0.1369	0.7706	0.9748	0.9994	0.3618	0.1100	0.0465	0.0239	0.0104	0.0048
AL	Sta. 62068 to 66172	1029.67	44.51	0.1407	0.1532	0.8104	0.9844	0.9998	0.3060	0.0548	0.0121	0.0037	0.0012	0.0005
AP	Sta. 66173 to 72006	8359.95	44.21	0.2507	0.2600	0.9507	0.9995	1.0000	0.0367	0.0019	0.0004	0.0001	<0.0001	<0.0001
AZ	Sta. 72007 to 76752	3084.02	46.36	0.2337	0.2324	0.929	0.9987	1.0000	0.1229	0.0311	0.0108	0.0037	0.0012	0.0006

*Elevations are shown in 1929 NGVD, 1973 adjustment

Table A2-42:
Comparison of Typical Channel Velocities for the TSP vs. WOP Condition for the 1Percent AEP

Location	HEC-RAS Station	Average Channel Velocity (fps)		
		WOP	TSP	Difference
Mouth	2140	1.3	1.29	-0.01
Federal Road	3105	5.09	0.98	-4.11
COH Water Plant	5741	2.44	1.04	-1.4
PTRA Railroad	9888	5.51	3.3	-2.21
Missouri Pacific Railroad	22170	4.3	3.9	-0.4
Market Street	22355	7.93	7.21	-0.72
IH 10	25519	3.54	3.15	-0.39
Wallisville Road	37123	2.66	2.65	-0.01
Manitou Road	46136	3.05	3.09	**0.04**
IH 610 (1st Crossing)	48040	2.18	2.17	-0.01
McCarty Road	49781	2.21	2.2	-0.01
Oil Tank Farm Road	53836	3.15	3.1	-0.05
HB&T Railroad	56185	3.52	3.98	**0.46**
Wayside Drive	56394	2.08	4.25	**2.17**
So. Pacific RR #1 (ERRY)	56630	4.56	4.04	-0.52
So. Pacific RR #2 (ERRY)	56730	4.43	3.99	-0.44
So. Pacific RR #3 (ERRY)	56848	4.37	3.98	-0.39
So. Pacific RR #4 (ERRY)	57199	3.96	3.2	-0.76
Liberty Road	57261	3.93	3.21	-0.72
IH 610 (2nd Crossing)	59960	3.26	2.36	-0.9
Homestead Road	63605	1.41	2	**0.59**
Kelley Road (Westbound)	64907	2.08	1.65	-0.43
Kelley Road (Eastbound)	65378	1.8	1.67	-0.13
IH 610 (3rd Crossing)	65919	1.46	1.68	**0.22**
Lockwood Road	68673	1.68	3.85	**2.17**
Wipprecht Street	70462	1.01	1.54	**0.53**
Wayne Street	71663	1.67	1.42	-0.25
Hirsch Road	72492	1.27	1.61	**0.34**
Leffingwell Street	72940	1.87	1.64	-0.23
Falls Street	73265	2.06	1.66	-0.4
US 59	76033	2.03	3.38	**1.35**
Neches Street	76202	0.62	2.33	**1.71**

6.0 RISK AND UNCERTAINTY PARAMETERS

This section describes the assumptions used to develop the risk and uncertainty parameters for the H&H analysis. These parameters are used for the economic analysis. The USACE Guidance Manual EM 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies* was followed (Ref. 13).

6.1 Discharge Uncertainty

Chapter 4 in EM 1110-2-1619 presents the guidelines for estimating the discharge-probability function's uncertainty. The equivalent record length describes the discharge uncertainty for a particular damage reach. Table 4-5 in EM 1110-2-1619 presents seven methods for estimating the equivalent record length. These methods are shown in *Table A2-43*.

Table A2-43:
Equivalent Record Length Guidelines*

Method #	Description	Equivalent Record Length[1]
1	Analytical distribution fitted with long-period gauged record available at site	Systematic record length
2	Estimated from analytical distribution fitted for long-period gauge on the same stream, with upstream DA within 20 percent of that interest point	90 percent to 100 percent of record length of gauged location
3	Estimated from analytical distribution fitted for long-period gauge within same watershed	50 percent to 90 percent of record length
4	Estimated with regional discharge-probability function parameters	Average length of record used in regional study
5	Estimated with rainfall-runoff-routing model calibrated to several events recorded at short-interval event gauge in watershed	20 to 30 years
6	Estimated with rainfall-runoff-routing model with regional model parameters (no rainfall-runoff-routing model calibration)	10 to 30 years
7	Estimated with rainfall-runoff-routing model with handbook or textbook model parameters	10 to 15 years

* *Adapted from EM 1110-2-1619, Table 4-5.*

[1] *Based on judgment to account for the quality of any data used in the analysis, for the degree of confidence in models and for previous experience with similar studies. The second and third methods from Table 4-5 in EM 1110-2-1619 were used to compute the discharge uncertainty for use in the economic analysis. These methods were selected due to the available stream gauge record for Hunting Bayou.*

6.1.1 Log Pearson Type III Analysis

See *Section 4.6.1* for details regarding the Log Pearson Type III analysis.

6.1.2 Adopted Values for Discharge Uncertainty

As previously stated, the second and third methods presented in Table 4-5 in EM 1110-2-1619 were used to estimate the equivalent record length. The second method recommends a 90 to 100 percent equivalent record length of the gauge location record length if the DA in a particular reach is within

20 percent of the gauge's DA. The third method suggests a 50 to 90 percent equivalent record length of the gauge record length if the particular reach is within the same watershed as the gauge.

In this study, the DA reported by the USGS at the stream gauge is 16.1 square miles. Any damage reach whose DA is within 20 percent of the gauge DA has an equivalent 34-year record length, which is 95 percent of the 36-year gauge record length. All other damage reaches outside 20 percent of the DA at the gauge have an equivalent 25-year record length, which is 70 percent of the gauge record length. *Table A2-44* lists each damage reach used in this study, along with the nearest HEC-1 node, DA and adopted equivalent record length.

Table A2-44:
Equivalent Record Length for Economic Damage Reaches

Economic Damage Reach	Nearest HEC-1 Node	DA of HEC-1 Node (mi^2)	Equivalent Record Length (years)
AZ	H100#1	2.65	25
AP	H100#2	4.01	25
AL	H100#3	10.10	25
AI	H100#4	12.18	25
AH	H100#5	13.15	25
AG	H100#6	14.65	34
AF	H100#6	14.65	34
AE	H100#7	15.23	34
Z	H100#8	16.10	34
X	H100#9	18.07	34
V	H100#10	19.26	34
U	H100#11	20.00	25
T	H100#11	20.00	25
R	H100#12	23.12	25
P	H100#13	24.00	25
O	H100#13	24.00	25
M	H100#14	27.29	25
L	H100#14	27.29	25
H	H100#14	27.29	25
D	H100#15	30.12	25

6.2 Stage-Discharge Uncertainty

Chapter 5 in EM 1110-2-1619 presents the guidelines for estimating the stage-discharge function's uncertainty. As outlined in Table 5-2 in EM 1110-2-1619, the minimum stage uncertainty to be used in an economic analysis is a function of the cross-section data and Manning's n-value reliability. For this study, the cross-sections are based on field surveys and a DTM. The Manning's n-value reliability is assumed to be fair since there is limited high water mark data on Hunting Bayou. Therefore, the modeling uncertainty used for this study is 0.7 foot according to Table 5-2 in EM 1110-2-1619. The stage-discharge uncertainty was computed using equations 5-1, 5-2 and 5-3 in EM 1110-2-1619. USGS stream gauge 08075770 (Hunting Bayou at IH-610) was used for calculating the natural uncertainty. The stage-discharge uncertainty was calculated from the modeling uncertainty and the natural uncertainty and equals 0.7 per equation 5-6.

EM 1110-2-1619 also states, *Professional judgment is required to validate the reasonable limits of uncertainty*. As such, based on a firm understanding about the study area's H&H nature, professional judgment was applied in calculating the standard deviation for total stage uncertainty. In this analysis, only the modeled uncertainty (i.e., Manning's n-values) was incorporated into the stage-discharge uncertainty analysis, because the floodplain does not yield significant variability in flood stage due to its relatively flat topography and large storage capacity in the floodplain.

Therefore, including topographic uncertainties would have unnecessarily increased the potential for flood damage inflation for the WOP conditions due to the random sampling for stage-discharge functions during the Monte Carlo simulations executed by the HEC-FDA flood damage model. Moreover, only the Manning's n-values for the main channel were included in the roughness uncertainty computation. Focusing on roughness uncertainty within the main channel better represented the seasonal roughness variability and accounted for debris accumulation, which could lead to bridge obstructions. Conversely, the study area overbanks contain little roughness variability due to Hunting Bayou watershed's fully developed nature.

6.2.1 Without Project (WOP) Conditions

Figure 5-4 in EM 1110-2-1619 was used as a starting point to determine the stage uncertainty for WOP conditions. The figure gives the estimated standard deviation for Manning's n-value based on an average Manning's n-value for a channel. Assuming the variation in stage is normally distributed, approximately 95 percent of the error range would be contained within two standard deviations above and below the mean. The standard deviation for error in stage, or stage uncertainty, would then be the average difference between the upper and lower limits in stage divided by four for a given economic reach.

For WOP conditions, 0.05 is the average channel n-value for Hunting Bayou. According to Figure 5-4 in EM 1110-2-1619, this would correspond to about a 0.015 standard deviation in the n-value estimate. The upper and lower bounds of Manning's n-value would then be 0.08 and 0.02, respectively. However, the lower 0.02 n-value bound seems too low to be reasonable. As a result, a 0.03 n-value was adopted as the lower bound.

The channel roughness coefficients were adjusted to 0.03 in HEC-RAS, and the storage-outflow run was made. The WOP conditions HEC-1 models were modified to reflect the new storage-outflow relationships for each reach. The resulting flows from HEC-1 were reinserted into HEC-RAS to obtain WSELs for the eight AEPs.

The channel roughness coefficients were adjusted to 0.08 in HEC-RAS, and the same procedure described above was followed to obtain WSELs for Manning's n-value's upper limit estimate. The lower limit WSELs were subtracted from the upper limit WSELs at each cross-section location. The differences were averaged for each economic damage reach based on the weighted distance between the cross-sections and then divided by four to obtain the standard deviation. This was performed on each of the eight AEPs.

The results from the stage uncertainty analysis for WOP conditions are shown in *Table A2-45*. Included is the standard deviation for each damage reach along with the average values based on the eight AEPs. The Adopted Uncertainty column contains the values to be used in the economic analysis. In all cases, the average standard deviation was less than or equal to 0.7 foot. Since this is the case, the minimum 0.7-foot value as specified in Table 5-2 in EM 1110-2-1619 is used for all of the economic damage reaches. The standard deviation was calculated for each reach for the given

AEPs 50, 20, 10, 4, 2, 1, 0.4 and 0.2. The overall averages were all less than or equal to the minimum uncertainty for fair n-value data of 0.7 foot, so the minimum requirement stated in Table 5-2 of the EM 1110-2-1619 was adopted. If the overbanks were included in the average n-value calculation, the average will be lowered due to the overbanks' highly urbanized conditions. The lower average n-value will result in even lower standard deviation value for n, as shown in Figure 5-4 in EM 1110-2-161. This means the minimum 0.7 foot requirement still stands.

Table A2-45:
WOP Conditions Discharge-Exceedance and Stage-Discharge Uncertainties

Economic Damage Reach	Standard Deviation (feet) for Given AEP (%)								Error Method	Error Distribution	Results	
	50	20	10	4	2	1	0.4	0.2			Average	Adopted Uncertainty
D	0.3	0.2	0.2	0.3	0.3	0.3	0.4	0.4	Graphical	Normal	0.3	0.7
H	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.1	Graphical	Normal	0.1	0.7
L	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.1	Graphical	Normal	0.1	0.7
M	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Graphical	Normal	0.1	0.7
O	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	Graphical	Normal	0.1	0.7
P	0.4	0.1	0.0	0.1	0.1	0.1	0.1	0.2	Graphical	Normal	0.1	0.7
R	0.5	0.2	0.1	0.2	0.2	0.3	0.3	0.2	Graphical	Normal	0.2	0.7
T	0.6	0.4	0.3	0.3	0.3	0.4	0.3	0.2	Graphical	Normal	0.3	0.7
U	0.7	0.5	0.3	0.4	0.3	0.3	0.3	0.2	Graphical	Normal	0.4	0.7
V	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.5	Graphical	Normal	0.7	0.7
X	1.0	1.0	0.7	0.5	0.4	0.3	0.3	0.3	Graphical	Normal	0.6	0.7
Z	1.0	1.0	0.7	0.6	0.5	0.5	0.5	0.5	Graphical	Normal	0.7	0.7
AE	1.0	1.0	0.7	0.6	0.5	0.4	0.3	0.3	Graphical	Normal	0.6	0.7
AF	1.0	0.9	0.7	0.5	0.4	0.3	0.2	0.2	Graphical	Normal	0.5	0.7
AG	1.0	0.9	0.6	0.4	0.3	0.2	0.2	0.2	Graphical	Normal	0.5	0.7
AH	0.5	0.7	0.5	0.3	0.2	0.2	0.2	0.2	Graphical	Normal	0.3	0.7
AI	0.7	0.8	0.6	0.6	0.7	0.5	0.5	0.4	Graphical	Normal	0.6	0.7
AL	0.7	0.8	0.6	0.5	0.5	0.4	0.4	0.4	Graphical	Normal	0.5	0.7
AP	0.8	0.6	0.4	0.3	0.3	0.3	0.3	0.3	Graphical	Normal	0.4	0.7
AZ	0.9	0.6	0.3	0.2	0.2	0.2	0.2	0.2	Graphical	Normal	0.4	0.7

Table A2-45 shows most standard deviations are less than the 0.7 foot minimum value, probably because most flow under WOP conditions are out-of-bank, so any variations in channel roughness coefficients will have little effect on WSELs. The graphical exceedance probability method was used for determining standard error.

6.2.2 With Project Conditions

The stage uncertainty determined for WOP conditions was adopted as the stage uncertainty for all With Project conditions components and alternatives. This was determined by assuming a federal project would be better maintained than the existing channel, thus making the variation in channel roughness coefficients less than under WOP conditions. Since the WOP conditions stage uncertainty was at or below the 0.7 foot minimum value for all damage reaches, the With Project conditions stage uncertainty would also be at or below the minimum value.

7.0 COMPONENT OPTIMIZATION

More detailed modeling techniques were used in this study phase. HEC-1 was used to compute peak flows in Hunting Bayou, and HEC-RAS 3.1.1 was used to compute WSELs along Hunting Bayou. HEC-RAS was used to perform unsteady flow modeling for the offline detention basins analyzed. The component optimization analyses were conducted during the 2005 GRR/EA update work effort.

As discussed in the following sections, the optimization included first evaluating components on a stand-alone basis (e.g., detention only or channel modifications only), then combining the most effective components and re-optimizing them. Nonstructural components such as buyout and flood-proofing were also included in the optimization.

7.1 Optimization for Upper Reach Components

The optimization for this combined component (channel plus detention) included evaluating the detention basins and channel modifications separately. The upper reach detention component is hereinafter referred to as Component A, while the channel modifications will be called Component B.

Since Hunting Bayou's upper reaches had the highest percentage of WOP conditions damages, the optimization for Components A and B would most likely result in the anchor component. The anchor component can be defined as the single component which produces the highest AAEV net benefits. Components A and B are described in more detail in the following sections.

7.1.1 Component A – Upper Reach Detention

Component A includes offline detention storage upstream from the second IH 610 crossing. This component reduces flood discharges downstream from the basin, which in turn provides flood damage reduction benefits to Hunting Bayou's middle reaches. The reduction in discharges also lowers tailwater elevations, which results in minor flood elevation reductions upstream from the basin.

Originally, seven detention basin sizes were evaluated for Component A, and the optimal size was determined based on net economic benefits. Components A1 through A7 are all offline basins and are in the Homestead Road vicinity. Component A1 uses 26 percent, Component A2 uses 52 percent and Component A3 uses 75 percent of the undeveloped railroad tract between Homestead Road and the second IH 610 crossing; while Component A4 uses the entire railroad tract. Component A5 uses the entire railroad tract in addition to 12 acres on an undeveloped tract to the west of the railroad tract. Component A6 also uses the entire railroad tract, but extends to the north into the Homestead subdivision. Component A7 includes the basins used in Component A5 in addition to 30 acres on a second undeveloped tract to the west of the railroad tract. The basin sizes and storage volumes are presented in *Table A2-46*.

Table A2-46:
Component A Basin Sizes

Component	Basin Area (acres)	Original Basin Volume (acre-feet)	Revised Basin Area after 2004 (acres)	Revised Basin Volume after 2004 (acre-feet)
A1 (A25)	40.0	560	25	468
A2 (A50)	80.0	1,127	50	753
A3 (A75)	116.5	1,780	75	1,025
A4	155.3	2,370	N/A	N/A
A5	167.4	2,540	N/A	N/A
A6	170.9	2,610	N/A	N/A
A7	197.8	2,930	N/A	N/A

During November 2004, the non-federal sponsor, HCFCD, in negotiations with the railroad company owning the property, learned expanded intermodal transport facilities would be planned for half the approximately 150-acre site where any A-Components were assumed to be located. Thus, only half the property would be readily available, limiting detention to 75 acres maximum. Therefore, alternatives using Homestead Site detention larger than 75 acres were assumed to have increased land costs to buy suitable replacement land for the planned intermodal facilities expansion. With the 75-acre limitation, the original B60-A2 combination was anticipated to be the best alternative using Homestead Site detention. Thus, A4 – A7 will not be discussed further in the appendix.

Component A was reconfigured assuming a 75-acre maximum available area. Three scales of Component A were considered at 25, 50 and 75 acres. The components were re-named A25, A50 and A75, respectively. Layout and grading for the revised A2 (A75) basin were based on the same non-federal sponsor, HCFCD, minimum grading criteria in effect when the original 80-acre basin was laid out and graded. Upon reconfiguration, the storage volume for Component A75 was reduced from its previous 1,127 acre-feet assumed volume to 1,025 acre-feet.

Once this was done, various combinations for the best performing upper reach channel modifications were modeled in HEC-1 and HEC-RAS 3.1.1 using the same techniques and steps described for Alternative B60-A in *Section 9.1*. These included B60-A75and B-Terrace-A75. The economic analysis showed B60-A2-75 performed better than all other alternatives using Homestead Site detention, including those with basins larger than 75 acres.

7.1.1.1 Component A1 (A25) through A3 (A75)

The layout for Components A1 through A3 offline detention basins is shown in *Exhibit A2-31* through *Exhibit A2-33*. The specific basin characteristics (e.g., side slopes or transverse slopes) were designed in accordance with the non-federal sponsor, HCFCD, design criteria manual (Ref. 14). The basins all have a 44-foot top-of-bank elevation and a 25-foot flow line elevation. *Table A2-47* shows the surface area and storage volume in the basin at 1-foot increments for Components A1 (A25) through A3 (A75).

For Components A1 (A25) through A3 (A75), the diversion structure between Hunting Bayou and the railroad tract includes five 450-foot long 15-foot by 15-foot reinforced concrete boxes (RCBs).

Table A2-47:
Offline Detention Basin Data – Components A25, A50 and A75

Elevation (feet)*	Component A25	Component A50	Component A75
	Storage Volume (acre-feet)	Storage Volume (acre-feet)	Storage Volume (acre-feet)
25	0	0	0
27	1	2	2
28	4	8	11
29	11	22	32
30	23	47	68
31	40	80	118
32	59	119	176
33	79	158	235
37	161	323	480
42	302	570	825
43	367	646	912
44	468	753	1,025

*All elevations referenced are 1929 NGVD, 1973 adjustment.

7.1.1.1.1 Modeling Procedure

The following list includes the steps taken to model these components.

1. Executed storage-outflow run in HEC-RAS.
   a. Computed storage-outflow relationships for input into HEC-1 models.
   b. Obtained stage-frequency curve at cross-section adjacent to equalization structure under railroad tract's connecting basin to Hunting Bayou (622+55).
   c. Based on stage frequency curve obtained in step 1.b, calculated basin storage.
   d. Added basin storage to storage-outflow relationships computed in step 1.a.
2. Created Existing With Project HEC-1 models.
   a. Inserted storage-outflow relationships determined in step 1.d into HEC-1 models.
   b. Computed peak discharges for the eight AEPs.
3. Inserted peak discharges into With Project HEC-RAS model and execute.
4. Repeated steps 1 through 3 for second model iterations. Repeated until storage-outflow curves become steady between iterations.

7.1.1.1.2 HEC-RAS Modeling

WOP geometry was used to model the resulting HEC-1 peak flow rates for Components A1 (A25) through A3 (A75). Five 15-foot by 15-foot RCBs were used to convey flow under the HB&T railroad tracks. The culvert flow lines were set at 27 feet, which allowed flow to enter and exit the detention pond based on head. Each culvert was 450 feet long. The total available conveyance from the culverts allowed the basin to function as an inline structure (due to insignificant headloss through structure) and was modeled as such. [All elevations referenced in this paragraph are 1929 NGVD, 1973 adjustment].

The area the various A-Components occupy is modeled as an ineffective flow area under existing conditions. Therefore, there would be no change in conveyance through this reach due to additional excavation volume. The additional volume created by excavating Components A1 (A25) through A3 (A75) was added at the appropriate storage vs. outflow ordinate in the HEC-1 routing curve.

The same station-discharge relationship used to compute storage-outflow relationships for the WOP conditions models was applied to Components A1 (A25) through A3 (A75) for the reaches below station 599+60.

7.1.1.1.3 HEC-1 Modeling

The updated storage-outflow relationships were put into the HEC-1 models. The detention basin reduces flood discharges downstream, which in turn lowers tailwater elevations upstream from the basin. This causes a drawdown effect immediately upstream from the basin which extends a short distance upstream. Although there are no channel modifications upstream from the basin, the stage-discharge relationship is modified due to the drawdown. Only the first three routing reaches in the model (from HEC-RAS station 732+65 to 686+73, station 686+73 to station 632+53 and station 632+53 to station 599+60) were updated since the downstream project limit is at HEC-RAS station 622+55. No modifications were made to the number of routing steps.

The With Project HEC-1 models were executed for the eight AEPs. The peak discharges were put into the With Project HEC-RAS model to compute WSELs in Hunting Bayou. The flow change locations were the same as those used under WOP conditions.

7.1.1.1.4 Model Iterations

Since the drawdown effect was not reflected in the original HEC-RAS storage-outflow run, it was determined the storage-outflow relationships should be recomputed for the routing reaches upstream from the basin. These re-computed routing reaches were inserted into the HEC-1 models and re-executed. Flows from the re-executed HEC-1 models were imported back into HEC-RAS, and the resulting storage-outflow curves were compared to the previous iteration. The process was repeated until the storage-outflow curves became stable.

7.1.1.2 Component A – Optimization Results

The results show all basin sizes reduce the AEP from WOP conditions, with the largest basin sizes providing the most reduction, as expected. In no cases were WSELs increased by Components A1 (A25) through A3 (A75) along Hunting Bayou. Economic analysis for flood damage reduction was performed, and is described in detail in *Appendix 5 – Economic Analysis*. Results indicated all basin sizes produced positive AAEV net benefits, with A3 (A75) providing the highest AAEV net annual benefit.

7.1.2 Component B – Upstream Earthen Trapezoidal Channel Modifications (US 59 to Englewood Railroad Yard [ERRY])

Component B includes approximately 20,100 feet (3.8 miles) of earthen trapezoidal channel modifications, from just downstream from US 59 to approximately 1,500 feet downstream from ERRY. The general layout for Component B is shown in *Exhibit A2-34*. In earlier rounds of component analysis, an inline detention basin was included as part of the Component B channel modifications. In 2009, it was determined the area proposed for the inline basin contained materials associated with an unregistered landfill. The non-federal sponsor, HCFCD, decided to avoid disturbing this area, and the inline basin was no longer considered part of Component B. Final plan formulation did not include the inline basin, but it is discussed in the following sections because it was part of the Component B analyses conducted during the 2005 work effort.

The B-60 Component includes the following channel sections.

- HEC-RAS station 750+60 to station 723+55 – 30-foot bottom width
- HEC-RAS station 720+06 to station 705+20 – 40-foot bottom width
- HEC-RAS station 704+62 to station 634+25 – 60-foot bottom width
- HEC-RAS station 633+00 to station 605+25 – inline detention
- HEC-RAS station 602+80 to station 549+50 – 10-foot bottom width

The B-40 Component includes the following channel sections:

- HEC-RAS station 750+60 to station 723+55 – 20-foot bottom width
- HEC-RAS station 720+06 to station 705+20 – 30-foot bottom width
- HEC-RAS station 704+62 to station 634+25 – 40-foot bottom width
- HEC-RAS station 633+00 to station 605+25 – inline detention
- HEC-RAS station 602+80 to station 549+50 – 10-foot bottom width

The B-70 Component includes the following channel sections:

- HEC-RAS station 750+60 to station 723+55 – 40-foot bottom width
- HEC-RAS station 720+06 to station 705+20 – 50-foot bottom width
- HEC-RAS station 704+62 to station 634+25 – 70-foot bottom width
- HEC-RAS station 633+00 to station 605+25 – inline detention
- HEC-RAS station 602+80 to station 549+50 – 10-foot bottom width

7.1.2.1 Component B Modeling Procedure

The first channel sized modeled included a 60-foot bottom width. This was followed by sizes which included 40-foot and 70-foot bottom widths. The following list has the steps taken to model this Component.

1. Input proposed channel configuration and inline storage to WOP HEC-RAS model to create With Project HEC-RAS model.
2. Executed storage-outflow run in HEC-RAS, and computed storage-outflow relationships for input into HEC-1 models.
3. Created Existing With Project HEC-1 models.
   a. Inserted storage-outflow relationships determined in step 2 into HEC-1 models.
   b. Computed peak discharges for the eight AEPs.
4. Inserted Existing With Project peak discharges into the HEC-RAS model, and executed to obtain water surface profiles.

7.1.2.1.1 HEC-RAS Modeling

The channel modifications and inline detention storage were modeled in HEC-RAS (Version 3.1.1). The channel modifications began at HEC-RAS station 750+60 and ended at station 549+50. The channel improvement option in HEC-RAS was used to input the proposed channel configuration.

The channel was modeled as an earthen trapezoidal section with 3:1 side slopes. The Manning's n-value for the proposed channel was set to 0.04, which is the value the non-federal sponsor, HCFCD, typically uses (Ref. 14).

The proposed flow line was selected based on reviewing existing and proposed storm sewer outfalls to Hunting Bayou in the upper watershed. All proposed storm sewer outfalls are above Hunting Bayou's existing flow line. However, two existing storm sewer outfalls at Homestead Road are 1 foot below the existing flow line. The proposed channel flow line was set 1 foot below these two storm sewer outfalls, and the non-federal sponsor's, HCFCD, allowable 0.05 percent minimum bottom slope was used upstream and downstream from Homestead Road (Ref. 14). This bottom slope set the project's downstream limit at HEC-RAS station 549+50, where the proposed flow line daylighted out.

Deepening and widening the channel would result in replacing the existing bridge and pipeline crossings due to structural necessity. This was modeled by removing the bridge deck, piers and ineffective flow boundaries associated with each crossing. Contraction and expansion loss coefficients were not adjusted. Twenty-four bridges and two pipelines were assumed to be replaced. The bridge replacement farthest downstream is the HB&T railroad crossing at HEC-RAS station 561+65 (refer to *Table A2-31* for the list with existing bridge and pipeline crossings).

In the reach between Homestead Road and the second IH 610 crossing, inline detention storage was modeled in HEC-RAS. Eight new cross-sections were cut from the DTM and added to HEC-RAS to more accurately model the inline storage. The stations for the eight new cross-sections are 633+00, 631+50, 626+55, 622+55, 617+05, 613+05, 610+30 and 608+95. Channel and overbank reach lengths were measured from area aerial photographs. The existing cross-sections at stations 632+53, 626+17, 620+67, 615+32 and 611+62 were removed from the model.

The inline detention begins at HEC-RAS station 633+00 and ends at HEC-RAS station 605+25. *Exhibit A2-35* shows a layout view for the inline detention. The inline basin was not carried forward during final formulation. The detention is essentially a wide earthen flood bench which provides additional storage when floodwaters overflow the main channel. The basin has a 2-foot deep, 10-foot bottom width pilot channel. The pilot channel was assumed to have 3:1 side slopes and be concrete-lined. A 0.015 Manning's n-value was assigned to the pilot channel, which is the standard value the non-federal sponsor, HCFCD, uses for concrete (Ref. 14).

The bottom of the inline detention basin slopes toward the pilot channel at a 0.5 percent minimum slope, which is the minimum the non-federal sponsor, HCFCD, allows for detention basin designs (Ref. 14). The basin side slopes up to natural ground are 3:1. Manning's n-value was set at 0.04 for the basin's portion on either side of the pilot channel. The inline detention was designed so no property acquisitions would be required for the commercial structures on Hunting Bayou's southern side or the Homestead WWTP on the northern side.

The same station-discharge relationship used to compute storage-outflow relationships for the WOP conditions models (refer to *Exhibit A2-4*) was used for Component B. The With Project HEC-RAS model was executed, and storage-outflow relationships were calculated. Since the downstream project limit is HEC-RAS station 549+50, the relationships downstream from this station were the same as the WOP conditions.

7.1.2.1.2 HEC-1 Modeling

The HEC-1 modeling procedure for Component B is similar to Component A. Please refer to *Section 7.1.1.1.3* for HEC-1 modeling details.

7.1.2.2 Component B – Optimization Results

Economic analysis for the three channel width components (B-40, B-60 and B-70) indicated B-60 provided the highest net annual benefits. Four channel lengths using the B-60 cross sections were analyzed to determine the optimized length for the B-60 channel modifications: from US 59 to just downstream from ERRY (Component B-60), from Tributary H112-00-00 to just downstream from ERRY (Component AB-2) and from US 59 to Wallisville Road (Component AB-3), from US 59 to just downstream from ERRY with bypass channel (Component AB-4). Economic analysis results indicated Component B-60 provided the highest AAEV net annual benefits. Therefore, Component B-60 was chosen as the optimal upper reach channel component.

8.0 ALTERNATIVE EVALUATION HYDROLOGY AND HYDRAULICS

This section describes the H&H modeling techniques used to analyze the alternatives evaluated during this study phase. These alternatives arrayed the best performing alternatives from the alternative formulation phase. *Appendix 5 – Economics Analysis* discusses the various alternatives considered and analyzed during the 2004 work effort. For conciseness, two alternatives are discussed in this section. One alternative is a full earthen channel modification from US 59 to the mouth of Hunting Bayou. The other alternative is a combined Component B-A. A discussion about the modeling procedure for each of the alternatives follows.

8.1 Alternative 1 – Full Earthen Channel Modification

In the 1988 USACE Feasibility Study, a full channelization plan was identified as the National Economic Development (NED) Plan for Hunting Bayou (Ref. 15). Thus, it was anticipated a full channelization plan would also be a valid candidate for the NED Plan in this current study effort.

Alternative 1 totally re-evaluates the 1988 USACE NED Plan and was developed using the most current hydrology and economics. It includes earthen channel modifications from US 59 to the mouth of Hunting Bayou, an approximately 72,900-foot (13.8 miles) distance. *Exhibit A2-37* shows a general layout for Alternative 1.

Alternative 1 was optimized by analyzing four different channel designs, with bottom widths ranging from 35 feet to 150 feet near the mouth. The modeling procedure for Alternative 1 is described in subsequent sections.

8.1.1 Alternative 1 Modeling Procedure

The following list includes steps taken to model this alternative.

1. Inserted proposed channel configuration into WOP HEC-RAS model to create With Project HEC-RAS model.
2. Executed storage-outflow run in HEC-RAS, and computed storage-outflow relationships for input into HEC-1 models.
3. Created Existing With Project HEC-1 models.
    a. Inserted storage-outflow relationships determined in step 2 into HEC-1 models.
    b. Computed peak discharges for the eight AEPs.
4. Inserted Existing With Project peak discharges into HEC-RAS model and executed.

8.1.2 HEC-RAS Modeling

The channel modifications were modeled in HEC-RAS (Version 3.1.1). The channel modifications began at HEC-RAS station 750+60 and ended at station 21+40. The channel improvement option in HEC-RAS was used to input the proposed channel configuration.

8.1.2.1 Channel Modeling

The channel was modeled as an earthen trapezoidal section with 4:1 side slopes. The Manning's n-value for the proposed channel was set to 0.04, which is the value the non-federal sponsor, HCFCD, typically uses (Ref. 14).

The proposed flow line was selected based on reviewing existing and proposed storm sewer outfalls to Hunting Bayou in the upper watershed. In addition, deepening the existing bottom was kept at a minimum. *Table A2-48* lists the channel bottom slopes used for all three designs under Alternative 1. The minimum bottom slope used was 0.05 percent, which is the minimum allowed by the non-federal sponsor, HCFCD, (Ref. 14). *Table A2-49* shows the channel bottom widths for the four channel designs evaluated under Alternative 1.

Table A2-48:
Alternative 1 – Channel Bottom Slopes

From HEC-RAS Station	To HEC-RAS Station	Channel Bottom Slope (%)
21+40	183+35	0.0500
183+35	307+49	0.0800
307+49	378+07	0.0864
378+07	750+60	0.0500

Table A2-49:
Alternative 1 – Channel Bottom Widths

From HEC-RAS Station	To HEC-RAS Station	Channel Bottom Width (feet) for Given Design			
		35 BW Design	65 BW Design	110 BW Design	150 BW Design
750+60	723+55	existing	25	30	30
720+06	705+20	existing	25	40	40
704+62	670+74	existing	25	50	60
666+05	640+90	15	25	60	80
637+54	522+67	15	40	85	100
498+31	378+07	25	55	95	115
371+70	370+29	30	60	95	115
346+58	183+35	30	60	95	125
171+39	21+40	35	65	110	150

Since the channel was deepened and widened, it was assumed all bridges and pipelines would be replaced along Hunting Bayou's main stem along the channel modification reach. This was modeled by removing the bridge deck, piers and ineffective flow boundaries associated with each crossing. Contraction and expansion loss coefficients were not adjusted. Thirty-five bridges and six pipelines were assumed to be replaced. The most downstream bridge replacement is the Federal Road crossing at HEC-RAS station 30+15 (refer to *Table A2-31* for the list with existing bridge and pipeline crossings).

8.1.2.2 Storage-Outflow Run

Alternative 1 used the same station-discharge relationship used to compute storage-outflow relationships for the WOP conditions models. The With Project HEC-RAS model was executed, and storage-outflow relationships were calculated for each of the four channel designs.

8.1.3 HEC-1 Modeling

Peak discharges in Hunting Bayou were computed using HEC-1. The WOP HEC-1 models were modified to updated storage-outflow relationships to create the With Project HEC-1 models. These modifications are discussed in the following sections.

8.1.3.1 Modifications to Storage-Outflow Relationships

The storage-outflow relationships determined for each channel design were input into the HEC-1 models. All routing reaches in the HEC-1 model required updating, since the channel modifications extend all the way to the mouth of Hunting Bayou. No modifications were made to the number of routing steps.

8.1.3.2 Executing HEC-1 Models

The With Project HEC-1 models were executed for the eight AEPs. The peak discharges were put into the With Project HEC-RAS model to compute WSELs in Hunting Bayou for each of the four channel designs. The flow change locations were the same as used under WOP conditions.

8.1.4 Alternative 1 Results

The WSELs were compared to the WOP WSELs to check for any impacts. All four channel designs had increases in WSELs near the mouth of Hunting Bayou. However, all WSELs in this location up to and including the 0.2 percent AEP are below the critical elevation line, indicating no increase in annual damages.

Table A2-50 compares the expected AEP for each design to WOP Existing conditions. The results indicate all four full channel designs significantly lower the risk for exceeding flood damage stages throughout all reaches, with larger channel designs lowering the risk even more.

Table A2-50:
Comparison for Expected AEP
Alternative 1 Versus WOP (Existing Conditions)

Economic Damage Reach	Expected AEP				
	WOP	35' BW	65' BW	110' BW	150' BW
D	0.998	0.894	0.866	0.789	0.727
H	0.999	0.865	0.813	0.721	0.647
L	0.024	0.009	0.002	0.001	0.001
M	0.204	0.101	0.051	0.013	0.001
O	0.071	0.039	0.017	0.001	<0.001
P	0.075	0.037	0.016	0.002	<0.001
R-left	0.227	0.039	0.013	0.001	<0.001
R-right	0.094	0.009	0.001	<0.001	<0.001
T-left	0.252	0.058	0.020	0.002	<0.001
T-right	0.128	0.026	0.007	<0.001	<0.001
U-left	0.133	0.034	0.007	<0.001	<0.001
U-right	0.090	0.023	0.003	<0.001	<0.001
V	0.061	0.012	0.001	0.001	0.001
X	0.297	0.077	0.016	0.001	<0.001
Z	0.225	0.059	0.011	<0.001	<0.001
AE	0.229	0.048	0.009	<0.001	<0.001
AF	0.253	0.070	0.016	<0.001	<0.001
AG	0.187	0.058	0.013	<0.001	<0.001
AH	0.202	0.043	0.009	<0.001	<0.001
AI	0.147	0.015	0.001	<0.001	<0.001
AL	0.175	0.025	0.004	<0.001	<0.001
AP	0.302	0.056	0.017	<0.001	<0.001
AZ	0.278	0.046	0.020	0.005	0.004

8.2 Optimal Combined Components (B-A)

Section 9.0 provides the details for the final B-A alternative plan formulation.

9.0 FINAL PLAN FORMULATION

This section discusses the modeling method implemented during the Final Plan Formulation Phase.

9.1 Final Plan Formulation Modeling Procedure

The final plan formulation focused on optimizing the highest AAEV net benefit scale for the alternative selected from the alternative formulation phase (B-A). These were upstream structural alternatives combining Component B channel modifications and Component A offline detention. For the B component, the formulation focused on channel sizes above and below the 60-foot bottom width size (B60), which was the channel component for the best performing B-A alternative from the alternative formulation phase. The channel sizes ranged from a 40-foot bottom-width channel (B40) to a 200-foot bottom-width channel (B200). The following B-Components were analyzed:

- B40 – maximum 40-foot bottom width channel
- B50 – maximum 50-foot bottom width channel
- B60 – maximum 60-foot bottom width channel
- B70 – maximum 70-foot bottom width channel
- B80 – maximum 80-foot bottom width channel
- B90 – maximum 90-foot bottom width channel
- B100 – maximum 100-foot bottom width channel
- B140 – maximum 140-foot bottom width channel
- B200 – maximum 200-foot bottom width channel

As discussed in *Section 7.1.2*, the inline detention basin feature for the B-Component was eliminated due to risks associated with the unregistered landfill located on it, and was removed from the B-Component for this final plan formulation step. For the A-Component, the formulation focused on detention basin sizes which could fit within the available 75 acres, ranging from 25 acres to 75 acres. The following A-Components were analyzed.

- A25 – 25-acre offline detention
- A50 – 50-acre offline detention
- A75 – 75-acre offline detention

The H&H analysis modeled 32 scales of the B-A Alternative, combining the various channel and detention sizes. The scales for the B-A Alternative general layout and extent are the same as before shown in *Exhibit A2-30*, except some bridges were not modified, as explained later in this section, and the inline detention feature was removed. The following general procedure was used to model each alternative.

1. Created B-A Alternative HEC-RAS/HEC-HMS model.
    a. Input proposed channel configuration into HEC-RAS steady state model.

b. Input proposed channel configuration and offline basin volume/control structure into truncated HEC-RAS unsteady state model. Model was truncated to include reach beginning approximately 6,000 feet downstream from project limits (cross-section 49831) to downstream face of Homestead Road (cross-section 63425).

c. Executed unsteady state model and extracted from model hydrograph(s) flowing through/over control structure and railroad embankment. Inserted combined hydrograph into HEC-HMS model and executed model.

d. Imported peak flows from HEC-HMS model Step C into steady state HEC-RAS model; executed model; computed storage-outflow values for all reaches and updated in HEC-HMS.

e. Executed HEC-HMS to re-compute flows based on updated storage-outflow reach routing.

f. Extracted from steady state HEC-RAS model cross-section 49831 rating curve.

g. Imported hydrographs from step E and rating curve from step F and repeated steps C through F until storage vs. discharge convergence was achieved in step D.

2. Computed final water surface profiles for B-A Alternatives.

9.2 HEC-RAS Modeling

The HEC-RAS model created for Component B and Component A was the basis for developing the hydraulic models for B-A Alternatives. With the revised analysis, existing low chord elevations were compared to 18 inches above the 1 percent AEP WSEL for the specific B-Component modeled, and raised above this elevation if needed. COH infrastructure design criteria require this minimum elevation for new and replaced crossings. Bridge roadway approaches were modified as necessary to meet the revised bridge decks with minimized grades between 2 and 5 percent as necessary. As a result of this more detailed analysis, not all bridges were identified for total replacement, with some bridges needing only extension to accommodate the needed widening.

Since the alternative formulation phase, several roadway and railroad improvement projects took place which coordinated with this federal study's channel widening needs. These improvements modified bridge crossings, thus eliminating the need for some bridge replacements. For the Lockwood Drive bridge, a revised northern approach presented a potential vertical clearance conflict with the nearby IH 610 overpass, as Lockwood traverses under this overpass. Therefore, it was elected to leave the existing Lockwood bridge facility in place. The bridges listed in *Table A2-51* were entered into the With Project HEC-RAS model with the existing geometry in place:

Table A2-51:
HEC-RAS Bridges Entered with Existing Geometry

Crossing	Stream Station
Lockwood Drive	686+66
Kelley Street (Eastbound)	653+78
Homestead Road	636+00
Liberty Road	572+38
Southern Pacific Railroad #4 (ERRY)	571+48
Southern Pacific Railroad #3 (ERRY)	571+48
Southern Pacific Railroad #2 (ERRY)	571+48
Southern Pacific Railroad #1 (ERRY)	571+48
HB&T Railroad	561+66

There are 16 bridge and 2 pipeline replacements/extensions along the project reach due to deepening and widening the channel. The cross section geometry for Component B was the same as described in *Section 7.1.2*, except for the following.

- The side slope ratios (4:1 for earthen sections and 2:1 for concrete-lined sections) were revised to match newer non-federal sponsor, HCFCD, criteria (Ref 22).
- The section through Lockwood Drive was modified to accommodate leaving the existing bridge in place.
- The inline detention section was removed.

The section through Lockwood was narrowed starting at approximately Station 691+47, which is approximately 507 feet upstream from the bridge, to meet the existing span width at the bridge, then expanded to meet the required section bottom width at approximately Station 674+90, approximately 1,150 feet downstream from the bridge. The section where the inline detention feature was removed was replaced with a channel section the same width as the section upstream from Homestead Road for widths up to the 80-foot bottom width component (B80). For component sizes wider than B80, the channel section used in B80 was used to replace the inline section, because sizes wider than B80 would begin to encroach on the existing landfill in the property north of the channel in this section. The same progression and extent for successively wider sections going from upstream to downstream (e.g., 30, 40 and 60-foot channel bottom widths for B60) were used as previously described in Section 7.1.2, and a transition to the same 10-foot bottom width most-downstream section.

For Component A, the basin characteristics were revised to match newer non-federal sponsor, HCFCD, side slope and basin grading criteria. The same 45-foot top-of-bank elevation as before was used with a 25.1-foot flow line elevation. The basin sizes with the revised grading range from about 600 acre-feet for A25 to about 1,350 acre-feet for A75. The diversion structure was changed to reuse the existing culverts between the basin property and Hunting Bayou as much as possible and to minimize modifications under the interceding railroad tracks to increase constructability. The diversion structure includes the three existing 96-inch culverts plus a new 72-inch culvert to convey flow under the HB&T railroad tracks to a control structure. The control structure is a 100-foot by

60-foot by 20-foot rectangular riser with a 100-foot sharp crested weir crest length at elevation 40.7 feet. The riser box includes two orifice openings. The lower orifice is a 6-foot by 6-foot opening at the riser's base with a 24.5-foot flow line elevation, and is equipped with a flap gate preventing flow from entering the basin from Hunting Bayou through the culverts in low flow events. When tailwater conditions recede, this opening allows the basin to empty into Hunting Bayou. The second orifice is designed to take flow into the basin during rainfall events exceeding a 50 percent AEP event and includes a 1-foot tall by 60-foot wide opening with a 38.35-foot flow line elevation. To accommodate a deeper basin, the 72-inch reinforced concrete pipe culvert is required below the railroad embankment, with a flow line set approximately 4 feet below the flow line for the three existing, 96-inch culverts. [All elevations referenced in this paragraph are 1929 NGVD, 1973 adjustment].

The appropriate versions for Component B and Component A were entered into the model together for the various alternative combinations. The With Project HEC-RAS model was executed, and storage-outflow relationships were calculated.

9.3 HEC-HMS Modeling

The storage-outflow relationships determined for each B-A design were input into the HEC-HMS models. The With Project HEC-HMS models were executed for the eight AEPs. The peak discharges were entered into the With Project HEC-RAS model to compute WSELs in Hunting Bayou for each B-A design. The flow change locations were the same as used for WOP conditions.

9.4 Model Iterations

As stated above, the peak flows from the With Project HEC-HMS models were entered into the With Project HEC-RAS model for the eight frequencies. The storage-outflow curves were compared to the previous iteration. The process was repeated until the differences in storage-outflow curves were insignificant between iterations. Unsteady state modeling was included in the iterations to capture any changes in the hydrograph routing through the offline basin.

9.5 A-B Alternative Results

HEC-FDA (Version 1.2.4) was used to optimize AAEV damages reduced associated with the various Component A-B scales. A table summary for economic performances for all 32 scales of the A-B combination is provided in *Appendix 5 – Economics Analysis, Table A5-32.*

10.0 TENTATIVELY SELECTED PLAN (TSP) EVALUATION

Carrying out the Plan Formulation process described in *Section 9.0*, and in congruency with alternative cost estimation (*Appendix 4 – Cost Estimates*), and flood damage analyses (*Appendix 5 – Economics Analysis*), the plan scale that reasonably maximized net excess benefits at least cost was identified as B50-A25, which consists of a channel modification containing a 50-foot maximum bottom width and a 25-acre detention basin footprint. However, due to induced flooding, issues regarding community cohesiveness and the social vulnerability of local communities, the recommended plan scale for implementation has been identified as B60-A75. B60-A75 consists of an upper reach channel modification containing a 60-foot maximum bottom width and a 75-acre detention basin footprint and is the TSP.

10.1 Hydrologic Performance

The WOP conditions and TSP peak flow comparisons at representative locations for the 10 percent, 4 percent, 1 percent, and 0.2 percent AEPs are summarized in *Table A2-52*.

Table A2-52:
Comparison of Peak Flows (cfs) for WOP and TSP at Selected Locations

Location	HEC-RAS Station	10% AEP		4% AEP		1% AEP		0.2% AEP	
		WOP	TSP	WOP	TSP	WOP	TSP	WOP	TSP
Federal Road	31+05	6418	6103	7596	7450	9272	9174	11582	11500
Market Street	223+55	5953	5593	6995	6773	8562	8454	10201	10131
IH 10	255+19	5752	5384	6669	6431	8069	8000	9785	9746
Wallisville Road	371+23	4610	4233	5114	4901	5935	5878	7212	7399
IH 610 (1st Crossing)	480+40	4071	3578	4563	4200	5164	5117	5472	7158
Wayside Drive	563+94	3710	3086	4264	3853	4886	5128	5587	7819
IH 610 (2nd Crossing)	599+60	3530	2755	4066	3453	4619	4641	5106	7597
Homestead Road	636+05	2893	2936	3615	3797	4570	5518	5808	7935
IH 610 (3rd Crossing)	659+19	2184	2226	2693	2875	3389	4321	4029	6317
Lockwood Drive	686+73	1760	1918	2145	2456	2664	3500	3249	4905

For the TSP and for the selected stations listed in *Table A2-52*, the 10 percent AEP results show the peak flows increase for the stations encompassed by the project reach (i.e. upstream from Wayside Drive), although the WSELs decrease (as shown in the following section). The flow increases are more pronounced in the channel segments containing the maximum 60-foot bottom width (i.e., from Wayne Drive downstream to Homestead Road). This is due to the increased channel conveyance capacity reducing the peak stage and associated floodplain storage attenuation effect. Downstream from the project reach (i.e., downstream from Wayside Drive), an average flow reduction is approximately 363 cfs for the 10 percent AEP event.

The same can similarly be stated for the TSP in regard to modeled flow increases throughout the project reach for the 4, 1 and 0.2 percent AEPs. Downstream from the project reach, an average flow reduction is approximately 218, 56 and -437 cfs for the 4, 1 and 0.2 percent AEP events, respectively. The offline basin located near the project's downstream limits serves to mitigate these increased peak flow rates prior to leaving the project limits.

10.1.1 Hydraulic Performance

The TSP provides approximately a 4 percent AEP protection level in the upper watershed. Presented in *Exhibit A2-43* through *Exhibit A2-46* are the 10, 4, 1 and 0.2 percent AEP water surface profiles, respectively, which illustrate the profile comparisons between the WOP condition and the TSP. *Exhibit A2-47* through *Exhibit A2-50* compares the WOP condition and TSP floodplains for the 10, 4, 1 and 0.2 percent AEP floodplains, respectively.

Exhibit A2-43 shows for the 10 percent probability event, the flood elevations are typically reduced in the range of 2.1 to 5.9 feet through the upper reach, upstream from Wayside Drive (Sta. 563+94). For the 4 percent event, the reductions are typically 1.4 to 5.0 feet, also in upper reach. For the 1 percent event, the reductions are typically 0.7 to 4.3 feet through the same reach. For the 0.2 percent event, the reductions are typically -0.4 to 3.0 feet through the same reaches.

Shown on *Exhibit A2-43* through *Exhibit A2-46* are the approximate 10, 4, 1 and 0.2 percent probability flood plain limits for the WOP condition and the TSP. *Table A2-53* presents the change in the inundation area.

Table A2-53:
Inundation Area Reduction

AEP (%)	WOP Approximate Area of Inundation (acres)	TSP Approximate Area of Inundation (acres)
10	2,550	800
4	3,700	1,450
1	5,600	2,250
0.2	6,750	4,500

For the 10 percent floodplain, the area subject to out-of-channel flooding is reduced from approximately 2,500 acres for the WOP condition to approximately 500 acres for the TSP. Average flood depths in the 10 percent TSP floodplain are reduced by approximately 2.7 feet. For the 4 percent floodplain, the area subject to flooding is reduced from approximately 3,600 acres for the WOP condition to approximately 900 acres for the TSP. For the 1 percent floodplain, the area subject to flooding is reduced from approximately 4,900 acres for the WOP condition to approximately 1,700 acres for the TSP. For the 0.2 percent floodplain, the area subject to flooding is reduced from approximately 6,750 acres for the WOP condition to approximately 4,500 acres for the TSP.

10.1.2 Sediment and Erosion

Preliminary soil borings along Hunting Bayou indicate the soils to be primarily clay. Due to the highly developed watershed area, sedimentation from upstream areas has not been a significant maintenance problem. No significant changes in the sedimentation and erosion processes are anticipated for the various components and alternatives considered if typical erosion protection measures normally required by the Local Sponsor are provided. A review of available geotechnical records of the area indicates the subsurface stratigraphy is composed of strong clays and medium dense sands. In general, the soils along most of the Hunting Bayou channel consist of strong clays and clay fill at top-of-bank elevation and silty sand stratum near the slope bottom and under the lowered channel bottom.

A comparison of average channel velocities in Hunting Bayou for the TSP versus the WOP channel velocities during the 1 percent AEP is presented in *Table A2-42*. The results show the velocities will not increase significantly, in comparison to the WOP condition.

The geotechnical reports generally support the use of 1 on 3 side slopes for the upper channel slopes and detention basin slopes. However, the TSP adopts the use of 1 on 4 side slopes to provide an extra measure of slope stability. All channel and detention basin side slopes will be revegetated, by seeding in most cases. In areas where exposed sand or silt is found alongside slopes turf establishment may be required.

Based on the available geotechnical data and the design factors discussed above, no significant changes in the existing erosion and sedimentation processes are anticipated for the TSP.

10.2 Flood Risk Performance

Table A2-54 summarizes the project flood risk performance achieved for the TSP based on the output from the HEC-FDA model. This information is provided to address the ER 1105-2-101 (Ref. 16) requirements.

The table summarizes the expected AEPs by economic damage reach after completing the TSP and the long-term risk associated with the project. Under the TSP condition, the target stages for the upper reaches from Station 565+55 to Station 767+52 show reduced expectations for exceedance which range from 10 to 30 percent within 10 years and from 23 to 58 percent in 30 years; and from 41 to 83 percent within 50 years. Downstream from Station 565+55, the probability the target stage will be exceeded varies by reach from 44 to 100 percent within 10 years and steadily increases to near certainty within 50 years for all reaches.

Conditional non-exceedance demonstrates the probability the various AEP events will be contained by the target stage in the TSP condition. As shown in *Table A2-54*, the chances of containing the various probabilistic flood events are improved with the TSP condition, where the 10 percent event is highly likely to be contained by the target stages in the project impact area upstream of Station 565+55 and slowly diminish in likelihood of non-exceedance as events become larger and less frequent.

Table A2-54:
TSP Flood Risk Performance

Economic Damage Reach	Damage Reach Description	Expected Annual Damage (1) (x $1,000)	Target Stage (feet)*	Target Stage AEP		Long-Term Risk			Conditional Non-Exceedance Probability by Events					
				Median	Expected	10-yrs	30-yrs	50-yrs	10%	4%	2%	1%	0.4%	0.2%
D	Sta. 2140 to 6110	0.86	2.07	0.7864	0.7781	1.0000	1.0000	1.0000	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
H	Sta. 6111 to 9930	0.06	8.20	0.5651	0.5588	0.9997	1.0000	1.0000	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
L	Sta. 9931 to 13551	3.34	16.07	0.0493	0.0698	0.515	0.8362	0.9732	0.7078	0.4360	0.2826	0.1861	0.1103	0.0755
M	Sta. 13552 to 17139	62.21	14.70	0.132	0.1405	0.7799	0.9773	0.9995	0.3571	0.1572	0.0843	0.0478	0.0246	0.0154
O	Sta. 17140 to 18385	4.25	16.68	0.0567	0.0788	0.5597	0.8714	0.9835	0.6621	0.4024	0.2673	0.176	0.1091	0.0783
P	Sta. 18386 to 22389	4.51	18.09	0.0331	0.0569	0.443	0.7685	0.9464	0.7788	0.5354	0.3824	0.2682	0.1764	0.1306
R-Right	Sta. 22390 to 25706 - Right	265.81	23.33	0.0526	0.0758	0.5452	0.8605	0.9805	0.6756	0.4306	0.2939	0.1925	0.1196	0.0786
R-Left	Sta. 22390 to 25706 - Left	353.14	22.66	0.0798	0.0975	0.6417	0.9231	0.9941	0.5622	0.3247	0.2086	0.1301	0.0768	0.0487
T-Left	Sta. 25707 to 28512 - Right	195.73	24.21	0.0839	0.1021	0.6593	0.9323	0.9954	0.5415	0.3273	0.2231	0.1568	0.0808	0.0424
T-Right	Sta. 25707 to 28512 - Left	773.73	22.66	0.18	0.1741	0.8524	0.9916	0.9999	0.2574	0.1239	0.0736	0.0469	0.0209	0.0096
U-Left	Sta. 28513 to 32049 - Right	9.04	26.10	0.0551	0.0812	0.5711	0.8796	0.9855	0.6455	0.4246	0.3056	0.2235	0.1237	0.0681
U-Right	Sta. 28513 to 32049 - Left	138.81	25.24	0.104	0.1158	0.7079	0.9539	0.9979	0.4807	0.2778	0.1855	0.1283	0.0642	0.0331
V	Sta. 32050 to 37029	7.21	29.10	0.0353	0.0605	0.4642	0.7899	0.9558	0.7587	0.5259	0.3831	0.2568	0.1467	0.0727
X	Sta. 37030 to 41700	143.53	31.48	0.2271	0.2191	0.9157	0.9979	1.0000	0.1161	0.0387	0.0182	0.0083	0.0029	0.0010
Z	Sta. 41701 to 46183	209.42	34.02	0.1375	0.1417	0.7832	0.9781	0.9995	0.3599	0.1607	0.0807	0.0477	0.0248	0.0037
AE	Sta. 46184 to 49831	1621.92	35.76	0.1802	0.1735	0.8513	0.9915	0.9999	0.2429	0.0856	0.0383	0.0179	0.0078	0.0010
AF	Sta. 49832 to 53772	684.56	37.25	0.17	0.1682	0.8415	0.99	0.9999	0.2525	0.0716	0.0254	0.0090	0.0008	0.0003
AG	Sta. 53773 to 56554	110.5	39.16	0.105	0.1145	0.7036	0.9522	0.9977	0.4938	0.2022	0.0896	0.0382	0.0045	0.0015
AH	Sta. 56555 to 59445	7.08	41.99	0.0177	0.0344	0.2954	0.5832	0.8263	0.9228	0.7256	0.5476	0.3677	0.1292	0.0554
AI	Sta. 59446 to 62067	58.82	43.63	0.0073	0.0154	0.1442	0.3225	0.541	0.9822	0.9086	0.8067	0.6056	0.3021	0.1586
AL	Sta. 62068 to 66172	53.53	44.51	0.0058	0.0104	0.0991	0.2297	0.4067	0.9972	0.9626	0.8478	0.6603	0.3938	0.2553
AP	Sta. 66173 to 72006	543.45	44.21	0.0144	0.0258	0.2304	0.4804	0.7301	0.9581	0.8005	0.6003	0.3989	0.2037	0.1278
AZ	Sta. 72007 to 76752	158.45	46.36	0.0125	0.023	0.2079	0.4416	0.6882	0.9672	0.8249	0.6394	0.4356	0.2342	0.1306

(1) FY2013 Price Levels

*(2) Target Stage - Estimated typical stage at which significant structural flood damage begins to occur. *Elevations are shown in 1929 NGVD, 1973 adjustment*

10.3 Capacity Exceedance

For the channel modifications along Hunting Bayou's upper reach, the consequences from capacity exceedance are that floodwaters will rise above the bayou banks. At first the floodwaters will enter the streets adjacent to the bayou and as waters continue to rise, they will enter adjacent properties and structures. No unusual or excessively rapid flood rises greater than the WOP condition would occur due to capacity exceedance.

The proposed channel modification and offline detention basin have been designed to provide flood storage consistent with maximizing net economic benefits. The excavated detention basin would operate with gravity-flow control structures. If the basin's storage capacity is exceeded, the flow along the bayou will be approximately the same as for the WOP condition. No unusual damage resulting from exceeding the detention basin's capacity is expected. No unusual or excessively rapid flood rises downstream from the detention basins greater than the WOP condition would occur.

For floods exceeding the project capacity, flooding of streets and structures may occur. Warning time for impending inundation is expected to range from 1 to 3 hours from the start of the flood producing rainfall, depending on the rainfall type and the location along the bayou. The flood levels' rise rate may be expected to range from 2 to 3 feet per hour. Typical 3- to 5-hour flooding durations are likely. Structural flooding depths may typically range from 1 to 3 feet for the 1 percent flood, and 2 to 4 feet for the 0.2 percent flood. Street flooding is likely to be 1 to 3 feet deeper than the structural flood depths.

Potential for loss of life due to capacity exceedance is considered to be relatively small, due to the relatively shallow depths of flooding and the relatively low velocity in the flood plain. Street and lot inundation may create a temporary loss of wastewater collection services due to excessive inflow to the wastewater collection system. Potential physical damages to structures, streets and utilities are expected due to capacity exceedance. The physical damages would result from inundation due to rising water.

When the TSP is implemented, flood damages upstream from the ERRY (where most damages are located) will be expected to occur with events more severe than the 4 percent AEP event based on the HEC-RAS modeling and critical elevation of structures from the economic analysis. The 2 percent AEP event is the most frequent modeled event that shows flooding resulting in damages for this area. For this event, the flooding depth is less than 1 foot and only occurs over a small portion of the reach above ERRY. For the 1 percent AEP event, the depth for damaging flooding could reach 2 feet, but would mostly be approximately 1 foot with most of the reach above ERRY experiencing some flooding level. For the 0.2 percent AEP event, the flooding depth could reach 3.5 feet, but would mostly be approximately 2 feet with the entire reach above ERRY experiencing some flooding level. Critical facilities include the Lyndon B. Johnson Hospital, which resides in the WOP 1 percent floodplain. The hospital will experience reduced risk with the TSP from a 0.2 percent event.

In accordance with ER 1110-2-1150 (Ref. 17), an additional analysis was performed to evaluate the consequences of potential capacity exceedance for the TSP detention basin by stressing the TSP with two back-to-back, 24-hour 1 percent storms, carried over a 48-hour period. The results showed the maximum out-of-bank flooding depth occurring in the upper reach (upstream from ERRY) for the 1 percent event was approximately 1 foot, equivalent to approximately a 2.5-foot reduction in comparison to the WOP single occurrence one percent event. Similarly, the maximum water surface increase above the WOP single occurrence 1 percent event in the lower reach (downstream from ERRY) is approximately 0.4 feet.

10.4 Residual Flooding

With the TSP, residual flooding would be expected when the flood water rises above the bayou banks during more severe events. Residual flooding could also be expected to continue to occur as a result of high tailwater conditions where the storm sewer system is surcharged and cannot convey or freely outfall the runoff collected from the DA. The flood water is contained within the bayou banks for higher frequency events for most of the study area reach. When flood water overflows the channel banks, the flow is expected to spread to the overbank areas. Since the overbank areas are relatively flat, the flooding depth would not be expected to be significant due to the spread of the flood water over a larger area. Since the rise rate and flow velocity are related to the flow area, the rise and the velocity are expected to be very low.

In isolated areas, such as depressions and roadway underpasses, the flooding depth could be significant and may create access problems for vehicular traffic. The potential for loss of life in some of these isolated areas where deep water ponding could occur would be expected from drivers attempting to, or accidentally passing through these areas during the more severe events that cause residual flooding. These areas would be expected to be limited mainly to more abrupt roadway or underpass grade changes adjacent to the bayou, such as along Homestead Road just north of the bayou.

10.5 Life Safety Criteria

Life safety is paramount for any FRM project. According to ER 1110-2-1156 (Ref. 18) requirements, three types of life safety tolerable risk guidelines must be used under the USACE tolerable risk guidelines. These include: 1) individual incremental life safety risk using probability of life loss, 2) societal incremental life safety risk expressed in two different ways, and 3) probability distribution of potential life loss. After public safety tolerable risk guidelines are met, other purposes and objectives can be considered.

Implementing the TSP is intended to manage flood water risks, not control or avoid them. The TSP does not have unlimited operational capacity to control extreme floods. For instance, the offline detention basin has a limited capacity to accept diverted water from the main channel. When the basin's maximum capacity has been reached, any additional channel flow is not attenuated. The maximum channel flows are large enough to cause damages downstream from the detention basin, but not to a greater degree than would have occurred under WOP conditions.

The project involves no new science, incorporates ongoing public involvement, and follows an established institutional process. Consequently, the project is not expected to encounter any technical, institutional or social challenges. Within the non-federal sponsor's, HCFCD, area of responsibility, human life is rarely lost in the study area due to flooding; therefore, the Hunting Bayou watershed is considered to have a low loss-of-life risk level due to flooding. The population at risk includes residential neighborhoods, industrial facilities and a nearby railroad yard. There are no dams or levees in the project study that could lead to structural failures along the channel main-stem during a flood event. Channel bank slope failures might occur during a major storm event, but the potential for bank slope failures also applies to WOP Conditions. Regarding the proposed offline detention basin, it is possible debris may clog the offline detention basin outlet, causing the basin to exceed capacity and overtop.

Typical loss-of-life due to flooding incidences occurs when motorists choose to ignore warning signs or messages and drive into high flood water conditions, or due to vehicular accidents occurring at or near ditches. Overall, flood waters within the Hunting Bayou watershed rise gradually (no flash flooding conditions) due to its relatively wide and flat floodplain. Project implementation is expected to lower the risk frequency and magnitude associated with flooding. It is not expected this risk would increase if the B60-A75 project fails to perform. However, should the project fail to perform, flooding could occur due to water levels gradually exceeding the channel overbanks (no massive flood waves). H&H analysis shows a few hours of lag time after peak rainfall typically occurs before the peak stage begins to occur at the project study, providing some warning time to those in affected areas.

The project design will not involve precedent-setting methods, use innovative materials, or change prevailing practices. One unique project aspect is to build the detention basin before channel widening construction, to prevent flooding downstream structures.

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Attachment A

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Memorandum

Date	May 5, 2010	Page	1
To	Wayne Crull, P.E.		
From	Lonnie Anderson, P.E., Matthew Zeve, P.E., and Jacob Torres, EIT		
Subject	Hunting Bayou - Without Project Model Conversion Results		

AECOM has converted the Hunting Bayou Federal Project - Without Project Conditions models from HEC-1 and HEC-RAS 3.1.1 to HEC-HMS 3.4.0 and HEC-RAS 4.1.0. The following summarizes the differences in the peak flow rate and water surface elevation model results. Economic runs using HEC-FDA were performed on the various model updates to determine the impact of proceeding with the updated models.

The conversion to current modeling software is recommended to simplify future modeling. The time required for future modeling efforts can be reduced by the use of automated scripts to supply flow files to HEC-RAS and storage discharge curves to HEC-HMS. Increased QA/QC can also be achieved with the conversion by reducing the number of hydrologic models used in the analysis. Currently, individual models are required for each storm frequency. This model update will result in a single hydrologic model containing all storm frequencies.

The current version of HEC-RAS has added features that allow for increased opportunities to describe individual geometry files as well as an improved user interface. Additionally, HEC-RAS 4.1.0 has fixed numerous known bugs present in previous versions including improved storage volume calculations.

Hydrology: HEC-1 Conversion to HEC-HMS 4.3.0

The HEC-1 models were imported into HEC-HMS using the HEC-HMS import tool. Three separate basin files were required for the 2-, 5-, and 10-year through 500-year events (50%, 20%, 10%, through 0.2% annual exceedance probability events, respectively) due to different loss rate parameters associated with each storm event.

When importing HEC-1 precipitation data into HEC-HMS, individual gage data is created for each event and each sub-basin based on areal reduction factors. This requires that each sub-basin have individually named gage data for each storm frequency. To simplify the conversion, precipitation data was entered into HEC-HMS as a frequency event. The point rainfalls used are based on the HEC-1 model rainfall intensities for a storm area of 0.01 square miles with a peak intensity position of 67 percent.

The Modified Puls routing data were not modified from those used in the HEC-1 model for the first conversion comparison. This allows for a direct comparison of the peak flows based solely on the software differences combined with the change in applied precipitation. **Table 1** (attached) compares the HEC-1 versus HEC-HMS computed peak flow rates. The summary table below presents the maximum decrease and increase in flowrates.

Table 1 Maximum Increase and Decrease				
	Cross Section	% Change	Flow Change (cfs)	Storm Event (AEP)
Maximum % Decrease	66605	- 11.1	122	50%
Maximum % Increase	54950	+ 6.8	186	0.4%
Average Change	+1%			

A second HEC-HMS model was created to incorporate the change in Modified Puls routing parameters (storage versus discharge rate). Updated Modified Puls routing parameters were calculated using the HEC-HMS model and the updated HEC-RAS 4.1.0 model. Storage versus discharge rating curves were updated for all of the Hunting Bayou mainstem reaches. **Table 2** (attached) compares the revised HEC-HMS versus HEC-1 model computed peak flow rates. The summary table below presents the maximum decrease and increase in flowrates.

Table 2 Maximum Increase and Decrease				
	Cross Section	% Change	Flow Change (cfs)	Storm Event (AEP)
Maximum % Decrease	22389	- 13.7	369	50%
Maximum % Increase	54950	+ 7.3	394	2%
Average Change	+1%			

Hydraulics: HEC-RAS 3.1.1 to HEC-RAS 4.1.0

No changes were made to the HEC-RAS 3.1.1 model geometry, boundary conditions, or computation parameters in the conversion to HEC-RAS 4.1.0. The HEC-RAS 4.1.0 model was run with several different flow scenarios:

- Flow rates from the HEC-1 model
- Flow rates from the HEC-HMS model with the original routing data
- Flow rates from the HEC-HMS model with the updated routing data

Table 3 (attached) presents the results of a comparison of WSE between HEC-RAS 3.1.1 and HEC-RAS 4.1.0. The peak flow rates used in both HEC-RAS models are from the HEC-1 model. This provides a direct comparison of the hydraulic calculation differences in the models. **Table 3** presents differences noted for all eight storm events and for all cross sections. The maximum increase noted was 0.13 feet and the maximum WSE decrease noted was -0.01 feet. The average change was an increase of 0.05 feet.

Table 4 (attached) presents the results of a comparison of WSE between HEC-RAS 3.1.1 with the peak flow rates from HEC-1 and HEC-RAS 4.1.0 with peak flows from the HEC-HMS model with the original reach routing data. This provides a comparison of the original model with the updated hydraulic model and updated hydrologic model. **Table 4** presents differences noted for all eight storm events and for all cross sections. The maximum increase noted was +0.60 feet and the maximum WSE decrease noted was -0.59 feet. The average change was an increase of +0.08 feet.

Table 5 (attached) presents the results of a comparison of WSE between HEC-RAS 3.1.1 with the peak flow rates from HEC-1 and HEC-RAS 4.1.0 with peak flows from the HEC-HMS model with the updated reach routing data. This provides a comparison of the original models with the proposed hydrologic and hydraulic model updates. The revised storage versus discharge curves were developed using automated scripts allowing the models to be iterated until flow rates converged within one percent or less of the previous iteration. **Table 5** presents the differences noted for all eight storm events and for all cross sections. The maximum increase noted was +0.57 feet and the maximum WSE decrease noted was -0.78 feet. The average change was an increase of +0.07 feet.

Calibration

The Hydrology and Hydraulics (H&H) Appendix of the Hunting Bayou GRR describes the calibration and model verification performed for the HEC-1 and HEC-RAS 3.1.1 models. At the time of the preparation of the H&H Appendix, hydrologic model calibration data was available for five storms and one storm was available to verify the HEC-RAS 3.1.1 model.

The HEC-RAS 3.1.1 model verification described in the H&H Appendix indicates that computed WSE varied from -1.3 feet to +2.1 feet from measured high water marks. The average difference between the computed WSE and the high water marks is +0.3 feet.

The comparison of computed WSE presented in **Table 5** indicates that variation in the water surface profile fall within the tolerances used in the earlier model verification work. As described in the previous section of this memo, the variance in computed WSE between the updated HEC-RAS 4.1.0 model and the HEC-RAS 3.1.1 is less than 1.0 foot and the overall average is +0.07 feet. Engineer Manual 1110-2-1416 (River Hydraulics) and 1110-2-1417 (Flood Runoff Analysis) discuss that the general accuracy of hydraulic model calibration to high water marks is +/- one foot.

Economics

In order to evaluate the effects of the updated water surface profiles on the study economics, the HEC-FDA model with the existing structure module and FY 2001 price level was prepared using the steady state water surface profile data from the HEC-RAS 4.1.0 model with peak flow rates from the HEC-HMS model containing no change in storage routing (**Table 4** results). The computed equivalent annual damages (EAD) for without project conditions are compared to the original HEC-1/HEC-RAS 3.1.1 modeling in **Table 6** below.

A second HEC-FDA model was prepared comparing the updated HEC-HMS/HEC-RAS models which contain the HEC-HMS model results based on updated storage versus discharge rating curves (**Table 5** results). The computed without project conditions EAD are compared to the original HEC-1/HEC-RAS 3.1.1 modeling in **Table 6** below.

Table 6. HEC-FDA Results				
	Comparing HEC-RAS 3.1.1 and HEC-RAS 4.1.0		**Comparing HEC-1 and HEC-HMS 3.4.0**	
	Column 1	Column 2	Column 3	Column 4
FDA Results	2010 EAD using: HEC-1 → RAS 3.1.1 (x 1,000's)	2010 EAD using: HEC-1 → RAS 4.1.0 (x 1,000's)	2010 EAD using: HEC-1 → HMS 3.4.0 → RAS 4.1.0 (x 1,000's)	2010 EAD using: HEC-1 → HMS 3.4.0 (updated routing) → RAS 4.1.0 (x 1,000's)
WOP	$22,419.79	$22,420.07	$24,351.81	$24,464.40

* All are costs are reported in FY 2001 price levels

The HEC-FDA model results provide the following information:

- The change from HEC-RAS 3.1.1 to HEC-RAS 4.1.0 results in an increase of $280 in EAD
- The change from HEC-RAS 3.1.1 to HEC-RAS 4.1.0 and from HEC-1 to HEC-HMS with the original reach routing data results in an increase of $1.93 million in EAD
- The change from HEC-RAS 3.1.1 to HEC-RAS 4.1.0 and from HEC-1 to HEC-HMS with the updated reach routing data results in an increase of $2.04 million in EAD

Despite the WSEL changes of less than one foot for all remaining storm frequencies, due to the number of structures in the affected area, the calculated damages increase. **Figure 1** below shows the change in 2010 EAD across all damages reaches. **Figure 2** below shows the locations of the HEC-FDA damage reaches.

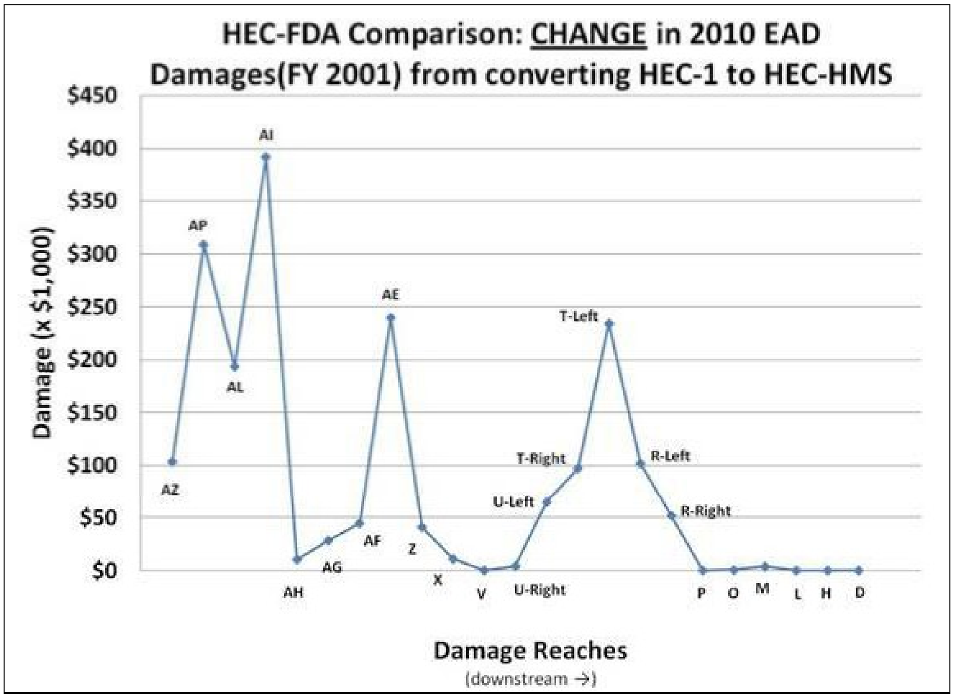

Figure 1. Change in 2010 EAD by Damage Reach

Figure 2. Location of HEC-FDA Damage Reaches

From the plot above, the largest increases in damages occur around damage reaches AZ to AI, AE, and U to R (i.e. Kashmere Gardens, Groveland Terrace, Wood Shadow, and Holiday Forest). These results coincide with the reaches of peak damages observed in the previous without project conditions damages prior to this analysis. These areas constitute high densities of residential structures (industrial in the case of reach "AI") spread over flat terrain, with scattered commercial structures. For a given residential structure, starting with a 0 foot flood depth, having just a 0.25 feet increase in water depth can increase damages by almost 10 percent for a given storm event. This is circled in the residential depth-damage curve below from the HEC-FDA model.

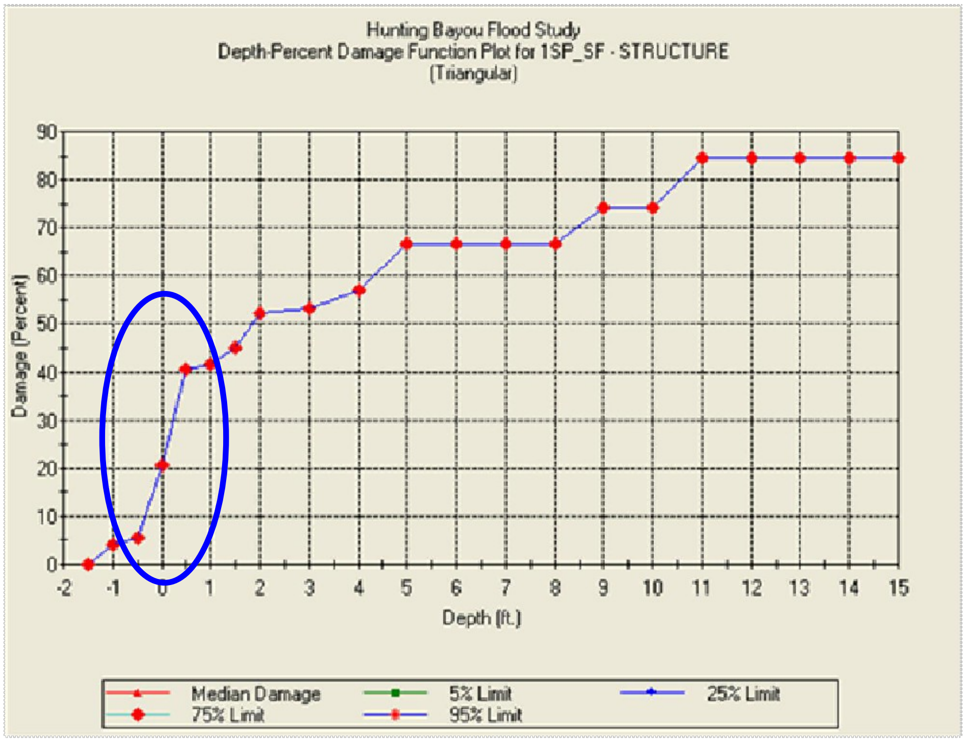

Figure 3. Residential Depth-Damage Curve

To illustrate the potential effect of the depth-damage curve on EAD, consider the damages obtained from a single storm event, for example the 4 percent storm. A 10 percent damage increase for a single structure worth $20,000 in Kashmere Gardens equals $2,000. Multiplying $2,000 by 4 percent yields an EAD increase of **$80/structure** for the 4 percent storm. Recalling that the total EAD change equals $1.9 Million, we divide $1.9 Million by the 19,800 structures in the Hunting Bayou structure inventory to produce an approximate EAD of **$96/structure**. The remaining seven storm events can easily make up the **$16/structure** EAD difference.

Figure 4 below illustrates that although the damages increased, the way in which the damages are distributed (the shape of the curves) remained virtually the same with a shift in magnitude, meaning that damage reaches that were considered "high priority" remain "high priority," and damage reaches considered "low priority" remain "low priority" following the "HEC-1→HMS 3.4.0" conversion. Although this can cause the magnitude of benefits to increase, the alternatives that had the highest net benefits before should still remain the highest since the shift was uniform.

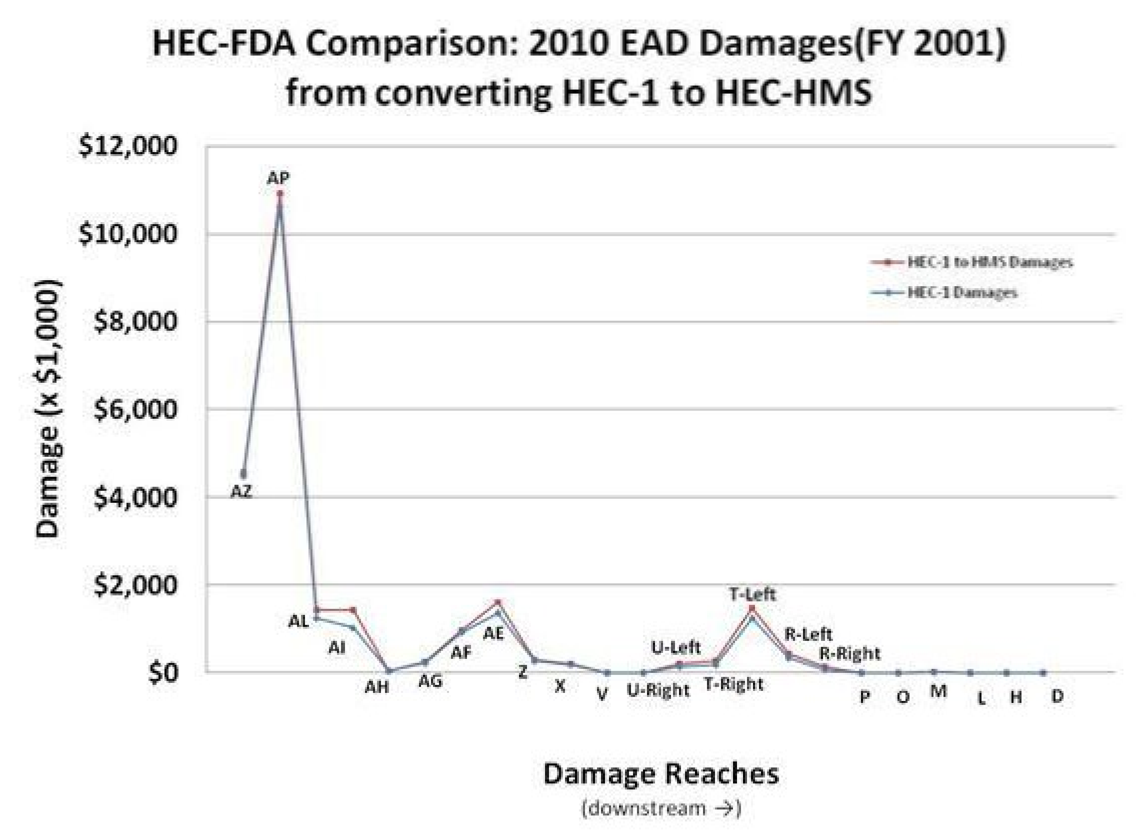

Figure 4. Comparison of Damage by Reach

Recommendations

AECOM recommends that the HEC-1 model be updated to HEC-HMS 3.4.0 including updates to the reach routing data. Additionally, AECOM recommends that the HEC-RAS 3.1.1 model be updated to HEC-RAS 4.1.0.

The change in peak flows caused a change in the computed water surface profiles which resulted in changes in the HEC-FDA damage output. However, the distribution of without project damages are virtually the same between the models never varying more than 2.5% with an average difference in percent distribution approaching zero. Therefore, the flood risk management alternatives that performed best when using HEC-1 / HEC-RAS 3.1.1 results will continue to do so when using HEC-HMS / HEC-RAS 4.1.0 results.

Additionally, the changes in the computed water surface profiles were of a magnitude that wouldn't invalidate the model verification described in the H&H Appendix. Lastly, by converting from HEC-1 to HEC-HMS and updating the HEC-RAS model version, refined modeling of the off-line basin can be performed to better account for the impact of the basin on flooding risk and mitigation of induced impacts due to upstream channel improvements.

Table 1. HEC-HMS Vs. HEC-1 Flow (HEC-1 Routings)

		Station	Flow (cfs)							
			2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	250 yr	500 yr
1	HEC-HMS	76752	294	517	662	792	892	994	1146	1249
	HEC-1		320	520	650	770	860	960	1110	1210
	Difference		-26	-3	12	22	32	34	36	39
	%		-8.7%	-0.5%	1.8%	2.8%	3.6%	3.4%	3.1%	3.1%
2	HEC-HMS	76153	491	862	1103	1320	1486	1656	1910	2081
	HEC-1		528	861	1076	1277	1438	1605	1856	2023
	Difference		-37	1	27	43	48	51	54	58
	%		-7.6%	0.1%	2.4%	3.2%	3.3%	3.1%	2.8%	2.8%
3	HEC-HMS	73319	775	1368	1772	2113	2387	2663	3083	3365
	HEC-1		837	1380	1729	2060	2319	2594	3003	3277
	Difference		-62	-12	43	53	68	69	80	88
	%		-8.0%	-0.9%	2.4%	2.5%	2.8%	2.6%	2.6%	2.6%
4	HEC-HMS	71037	937	1667	1952	2205	2425	2654	2965	3144
	HEC-1		1040	1672	1916	2166	2374	2599	2915	3093
	Difference		-103	-5	36	39	51	55	50	51
	%		-10.9%	-0.3%	1.8%	1.8%	2.1%	2.1%	1.7%	1.6%
5	HEC-HMS	66605	1103	2037	2408	2740	3023	3329	3708	3932
	HEC-1		1225	2053	2371	2695	2965	3261	3648	3876
	Difference		-122	-16	37	45	58	68	60	56
	%		-11.1%	-0.8%	1.6%	1.6%	1.9%	2.1%	1.6%	1.4%
6	HEC-HMS	64090	1399	2627	3206	3702	4116	4549	5084	5348
	HEC-1		1551	2659	3155	3667	4052	4471	5027	5329
	Difference		-152	-32	51	35	64	78	57	19
	%		-10.8%	-1.2%	1.6%	1.0%	1.6%	1.7%	1.1%	0.3%
7	HEC-HMS	60280	1685	3159	3968	4446	4770	5180	5625	5918
	HEC-1		1854	3187	3888	4399	4702	5071	5555	5856
	Difference		-169	-28	80	47	68	109	70	62
	%		-10.0%	-0.9%	2.0%	1.0%	1.4%	2.1%	1.2%	1.0%
8	HEC-HMS	57533	1865	3332	4029	4548	4934	5356	5790	6077
	HEC-1		2044	3337	3929	4429	4778	5182	5639	5917
	Difference		-179	-5	100	119	156	174	151	160
	%		-9.6%	-0.1%	2.5%	2.6%	3.2%	3.2%	2.6%	2.6%
9	HEC-HMS	54950	2058	3607	4403	4844	5241	5707	6351	6737
	HEC-1		2244	3600	4293	4682	5006	5409	5922	6318
	Difference		-186	7	110	162	235	298	429	419
	%		-9.0%	0.2%	2.5%	3.4%	4.5%	5.2%	6.8%	6.2%
10	HEC-HMS	49831	2132	3658	4247	4669	5017	5338	5685	5931
	HEC-1		2321	3640	4155	4502	4808	5180	5483	5724
	Difference		-189	18	92	167	209	158	202	207
	%		-8.9%	0.5%	2.2%	3.6%	4.2%	3.0%	3.6%	3.5%
11	HEC-HMS	46183	2228	3823	4411	4794	5137	5468	5789	6030
	HEC-1		2421	3795	4347	4631	4936	5309	5615	5830
	Difference		-193	28	64	163	201	159	174	200
	%		-8.7%	0.7%	1.4%	3.4%	3.9%	2.9%	3.0%	3.3%
12	HEC-HMS	41700	2405	4109	4843	5246	5513	5821	6222	6520
	HEC-1		2599	4063	4758	5118	5395	5707	6114	6428
	Difference		-194	46	85	128	118	114	108	92
	%		-8.1%	1.1%	1.7%	2.4%	2.1%	2.0%	1.7%	1.4%
13	HEC-HMS	32049	2513	4297	5139	5630	5977	6379	6901	7273
	HEC-1		2710	4238	5038	5461	5820	6229	6759	7168
	Difference		-197	59	101	169	157	150	142	105
	%		-7.8%	1.4%	2.0%	3.0%	2.6%	2.3%	2.1%	1.4%
14	HEC-HMS	30749	2561	4419	5326	5876	6270	6728	7211	7607
	HEC-1		2762	4354	5205	5688	6092	6558	7052	7454
	Difference		-201	65	121	188	178	170	159	153
	%		-7.8%	1.5%	2.3%	3.2%	2.8%	2.5%	2.2%	2.0%
15	HEC-HMS	25706	2818	4890	6010	6805	7379	8009	8642	9002
	HEC-1		3015	4815	5821	6603	7182	7842	8533	8886
	Difference		-197	75	189	202	197	167	109	116
	%		-7.0%	1.5%	3.1%	3.0%	2.7%	2.1%	1.3%	1.3%
16	HEC-HMS	24429	2839	4953	6097	6938	7538	8208	8905	9320
	HEC-1		3040	4880	5910	6740	7360	8030	8780	9180
	Difference		-201	73	187	198	178	178	125	140
	%		-7.1%	1.5%	3.1%	2.9%	2.4%	2.2%	1.4%	1.5%
17	HEC-HMS	22389	2873	5054	6235	7151	7792	8525	9326	9827
	HEC-1		3072	4995	6055	6957	7644	8348	9192	9679
	Difference		-199	59	180	194	148	177	134	148
	%		-6.9%	1.2%	2.9%	2.7%	1.9%	2.1%	1.4%	1.5%
18	HEC-HMS	17139	2866	5343	6755	7899	8709	9633	10694	11411
	HEC-1		3050	5250	6520	7600	8420	9330	10440	11160
	Difference		-184	93	235	299	289	303	254	251
	%		-6.4%	1.7%	3.5%	3.8%	3.3%	3.1%	2.4%	2.2%
19	HEC-HMS	16284	2864	5390	6840	8021	8858	9813	10916	11669
	HEC-1		3050	5289	6598	7713	8553	9505	10658	11427
	Difference		-186	101	242	308	305	308	258	242
	%		-6.5%	1.9%	3.5%	3.8%	3.4%	3.1%	2.4%	2.1%
20	HEC-HMS	12170	2942	5608	7156	8441	9353	10392	11607	12444
	HEC-1		3120	5490	6880	8080	8990	10020	11260	12110
	Difference		-178	118	276	361	363	372	347	334
	%		-6.0%	2.1%	3.9%	4.3%	3.9%	3.6%	3.0%	2.7%
21	HEC-HMS	9888	2986	5729	7331	8674	9628	10713	11989	12875
	HEC-1		3154	5603	7046	8293	9236	10316	11615	12508
	Difference		-168	126	285	381	392	397	374	367
	%		-5.6%	2.2%	3.9%	4.4%	4.1%	3.7%	3.1%	2.8%

Table 2. HEC-HMS Vs. HEC-1 Flow (HEC-HMS Routings Updated)

		Station	Flow (cfs)							
			2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	250 yr	500 yr
1	HEC-HMS	76752	294	517	662	792	892	993	1146	1249
	HEC-1		320	520	650	770	860	960	1110	1210
	Difference		-26	-3	12	22	32	33	36	39
	%		-8.7%	-0.5%	1.8%	2.8%	3.6%	3.4%	3.1%	3.1%
2	HEC-HMS	76153	491	862	1103	1320	1486	1656	1910	2081
	HEC-1		528	861	1076	1277	1438	1605	1856	2023
	Difference		-37	1	27	43	48	51	54	58
	%		-7.6%	0.1%	2.4%	3.2%	3.3%	3.1%	2.8%	2.8%
3	HEC-HMS	73319	775	1368	1772	2113	2387	2663	3083	3365
	HEC-1		837	1380	1729	2060	2319	2594	3003	3277
	Difference		-62	-12	43	53	68	69	80	88
	%		-8.0%	-0.9%	2.4%	2.5%	2.8%	2.6%	2.6%	2.6%
4	HEC-HMS	71037	936	1596	1916	2196	2434	2677	2949	3119
	HEC-1		1040	1672	1916	2166	2374	2599	2915	3093
	Difference		-104	-76	0	30	60	78	34	26
	%		-11.2%	-4.8%	0.0%	1.4%	2.5%	2.9%	1.1%	0.8%
5	HEC-HMS	66605	1098	1948	2365	2726	3032	3336	3675	3871
	HEC-1		1225	2053	2371	2695	2965	3261	3648	3876
	Difference		-127	-105	-6	31	67	75	27	-5
	%		-11.6%	-5.4%	-0.2%	1.1%	2.2%	2.2%	0.7%	-0.1%
6	HEC-HMS	64090	1395	2537	3167	3693	4125	4549	4999	5254
	HEC-1		1551	2659	3155	3667	4052	4471	5027	5329
	Difference		-156	-122	12	26	73	78	-28	-75
	%		-11.2%	-4.8%	0.4%	0.7%	1.8%	1.7%	-0.6%	-1.4%
7	HEC-HMS	60280	1679	3076	3911	4350	4720	5146	5590	5870
	HEC-1		1854	3187	3888	4399	4702	5071	5555	5856
	Difference		-175	-111	23	-49	18	75	35	14
	%		-10.4%	-3.6%	0.6%	-1.1%	0.4%	1.5%	0.6%	0.2%
8	HEC-HMS	57533	1851	3327	4079	4577	4975	5349	5771	6061
	HEC-1		2044	3337	3929	4429	4778	5182	5639	5917
	Difference		-193	-10	150	148	197	167	132	144
	%		-10.4%	-0.3%	3.7%	3.2%	4.0%	3.1%	2.3%	2.4%
9	HEC-HMS	54950	2024	3658	4384	4946	5400	5802	6346	6759
	HEC-1		2244	3600	4293	4682	5006	5409	5922	6318
	Difference		-220	58	91	264	394	393	424	441
	%		-10.9%	1.6%	2.1%	5.3%	7.3%	6.8%	6.7%	6.5%
10	HEC-HMS	49831	2085	3747	4365	4642	5102	5567	5681	5755
	HEC-1		2321	3640	4155	4502	4808	5180	5483	5724
	Difference		-236	107	210	140	294	387	198	31
	%		-11.3%	2.8%	4.8%	3.0%	5.8%	7.0%	3.5%	0.5%
11	HEC-HMS	46183	2168	3929	4523	4812	5227	5695	5872	6003
	HEC-1		2421	3795	4347	4631	4936	5309	5615	5830
	Difference		-253	134	176	181	291	386	257	173
	%		-11.7%	3.4%	3.9%	3.8%	5.6%	6.8%	4.4%	2.9%
12	HEC-HMS	41700	2316	4274	4923	5293	5564	5962	6339	6629
	HEC-1		2599	4063	4758	5118	5395	5707	6114	6428
	Difference		-283	211	165	175	169	255	225	201
	%		-12.2%	4.9%	3.4%	3.3%	3.0%	4.3%	3.6%	3.0%
13	HEC-HMS	32049	2397	4489	5214	5676	6027	6427	6933	7332
	HEC-1		2710	4238	5038	5461	5820	6229	6759	7168
	Difference		-313	251	176	215	207	198	174	164
	%		-13.1%	5.6%	3.4%	3.8%	3.4%	3.1%	2.5%	2.2%
14	HEC-HMS	30749	2437	4615	5405	5915	6288	6680	7140	7506
	HEC-1		2762	4354	5205	5688	6092	6558	7052	7454
	Difference		-325	261	200	227	196	122	88	52
	%		-13.3%	5.7%	3.7%	3.8%	3.1%	1.8%	1.2%	0.7%
15	HEC-HMS	25706	2660	5094	6126	6870	7416	7997	8708	9165
	HEC-1		3015	4815	5821	6603	7182	7842	8533	8886
	Difference		-355	279	305	267	234	155	175	279
	%		-13.3%	5.5%	5.0%	3.9%	3.2%	1.9%	2.0%	3.0%
16	HEC-HMS	24429	2677	5142	6217	6995	7567	8180	8934	9429
	HEC-1		3040	4880	5910	6740	7360	8030	8780	9180
	Difference		-363	262	307	255	207	150	154	249
	%		-13.6%	5.1%	4.9%	3.7%	2.7%	1.8%	1.7%	2.6%
17	HEC-HMS	22389	2703	5221	6364	7201	7814	8481	9308	9868
	HEC-1		3072	4995	6055	6957	7644	8348	9192	9679
	Difference		-369	226	309	244	170	133	116	189
	%		-13.7%	4.3%	4.9%	3.4%	2.2%	1.6%	1.2%	1.9%
18	HEC-HMS	17139	2758	5426	6793	7875	8637	9522	10605	11349
	HEC-1		3050	5250	6520	7600	8420	9330	10440	11160
	Difference		-292	176	273	275	217	192	165	189
	%		-10.6%	3.2%	4.0%	3.5%	2.5%	2.0%	1.6%	1.7%
19	HEC-HMS	16284	2768	5460	6866	7990	8779	9703	10833	11610
	HEC-1		3050	5289	6598	7713	8553	9505	10658	11427
	Difference		-282	171	268	277	226	198	175	183
	%		-10.2%	3.1%	3.9%	3.5%	2.6%	2.0%	1.6%	1.6%
20	HEC-HMS	12170	2847	5658	7163	8389	9256	10275	11509	12363
	HEC-1		3120	5490	6880	8080	8990	10020	11260	12110
	Difference		-273	168	283	309	266	255	249	253
	%		-9.6%	3.0%	4.0%	3.7%	2.9%	2.5%	2.2%	2.0%
21	HEC-HMS	9888	2892	5770	7333	8619	9531	10607	11902	12801
	HEC-1		3154	5603	7046	8293	9236	10316	11615	12508
	Difference		-262	167	287	326	295	291	287	293
	%		8.3%	3.0%	4.1%	3.9%	3.2%	2.8%	2.5%	2.3%

Table 3. Comparison of WSEL using HEC-RAS 3.1.1 and HEC-RAS 4.1.0

Profile	Station	Q Total (cfs)	W.S. Elev (ft)		Difference
			RAS 3.1.1	RAS 4.1.0	
50-yr	59540	4702	44.48	44.49	0.01
10-yr	53836	4293	40.15	40.16	0.01
100-yr	46183	5309	37.75	37.76	0.01
10-yr	37807	4758	32.36	32.37	0.01
100-yr	37123	5707	32.81	32.82	0.01
100-yr	37029	5707	32.26	32.27	0.01
100-yr	34658	5707	30.18	30.2	0.02
100-yr	32049	6229	28.51	28.53	0.02
100-yr	30749	6558	27.84	27.87	0.03
100-yr	28512	6558	26.79	26.86	0.07
100-yr	25706	7842	25.41	25.52	0.11
100-yr	25647	7842	25.42	25.54	0.12
100-yr	25643	7842	25.37	25.48	0.11
25-yr	25591	6603	23.78	23.77	-0.01
100-yr	25591	7842	25.35	25.46	0.11
250-yr	25591	8533	26.61	26.6	-0.01
2-yr	25577	3015	18.53	18.54	0.01
100-yr	25577	7842	25.26	25.37	0.11
250-yr	25577	8533	26.52	26.51	-0.01
100-yr	25519	7842	25.22	25.33	0.11
100-yr	25152	7842	24.42	24.54	0.12
100-yr	25105	7842	24.38	24.51	0.13
250-yr	25105	8533	25.23	25.22	-0.01
100-yr	24429	8030	24	24.1	0.1
250-yr	24429	8780	24.86	24.85	-0.01

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
Station	Profile	Q Total (cfs)	W.S. Elev (ft)	Q Total (cfs)	W.S. Elev (ft)	W.S. Elev (ft)	
76752	2-yr	320	44.58	294.4	44.1	-0.48	
76752	5-yr	520	47.42	517.3	47.4	-0.02	
76752	10-yr	650	48.19	661.7	48.22	0.03	
76752	25-yr	770	48.45	791.9	48.6	0.15	
76752	50-yr	860	48.92	891.8	49.02	0.1	
76752	100-yr	960	49.33	993.5	49.53	0.2	
76752	250-yr	1110	49.91	1145.9	50.01	0.1	
76752	500-yr	1210	50.07	1248.5	50.08	0.01	
76249	2-yr	320	44.43	294.4	43.95	-0.48	
76249	5-yr	520	47.38	517.3	47.36	-0.02	
76249	10-yr	650	48.16	661.7	48.2	0.04	
76249	25-yr	770	48.43	791.9	48.58	0.15	
76249	50-yr	860	48.9	891.8	49	0.1	
76249	100-yr	960	49.31	993.5	49.51	0.2	
76249	250-yr	1110	49.89	1145.9	49.99	0.1	
76249	500-yr	1210	50.07	1248.5	50.07	0	
76249	2-yr	320	44.42	294.4	43.94	-0.48	
76202	5-yr	520	47.38	517.3	47.36	-0.02	
76202	10-yr	650	48.16	661.7	48.19	0.03	
76202	25-yr	770	48.42	791.9	48.57	0.15	
76202	50-yr	860	48.9	891.8	49	0.1	
76202	100-yr	960	49.3	993.5	49.51	0.21	
76202	250-yr	1110	49.89	1145.9	49.99	0.1	
76202	500-yr	1210	50.07	1248.5	50.07	0	
76196.5	NECHES STREET						Bridge
76153	2-yr	528	44.41	490.62	43.92	-0.49	
76153	5-yr	861	47.37	862.25	47.35	-0.02	
76153	10-yr	1076	48.16	1102.81	48.19	0.03	
76153	25-yr	1277	48.42	1319.78	48.57	0.15	
76153	50-yr	1438	48.89	1486.34	49	0.11	
76153	100-yr	1605	49.3	1655.77	49.5	0.2	
76153	250-yr	1856	49.88	1909.78	49.99	0.11	
76153	500-yr	2023	50.07	2080.91	50.07	0	
76033	2-yr	528	44.41	490.62	43.93	-0.48	
76033	5-yr	861	47.34	862.25	47.32	-0.02	
76033	10-yr	1076	48.12	1102.81	48.15	0.03	
76033	25-yr	1277	48.37	1319.78	48.52	0.15	
76033	50-yr	1438	48.84	1486.34	48.94	0.1	
76033	100-yr	1605	49.24	1655.77	49.45	0.21	
76033	250-yr	1856	49.82	1909.78	49.92	0.1	
76033	500-yr	2023	50.03	2080.91	50.04	0.01	
76027.5	US 59 BRIDGE						Culvert
75223	2-yr	528	44.31	490.62	43.83	-0.48	
75223	5-yr	861	47.05	862.25	47.03	-0.02	
75223	10-yr	1076	47.85	1102.81	47.92	0.07	
75223	25-yr	1277	48.37	1319.78	48.53	0.16	
75223	50-yr	1438	48.86	1486.34	48.96	0.1	
75223	100-yr	1605	49.27	1655.77	49.47	0.2	
75223	250-yr	1856	49.85	1909.78	49.95	0.1	
75223	500-yr	2023	50.04	2080.91	50.04	0	
75060	2-yr	528	44.3	490.62	43.82	-0.48	
75060	5-yr	861	47.05	862.25	47.03	-0.02	
75060	10-yr	1076	47.85	1102.81	47.92	0.07	
75060	25-yr	1277	48.37	1319.78	48.53	0.16	
75060	50-yr	1438	48.86	1486.34	48.96	0.1	
75060	100-yr	1605	49.27	1655.77	49.47	0.2	
75060	250-yr	1856	49.85	1909.78	49.95	0.1	
75060	500-yr	2023	50.04	2080.91	50.05	0.01	
74271	2-yr	528	43.89	490.62	43.43	-0.46	
74271	5-yr	861	46.91	862.25	46.88	-0.03	
74271	10-yr	1076	47.76	1102.81	47.83	0.07	
74271	25-yr	1277	48.29	1319.78	48.46	0.17	
74271	50-yr	1438	48.8	1486.34	48.9	0.1	
74271	100-yr	1605	49.22	1655.77	49.43	0.21	
74271	250-yr	1856	49.81	1909.78	49.91	0.1	
74271	500-yr	2023	50.03	2080.91	50.04	0.01	
73925	2-yr	528	43.73	490.62	43.25	-0.48	
73925	5-yr	861	46.84	862.25	46.82	-0.02	
73925	10-yr	1076	47.71	1102.81	47.79	0.08	
73925	25-yr	1277	48.25	1319.78	48.42	0.17	
73925	50-yr	1438	48.77	1486.34	48.87	0.1	
73925	100-yr	1605	49.19	1655.77	49.41	0.22	
73925	250-yr	1856	49.79	1909.78	49.89	0.1	
73925	500-yr	2023	50.03	2080.91	50.04	0.01	
73878	2-yr	528	43.72	490.62	43.23	-0.49	
73878	5-yr	861	46.83	862.25	46.81	-0.02	
73878	10-yr	1076	47.71	1102.81	47.78	0.07	
73878	25-yr	1277	48.25	1319.78	48.42	0.17	
73878	50-yr	1438	48.77	1486.34	48.87	0.1	
73878	100-yr	1605	49.19	1655.77	49.4	0.21	
73878	250-yr	1856	49.79	1909.78	49.89	0.1	
73878	500-yr	2023	50.03	2080.91	50.04	0.01	
73877.5	PEDESTRIAN BRIDG						Bridge
73816	2-yr	528	43.67	490.62	43.19	-0.48	
73816	5-yr	861	46.81	862.25	46.78	-0.03	
73816	10-yr	1076	47.69	1102.81	47.76	0.07	
73816	25-yr	1277	48.23	1319.78	48.41	0.18	
73816	50-yr	1438	48.75	1486.34	48.86	0.11	
73816	100-yr	1605	49.18	1655.77	49.4	0.22	
73816	250-yr	1856	49.78	1909.78	49.88	0.1	
73816	500-yr	2023	50.03	2080.91	50.03	0	
73769	2-yr	528	43.65	490.62	43.17	-0.48	
73769	5-yr	861	46.8	862.25	46.77	-0.03	
73769	10-yr	1076	47.69	1102.81	47.76	0.07	
73769	25-yr	1277	48.23	1319.78	48.4	0.17	
73769	50-yr	1438	48.75	1486.34	48.86	0.11	
73769	100-yr	1605	49.18	1655.77	49.39	0.21	
73769	250-yr	1856	49.78	1909.78	49.88	0.1	
73769	500-yr	2023	50.03	2080.91	50.03	0	
73319	2-yr	837	43.42	775.16	42.92	-0.5	
73319	5-yr	1380	46.69	1368.33	46.67	-0.02	
73319	10-yr	1729	47.59	1772.1	47.66	0.07	
73319	25-yr	2060	48.12	2113.41	48.3	0.18	
73319	50-yr	2319	48.66	2386.82	48.76	0.1	
73319	100-yr	2594	49.09	2663.28	49.31	0.22	
73319	250-yr	3003	49.7	3082.68	49.8	0.1	
73319	500-yr	3277	50.02	3364.69	50.02	0	
73265	2-yr	837	43.39	775.16	42.89	-0.5	
73265	5-yr	1380	46.68	1368.33	46.65	-0.03	
73265	10-yr	1729	47.58	1772.1	47.65	0.07	
73265	25-yr	2060	48.11	2113.41	48.29	0.18	
73265	50-yr	2319	48.65	2386.82	48.75	0.1	
73265	100-yr	2594	49.08	2663.28	49.3	0.22	
73265	250-yr	3003	49.69	3082.68	49.79	0.1	
73265	500-yr	3277	49.97	3364.69	50.02	0.05	
73239.5	FALLS STREET BRI						Bridge
73213	2-yr	837	43.33	775.16	42.84	-0.49	
73213	5-yr	1380	46.48	1368.33	46.46	-0.02	
73213	10-yr	1729	47.41	1772.1	47.49	0.08	
73213	25-yr	2060	47.99	2113.41	48.19	0.2	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
73213	50-yr	2319	48.56	2386.82	48.68	0.12	
73213	100-yr	2594	49.01	2663.28	49.24	0.23	
73213	250-yr	3003	49.63	3082.68	49.74	0.11	
73213	500-yr	3277	49.92	3364.69	50.01	0.09	
73180	2-yr	837	43.32	775.16	42.82	-0.5	
73180	5-yr	1380	46.47	1368.33	46.45	-0.02	
73180	10-yr	1729	47.4	1772.1	47.48	0.08	
73180	25-yr	2060	47.98	2113.41	48.18	0.2	
73180	50-yr	2319	48.56	2386.82	48.67	0.11	
73180	100-yr	2594	49	2663.28	49.23	0.23	
73180	250-yr	3003	49.62	3082.68	49.73	0.11	
73180	500-yr	3277	49.91	3364.69	50.01	0.1	
72989	2-yr	837	43.22	775.16	42.72	-0.5	
72989	5-yr	1380	46.43	1368.33	46.41	-0.02	
72989	10-yr	1729	47.36	1772.1	47.44	0.08	
72989	25-yr	2060	47.94	2113.41	48.14	0.2	
72989	50-yr	2319	48.52	2386.82	48.63	0.11	
72989	100-yr	2594	48.97	2663.28	49.2	0.23	
72989	250-yr	3003	49.59	3082.68	49.7	0.11	
72989	500-yr	3277	49.87	3364.69	50	0.13	
72940	2-yr	837	43.19	775.16	42.69	-0.5	
72940	5-yr	1380	46.42	1368.33	46.4	-0.02	
72940	10-yr	1729	47.35	1772.1	47.43	0.08	
72940	25-yr	2060	47.93	2113.41	48.13	0.2	
72940	50-yr	2319	48.51	2386.82	48.62	0.11	
72940	100-yr	2594	48.96	2663.28	49.19	0.23	
72940	250-yr	3003	49.58	3082.68	49.69	0.11	
72940	500-yr	3277	49.87	3364.69	49.96	0.09	
72914.5	LEFFINGWELL ST						Bridge
72889	2-yr	837	43.16	775.16	42.65	-0.51	
72889	5-yr	1380	46.39	1368.33	46.37	-0.02	
72889	10-yr	1729	47.3	1772.1	47.38	0.08	
72889	25-yr	2060	47.87	2113.41	48.08	0.21	
72889	50-yr	2319	48.45	2386.82	48.57	0.12	
72889	100-yr	2594	48.91	2663.28	49.15	0.24	
72889	250-yr	3003	49.54	3082.68	49.65	0.11	
72889	500-yr	3277	49.83	3364.69	49.92	0.09	
72859	2-yr	837	43.14	775.16	42.63	-0.51	
72859	5-yr	1380	46.38	1368.33	46.35	-0.03	
72859	10-yr	1729	47.29	1772.1	47.37	0.08	
72859	25-yr	2060	47.86	2113.41	48.06	0.2	
72859	50-yr	2319	48.44	2386.82	48.55	0.11	
72859	100-yr	2594	48.9	2663.28	49.14	0.24	
72859	250-yr	3003	49.53	3082.68	49.64	0.11	
72859	500-yr	3277	49.82	3364.69	49.91	0.09	
72524	2-yr	837	42.97	775.16	42.46	-0.51	
72524	5-yr	1380	46.3	1368.33	46.27	-0.03	
72524	10-yr	1729	47.23	1772.1	47.31	0.08	
72524	25-yr	2060	47.81	2113.41	48.02	0.21	
72524	50-yr	2319	48.41	2386.82	48.52	0.11	
72524	100-yr	2594	48.87	2663.28	49.11	0.24	
72524	250-yr	3003	49.51	3082.68	49.61	0.1	
72524	500-yr	3277	49.79	3364.69	49.89	0.1	
72504	2-yr	837	42.96	775.16	42.45	-0.51	
72504	5-yr	1380	46.28	1368.33	46.26	-0.02	
72504	10-yr	1729	47.23	1772.1	47.31	0.08	
72504	25-yr	2060	47.81	2113.41	48.02	0.21	
72504	50-yr	2319	48.4	2386.82	48.52	0.12	
72504	100-yr	2594	48.87	2663.28	49.11	0.24	
72504	250-yr	3003	49.51	3082.68	49.61	0.1	
72504	500-yr	3277	49.79	3364.69	49.89	0.1	
72503.5	COH WATERLINE						Bridge
72495	2-yr	837	42.96	775.16	42.45	-0.51	
72495	5-yr	1380	46.27	1368.33	46.25	-0.02	
72495	10-yr	1729	47.22	1772.1	47.3	0.08	
72495	25-yr	2060	47.8	2113.41	48.01	0.21	
72495	50-yr	2319	48.4	2386.82	48.51	0.11	
72495	100-yr	2594	48.86	2663.28	49.11	0.25	
72495	250-yr	3003	49.5	3082.68	49.61	0.11	
72495	500-yr	3277	49.79	3364.69	49.88	0.09	
72492	2-yr	837	42.96	775.16	42.45	-0.51	
72492	5-yr	1380	46.27	1368.33	46.24	-0.03	
72492	10-yr	1729	47.22	1772.1	47.3	0.08	
72492	25-yr	2060	47.8	2113.41	48.01	0.21	
72492	50-yr	2319	48.4	2386.82	48.51	0.11	
72492	100-yr	2594	48.86	2663.28	49.11	0.25	
72492	250-yr	3003	49.5	3082.68	49.61	0.11	
72492	500-yr	3277	49.78	3364.69	49.88	0.1	
72491.5	HIRSCH STREET						Bridge
72402	2-yr	837	42.89	775.16	42.38	-0.51	
72402	5-yr	1380	46.05	1368.33	46.02	-0.03	
72402	10-yr	1729	47.11	1772.1	47.2	0.09	
72402	25-yr	2060	47.72	2113.41	47.95	0.23	
72402	50-yr	2319	48.35	2386.82	48.47	0.12	
72402	100-yr	2594	48.82	2663.28	49.08	0.26	
72402	250-yr	3003	49.47	3082.68	49.58	0.11	
72402	500-yr	3277	49.76	3364.69	49.85	0.09	
72355	2-yr	837	42.87	775.16	42.35	-0.52	
72355	5-yr	1380	46.03	1368.33	46.01	-0.02	
72355	10-yr	1729	47.1	1772.1	47.19	0.09	
72355	25-yr	2060	47.72	2113.41	47.94	0.22	
72355	50-yr	2319	48.34	2386.82	48.46	0.12	
72355	100-yr	2594	48.82	2663.28	49.07	0.25	
72355	250-yr	3003	49.47	3082.68	49.57	0.1	
72355	500-yr	3277	49.75	3364.69	49.85	0.1	
72006	2-yr	837	42.73	775.16	42.22	-0.51	
72006	5-yr	1380	45.9	1368.33	45.88	-0.02	
72006	10-yr	1729	47.02	1772.1	47.11	0.09	
72006	25-yr	2060	47.64	2113.41	47.87	0.23	
72006	50-yr	2319	48.28	2386.82	48.4	0.12	
72006	100-yr	2594	48.76	2663.28	49.02	0.26	
72006	250-yr	3003	49.41	3082.68	49.52	0.11	
72006	500-yr	3277	49.7	3364.69	49.79	0.09	
71710	2-yr	837	42.67	775.16	42.15	-0.52	
71710	5-yr	1380	45.84	1368.33	45.82	-0.02	
71710	10-yr	1729	46.98	1772.1	47.07	0.09	
71710	25-yr	2060	47.6	2113.41	47.84	0.24	
71710	50-yr	2319	48.25	2386.82	48.37	0.12	
71710	100-yr	2594	48.73	2663.28	48.99	0.26	
71710	250-yr	3003	49.38	3082.68	49.49	0.11	
71710	500-yr	3277	49.67	3364.69	49.76	0.09	
71663	2-yr	837	42.66	775.16	42.14	-0.52	
71663	5-yr	1380	45.84	1368.33	45.81	-0.03	
71663	10-yr	1729	46.97	1772.1	47.06	0.09	
71663	25-yr	2060	47.6	2113.41	47.83	0.23	
71663	50-yr	2319	48.24	2386.82	48.36	0.12	
71663	100-yr	2594	48.72	2663.28	48.98	0.26	
71663	250-yr	3003	49.38	3082.68	49.49	0.11	
71663	500-yr	3277	49.66	3364.69	49.76	0.1	
71657.5	WAYNE STREET						Bridge
71607	2-yr	837	42.64	775.16	42.12	-0.52	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
71607	5-yr	1380	45.8	1368.33	45.78	-0.02	
71607	10-yr	1729	46.89	1772.1	46.98	0.09	
71607	25-yr	2060	47.52	2113.41	47.77	0.25	
71607	50-yr	2319	48.19	2386.82	48.31	0.12	
71607	100-yr	2594	48.68	2663.28	48.95	0.27	
71607	250-yr	3003	49.34	3082.68	49.45	0.11	
71607	500-yr	3277	49.63	3364.69	49.72	0.09	
71360	2-yr	837	42.59	775.16	42.06	-0.53	
71360	5-yr	1380	45.76	1368.33	45.74	-0.02	
71360	10-yr	1729	46.86	1772.1	46.95	0.09	
71360	25-yr	2060	47.49	2113.41	47.74	0.25	
71360	50-yr	2319	48.17	2386.82	48.29	0.12	
71360	100-yr	2594	48.66	2663.28	48.93	0.27	
71360	250-yr	3003	49.32	3082.68	49.43	0.11	
71360	500-yr	3277	49.61	3364.69	49.71	0.1	
71037	2-yr	1040	42.44	937.4	41.92	-0.52	
71037	5-yr	1672	45.68	1667.02	45.66	-0.02	
71037	10-yr	1916	46.83	1952.05	46.92	0.09	
71037	25-yr	2166	47.46	2205.33	47.72	0.26	
71037	50-yr	2374	48.14	2424.7	48.26	0.12	
71037	100-yr	2599	48.64	2654.4	48.91	0.27	
71037	250-yr	2915	49.31	2965.32	49.42	0.11	
71037	500-yr	3093	49.59	3143.76	49.69	0.1	
70520	2-yr	1040	42.34	937.4	41.81	-0.53	
70520	5-yr	1672	45.62	1667.02	45.6	-0.02	
70520	10-yr	1916	46.79	1952.05	46.89	0.1	
70520	25-yr	2166	47.44	2205.33	47.7	0.26	
70520	50-yr	2374	48.12	2424.7	48.24	0.12	
70520	100-yr	2599	48.62	2654.4	48.9	0.28	
70520	250-yr	2915	49.29	2965.32	49.4	0.11	
70520	500-yr	3093	49.58	3143.76	49.68	0.1	
70462	2-yr	1040	42.33	937.4	41.8	-0.53	
70462	5-yr	1672	45.61	1667.02	45.58	-0.03	
70462	10-yr	1916	46.78	1952.05	46.88	0.1	
70462	25-yr	2166	47.43	2205.33	47.69	0.26	
70462	50-yr	2374	48.11	2424.7	48.24	0.13	
70462	100-yr	2599	48.61	2654.4	48.89	0.28	
70462	250-yr	2915	49.29	2965.32	49.4	0.11	
70462	500-yr	3093	49.57	3143.76	49.67	0.1	
70436.5	WIPPRECHT STREET						Bridge
70411	2-yr	1040	42.31	937.4	41.79	-0.52	
70411	5-yr	1672	45.59	1667.02	45.56	-0.03	
70411	10-yr	1916	46.77	1952.05	46.86	0.09	
70411	25-yr	2166	47.42	2205.33	47.68	0.26	
70411	50-yr	2374	48.1	2424.7	48.23	0.13	
70411	100-yr	2599	48.61	2654.4	48.88	0.27	
70411	250-yr	2915	49.28	2965.32	49.39	0.11	
70411	500-yr	3093	49.57	3143.76	49.67	0.1	
70399	2-yr	1040	42.31	937.4	41.78	-0.53	
70399	5-yr	1672	45.59	1667.02	45.57	-0.02	
70399	10-yr	1916	46.77	1952.05	46.86	0.09	
70399	25-yr	2166	47.42	2205.33	47.68	0.26	
70399	50-yr	2374	48.1	2424.7	48.23	0.13	
70399	100-yr	2599	48.61	2654.4	48.88	0.27	
70399	250-yr	2915	49.28	2965.32	49.39	0.11	
70399	500-yr	3093	49.57	3143.76	49.67	0.1	
69347	2-yr	1040	42.05	937.4	41.52	-0.53	
69347	5-yr	1672	45.41	1667.02	45.39	-0.02	
69347	10-yr	1916	46.67	1952.05	46.76	0.09	
69347	25-yr	2166	47.33	2205.33	47.6	0.27	
69347	50-yr	2374	48.03	2424.7	48.16	0.13	
69347	100-yr	2599	48.55	2654.4	48.83	0.28	
69347	250-yr	2915	49.23	2965.32	49.34	0.11	
69347	500-yr	3093	49.52	3143.76	49.62	0.1	
69306	2-yr	1040	42.04	937.4	41.51	-0.53	
69306	5-yr	1672	45.4	1667.02	45.38	-0.02	
69306	10-yr	1916	46.66	1952.05	46.76	0.1	
69306	25-yr	2166	47.33	2205.33	47.6	0.27	
69306	50-yr	2374	48.03	2424.7	48.16	0.13	
69306	100-yr	2599	48.54	2654.4	48.83	0.29	
69306	250-yr	2915	49.23	2965.32	49.34	0.11	
69306	500-yr	3093	49.51	3143.76	49.61	0.1	
69305.5	PICKFAIR WALKWAY						Bridge
69290	2-yr	1040	42.03	937.4	41.5	-0.53	
69290	5-yr	1672	45.39	1667.02	45.36	-0.03	
69290	10-yr	1916	46.65	1952.05	46.74	0.09	
69290	25-yr	2166	47.31	2205.33	47.59	0.28	
69290	50-yr	2374	48.02	2424.7	48.14	0.12	
69290	100-yr	2599	48.53	2654.4	48.82	0.29	
69290	250-yr	2915	49.22	2965.32	49.33	0.11	
69290	500-yr	3093	49.5	3143.76	49.6	0.1	
69226	2-yr	1040	42.01	937.4	41.49	-0.52	
69226	5-yr	1672	45.38	1667.02	45.35	-0.03	
69226	10-yr	1916	46.64	1952.05	46.74	0.1	
69226	25-yr	2166	47.31	2205.33	47.58	0.27	
69226	50-yr	2374	48.01	2424.7	48.14	0.13	
69226	100-yr	2599	48.53	2654.4	48.81	0.28	
69226	250-yr	2915	49.21	2965.32	49.32	0.11	
69226	500-yr	3093	49.5	3143.76	49.6	0.1	
68720	2-yr	1040	41.9	937.4	41.37	-0.53	
68720	5-yr	1672	45.32	1667.02	45.29	-0.03	
68720	10-yr	1916	46.6	1952.05	46.69	0.09	
68720	25-yr	2166	47.26	2205.33	47.54	0.28	
68720	50-yr	2374	47.97	2424.7	48.1	0.13	
68720	100-yr	2599	48.49	2654.4	48.78	0.29	
68720	250-yr	2915	49.17	2965.32	49.28	0.11	
68720	500-yr	3093	49.46	3143.76	49.56	0.1	
68673	2-yr	1040	41.84	937.4	41.32	-0.52	
68673	5-yr	1672	45.27	1667.02	45.25	-0.02	
68673	10-yr	1916	46.57	1952.05	46.67	0.1	
68673	25-yr	2166	47.24	2205.33	47.52	0.28	
68673	50-yr	2374	47.96	2424.7	48.08	0.12	
68673	100-yr	2599	48.47	2654.4	48.76	0.29	
68673	250-yr	2915	49.16	2965.32	49.27	0.11	
68673	500-yr	3093	49.45	3143.76	49.55	0.1	
68665.5	LOCKWOOD STREET						Bridge
68611	2-yr	1040	41.78	937.4	41.26	-0.52	
68611	5-yr	1672	45.09	1667.02	45.07	-0.02	
68611	10-yr	1916	46.37	1952.05	46.48	0.11	
68611	25-yr	2166	47.13	2205.33	47.43	0.3	
68611	50-yr	2374	47.89	2424.7	48.02	0.13	
68611	100-yr	2599	48.42	2654.4	48.72	0.3	
68611	250-yr	2915	49.12	2965.32	49.23	0.11	
68611	500-yr	3093	49.41	3143.76	49.51	0.1	
68564	2-yr	1040	41.77	937.4	41.24	-0.53	
68564	5-yr	1672	45.07	1667.02	45.05	-0.02	
68564	10-yr	1916	46.36	1952.05	46.47	0.11	
68564	25-yr	2166	47.12	2205.33	47.42	0.3	
68564	50-yr	2374	47.88	2424.7	48.01	0.13	
68564	100-yr	2599	48.41	2654.4	48.71	0.3	
68564	250-yr	2915	49.11	2965.32	49.22	0.11	
68564	500-yr	3093	49.4	3143.76	49.5	0.1	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
67705	2-yr	1040	41.43	937.4	40.9	-0.53	
67705	5-yr	1672	44.82	1667.02	44.8	-0.02	
67705	10-yr	1916	46.19	1952.05	46.31	0.12	
67705	25-yr	2166	46.98	2205.33	47.3	0.32	
67705	50-yr	2374	47.77	2424.7	47.91	0.14	
67705	100-yr	2599	48.32	2654.4	48.63	0.31	
67705	250-yr	2915	49.03	2965.32	49.14	0.11	
67705	500-yr	3093	49.32	3143.76	49.42	0.1	
67655	2-yr	1040	41.41	937.4	40.89	-0.52	
67655	5-yr	1672	44.81	1667.02	44.78	-0.03	
67655	10-yr	1916	46.19	1952.05	46.3	0.11	
67655	25-yr	2166	46.97	2205.33	47.3	0.33	
67655	50-yr	2374	47.77	2424.7	47.9	0.13	
67655	100-yr	2599	48.31	2654.4	48.62	0.31	
67655	250-yr	2915	49.02	2965.32	49.14	0.12	
67655	500-yr	3093	49.32	3143.76	49.42	0.1	
67630	2-yr	1040	41.4	937.4	40.88	-0.52	
67630	5-yr	1672	44.8	1667.02	44.78	-0.02	
67630	10-yr	1916	46.18	1952.05	46.3	0.12	
67630	25-yr	2166	46.97	2205.33	47.29	0.32	
67630	50-yr	2374	47.76	2424.7	47.9	0.14	
67630	100-yr	2599	48.31	2654.4	48.62	0.31	
67630	250-yr	2915	49.02	2965.32	49.14	0.12	
67630	500-yr	3093	49.31	3143.76	49.42	0.11	
67605	2-yr	1040	41.4	937.4	40.87	-0.53	
67605	5-yr	1672	44.8	1667.02	44.77	-0.03	
67605	10-yr	1916	46.18	1952.05	46.29	0.11	
67605	25-yr	2166	46.96	2205.33	47.29	0.33	
67605	50-yr	2374	47.76	2424.7	47.9	0.14	
67605	100-yr	2599	48.31	2654.4	48.62	0.31	
67605	250-yr	2915	49.02	2965.32	49.14	0.12	
67605	500-yr	3093	49.31	3143.76	49.41	0.1	
67580	2-yr	1040	41.39	937.4	40.86	-0.53	
67580	5-yr	1672	44.79	1667.02	44.76	-0.03	
67580	10-yr	1916	46.17	1952.05	46.29	0.12	
67580	25-yr	2166	46.96	2205.33	47.28	0.32	
67580	50-yr	2374	47.76	2424.7	47.89	0.13	
67580	100-yr	2599	48.3	2654.4	48.62	0.32	
67580	250-yr	2915	49.02	2965.32	49.13	0.11	
67580	500-yr	3093	49.31	3143.76	49.41	0.1	
67555	2-yr	1040	41.38	937.4	40.85	-0.53	
67555	5-yr	1672	44.78	1667.02	44.75	-0.03	
67555	10-yr	1916	46.17	1952.05	46.28	0.11	
67555	25-yr	2166	46.96	2205.33	47.28	0.32	
67555	50-yr	2374	47.75	2424.7	47.89	0.14	
67555	100-yr	2599	48.3	2654.4	48.61	0.31	
67555	250-yr	2915	49.01	2965.32	49.13	0.12	
67555	500-yr	3093	49.31	3143.76	49.41	0.1	
67530	2-yr	1040	41.37	937.4	40.84	-0.53	
67530	5-yr	1672	44.78	1667.02	44.75	-0.03	
67530	10-yr	1916	46.16	1952.05	46.28	0.12	
67530	25-yr	2166	46.95	2205.33	47.28	0.33	
67530	50-yr	2374	47.75	2424.7	47.89	0.14	
67530	100-yr	2599	48.3	2654.4	48.61	0.31	
67530	250-yr	2915	49.01	2965.32	49.13	0.12	
67530	500-yr	3093	49.31	3143.76	49.41	0.1	
67505	2-yr	1040	41.39	937.4	40.86	-0.53	
67505	5-yr	1672	44.79	1667.02	44.77	-0.02	
67505	10-yr	1916	46.17	1952.05	46.29	0.12	
67505	25-yr	2166	46.96	2205.33	47.28	0.32	
67505	50-yr	2374	47.75	2424.7	47.89	0.14	
67505	100-yr	2599	48.3	2654.4	48.61	0.31	
67505	250-yr	2915	49.01	2965.32	49.13	0.12	
67505	500-yr	3093	49.31	3143.76	49.41	0.1	
67382	2-yr	1040	41.35	937.4	40.83	-0.52	
67382	5-yr	1672	44.76	1667.02	44.74	-0.02	
67382	10-yr	1916	46.15	1952.05	46.27	0.12	
67382	25-yr	2166	46.94	2205.33	47.27	0.33	
67382	50-yr	2374	47.74	2424.7	47.88	0.14	
67382	100-yr	2599	48.29	2654.4	48.6	0.31	
67382	250-yr	2915	49	2965.32	49.12	0.12	
67382	500-yr	3093	49.3	3143.76	49.4	0.1	
67351	2-yr	1040	41.33	937.4	40.8	-0.53	
67351	5-yr	1672	44.75	1667.02	44.73	-0.02	
67351	10-yr	1916	46.15	1952.05	46.27	0.12	
67351	25-yr	2166	46.94	2205.33	47.27	0.33	
67351	50-yr	2374	47.74	2424.7	47.88	0.14	
67351	100-yr	2599	48.29	2654.4	48.6	0.31	
67351	250-yr	2915	49	2965.32	49.12	0.12	
67351	500-yr	3093	49.3	3143.76	49.4	0.1	
67343.5	PEDESTRIAN BRIDG						Bridge
67336	2-yr	1040	41.32	937.4	40.79	-0.53	
67336	5-yr	1672	44.74	1667.02	44.71	-0.03	
67336	10-yr	1916	46.14	1952.05	46.25	0.11	
67336	25-yr	2166	46.93	2205.33	47.25	0.32	
67336	50-yr	2374	47.73	2424.7	47.87	0.14	
67336	100-yr	2599	48.28	2654.4	48.6	0.32	
67336	250-yr	2915	49	2965.32	49.11	0.11	
67336	500-yr	3093	49.29	3143.76	49.39	0.1	
67274	2-yr	1040	41.31	937.4	40.78	-0.53	
67274	5-yr	1672	44.73	1667.02	44.7	-0.03	
67274	10-yr	1916	46.13	1952.05	46.25	0.12	
67274	25-yr	2166	46.92	2205.33	47.25	0.33	
67274	50-yr	2374	47.73	2424.7	47.86	0.13	
67274	100-yr	2599	48.28	2654.4	48.59	0.31	
67274	250-yr	2915	48.99	2965.32	49.11	0.12	
67274	500-yr	3093	49.29	3143.76	49.39	0.1	
67074	2-yr	1040	41.27	937.4	40.74	-0.53	
67074	5-yr	1672	44.7	1667.02	44.67	-0.03	
67074	10-yr	1916	46.11	1952.05	46.22	0.11	
67074	25-yr	2166	46.9	2205.33	47.23	0.33	
67074	50-yr	2374	47.7	2424.7	47.84	0.14	
67074	100-yr	2599	48.25	2654.4	48.57	0.32	
67074	250-yr	2915	48.97	2965.32	49.08	0.11	
67074	500-yr	3093	49.26	3143.76	49.36	0.1	
66605	2-yr	1225	41.14	1102.67	40.6	-0.54	
66605	5-yr	2053	44.62	2036.99	44.59	-0.03	
66605	10-yr	2371	46.06	2408.33	46.18	0.12	
66605	25-yr	2695	46.86	2740.19	47.2	0.34	
66605	50-yr	2965	47.68	3023.23	47.82	0.14	
66605	100-yr	3261	48.23	3329.44	48.55	0.32	
66605	250-yr	3648	48.95	3707.73	49.07	0.12	
66605	500-yr	3876	49.25	3932.31	49.35	0.1	
66172	2-yr	1225	41	1102.67	40.47	-0.53	
66172	5-yr	2053	44.51	2036.99	44.48	-0.03	
66172	10-yr	2371	45.98	2408.33	46.12	0.14	
66172	25-yr	2695	46.81	2740.19	47.15	0.34	
66172	50-yr	2965	47.64	3023.23	47.78	0.14	
66172	100-yr	3261	48.19	3329.44	48.52	0.33	
66172	250-yr	3648	48.92	3707.73	49.04	0.12	
66172	500-yr	3876	49.21	3932.31	49.31	0.1	
66156	2-yr	1225	40.98	1102.67	40.45	-0.53	
66156	5-yr	2053	44.49	2036.99	44.46	-0.03	
66156	10-yr	2371	45.98	2408.33	46.11	0.13	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
66156	25-yr	2695	46.81	2740.19	47.15	0.34	
66156	50-yr	2965	47.63	3023.23	47.77	0.14	
66156	100-yr	3261	48.19	3329.44	48.52	0.33	
66156	250-yr	3648	48.92	3707.73	49.03	0.11	
66156	500-yr	3876	49.21	3932.31	49.31	0.1	
66155.5	PEDESTRIAN BRIDG						Bridge
66141	2-yr	1225	40.97	1102.67	40.44	-0.53	
66141	5-yr	2053	44.46	2036.99	44.44	-0.02	
66141	10-yr	2371	45.97	2408.33	46.1	0.13	
66141	25-yr	2695	46.8	2740.19	47.14	0.34	
66141	50-yr	2965	47.62	3023.23	47.76	0.14	
66141	100-yr	3261	48.18	3329.44	48.51	0.33	
66141	250-yr	3648	48.91	3707.73	49.03	0.12	
66141	500-yr	3876	49.2	3932.31	49.3	0.1	
66080	2-yr	1225	40.96	1102.67	40.43	-0.53	
66080	5-yr	2053	44.46	2036.99	44.43	-0.03	
66080	10-yr	2371	45.96	2408.33	46.1	0.14	
66080	25-yr	2695	46.79	2740.19	47.13	0.34	
66080	50-yr	2965	47.62	3023.23	47.76	0.14	
66080	100-yr	3261	48.18	3329.44	48.5	0.32	
66080	250-yr	3648	48.9	3707.73	49.02	0.12	
66080	500-yr	3876	49.2	3932.31	49.3	0.1	
65994	2-yr	1225	40.96	1102.67	40.42	-0.54	
65994	5-yr	2053	44.46	2036.99	44.43	-0.03	
65994	10-yr	2371	45.96	2408.33	46.09	0.13	
65994	25-yr	2695	46.79	2740.19	47.13	0.34	
65994	50-yr	2965	47.61	3023.23	47.75	0.14	
65994	100-yr	3261	48.17	3329.44	48.5	0.33	
65994	250-yr	3648	48.9	3707.73	49.02	0.12	
65994	500-yr	3876	49.19	3932.31	49.29	0.1	
65919	2-yr	1225	40.92	1102.67	40.39	-0.53	
65919	5-yr	2053	44.42	2036.99	44.39	-0.03	
65919	10-yr	2371	45.94	2408.33	46.07	0.13	
65919	25-yr	2695	46.77	2740.19	47.12	0.35	
65919	50-yr	2965	47.6	3023.23	47.75	0.15	
65919	100-yr	3261	48.16	3329.44	48.49	0.33	
65919	250-yr	3648	48.89	3707.73	49.01	0.12	
65919	500-yr	3876	49.19	3932.31	49.29	0.1	
65913.5	LOOP 610 3RD CRO						Bridge
65649	2-yr	1225	40.79	1102.67	40.26	-0.53	
65649	5-yr	2053	44.31	2036.99	44.28	-0.03	
65649	10-yr	2371	45.67	2408.33	45.79	0.12	
65649	25-yr	2695	46.43	2740.19	46.77	0.34	
65649	50-yr	2965	47.23	3023.23	47.36	0.13	
65649	100-yr	3261	47.76	3329.44	48.12	0.36	
65649	250-yr	3648	48.5	3707.73	48.63	0.13	
65649	500-yr	3876	48.79	3932.31	48.9	0.11	
65474	2-yr	1225	40.77	1102.67	40.24	-0.53	
65474	5-yr	2053	44.28	2036.99	44.26	-0.02	
65474	10-yr	2371	45.65	2408.33	45.77	0.12	
65474	25-yr	2695	46.4	2740.19	46.75	0.35	
65474	50-yr	2965	47.21	3023.23	47.35	0.14	
65474	100-yr	3261	47.75	3329.44	48.1	0.35	
65474	250-yr	3648	48.49	3707.73	48.61	0.12	
65474	500-yr	3876	48.78	3932.31	48.89	0.11	
65378	2-yr	1225	40.72	1102.67	40.19	-0.53	
65378	5-yr	2053	44.23	2036.99	44.2	-0.03	
65378	10-yr	2371	45.6	2408.33	45.72	0.12	
65378	25-yr	2695	46.37	2740.19	46.73	0.36	
65378	50-yr	2965	47.19	3023.23	47.33	0.14	
65378	100-yr	3261	47.73	3329.44	48.09	0.36	
65378	250-yr	3648	48.48	3707.73	48.6	0.12	
65378	500-yr	3876	48.77	3932.31	48.88	0.11	
65377.5	KELLEY STREET EA						Bridge
65332	2-yr	1225	40.69	1102.67	40.16	-0.53	
65332	5-yr	2053	44.19	2036.99	44.16	-0.03	
65332	10-yr	2371	45.57	2408.33	45.69	0.12	
65332	25-yr	2695	46.34	2740.19	46.7	0.36	
65332	50-yr	2965	47.17	3023.23	47.31	0.14	
65332	100-yr	3261	47.71	3329.44	48.07	0.36	
65332	250-yr	3648	48.46	3707.73	48.59	0.13	
65332	500-yr	3876	48.76	3932.31	48.87	0.11	
65286	2-yr	1225	40.7	1102.67	40.17	-0.53	
65286	5-yr	2053	44.2	2036.99	44.18	-0.02	
65286	10-yr	2371	45.58	2408.33	45.7	0.12	
65286	25-yr	2695	46.34	2740.19	46.7	0.36	
65286	50-yr	2965	47.17	3023.23	47.31	0.14	
65286	100-yr	3261	47.71	3329.44	48.08	0.37	
65286	250-yr	3648	48.46	3707.73	48.59	0.13	
65286	500-yr	3876	48.76	3932.31	48.87	0.11	
65251	2-yr	1225	40.7	1102.67	40.17	-0.53	
65251	5-yr	2053	44.2	2036.99	44.17	-0.03	
65251	10-yr	2371	45.57	2408.33	45.69	0.12	
65251	25-yr	2695	46.34	2740.19	46.7	0.36	
65251	50-yr	2965	47.17	3023.23	47.31	0.14	
65251	100-yr	3261	47.71	3329.44	48.07	0.36	
65251	250-yr	3648	48.46	3707.73	48.59	0.13	
65251	500-yr	3876	48.76	3932.31	48.87	0.11	
64923	2-yr	1225	40.64	1102.67	40.12	-0.52	
64923	5-yr	2053	44.14	2036.99	44.12	-0.02	
64923	10-yr	2371	45.53	2408.33	45.65	0.12	
64923	25-yr	2695	46.3	2740.19	46.66	0.36	
64923	50-yr	2965	47.13	3023.23	47.27	0.14	
64923	100-yr	3261	47.68	3329.44	48.04	0.36	
64923	250-yr	3648	48.43	3707.73	48.56	0.13	
64923	500-yr	3876	48.72	3932.31	48.84	0.12	
64907	2-yr	1225	40.57	1102.67	40.04	-0.53	
64907	5-yr	2053	44.08	2036.99	44.05	-0.03	
64907	10-yr	2371	45.49	2408.33	45.62	0.13	
64907	25-yr	2695	46.27	2740.19	46.64	0.37	
64907	50-yr	2965	47.1	3023.23	47.25	0.15	
64907	100-yr	3261	47.65	3329.44	48.02	0.37	
64907	250-yr	3648	48.4	3707.73	48.53	0.13	
64907	500-yr	3876	48.7	3932.31	48.82	0.12	
64901.5	KELLEY STREET WE						Bridge
64858	2-yr	1225	40.49	1102.67	39.97	-0.52	
64858	5-yr	2053	44.01	2036.99	43.99	-0.02	
64858	10-yr	2371	45.36	2408.33	45.48	0.12	
64858	25-yr	2695	46.08	2740.19	46.43	0.35	
64858	50-yr	2965	46.84	3023.23	47	0.16	
64858	100-yr	3261	47.47	3329.44	47.91	0.44	
64858	250-yr	3648	48.32	3707.73	48.46	0.14	
64858	500-yr	3876	48.63	3932.31	48.75	0.12	
64850	2-yr	1225	40.49	1102.67	39.97	-0.52	
64850	5-yr	2053	44.01	2036.99	43.98	-0.03	
64850	10-yr	2371	45.35	2408.33	45.47	0.12	
64850	25-yr	2695	46.07	2740.19	46.43	0.36	
64850	50-yr	2965	46.83	3023.23	46.99	0.16	
64850	100-yr	3261	47.47	3329.44	47.91	0.44	
64850	250-yr	3648	48.32	3707.73	48.46	0.14	
64850	500-yr	3876	48.63	3932.31	48.75	0.12	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
64775	2-yr	1225	40.48	1102.67	39.96	-0.52	
64775	5-yr	2053	44	2036.99	43.98	-0.02	
64775	10-yr	2371	45.35	2408.33	45.47	0.12	
64775	25-yr	2695	46.07	2740.19	46.43	0.36	
64775	50-yr	2965	46.83	3023.23	46.99	0.16	
64775	100-yr	3261	47.47	3329.44	47.91	0.44	
64775	250-yr	3648	48.32	3707.73	48.46	0.14	
64775	500-yr	3876	48.63	3932.31	48.75	0.12	
64773.5	COH WATERLINE CR						Bridge
64770	2-yr	1225	40.47	1102.67	39.95	-0.52	
64770	5-yr	2053	43.99	2036.99	43.97	-0.02	
64770	10-yr	2371	45.35	2408.33	45.47	0.12	
64770	25-yr	2695	46.07	2740.19	46.42	0.35	
64770	50-yr	2965	46.83	3023.23	46.99	0.16	
64770	100-yr	3261	47.46	3329.44	47.9	0.44	
64770	250-yr	3648	48.31	3707.73	48.45	0.14	
64770	500-yr	3876	48.63	3932.31	48.75	0.12	
64684	2-yr	1225	40.46	1102.67	39.93	-0.53	
64684	5-yr	2053	43.98	2036.99	43.96	-0.02	
64684	10-yr	2371	45.34	2408.33	45.46	0.12	
64684	25-yr	2695	46.06	2740.19	46.42	0.36	
64684	50-yr	2965	46.82	3023.23	46.98	0.16	
64684	100-yr	3261	47.45	3329.44	47.89	0.44	
64684	250-yr	3648	48.31	3707.73	48.45	0.14	
64684	500-yr	3876	48.62	3932.31	48.74	0.12	
64090	2-yr	1551	40.28	1399.4	39.76	-0.52	
64090	5-yr	2659	43.83	2626.66	43.81	-0.02	
64090	10-yr	3155	45.21	3206.06	45.34	0.13	
64090	25-yr	3667	45.95	3702.32	46.33	0.38	
64090	50-yr	4052	46.74	4116.3	46.91	0.17	
64090	100-yr	4471	47.39	4549.19	47.85	0.46	
64090	250-yr	5027	48.26	5084.09	48.41	0.15	
64090	500-yr	5329	48.58	5347.58	48.71	0.13	
63754	2-yr	1551	40.17	1399.4	39.64	-0.53	
63754	5-yr	2659	43.73	2626.66	43.71	-0.02	
63754	10-yr	3155	45.14	3206.06	45.26	0.12	
63754	25-yr	3667	45.88	3702.32	46.28	0.4	
63754	50-yr	4052	46.69	4116.3	46.86	0.17	
63754	100-yr	4471	47.35	4549.19	47.81	0.46	
63754	250-yr	5027	48.23	5084.09	48.37	0.14	
63754	500-yr	5329	48.55	5347.58	48.68	0.13	
63620	2-yr	1551	40.16	1399.4	39.63	-0.53	
63620	5-yr	2659	43.72	2626.66	43.7	-0.02	
63620	10-yr	3155	45.13	3206.06	45.25	0.12	
63620	25-yr	3667	45.87	3702.32	46.27	0.4	
63620	50-yr	4052	46.68	4116.3	46.85	0.17	
63620	100-yr	4471	47.34	4549.19	47.81	0.47	
63620	250-yr	5027	48.22	5084.09	48.37	0.15	
63620	500-yr	5329	48.54	5347.58	48.67	0.13	
63618.5	UTILITY BRIDGE						Bridge
63616	2-yr	1551	40.15	1399.4	39.63	-0.52	
63616	5-yr	2659	43.71	2626.66	43.7	-0.01	
63616	10-yr	3155	45.11	3206.06	45.24	0.13	
63616	25-yr	3667	45.85	3702.32	46.25	0.4	
63616	50-yr	4052	46.66	4116.3	46.84	0.18	
63616	100-yr	4471	47.33	4549.19	47.8	0.47	
63616	250-yr	5027	48.21	5084.09	48.36	0.15	
63616	500-yr	5329	48.54	5347.58	48.67	0.13	
63605	2-yr	1551	40.15	1399.4	39.63	-0.52	
63605	5-yr	2659	43.71	2626.66	43.7	-0.01	
63605	10-yr	3155	45.11	3206.06	45.24	0.13	
63605	25-yr	3667	45.85	3702.32	46.25	0.4	
63605	50-yr	4052	46.66	4116.3	46.84	0.18	
63605	100-yr	4471	47.33	4549.19	47.8	0.47	
63605	250-yr	5027	48.21	5084.09	48.36	0.15	
63605	500-yr	5329	48.54	5347.58	48.67	0.13	
63599.5	HOMESTEAD ROAD						Bridge
63425	2-yr	1551	40.11	1399.4	39.58	-0.53	
63425	5-yr	2659	43.67	2626.66	43.65	-0.02	
63425	10-yr	3155	45.06	3206.06	45.19	0.13	
63425	25-yr	3667	45.8	3702.32	46.2	0.4	
63425	50-yr	4052	46.61	4116.3	46.78	0.17	
63425	100-yr	4471	47.27	4549.19	47.74	0.47	
63425	250-yr	5027	48.16	5084.09	48.3	0.14	
63425	500-yr	5329	48.48	5347.58	48.61	0.13	
63253	2-yr	1551	40.06	1399.4	39.54	-0.52	
63253	5-yr	2659	43.63	2626.66	43.61	-0.02	
63253	10-yr	3155	45.03	3206.06	45.16	0.13	
63253	25-yr	3667	45.77	3702.32	46.18	0.41	
63253	50-yr	4052	46.59	4116.3	46.77	0.18	
63253	100-yr	4471	47.25	4549.19	47.73	0.48	
63253	250-yr	5027	48.14	5084.09	48.29	0.15	
63253	500-yr	5329	48.47	5347.58	48.6	0.13	
62617	2-yr	1551	39.86	1399.4	39.34	-0.52	
62617	5-yr	2659	43.48	2626.66	43.47	-0.01	
62617	10-yr	3155	44.92	3206.06	45.05	0.13	
62617	25-yr	3667	45.66	3702.32	46.09	0.43	
62617	50-yr	4052	46.53	4116.3	46.71	0.18	
62617	100-yr	4471	47.2	4549.19	47.69	0.49	
62617	250-yr	5027	48.1	5084.09	48.25	0.15	
62617	500-yr	5329	48.43	5347.58	48.56	0.13	
62067	2-yr	1551	39.7	1399.4	39.17	-0.53	
62067	5-yr	2659	43.36	2626.66	43.35	-0.01	
62067	10-yr	3155	44.82	3206.06	44.95	0.13	
62067	25-yr	3667	45.56	3702.32	46	0.44	
62067	50-yr	4052	46.44	4116.3	46.64	0.2	
62067	100-yr	4471	47.14	4549.19	47.64	0.5	
62067	250-yr	5027	48.05	5084.09	48.2	0.15	
62067	500-yr	5329	48.38	5347.58	48.51	0.13	
61532	2-yr	1551	39.51	1399.4	38.98	-0.53	
61532	5-yr	2659	43.17	2626.66	43.16	-0.01	
61532	10-yr	3155	44.65	3206.06	44.79	0.14	
61532	25-yr	3667	45.39	3702.32	45.86	0.47	
61532	50-yr	4052	46.29	4116.3	46.51	0.22	
61532	100-yr	4471	47.01	4549.19	47.53	0.52	
61532	250-yr	5027	47.94	5084.09	48.1	0.16	
61532	500-yr	5329	48.27	5347.58	48.41	0.14	
61162	2-yr	1551	39.46	1399.4	38.92	-0.54	
61162	5-yr	2659	43.15	2626.66	43.15	0	
61162	10-yr	3155	44.65	3206.06	44.78	0.13	
61162	25-yr	3667	45.39	3702.32	45.86	0.47	
61162	50-yr	4052	46.29	4116.3	46.51	0.22	
61162	100-yr	4471	47.01	4549.19	47.53	0.52	
61162	250-yr	5027	47.94	5084.09	48.09	0.15	
61162	500-yr	5329	48.27	5347.58	48.41	0.14	
60525	2-yr	1551	39.43	1399.4	38.89	-0.54	
60525	5-yr	2659	43.13	2626.66	43.13	0	
60525	10-yr	3155	44.63	3206.06	44.76	0.13	
60525	25-yr	3667	45.38	3702.32	45.84	0.46	
60525	50-yr	4052	46.28	4116.3	46.5	0.22	
60525	100-yr	4471	46.99	4549.19	47.52	0.53	
60525	250-yr	5027	47.93	5084.09	48.08	0.15	
60525	500-yr	5329	48.26	5347.58	48.4	0.14	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
60280	2-yr	1854	39.41	1685.02	38.87	-0.54	
60280	5-yr	3187	43.12	3158.84	43.12	0	
60280	10-yr	3888	44.62	3967.68	44.76	0.14	
60280	25-yr	4399	45.37	4445.55	45.84	0.47	
60280	50-yr	4702	46.27	4769.83	46.49	0.22	
60280	100-yr	5071	46.99	5179.51	47.51	0.52	
60280	250-yr	5555	47.92	5624.67	48.08	0.16	
60280	500-yr	5856	48.25	5917.8	48.39	0.14	
60038	2-yr	1854	39.41	1685.02	38.87	-0.54	
60038	5-yr	3187	43.12	3158.84	43.11	-0.01	
60038	10-yr	3888	44.61	3967.68	44.75	0.14	
60038	25-yr	4399	45.36	4445.55	45.83	0.47	
60038	50-yr	4702	46.27	4769.83	46.49	0.22	
60038	100-yr	5071	46.99	5179.51	47.51	0.52	
60038	250-yr	5555	47.92	5624.67	48.08	0.16	
60038	500-yr	5856	48.25	5917.8	48.39	0.14	
60031.5	UTILITY BRIDGE						Bridge
60025	2-yr	1854	39.41	1685.02	38.87	-0.54	
60025	5-yr	3187	43.11	3158.84	43.11	0	
60025	10-yr	3888	44.61	3967.68	44.75	0.14	
60025	25-yr	4399	45.36	4445.55	45.83	0.47	
60025	50-yr	4702	46.26	4769.83	46.48	0.22	
60025	100-yr	5071	46.98	5179.51	47.51	0.53	
60025	250-yr	5555	47.92	5624.67	48.08	0.16	
60025	500-yr	5856	48.25	5917.8	48.39	0.14	
60003	2-yr	1854	39.3	1685.02	38.76	-0.54	
60003	5-yr	3187	42.97	3158.84	42.96	-0.01	
60003	10-yr	3888	44.44	3967.68	44.58	0.14	
60003	25-yr	4399	45.17	4445.55	45.65	0.48	
60003	50-yr	4702	46.07	4769.83	46.29	0.22	
60003	100-yr	5071	46.78	5179.51	47.36	0.58	
60003	250-yr	5555	47.77	5624.67	47.94	0.17	
60003	500-yr	5856	48.11	5917.8	48.26	0.15	
59960	2-yr	1854	39.28	1685.02	38.74	-0.54	
59960	5-yr	3187	42.95	3158.84	42.94	-0.01	
59960	10-yr	3888	44.42	3967.68	44.55	0.13	
59960	25-yr	4399	45.14	4445.55	45.62	0.48	
59960	50-yr	4702	46.05	4769.83	46.27	0.22	
59960	100-yr	5071	46.76	5179.51	47.34	0.58	
59960	250-yr	5555	47.75	5624.67	47.92	0.17	
59960	500-yr	5856	48.09	5917.8	48.24	0.15	
59750.5	LOOP 610 CROSSIN						Bridge
59540	2-yr	1854	38.74	1685.02	38.22	-0.52	
59540	5-yr	3187	42.35	3158.84	42.36	0.01	
59540	10-yr	3888	43.55	3967.68	43.66	0.11	
59540	25-yr	4399	44.1	4445.55	44.23	0.13	
59540	50-yr	4702	44.48	4769.83	44.66	0.18	
59540	100-yr	5071	44.93	5179.51	45.13	0.2	
59540	250-yr	5555	45.47	5624.67	45.72	0.25	
59540	500-yr	5856	45.86	5917.8	46.1	0.24	
59497	2-yr	1854	38.71	1685.02	38.18	-0.53	
59497	5-yr	3187	42.31	3158.84	42.32	0.01	
59497	10-yr	3888	43.51	3967.68	43.62	0.11	
59497	25-yr	4399	44.05	4445.55	44.19	0.14	
59497	50-yr	4702	44.44	4769.83	44.62	0.18	
59497	100-yr	5071	44.89	5179.51	45.09	0.2	
59497	250-yr	5555	45.43	5624.67	45.67	0.24	
59497	500-yr	5856	45.81	5917.8	46.05	0.24	
59445	2-yr	1854	38.67	1685.02	38.15	-0.52	
59445	5-yr	3187	42.28	3158.84	42.29	0.01	
59445	10-yr	3888	43.47	3967.68	43.58	0.11	
59445	25-yr	4399	44.01	4445.55	44.15	0.14	
59445	50-yr	4702	44.4	4769.83	44.58	0.18	
59445	100-yr	5071	44.85	5179.51	45.05	0.2	
59445	250-yr	5555	45.38	5624.67	45.63	0.25	
59445	500-yr	5856	45.77	5917.8	46.01	0.24	
58305	2-yr	1854	38.06	1685.02	37.53	-0.53	
58305	5-yr	3187	41.76	3158.84	41.78	0.02	
58305	10-yr	3888	43.04	3967.68	43.15	0.11	
58305	25-yr	4399	43.61	4445.55	43.77	0.16	
58305	50-yr	4702	44.04	4769.83	44.25	0.21	
58305	100-yr	5071	44.54	5179.51	44.77	0.23	
58305	250-yr	5555	45.13	5624.67	45.42	0.29	
58305	500-yr	5856	45.56	5917.8	45.84	0.28	
57533	2-yr	2044	37.76	1865.32	37.23	-0.53	
57533	5-yr	3337	41.53	3332.43	41.55	0.02	
57533	10-yr	3929	42.83	4028.59	42.94	0.11	
57533	25-yr	4429	43.39	4547.96	43.56	0.17	
57533	50-yr	4778	43.83	4933.7	44.05	0.22	
57533	100-yr	5182	44.34	5355.56	44.58	0.24	
57533	250-yr	5639	44.94	5790.43	45.24	0.3	
57533	500-yr	5917	45.38	6077.07	45.66	0.28	
57306	2-yr	2044	37.61	1865.32	37.09	-0.52	
57306	5-yr	3337	41.36	3332.43	41.39	0.03	
57306	10-yr	3929	42.66	4028.59	42.77	0.11	
57306	25-yr	4429	43.2	4547.96	43.36	0.16	
57306	50-yr	4778	43.63	4933.7	43.84	0.21	
57306	100-yr	5182	44.12	5355.56	44.35	0.23	
57306	250-yr	5639	44.7	5790.43	45	0.3	
57306	500-yr	5917	45.14	6077.07	45.42	0.28	
57261	2-yr	2044	37.58	1865.32	37.06	-0.52	
57261	5-yr	3337	41.31	3332.43	41.34	0.03	
57261	10-yr	3929	42.6	4028.59	42.71	0.11	
57261	25-yr	4429	43.13	4547.96	43.28	0.15	
57261	50-yr	4778	43.54	4933.7	43.75	0.21	
57261	100-yr	5182	44.02	5355.56	44.25	0.23	
57261	250-yr	5639	44.6	5790.43	44.89	0.29	
57261	500-yr	5917	45.03	6077.07	45.31	0.28	
57237.5	LIBERTY ROAD						Bridge
57213	2-yr	2044	37.53	1865.32	37.01	-0.52	
57213	5-yr	3337	41.25	3332.43	41.28	0.03	
57213	10-yr	3929	42.54	4028.59	42.65	0.11	
57213	25-yr	4429	43.06	4547.96	43.22	0.16	
57213	50-yr	4778	43.48	4933.7	43.69	0.21	
57213	100-yr	5182	43.96	5355.56	44.18	0.22	
57213	250-yr	5639	44.5	5790.43	44.74	0.24	
57213	500-yr	5917	44.86	6077.07	45.11	0.25	
57199	2-yr	2044	37.52	1865.32	37	-0.52	
57199	5-yr	3337	41.24	3332.43	41.27	0.03	
57199	10-yr	3929	42.53	4028.59	42.64	0.11	
57199	25-yr	4429	43.06	4547.96	43.22	0.16	
57199	50-yr	4778	43.47	4933.7	43.68	0.21	
57199	100-yr	5182	43.95	5355.56	44.18	0.23	
57199	250-yr	5639	44.49	5790.43	44.73	0.24	
57199	500-yr	5917	44.85	6077.07	45.11	0.26	
57147.5	ENGLEWOOD YARD						Bridge
57097	2-yr	2044	37.33	1865.32	36.83	-0.5	
57097	5-yr	3337	41	3332.43	41.03	0.03	
57097	10-yr	3929	42.07	4028.59	42.15	0.08	
57097	25-yr	4429	42.43	4547.96	42.55	0.12	
57097	50-yr	4778	42.72	4933.7	42.86	0.14	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
57097	100-yr	5182	43.03	5355.56	43.18	0.15	
57097	250-yr	5639	43.37	5790.43	43.54	0.17	
57097	500-yr	5917	43.59	6077.07	43.76	0.17	
57090	2-yr	2044	37.33	1865.32	36.83	-0.5	
57090	5-yr	3337	41	3332.43	41.03	0.03	
57090	10-yr	3929	42.06	4028.59	42.14	0.08	
57090	25-yr	4429	42.43	4547.96	42.55	0.12	
57090	50-yr	4778	42.72	4933.7	42.86	0.14	
57090	100-yr	5182	43.03	5355.56	43.18	0.15	
57090	250-yr	5639	43.36	5790.43	43.53	0.17	
57090	500-yr	5917	43.59	6077.07	43.76	0.17	
56883	2-yr	2044	37.07	1865.32	36.54	-0.53	
56883	5-yr	3337	40.9	3332.43	40.93	0.03	
56883	10-yr	3929	41.97	4028.59	42.05	0.08	
56883	25-yr	4429	42.32	4547.96	42.43	0.11	
56883	50-yr	4778	42.6	4933.7	42.74	0.14	
56883	100-yr	5182	42.9	5355.56	43.04	0.14	
56883	250-yr	5639	43.21	5790.43	43.38	0.17	
56883	500-yr	5917	43.43	6077.07	43.59	0.16	
56848	2-yr	2044	37.06	1865.32	36.54	-0.52	
56848	5-yr	3337	40.9	3332.43	40.93	0.03	
56848	10-yr	3929	41.97	4028.59	42.04	0.07	
56848	25-yr	4429	42.32	4547.96	42.43	0.11	
56848	50-yr	4778	42.59	4933.7	42.73	0.14	
56848	100-yr	5182	42.89	5355.56	43.04	0.15	
56848	250-yr	5639	43.21	5790.43	43.37	0.16	
56848	500-yr	5917	43.43	6077.07	43.59	0.16	
56833.5	ENGLEWOOD YARD						Bridge
56818	2-yr	2044	36.95	1865.32	36.42	-0.53	
56818	5-yr	3337	40.82	3332.43	40.85	0.03	
56818	10-yr	3929	41.88	4028.59	41.96	0.08	
56818	25-yr	4429	42.22	4547.96	42.33	0.11	
56818	50-yr	4778	42.48	4933.7	42.62	0.14	
56818	100-yr	5182	42.77	5355.56	42.91	0.14	
56818	250-yr	5639	43.07	5790.43	43.24	0.17	
56818	500-yr	5917	43.28	6077.07	43.44	0.16	
56730	2-yr	2044	36.93	1865.32	36.39	-0.54	
56730	5-yr	3337	40.81	3332.43	40.84	0.03	
56730	10-yr	3929	41.87	4028.59	41.95	0.08	
56730	25-yr	4429	42.21	4547.96	42.32	0.11	
56730	50-yr	4778	42.47	4933.7	42.61	0.14	
56730	100-yr	5182	42.76	5355.56	42.9	0.14	
56730	250-yr	5639	43.06	5790.43	43.22	0.16	
56730	500-yr	5917	43.27	6077.07	43.43	0.16	
56715.5	ENGLEWOOD YARD						Bridge
56700	2-yr	2044	36.88	1865.32	36.34	-0.54	
56700	5-yr	3337	40.78	3332.43	40.81	0.03	
56700	10-yr	3929	41.84	4028.59	41.91	0.07	
56700	25-yr	4429	42.17	4547.96	42.28	0.11	
56700	50-yr	4778	42.43	4933.7	42.56	0.13	
56700	100-yr	5182	42.71	5355.56	42.85	0.14	
56700	250-yr	5639	43.01	5790.43	43.17	0.16	
56700	500-yr	5917	43.22	6077.07	43.38	0.16	
56630	2-yr	2044	36.8	1865.32	36.24	-0.56	
56630	5-yr	3337	40.75	3332.43	40.78	0.03	
56630	10-yr	3929	41.81	4028.59	41.89	0.08	
56630	25-yr	4429	42.14	4547.96	42.25	0.11	
56630	50-yr	4778	42.4	4933.7	42.53	0.13	
56630	100-yr	5182	42.68	5355.56	42.82	0.14	
56630	250-yr	5639	42.97	5790.43	43.13	0.16	
56630	500-yr	5917	43.17	6077.07	43.33	0.16	
56610.5	ENGLEWOOD YARD						Bridge
56590	2-yr	2044	36.63	1865.32	36.05	-0.58	
56590	5-yr	3337	40.66	3332.43	40.7	0.04	
56590	10-yr	3929	41.72	4028.59	41.79	0.07	
56590	25-yr	4429	42.03	4547.96	42.14	0.11	
56590	50-yr	4778	42.28	4933.7	42.41	0.13	
56590	100-yr	5182	42.55	5355.56	42.68	0.13	
56590	250-yr	5639	42.82	5790.43	42.98	0.16	
56590	500-yr	5917	43.02	6077.07	43.18	0.16	
56565	2-yr	2044	36.63	1865.32	36.05	-0.58	
56565	5-yr	3337	40.66	3332.43	40.7	0.04	
56565	10-yr	3929	41.72	4028.59	41.79	0.07	
56565	25-yr	4429	42.03	4547.96	42.14	0.11	
56565	50-yr	4778	42.28	4933.7	42.41	0.13	
56565	100-yr	5182	42.55	5355.56	42.68	0.13	
56565	250-yr	5639	42.82	5790.43	42.98	0.16	
56565	500-yr	5917	43.02	6077.07	43.18	0.16	
56555	2-yr	2044	36.63	1865.32	36.04	-0.59	
56555	5-yr	3337	40.66	3332.43	40.69	0.03	
56555	10-yr	3929	41.72	4028.59	41.79	0.07	
56555	25-yr	4429	42.03	4547.96	42.13	0.1	
56555	50-yr	4778	42.28	4933.7	42.41	0.13	
56555	100-yr	5182	42.54	5355.56	42.68	0.14	
56555	250-yr	5639	42.82	5790.43	42.98	0.16	
56555	500-yr	5917	43.02	6077.07	43.18	0.16	
56461	2-yr	2044	36.63	1865.32	36.05	-0.58	
56461	5-yr	3337	40.67	3332.43	40.71	0.04	
56461	10-yr	3929	41.74	4028.59	41.81	0.07	
56461	25-yr	4429	42.05	4547.96	42.16	0.11	
56461	50-yr	4778	42.3	4933.7	42.43	0.13	
56461	100-yr	5182	42.57	5355.56	42.71	0.14	
56461	250-yr	5639	42.85	5790.43	43.02	0.17	
56461	500-yr	5917	43.05	6077.07	43.21	0.16	
56394	2-yr	2044	36.59	1865.32	36.01	-0.58	
56394	5-yr	3337	40.65	3332.43	40.68	0.03	
56394	10-yr	3929	41.72	4028.59	41.79	0.07	
56394	25-yr	4429	42.04	4547.96	42.15	0.11	
56394	50-yr	4778	42.3	4933.7	42.43	0.13	
56394	100-yr	5182	42.57	5355.56	42.71	0.14	
56394	250-yr	5639	42.85	5790.43	43.02	0.17	
56394	500-yr	5917	43.06	6077.07	43.22	0.16	
56314.5	WAYSIDE DRIVE BR						Bridge
56234	2-yr	2044	36.46	1865.32	35.89	-0.57	
56234	5-yr	3337	40.04	3332.43	40.08	0.04	
56234	10-yr	3929	41.23	4028.59	41.31	0.08	
56234	25-yr	4429	41.61	4547.96	41.76	0.15	
56234	50-yr	4778	41.94	4933.7	42.16	0.22	
56234	100-yr	5182	42.34	5355.56	42.52	0.18	
56234	250-yr	5639	42.69	5790.43	42.88	0.19	
56234	500-yr	5917	42.92	6077.07	43.1	0.18	
56185	2-yr	2044	36.43	1865.32	35.86	-0.57	
56185	5-yr	3337	39.98	3332.43	40.02	0.04	
56185	10-yr	3929	41.14	4028.59	41.2	0.06	
56185	25-yr	4429	41.48	4547.96	41.61	0.13	
56185	50-yr	4778	41.78	4933.7	41.97	0.19	
56185	100-yr	5182	42.12	5355.56	42.27	0.15	
56185	250-yr	5639	42.41	5790.43	42.59	0.18	
56185	500-yr	5917	42.61	6077.07	42.78	0.17	
56165.5	HB&T RAILROAD BR						Bridge

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
56146	2-yr	2044	36.32	1865.32	35.76	-0.56	
56146	5-yr	3337	39.85	3332.43	39.9	0.05	
56146	10-yr	3929	41	4028.59	41.06	0.06	
56146	25-yr	4429	41.31	4547.96	41.44	0.13	
56146	50-yr	4778	41.57	4933.7	41.71	0.14	
56146	100-yr	5182	41.83	5355.56	41.95	0.12	
56146	250-yr	5639	42.05	5790.43	42.2	0.15	
56146	500-yr	5917	42.21	6077.07	42.35	0.14	
56121	2-yr	2044	36.3	1865.32	35.74	-0.56	
56121	5-yr	3337	39.84	3332.43	39.88	0.04	
56121	10-yr	3929	40.98	4028.59	41.04	0.06	
56121	25-yr	4429	41.29	4547.96	41.42	0.13	
56121	50-yr	4778	41.54	4933.7	41.69	0.15	
56121	100-yr	5182	41.8	5355.56	41.93	0.13	
56121	250-yr	5639	42.03	5790.43	42.18	0.15	
56121	500-yr	5917	42.18	6077.07	42.32	0.14	
54950	2-yr	2244	35.78	2057.92	35.23	-0.55	
54950	5-yr	3600	39.37	3607.46	39.42	0.05	
54950	10-yr	4293	40.6	4402.73	40.65	0.05	
54950	25-yr	4682	40.91	4844.46	41.05	0.14	
54950	50-yr	5006	41.17	5241.37	41.32	0.15	
54950	100-yr	5409	41.44	5706.76	41.56	0.12	
54950	250-yr	5922	41.65	6351	41.8	0.15	
54950	500-yr	6318	41.81	6736.97	41.94	0.13	
53883	2-yr	2244	35.36	2057.92	34.82	-0.54	
53883	5-yr	3600	38.94	3607.46	39	0.06	
53883	10-yr	4293	40.18	4402.73	40.22	0.04	
53883	25-yr	4682	40.51	4844.46	40.67	0.16	
53883	50-yr	5006	40.81	5241.37	40.98	0.17	
53883	100-yr	5409	41.11	5706.76	41.22	0.11	
53883	250-yr	5922	41.32	6351	41.45	0.13	
53883	500-yr	6318	41.47	6736.97	41.59	0.12	
53836	2-yr	2244	35.34	2057.92	34.8	-0.54	
53836	5-yr	3600	38.91	3607.46	38.97	0.06	
53836	10-yr	4293	40.15	4402.73	40.2	0.05	
53836	25-yr	4682	40.49	4844.46	40.65	0.16	
53836	50-yr	5006	40.79	5241.37	40.95	0.16	
53836	100-yr	5409	41.09	5706.76	41.2	0.11	
53836	250-yr	5922	41.3	6351	41.43	0.13	
53836	500-yr	6318	41.45	6736.97	41.57	0.12	
53820.5	TANK FARM ROAD B						Bridge
53805	2-yr	2244	35.31	2057.92	34.77	-0.54	
53805	5-yr	3600	38.86	3607.46	38.92	0.06	
53805	10-yr	4293	40.05	4402.73	40.09	0.04	
53805	25-yr	4682	40.42	4844.46	40.59	0.17	
53805	50-yr	5006	40.73	5241.37	40.89	0.16	
53805	100-yr	5409	40.99	5706.76	41.11	0.12	
53805	250-yr	5922	41.2	6351	41.33	0.13	
53805	500-yr	6318	41.35	6736.97	41.47	0.12	
53772	2-yr	2244	35.3	2057.92	34.76	-0.54	
53772	5-yr	3600	38.85	3607.46	38.91	0.06	
53772	10-yr	4293	40.03	4402.73	40.07	0.04	
53772	25-yr	4682	40.4	4844.46	40.58	0.18	
53772	50-yr	5006	40.72	5241.37	40.87	0.15	
53772	100-yr	5409	40.98	5706.76	41.09	0.11	
53772	250-yr	5922	41.19	6351	41.32	0.13	
53772	500-yr	6318	41.34	6736.97	41.46	0.12	
52267	2-yr	2244	34.83	2057.92	34.3	-0.53	
52267	5-yr	3600	38.36	3607.46	38.42	0.06	
52267	10-yr	4293	39.56	4402.73	39.58	0.02	
52267	25-yr	4682	39.93	4844.46	40.12	0.19	
52267	50-yr	5006	40.28	5241.37	40.45	0.17	
52267	100-yr	5409	40.57	5706.76	40.68	0.11	
52267	250-yr	5922	40.77	6351	40.89	0.12	
52267	500-yr	6318	40.92	6736.97	41.03	0.11	
49831	2-yr	2321	34.06	2131.7	33.54	-0.52	
49831	5-yr	3640	37.61	3658.38	37.67	0.06	
49831	10-yr	4155	38.86	4247.24	39.03	0.17	
49831	25-yr	4502	39.43	4668.91	39.65	0.22	
49831	50-yr	4808	39.76	5016.86	39.96	0.2	
49831	100-yr	5180	40.1	5337.54	40.21	0.11	
49831	250-yr	5483	40.32	5685.16	40.43	0.11	
49831	500-yr	5724	40.48	5931.42	40.58	0.1	
49781	2-yr	2321	34.04	2131.7	33.52	-0.52	
49781	5-yr	3640	37.58	3658.38	37.64	0.06	
49781	10-yr	4155	38.83	4247.24	38.95	0.12	
49781	25-yr	4502	39.42	4668.91	39.64	0.22	
49781	50-yr	4808	39.75	5016.86	39.95	0.2	
49781	100-yr	5180	40.09	5337.54	40.2	0.11	
49781	250-yr	5483	40.31	5685.16	40.42	0.11	
49781	500-yr	5724	40.47	5931.42	40.57	0.1	
49751.5	MCCARTY ROAD BRI						Bridge
49722	2-yr	2321	34	2131.7	33.48	-0.52	
49722	5-yr	3640	37.49	3658.38	37.56	0.07	
49722	10-yr	4155	38.7	4247.24	38.82	0.12	
49722	25-yr	4502	39.24	4668.91	39.44	0.2	
49722	50-yr	4808	39.57	5016.86	39.76	0.19	
49722	100-yr	5180	39.91	5337.54	40.02	0.11	
49722	250-yr	5483	40.15	5685.16	40.28	0.13	
49722	500-yr	5724	40.34	5931.42	40.47	0.13	
49712	2-yr	2321	34	2131.7	33.48	-0.52	
49712	5-yr	3640	37.49	3658.38	37.55	0.06	
49712	10-yr	4155	38.7	4247.24	38.82	0.12	
49712	25-yr	4502	39.24	4668.91	39.44	0.2	
49712	50-yr	4808	39.57	5016.86	39.76	0.19	
49712	100-yr	5180	39.9	5337.54	40.02	0.12	
49712	250-yr	5483	40.15	5685.16	40.28	0.13	
49712	500-yr	5724	40.34	5931.42	40.46	0.12	
48479	2-yr	2321	33.34	2131.7	32.82	-0.52	
48479	5-yr	3640	36.95	3658.38	37.02	0.07	
48479	10-yr	4155	38.26	4247.24	38.38	0.12	
48479	25-yr	4502	38.87	4668.91	39.09	0.22	
48479	50-yr	4808	39.22	5016.86	39.42	0.2	
48479	100-yr	5180	39.58	5337.54	39.71	0.13	
48479	250-yr	5483	39.84	5685.16	39.98	0.14	
48479	500-yr	5724	40.04	5931.42	40.17	0.13	
48100	2-yr	2321	33.18	2131.7	32.67	-0.51	
48100	5-yr	3640	36.79	3658.38	36.87	0.08	
48100	10-yr	4155	38.1	4247.24	38.22	0.12	
48100	25-yr	4502	38.7	4668.91	38.92	0.22	
48100	50-yr	4808	39.14	5016.86	39.35	0.21	
48100	100-yr	5180	39.51	5337.54	39.63	0.12	
48100	250-yr	5483	39.77	5685.16	39.91	0.14	
48100	500-yr	5724	39.97	5931.42	40.1	0.13	
48040	2-yr	2321	33.16	2131.7	32.64	-0.52	
48040	5-yr	3640	36.77	3658.38	36.85	0.08	
48040	10-yr	4155	38.09	4247.24	38.2	0.11	
48040	25-yr	4502	38.69	4668.91	38.91	0.22	
48040	50-yr	4808	39.14	5016.86	39.34	0.2	
48040	100-yr	5180	39.5	5337.54	39.63	0.13	
48040	250-yr	5483	39.77	5685.16	39.91	0.14	
48040	500-yr	5724	39.97	5931.42	40.1	0.13	
47870.5	LOOP 610						Bridge

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
47700	2-yr	2321	32.83	2131.7	32.32	-0.51	
47700	5-yr	3640	36.42	3658.38	36.5	0.08	
47700	10-yr	4155	37.58	4247.24	37.67	0.09	
47700	25-yr	4502	37.93	4668.91	38.08	0.15	
47700	50-yr	4808	38.19	5016.86	38.33	0.14	
47700	100-yr	5180	38.46	5337.54	38.56	0.1	
47700	250-yr	5483	38.7	5685.16	38.82	0.12	
47700	500-yr	5724	38.9	5931.42	39.06	0.16	
47646	2-yr	2321	32.8	2131.7	32.29	-0.51	
47646	5-yr	3640	36.39	3658.38	36.47	0.08	
47646	10-yr	4155	37.55	4247.24	37.64	0.09	
47646	25-yr	4502	37.91	4668.91	38.06	0.15	
47646	50-yr	4808	38.17	5016.86	38.31	0.14	
47646	100-yr	5180	38.45	5337.54	38.55	0.1	
47646	250-yr	5483	38.69	5685.16	38.82	0.13	
47646	500-yr	5724	38.91	5931.42	39.04	0.13	
47641	2-yr	2321	32.8	2131.7	32.29	-0.51	
47641	5-yr	3640	36.39	3658.38	36.47	0.08	
47641	10-yr	4155	37.55	4247.24	37.65	0.1	
47641	25-yr	4502	37.91	4668.91	38.06	0.15	
47641	50-yr	4808	38.17	5016.86	38.31	0.14	
47641	100-yr	5180	38.45	5337.54	38.55	0.1	
47641	250-yr	5483	38.7	5685.16	38.82	0.12	
47641	500-yr	5724	38.91	5931.42	39.04	0.13	
47634.5	COH WATERLINE						Bridge
47628	2-yr	2321	32.77	2131.7	32.26	-0.51	
47628	5-yr	3640	36.36	3658.38	36.44	0.08	
47628	10-yr	4155	37.52	4247.24	37.61	0.09	
47628	25-yr	4502	37.86	4668.91	38.01	0.15	
47628	50-yr	4808	38.13	5016.86	38.27	0.14	
47628	100-yr	5180	38.41	5337.54	38.52	0.11	
47628	250-yr	5483	38.68	5685.16	38.8	0.12	
47628	500-yr	5724	38.88	5931.42	39	0.12	
47102	2-yr	2321	32.44	2131.7	31.92	-0.52	
47102	5-yr	3640	36.12	3658.38	36.2	0.08	
47102	10-yr	4155	37.33	4247.24	37.42	0.09	
47102	25-yr	4502	37.68	4668.91	37.82	0.14	
47102	50-yr	4808	37.94	5016.86	38.08	0.14	
47102	100-yr	5180	38.22	5337.54	38.33	0.11	
47102	250-yr	5483	38.49	5685.16	38.61	0.12	
47102	500-yr	5724	38.7	5931.42	38.82	0.12	
46183	2-yr	2421	31.81	2227.73	31.28	-0.53	
46183	5-yr	3795	35.59	3822.51	35.68	0.09	
46183	10-yr	4347	36.87	4410.53	36.96	0.09	
46183	25-yr	4631	37.22	4794.36	37.36	0.14	
46183	50-yr	4936	37.48	5137.34	37.61	0.13	
46183	100-yr	5309	37.75	5467.54	37.86	0.11	
46183	250-yr	5615	38.03	5789.33	38.15	0.12	
46183	500-yr	5830	38.25	6029.99	38.37	0.12	
46136	2-yr	2421	31.78	2227.73	31.25	-0.53	
46136	5-yr	3795	35.55	3822.51	35.64	0.09	
46136	10-yr	4347	36.84	4410.53	36.93	0.09	
46136	25-yr	4631	37.19	4794.36	37.33	0.14	
46136	50-yr	4936	37.45	5137.34	37.58	0.13	
46136	100-yr	5309	37.73	5467.54	37.83	0.1	
46136	250-yr	5615	38	5789.33	38.12	0.12	
46136	500-yr	5830	38.22	6029.99	38.34	0.12	
46118.5	MANITOU ROAD BRI						Bridge
46095	2-yr	2421	31.72	2227.73	31.19	-0.53	
46095	5-yr	3795	35.27	3822.51	35.35	0.08	
46095	10-yr	4347	36.45	4410.53	36.55	0.1	
46095	25-yr	4631	36.86	4794.36	37.01	0.15	
46095	50-yr	4936	37.17	5137.34	37.32	0.15	
46095	100-yr	5309	37.51	5467.54	37.63	0.12	
46095	250-yr	5615	37.84	5789.33	37.96	0.12	
46095	500-yr	5830	38.07	6029.99	38.19	0.12	
46074	2-yr	2421	31.7	2227.73	31.18	-0.52	
46074	5-yr	3795	35.26	3822.51	35.34	0.08	
46074	10-yr	4347	36.44	4410.53	36.54	0.1	
46074	25-yr	4631	36.84	4794.36	37	0.16	
46074	50-yr	4936	37.16	5137.34	37.31	0.15	
46074	100-yr	5309	37.49	5467.54	37.62	0.13	
46074	250-yr	5615	37.83	5789.33	37.95	0.12	
46074	500-yr	5830	38.06	6029.99	38.17	0.11	
44208	2-yr	2421	30.81	2227.73	30.29	-0.52	
44208	5-yr	3795	34.45	3822.51	34.53	0.08	
44208	10-yr	4347	35.62	4410.53	35.72	0.1	
44208	25-yr	4631	36.01	4794.36	36.15	0.14	
44208	50-yr	4936	36.29	5137.34	36.41	0.12	
44208	100-yr	5309	36.58	5467.54	36.69	0.11	
44208	250-yr	5615	36.91	5789.33	37.01	0.1	
44208	500-yr	5830	37.14	6029.99	37.23	0.09	
41700	2-yr	2599	29.82	2405.22	29.3	-0.52	
41700	5-yr	4063	33.52	4109.45	33.61	0.09	
41700	10-yr	4758	34.67	4842.71	34.75	0.08	
41700	25-yr	5118	35	5246.38	35.1	0.1	
41700	50-yr	5395	35.22	5512.55	35.3	0.08	
41700	100-yr	5707	35.44	5820.59	35.51	0.07	
41700	250-yr	6114	35.7	6221.74	35.76	0.06	
41700	500-yr	6428	35.88	6520.02	35.93	0.05	
39460	2-yr	2599	28.59	2405.22	28.09	-0.5	
39460	5-yr	4063	32.25	4109.45	32.35	0.1	
39460	10-yr	4758	33.6	4842.71	33.69	0.09	
39460	25-yr	5118	33.92	5246.38	34.02	0.1	
39460	50-yr	5395	34.13	5512.55	34.21	0.08	
39460	100-yr	5707	34.35	5820.59	34.42	0.07	
39460	250-yr	6114	34.6	6221.74	34.66	0.06	
39460	500-yr	6428	34.78	6520.02	34.84	0.06	
37807	2-yr	2599	27.19	2405.22	26.7	-0.49	
37807	5-yr	4063	30.59	4109.45	30.71	0.12	
37807	10-yr	4758	32.36	4842.71	32.47	0.11	
37807	25-yr	5118	32.76	5246.38	32.88	0.12	
37807	50-yr	5395	33	5512.55	33.09	0.09	
37807	100-yr	5707	33.26	5820.59	33.35	0.09	
37807	250-yr	6114	33.55	6221.74	33.62	0.07	
37807	500-yr	6428	33.76	6520.02	33.82	0.06	
37170	2-yr	2599	26.66	2405.22	26.18	-0.48	
37170	5-yr	4063	29.93	4109.45	30.04	0.11	
37170	10-yr	4758	31.87	4842.71	32	0.13	
37170	25-yr	5118	32.31	5246.38	32.44	0.13	
37170	50-yr	5395	32.58	5512.55	32.67	0.09	
37170	100-yr	5707	32.85	5820.59	32.94	0.09	
37170	250-yr	6114	33.16	6221.74	33.23	0.07	
37170	500-yr	6428	33.38	6520.02	33.44	0.06	
37123	2-yr	2599	26.62	2405.22	26.14	-0.48	
37123	5-yr	4063	29.87	4109.45	29.97	0.1	
37123	10-yr	4758	31.83	4842.71	31.96	0.13	
37123	25-yr	5118	32.28	5246.38	32.4	0.12	
37123	50-yr	5395	32.54	5512.55	32.64	0.1	
37123	100-yr	5707	32.81	5820.59	32.91	0.1	
37123	250-yr	6114	33.13	6221.74	33.2	0.07	
37123	500-yr	6428	33.35	6520.02	33.41	0.06	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
37076.5	WALLISVILLE ROAD						Bridge
37029	2-yr	2599	26.47	2405.22	26	-0.47	
37029	5-yr	4063	29.34	4109.45	29.43	0.09	
37029	10-yr	4758	30.97	4842.71	31.09	0.12	
37029	25-yr	5118	31.48	5246.38	31.64	0.16	
37029	50-yr	5395	31.85	5512.55	32	0.15	
37029	100-yr	5707	32.26	5820.59	32.41	0.15	
37029	250-yr	6114	32.71	6221.74	32.81	0.1	
37029	500-yr	6428	33	6520.02	33.08	0.08	
34658	2-yr	2599	24.76	2405.22	24.33	-0.43	
34658	5-yr	4063	27.44	4109.45	27.52	0.08	
34658	10-yr	4758	28.55	4842.71	28.7	0.15	
34658	25-yr	5118	29.19	5246.38	29.39	0.2	
34658	50-yr	5395	29.67	5512.55	29.84	0.17	
34658	100-yr	5707	30.18	5820.59	30.38	0.2	
34658	250-yr	6114	30.74	6221.74	30.85	0.11	
34658	500-yr	6428	31.07	6520.02	31.16	0.09	
32049	2-yr	2710	23	2512.89	22.59	-0.41	
32049	5-yr	4238	25.58	4296.81	25.67	0.09	
32049	10-yr	5038	26.7	5138.96	26.87	0.17	
32049	25-yr	5461	27.42	5630.09	27.63	0.21	
32049	50-yr	5820	27.95	5977.25	28.12	0.17	
32049	100-yr	6229	28.51	6378.88	28.73	0.22	
32049	250-yr	6759	29.08	6901.27	29.17	0.09	
32049	500-yr	7168	29.38	7273.2	29.47	0.09	
30749	2-yr	2762	22.03	2561.22	21.63	-0.4	
30749	5-yr	4354	24.7	4418.65	24.79	0.09	
30749	10-yr	5205	25.88	5325.53	26.06	0.18	
30749	25-yr	5688	26.67	5875.95	26.88	0.21	
30749	50-yr	6092	27.23	6269.6	27.41	0.18	
30749	100-yr	6558	27.84	6728.12	28.07	0.23	
30749	250-yr	7052	28.44	7210.86	28.52	0.08	
30749	500-yr	7454	28.73	7607.24	28.81	0.08	
28512	2-yr	2762	20.43	2561.22	20.04	-0.39	
28512	5-yr	4354	23.21	4418.65	23.31	0.1	
28512	10-yr	5205	24.48	5325.53	24.69	0.21	
28512	25-yr	5688	25.42	5875.95	25.64	0.22	
28512	50-yr	6092	26.06	6269.6	26.24	0.18	
28512	100-yr	6558	26.79	6728.12	27.18	0.39	
28512	250-yr	7052	27.71	7210.86	27.8	0.09	
28512	500-yr	7454	28.05	7607.24	28.13	0.08	
25706	2-yr	3015	18.65	2817.78	18.27	-0.38	
25706	5-yr	4815	21.47	4889.52	21.56	0.09	
25706	10-yr	5821	22.78	6009.9	23.01	0.23	
25706	25-yr	6603	23.84	6804.69	24.06	0.22	
25706	50-yr	7182	24.52	7379.42	24.7	0.18	
25706	100-yr	7842	25.41	8008.8	25.98	0.57	
25706	250-yr	8533	26.67	8641.61	26.79	0.12	
25706	500-yr	8886	27.13	9002.15	27.23	0.1	
25647	2-yr	3015	18.63	2817.78	18.25	-0.38	
25647	5-yr	4815	21.46	4889.52	21.55	0.09	
25647	10-yr	5821	22.78	6009.9	23.01	0.23	
25647	25-yr	6603	23.84	6804.69	24.07	0.23	
25647	50-yr	7182	24.54	7379.42	24.71	0.17	
25647	100-yr	7842	25.42	8008.8	26	0.58	
25647	250-yr	8533	26.68	8641.61	26.81	0.13	
25647	500-yr	8886	27.14	9002.15	27.24	0.1	
25645.5	UTILITY CROSSING						Bridge
25643	2-yr	3015	18.61	2817.78	18.22	-0.39	
25643	5-yr	4815	21.45	4889.52	21.54	0.09	
25643	10-yr	5821	22.75	6009.9	22.98	0.23	
25643	25-yr	6603	23.8	6804.69	24.02	0.22	
25643	50-yr	7182	24.49	7379.42	24.66	0.17	
25643	100-yr	7842	25.37	8008.8	25.96	0.59	
25643	250-yr	8533	26.62	8641.61	26.75	0.13	
25643	500-yr	8886	27.09	9002.15	27.19	0.1	
25591	2-yr	3015	18.58	2817.78	18.2	-0.38	
25591	5-yr	4815	21.42	4889.52	21.51	0.09	
25591	10-yr	5821	22.72	6009.9	22.95	0.23	
25591	25-yr	6603	23.78	6804.69	24	0.22	
25591	50-yr	7182	24.46	7379.42	24.63	0.17	
25591	100-yr	7842	25.35	8008.8	25.94	0.59	
25591	250-yr	8533	26.61	8641.61	26.73	0.12	
25591	500-yr	8886	27.07	9002.15	27.17	0.1	
25584.5	42" COH WATERLIN						Bridge
25577	2-yr	3015	18.53	2817.78	18.16	-0.37	
25577	5-yr	4815	21.34	4889.52	21.43	0.09	
25577	10-yr	5821	22.68	6009.9	22.91	0.23	
25577	25-yr	6603	23.72	6804.69	23.93	0.21	
25577	50-yr	7182	24.39	7379.42	24.56	0.17	
25577	100-yr	7842	25.26	8008.8	25.86	0.6	
25577	250-yr	8533	26.52	8641.61	26.64	0.12	
25577	500-yr	8886	26.99	9002.15	27.09	0.1	
25519	2-yr	3015	18.53	2817.78	18.16	-0.37	
25519	5-yr	4815	21.34	4889.52	21.42	0.08	
25519	10-yr	5821	22.67	6009.9	22.9	0.23	
25519	25-yr	6603	23.7	6804.69	23.92	0.22	
25519	50-yr	7182	24.37	7379.42	24.53	0.16	
25519	100-yr	7842	25.22	8008.8	25.8	0.58	
25519	250-yr	8533	26.5	8641.61	26.63	0.13	
25519	500-yr	8886	26.97	9002.15	27.08	0.11	
25333.5	IH-10 BRIDGE						Bridge
25152	2-yr	3015	18.13	2817.78	17.77	-0.36	
25152	5-yr	4815	20.83	4889.52	20.91	0.08	
25152	10-yr	5821	22.13	6009.9	22.34	0.21	
25152	25-yr	6603	23.13	6804.69	23.34	0.21	
25152	50-yr	7182	23.78	7379.42	23.93	0.15	
25152	100-yr	7842	24.42	8008.8	24.75	0.33	
25152	250-yr	8533	25.26	8641.61	25.37	0.11	
25152	500-yr	8886	25.71	9002.15	25.88	0.17	
25105	2-yr	3015	18.1	2817.78	17.74	-0.36	
25105	5-yr	4815	20.8	4889.52	20.88	0.08	
25105	10-yr	5821	22.09	6009.9	22.31	0.22	
25105	25-yr	6603	23.1	6804.69	23.3	0.2	
25105	50-yr	7182	23.74	7379.42	23.89	0.15	
25105	100-yr	7842	24.38	8008.8	24.71	0.33	
25105	250-yr	8533	25.23	8641.61	25.34	0.11	
25105	500-yr	8886	25.67	9002.15	25.85	0.18	
24429	2-yr	3040	17.65	2839.22	17.28	-0.37	
24429	5-yr	4880	20.37	4952.88	20.45	0.08	
24429	10-yr	5910	21.67	6096.74	21.88	0.21	
24429	25-yr	6740	22.68	6937.97	22.89	0.21	
24429	50-yr	7360	23.34	7538.13	23.49	0.15	
24429	100-yr	8030	24	8207.52	24.31	0.31	
24429	250-yr	8780	24.86	8905.07	24.97	0.11	
24429	500-yr	9180	25.32	9319.7	25.51	0.19	
22389	2-yr	3072	15.01	2873.48	14.66	-0.35	
22389	5-yr	4995	17.44	5054.09	17.51	0.07	
22389	10-yr	6055	18.55	6235.46	18.73	0.18	
22389	25-yr	6957	19.44	7150.89	19.63	0.19	
22389	50-yr	7644	20.04	7791.66	20.18	0.14	
22389	100-yr	8348	20.63	8524.97	20.85	0.22	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
22389	250-yr	9192	21.48	9325.95	21.63	0.15	
22389	500-yr	9679	22.01	9826.97	22.32	0.31	
22355	2-yr	3072	14.92	2873.48	14.58	-0.34	
22355	5-yr	4995	17.34	5054.09	17.41	0.07	
22355	10-yr	6055	18.43	6235.46	18.61	0.18	
22355	25-yr	6957	19.32	7150.89	19.5	0.18	
22355	50-yr	7644	19.9	7791.66	20.05	0.15	
22355	100-yr	8348	20.49	8524.97	20.7	0.21	
22355	250-yr	9192	21.34	9325.95	21.49	0.15	
22355	500-yr	9679	21.87	9826.97	22.18	0.31	
22315.5	MARKET STREET BR						Bridge
22275	2-yr	3072	14.47	2873.48	14.15	-0.32	
22275	5-yr	4995	16.65	5054.09	16.72	0.07	
22275	10-yr	6055	17.62	6235.46	17.77	0.15	
22275	25-yr	6957	18.41	7150.89	18.56	0.15	
22275	50-yr	7644	18.89	7791.66	19.03	0.14	
22275	100-yr	8348	19.39	8524.97	19.55	0.16	
22275	250-yr	9192	20.04	9325.95	20.17	0.13	
22275	500-yr	9679	20.45	9826.97	20.59	0.14	
22258	2-yr	3072	14.43	2873.48	14.11	-0.32	
22258	5-yr	4995	16.6	5054.09	16.66	0.06	
22258	10-yr	6055	17.55	6235.46	17.71	0.16	
22258	25-yr	6957	18.33	7150.89	18.49	0.16	
22258	50-yr	7644	18.82	7791.66	18.95	0.13	
22258	100-yr	8348	19.31	8524.97	19.46	0.15	
22258	250-yr	9192	19.95	9325.95	20.08	0.13	
22258	500-yr	9679	20.36	9826.97	20.5	0.14	
22170	2-yr	3072	14.53	2873.48	14.2	-0.33	
22170	5-yr	4995	16.77	5054.09	16.84	0.07	
22170	10-yr	6055	17.77	6235.46	17.93	0.16	
22170	25-yr	6957	18.59	7150.89	18.76	0.17	
22170	50-yr	7644	19.1	7791.66	19.24	0.14	
22170	100-yr	8348	19.63	8524.97	19.79	0.16	
22170	250-yr	9192	20.31	9325.95	20.45	0.14	
22170	500-yr	9679	20.73	9826.97	20.88	0.15	
22159.5	MISSOURI PACIFIC						Bridge
22148	2-yr	3072	14.49	2873.48	14.17	-0.32	
22148	5-yr	4995	16.72	5054.09	16.78	0.06	
22148	10-yr	6055	17.7	6235.46	17.87	0.17	
22148	25-yr	6957	18.52	7150.89	18.68	0.16	
22148	50-yr	7644	19.02	7791.66	19.16	0.14	
22148	100-yr	8348	19.54	8524.97	19.7	0.16	
22148	250-yr	9192	20.16	9325.95	20.29	0.13	
22148	500-yr	9679	20.56	9826.97	20.7	0.14	
22102	2-yr	3072	14.47	2873.48	14.14	-0.33	
22102	5-yr	4995	16.69	5054.09	16.75	0.06	
22102	10-yr	6055	17.67	6235.46	17.83	0.16	
22102	25-yr	6957	18.49	7150.89	18.65	0.16	
22102	50-yr	7644	18.99	7791.66	19.13	0.14	
22102	100-yr	8348	19.51	8524.97	19.67	0.16	
22102	250-yr	9192	20.13	9325.95	20.26	0.13	
22102	500-yr	9679	20.53	9826.97	20.66	0.13	
20985	2-yr	3072	13.64	2873.48	13.33	-0.31	
20985	5-yr	4995	15.6	5054.09	15.67	0.07	
20985	10-yr	6055	16.5	6235.46	16.65	0.15	
20985	25-yr	6957	17.23	7150.89	17.4	0.17	
20985	50-yr	7644	17.7	7791.66	17.86	0.16	
20985	100-yr	8348	18.22	8524.97	18.38	0.16	
20985	250-yr	9192	18.83	9325.95	18.98	0.15	
20985	500-yr	9679	19.23	9826.97	19.38	0.15	
18335	2-yr	3072	12.18	2873.48	11.89	-0.29	
18335	5-yr	4995	14.35	5054.09	14.44	0.09	
18335	10-yr	6055	15.42	6235.46	15.6	0.18	
18335	25-yr	6957	16.27	7150.89	16.5	0.23	
18335	50-yr	7644	16.85	7791.66	17.06	0.21	
18335	100-yr	8348	17.47	8524.97	17.68	0.21	
18335	250-yr	9192	18.19	9325.95	18.37	0.18	
18335	500-yr	9679	18.66	9826.97	18.83	0.17	
17139	2-yr	3050	11.26	2865.51	11	-0.26	
17139	5-yr	5250	13.86	5343.35	13.96	0.1	
17139	10-yr	6520	15.05	6755.17	15.25	0.2	
17139	25-yr	7600	15.96	7898.93	16.21	0.25	
17139	50-yr	8420	16.59	8708.95	16.81	0.22	
17139	100-yr	9330	17.24	9632.85	17.47	0.23	
17139	250-yr	10440	17.99	10693.59	18.19	0.2	
17139	500-yr	11160	18.48	11410.93	18.66	0.18	
16284	2-yr	3050	10.84	2864.21	10.57	-0.27	
16284	5-yr	5289	13.51	5390.45	13.62	0.11	
16284	10-yr	6598	14.73	6839.81	14.94	0.21	
16284	25-yr	7713	15.67	8020.76	15.92	0.25	
16284	50-yr	8553	16.31	8858.34	16.54	0.23	
16284	100-yr	9505	16.98	9813.28	17.21	0.23	
16284	250-yr	10658	17.75	10916.32	17.95	0.2	
16284	500-yr	11427	18.25	11668.89	18.44	0.19	
13551	2-yr	3050	9.87	2864.21	9.61	-0.26	
13551	5-yr	5289	12.56	5390.45	12.67	0.11	
13551	10-yr	6598	13.8	6839.81	14.02	0.22	
13551	25-yr	7713	14.77	8020.76	15.03	0.26	
13551	50-yr	8553	15.42	8858.34	15.67	0.25	
13551	100-yr	9505	16.11	9813.28	16.37	0.26	
13551	250-yr	10658	16.92	10916.32	17.14	0.22	
13551	500-yr	11427	17.44	11668.89	17.65	0.21	
12170	2-yr	3120	9.19	2942.46	8.96	-0.23	
12170	5-yr	5490	11.73	5608.32	11.84	0.11	
12170	10-yr	6880	12.95	7156.05	13.16	0.21	
12170	25-yr	8080	13.91	8440.73	14.18	0.27	
12170	50-yr	8990	14.56	9353.18	14.81	0.25	
12170	100-yr	10020	15.25	10391.68	15.51	0.26	
12170	250-yr	11260	16.06	11606.57	16.28	0.22	
12170	500-yr	12110	16.58	12444.47	16.78	0.2	
9930	2-yr	3120	8.46	2942.46	8.26	-0.2	
9930	5-yr	5490	10.66	5608.32	10.76	0.1	
9930	10-yr	6880	11.76	7156.05	11.94	0.18	
9930	25-yr	8080	12.64	8440.73	12.88	0.24	
9930	50-yr	8990	13.21	9353.18	13.45	0.24	
9930	100-yr	10020	13.84	10391.68	14.08	0.24	
9930	250-yr	11260	14.57	11606.57	14.77	0.2	
9930	500-yr	12110	15.04	12444.47	15.22	0.18	
9888	2-yr	3154	8.36	2985.87	8.17	-0.19	
9888	5-yr	5603	10.48	5729.18	10.58	0.1	
9888	10-yr	7046	11.54	7331.46	11.71	0.17	
9888	25-yr	8293	12.38	8673.69	12.6	0.22	
9888	50-yr	9236	12.92	9627.67	13.14	0.22	
9888	100-yr	10316	13.51	10712.51	13.74	0.23	
9888	250-yr	11615	14.21	11989.45	14.39	0.18	
9888	500-yr	12508	14.64	12874.67	14.82	0.18	
9856.5	PTRA RR BRIDGES						Bridge
9824	2-yr	3154	8.22	2985.87	8.03	-0.19	
9824	5-yr	5603	10.21	5729.18	10.3	0.09	
9824	10-yr	7046	11.19	7331.46	11.35	0.16	
9824	25-yr	8293	11.97	8673.69	12.17	0.2	
9824	50-yr	9236	12.46	9627.67	12.66	0.2	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
9824	100-yr	10316	13	10712.51	13.21	0.21	
9824	250-yr	11615	13.63	11989.45	13.8	0.17	
9824	500-yr	12508	14.02	12874.67	14.18	0.16	
9735	2-yr	3154	8.17	2985.87	7.98	-0.19	
9735	5-yr	5603	10.12	5729.18	10.2	0.08	
9735	10-yr	7046	11.08	7331.46	11.23	0.15	
9735	25-yr	8293	11.85	8673.69	12.05	0.2	
9735	50-yr	9236	12.34	9627.67	12.53	0.19	
9735	100-yr	10316	12.86	10712.51	13.07	0.21	
9735	250-yr	11615	13.49	11989.45	13.65	0.16	
9735	500-yr	12508	13.87	12874.67	14.03	0.16	
8375	2-yr	3154	7.2	2985.87	7	-0.2	
8375	5-yr	5603	9.17	5729.18	9.26	0.09	
8375	10-yr	7046	10.22	7331.46	10.37	0.15	
8375	25-yr	8293	11.07	8673.69	11.28	0.21	
8375	50-yr	9236	11.57	9627.67	11.78	0.21	
8375	100-yr	10316	12.12	10712.51	12.35	0.23	
8375	250-yr	11615	12.79	11989.45	12.96	0.17	
8375	500-yr	12508	13.2	12874.67	13.36	0.16	
6110	2-yr	3154	4.47	2985.87	4.23	-0.24	
6110	5-yr	5603	7.02	5729.18	7.14	0.12	
6110	10-yr	7046	8.47	7331.46	8.8	0.33	
6110	25-yr	8293	9.7	8673.69	9.92	0.22	
6110	50-yr	9236	10.24	9627.67	10.45	0.21	
6110	100-yr	10316	10.81	10712.51	11.01	0.2	
6110	250-yr	11615	11.5	11989.45	11.69	0.19	
6110	500-yr	12508	11.94	12874.67	12.12	0.18	
6075	2-yr	3154	4.4	2985.87	4.15	-0.25	
6075	5-yr	5603	6.89	5729.18	7	0.11	
6075	10-yr	7046	8.37	7331.46	8.78	0.41	
6075	25-yr	8293	9.68	8673.69	9.9	0.22	
6075	50-yr	9236	10.21	9627.67	10.43	0.22	
6075	100-yr	10316	10.79	10712.51	11	0.21	
6075	250-yr	11615	11.48	11989.45	11.67	0.19	
6075	500-yr	12508	11.92	12874.67	12.1	0.18	
6064.5	ABANDONED RAILRO						Bridge
6053	2-yr	3154	4.32	2985.87	4.07	-0.25	
6053	5-yr	5603	6.83	5729.18	6.94	0.11	
6053	10-yr	7046	8.07	7331.46	8.34	0.27	
6053	25-yr	8293	9.25	8673.69	9.52	0.27	
6053	50-yr	9236	9.9	9627.67	10.15	0.25	
6053	100-yr	10316	10.57	10712.51	10.81	0.24	
6053	250-yr	11615	11.34	11989.45	11.55	0.21	
6053	500-yr	12508	11.83	12874.67	12.02	0.19	
5916	2-yr	3154	3.98	2985.87	3.71	-0.27	
5916	5-yr	5603	6.68	5729.18	6.79	0.11	
5916	10-yr	7046	7.96	7331.46	8.22	0.26	
5916	25-yr	8293	9.14	8673.69	9.42	0.28	
5916	50-yr	9236	9.81	9627.67	10.06	0.25	
5916	100-yr	10316	10.48	10712.51	10.72	0.24	
5916	250-yr	11615	11.25	11989.45	11.47	0.22	
5916	500-yr	12508	11.75	12874.67	11.94	0.19	
5741	2-yr	3154	3.77	2985.87	3.49	-0.28	
5741	5-yr	5603	6.61	5729.18	6.73	0.12	
5741	10-yr	7046	7.96	7331.46	8.23	0.27	
5741	25-yr	8293	9.14	8673.69	9.42	0.28	
5741	50-yr	9236	9.81	9627.67	10.07	0.26	
5741	100-yr	10316	10.5	10712.51	10.74	0.24	
5741	250-yr	11615	11.27	11989.45	11.49	0.22	
5741	500-yr	12508	11.77	12874.67	11.96	0.19	
5718.5	COH WATERPLANT B						Bridge
5695	2-yr	3154	3.66	2985.87	3.37	-0.29	
5695	5-yr	5603	6.54	5729.18	6.67	0.13	
5695	10-yr	7046	7.92	7331.46	8.18	0.26	
5695	25-yr	8293	9.11	8673.69	9.39	0.28	
5695	50-yr	9236	9.78	9627.67	10.04	0.26	
5695	100-yr	10316	10.47	10712.51	10.71	0.24	
5695	250-yr	11615	11.25	11989.45	11.46	0.21	
5695	500-yr	12508	11.74	12874.67	11.94	0.2	
5691	2-yr	3154	3.53	2985.87	3.27	-0.26	
5691	5-yr	5603	6.01	5729.18	6.12	0.11	
5691	10-yr	7046	7.34	7331.46	7.58	0.24	
5691	25-yr	8293	8.43	8673.69	8.68	0.25	
5691	50-yr	9236	9.01	9627.67	9.23	0.22	
5691	100-yr	10316	9.59	10712.51	9.79	0.2	
5691	250-yr	11615	10.24	11989.45	10.43	0.19	
5691	500-yr	12508	10.66	12874.67	10.82	0.16	
5680.5	ABANDONED TIMBER						Bridge
5669	2-yr	3154	3.43	2985.87	3.18	-0.25	
5669	5-yr	5603	5.75	5729.18	5.83	0.08	
5669	10-yr	7046	6.62	7331.46	6.78	0.16	
5669	25-yr	8293	7.45	8673.69	7.69	0.24	
5669	50-yr	9236	8.01	9627.67	8.21	0.2	
5669	100-yr	10316	8.55	10712.51	8.74	0.19	
5669	250-yr	11615	9.17	11989.45	9.34	0.17	
5669	500-yr	12508	9.57	12874.67	9.72	0.15	
5597	2-yr	3154	3.42	2985.87	3.17	-0.25	
5597	5-yr	5603	5.75	5729.18	5.84	0.09	
5597	10-yr	7046	6.64	7331.46	6.8	0.16	
5597	25-yr	8293	7.37	8673.69	7.6	0.23	
5597	50-yr	9236	7.92	9627.67	8.12	0.2	
5597	100-yr	10316	8.46	10712.51	8.65	0.19	
5597	250-yr	11615	9.08	11989.45	9.26	0.18	
5597	500-yr	12508	9.49	12874.67	9.65	0.16	
5585	2-yr	3154	3.42	2985.87	3.16	-0.26	
5585	5-yr	5603	5.74	5729.18	5.83	0.09	
5585	10-yr	7046	6.63	7331.46	6.79	0.16	
5585	25-yr	8293	7.35	8673.69	7.58	0.23	
5585	50-yr	9236	7.89	9627.67	8.09	0.2	
5585	100-yr	10316	8.43	10712.51	8.61	0.18	
5585	250-yr	11615	9.04	11989.45	9.21	0.17	
5585	500-yr	12508	9.44	12874.67	9.6	0.16	
5543	2-yr	3154	3.39	2985.87	3.14	-0.25	
5543	5-yr	5603	5.7	5729.18	5.78	0.08	
5543	10-yr	7046	6.58	7331.46	6.73	0.15	
5543	25-yr	8293	7.27	8673.69	7.49	0.22	
5543	50-yr	9236	7.79	9627.67	7.98	0.19	
5543	100-yr	10316	8.3	10712.51	8.47	0.17	
5543	250-yr	11615	8.87	11989.45	9.03	0.16	
5543	500-yr	12508	9.25	12874.67	9.39	0.14	
4062	2-yr	3154	1.72	2985.87	1.5	-0.22	
4062	5-yr	5603	4.21	5729.18	4.32	0.11	
4062	10-yr	7046	5.29	7331.46	5.49	0.2	
4062	25-yr	8293	6.14	8673.69	6.4	0.26	
4062	50-yr	9236	6.74	9627.67	6.96	0.22	
4062	100-yr	10316	7.32	10712.51	7.53	0.21	
4062	250-yr	11615	7.97	11989.45	8.15	0.18	
4062	500-yr	12508	8.39	12874.67	8.55	0.16	
3171	2-yr	3154	1.39	2985.87	1.17	-0.22	
3171	5-yr	5603	3.72	5729.18	3.82	0.1	
3171	10-yr	7046	4.74	7331.46	4.93	0.19	
3171	25-yr	8293	5.58	8673.69	5.85	0.27	

Table 4. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Original Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
3171	50-yr	9236	6.21	9627.67	6.44	0.23	
3171	100-yr	10316	6.84	10712.51	7.06	0.22	
3171	250-yr	11615	7.54	11989.45	7.73	0.19	
3171	500-yr	12508	7.98	12874.67	8.16	0.18	
3116	2-yr	3154	1.37	2985.87	1.15	-0.22	
3116	5-yr	5603	3.7	5729.18	3.79	0.09	
3116	10-yr	7046	4.71	7331.46	4.9	0.19	
3116	25-yr	8293	5.55	8673.69	5.81	0.26	
3116	50-yr	9236	6.16	9627.67	6.39	0.23	
3116	100-yr	10316	6.77	10712.51	6.98	0.21	
3116	250-yr	11615	7.44	11989.45	7.62	0.18	
3116	500-yr	12508	7.87	12874.67	8.04	0.17	
3113.5	COH WATERLINE						Bridge
3110	2-yr	3154	1.35	2985.87	1.14	-0.21	
3110	5-yr	5603	3.67	5729.18	3.77	0.1	
3110	10-yr	7046	4.66	7331.46	4.84	0.18	
3110	25-yr	8293	5.44	8673.69	5.69	0.25	
3110	50-yr	9236	6.02	9627.67	6.24	0.22	
3110	100-yr	10316	6.61	10712.51	6.82	0.21	
3110	250-yr	11615	7.28	11989.45	7.48	0.2	
3110	500-yr	12508	7.73	12874.67	7.92	0.19	
3105	2-yr	3154	1.29	2985.87	1.08	-0.21	
3105	5-yr	5603	3.56	5729.18	3.65	0.09	
3105	10-yr	7046	4.52	7331.46	4.69	0.17	
3105	25-yr	8293	5.27	8673.69	5.51	0.24	
3105	50-yr	9236	5.82	9627.67	6.03	0.21	
3105	100-yr	10316	6.37	10712.51	6.56	0.19	
3105	250-yr	11615	6.99	11989.45	7.17	0.18	
3105	500-yr	12508	7.4	12874.67	7.56	0.16	
3015.5	FEDERAL RD BRIDG						Bridge
2985	2-yr	3154	1.19	2985.87	0.99	-0.2	
2985	5-yr	5603	3.4	5729.18	3.49	0.09	
2985	10-yr	7046	4.32	7331.46	4.49	0.17	
2985	25-yr	8293	5.04	8673.69	5.26	0.22	
2985	50-yr	9236	5.56	9627.67	5.76	0.2	
2985	100-yr	10316	6.11	10712.51	6.3	0.19	
2985	250-yr	11615	6.73	11989.45	6.9	0.17	
2985	500-yr	12508	7.13	12874.67	7.3	0.17	
2942	2-yr	3154	1.18	2985.87	0.97	-0.21	
2942	5-yr	5603	3.38	5729.18	3.47	0.09	
2942	10-yr	7046	4.31	7331.46	4.48	0.17	
2942	25-yr	8293	5.03	8673.69	5.24	0.21	
2942	50-yr	9236	5.54	9627.67	5.74	0.2	
2942	100-yr	10316	6.09	10712.51	6.28	0.19	
2942	250-yr	11615	6.71	11989.45	6.89	0.18	
2942	500-yr	12508	7.12	12874.67	7.29	0.17	
2140	2-yr	3154	0.43	2985.87	0.24	-0.19	
2140	5-yr	5603	2.53	5729.18	2.62	0.09	
2140	10-yr	7046	3.42	7331.46	3.58	0.16	
2140	25-yr	8293	4.11	8673.69	4.32	0.21	
2140	50-yr	9236	4.61	9627.67	4.82	0.21	
2140	100-yr	10316	5.16	10712.51	5.35	0.19	
2140	250-yr	11615	5.78	11989.45	5.95	0.17	
2140	500-yr	12508	6.19	12874.67	6.35	0.16	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
Station	Profile	Q Total (cfs)	W.S. Elev (ft)	Q Total (cfs)	W.S. Elev (ft)	W.S. Elev (ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
76752	5-yr	520	47.42	517.35	47.35	-0.07	
76752	10-yr	650	48.19	661.69	48.22	0.03	
76752	25-yr	770	48.45	791.87	48.59	0.14	
76752	50-yr	860	48.92	891.8	49.03	0.11	
76752	100-yr	960	49.33	993.46	49.53	0.2	
76752	250-yr	1110	49.91	1145.87	49.99	0.08	
76752	500-yr	1210	50.07	1248.55	50.08	0.01	
76249	2-yr	320	44.43	294.37	43.94	-0.49	
76249	5-yr	520	47.38	517.35	47.31	-0.07	
76249	10-yr	650	48.16	661.69	48.19	0.03	
76249	25-yr	770	48.43	791.87	48.56	0.13	
76249	50-yr	860	48.9	891.8	49.01	0.11	
76249	100-yr	960	49.31	993.46	49.51	0.2	
76249	250-yr	1110	49.89	1145.87	49.97	0.08	
76249	500-yr	1210	50.07	1248.55	50.07	0	
76202	2-yr	320	44.42	294.37	43.93	-0.49	
76202	5-yr	520	47.38	517.35	47.3	-0.08	
76202	10-yr	650	48.16	661.69	48.19	0.03	
76202	25-yr	770	48.42	791.87	48.56	0.14	
76202	50-yr	860	48.9	891.8	49.01	0.11	
76202	100-yr	960	49.3	993.46	49.51	0.21	
76202	250-yr	1110	49.89	1145.87	49.97	0.08	
76202	500-yr	1210	50.07	1248.55	50.07	0	
76196.5	NECHES STREET						Bridge
76153	2-yr	528	44.41	490.62	43.91	-0.5	
76153	5-yr	861	47.37	862.25	47.29	-0.08	
76153	10-yr	1076	48.16	1102.81	48.18	0.02	
76153	25-yr	1277	48.42	1319.78	48.55	0.13	
76153	50-yr	1438	48.89	1486.34	49	0.11	
76153	100-yr	1605	49.3	1655.77	49.51	0.21	
76153	250-yr	1856	49.88	1909.78	49.97	0.09	
76153	500-yr	2023	50.07	2080.91	50.07	0	
76033	2-yr	528	44.41	490.62	43.92	-0.49	
76033	5-yr	861	47.34	862.25	47.26	-0.08	
76033	10-yr	1076	48.12	1102.81	48.14	0.02	
76033	25-yr	1277	48.37	1319.78	48.5	0.13	
76033	50-yr	1438	48.84	1486.34	48.95	0.11	
76033	100-yr	1605	49.24	1655.77	49.45	0.21	
76033	250-yr	1856	49.82	1909.78	49.9	0.08	
76033	500-yr	2023	50.03	2080.91	50.03	0	
76027.5	US 59 BRIDGE						Culvert
75223	2-yr	528	44.31	490.62	43.82	-0.49	
75223	5-yr	861	47.05	862.25	46.97	-0.08	
75223	10-yr	1076	47.85	1102.81	47.9	0.05	
75223	25-yr	1277	48.37	1319.78	48.51	0.14	
75223	50-yr	1438	48.86	1486.34	48.97	0.11	
75223	100-yr	1605	49.27	1655.77	49.47	0.2	
75223	250-yr	1856	49.85	1909.78	49.93	0.08	
75223	500-yr	2023	50.04	2080.91	50.05	0.01	
75060	2-yr	528	44.3	490.62	43.81	-0.49	
75060	5-yr	861	47.05	862.25	46.97	-0.08	
75060	10-yr	1076	47.85	1102.81	47.9	0.05	
75060	25-yr	1277	48.37	1319.78	48.51	0.14	
75060	50-yr	1438	48.86	1486.34	48.97	0.11	
75060	100-yr	1605	49.27	1655.77	49.48	0.21	
75060	250-yr	1856	49.85	1909.78	49.93	0.08	
75060	500-yr	2023	50.04	2080.91	50.05	0.01	
74271	2-yr	528	43.89	490.62	43.42	-0.47	
74271	5-yr	861	46.91	862.25	46.82	-0.09	
74271	10-yr	1076	47.76	1102.81	47.81	0.05	
74271	25-yr	1277	48.29	1319.78	48.44	0.15	
74271	50-yr	1438	48.8	1486.34	48.91	0.11	
74271	100-yr	1605	49.22	1655.77	49.43	0.21	
74271	250-yr	1856	49.81	1909.78	49.89	0.08	
74271	500-yr	2023	50.03	2080.91	50.04	0.01	
73925	2-yr	528	43.73	490.62	43.24	-0.49	
73925	5-yr	861	46.84	862.25	46.75	-0.09	
73925	10-yr	1076	47.71	1102.81	47.77	0.06	
73925	25-yr	1277	48.25	1319.78	48.4	0.15	
73925	50-yr	1438	48.77	1486.34	48.88	0.11	
73925	100-yr	1605	49.19	1655.77	49.41	0.22	
73925	250-yr	1856	49.79	1909.78	49.87	0.08	
73925	500-yr	2023	50.03	2080.91	50.04	0.01	
73878	2-yr	528	43.72	490.62	43.22	-0.5	
73878	5-yr	861	46.83	862.25	46.74	-0.09	
73878	10-yr	1076	47.71	1102.81	47.76	0.05	
73878	25-yr	1277	48.25	1319.78	48.4	0.15	
73878	50-yr	1438	48.77	1486.34	48.88	0.11	
73878	100-yr	1605	49.19	1655.77	49.41	0.22	
73878	250-yr	1856	49.79	1909.78	49.87	0.08	
73878	500-yr	2023	50.03	2080.91	50.04	0.01	
73877.5	PEDESTRIAN BRIDG						Bridge
73816	2-yr	528	43.67	490.62	43.18	-0.49	
73816	5-yr	861	46.81	862.25	46.71	-0.1	
73816	10-yr	1076	47.69	1102.81	47.74	0.05	
73816	25-yr	1277	48.23	1319.78	48.39	0.16	
73816	50-yr	1438	48.75	1486.34	48.87	0.12	
73816	100-yr	1605	49.18	1655.77	49.4	0.22	
73816	250-yr	1856	49.78	1909.78	49.86	0.08	
73816	500-yr	2023	50.03	2080.91	50.04	0.01	
73769	2-yr	528	43.65	490.62	43.16	-0.49	
73769	5-yr	861	46.8	862.25	46.7	-0.1	
73769	10-yr	1076	47.69	1102.81	47.74	0.05	
73769	25-yr	1277	48.23	1319.78	48.38	0.15	
73769	50-yr	1438	48.75	1486.34	48.86	0.11	
73769	100-yr	1605	49.18	1655.77	49.39	0.21	
73769	250-yr	1856	49.78	1909.78	49.85	0.07	
73769	500-yr	2023	50.03	2080.91	50.04	0.01	
73319	2-yr	837	43.42	775.16	42.91	-0.51	
73319	5-yr	1380	46.69	1368.33	46.59	-0.1	
73319	10-yr	1729	47.59	1772.1	47.64	0.05	
73319	25-yr	2060	48.12	2113.41	48.28	0.16	
73319	50-yr	2319	48.66	2386.82	48.77	0.11	
73319	100-yr	2594	49.09	2663.28	49.31	0.22	
73319	250-yr	3003	49.7	3082.68	49.78	0.08	
73319	500-yr	3277	50.02	3364.69	50.02	0	
73265	2-yr	837	43.39	775.16	42.87	-0.52	
73265	5-yr	1380	46.68	1368.33	46.58	-0.1	
73265	10-yr	1729	47.58	1772.1	47.63	0.05	
73265	25-yr	2060	48.11	2113.41	48.27	0.16	
73265	50-yr	2319	48.65	2386.82	48.76	0.11	
73265	100-yr	2594	49.08	2663.28	49.3	0.22	
73265	250-yr	3003	49.69	3082.68	49.77	0.08	
73265	500-yr	3277	49.97	3364.69	50.02	0.05	
73239.5	FALLS STREET BRI						Bridge
73213	2-yr	837	43.33	775.16	42.82	-0.51	
73213	5-yr	1380	46.48	1368.33	46.38	-0.1	
73213	10-yr	1729	47.41	1772.1	47.46	0.05	
73213	25-yr	2060	47.99	2113.41	48.16	0.17	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

Station	Profile	HEC-1 / RAS 3.1.1 Q Total (cfs)	HEC-1 / RAS 3.1.1 W.S. Elev (ft)	HEC-HMS with HEC-1 Q Total (cfs)	HEC-HMS with HEC-1 W.S. Elev (ft)	Difference W.S. Elev (ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
73213	50-yr	2319	48.56	2386.82	48.69	0.13	
73213	100-yr	2594	49.01	2663.28	49.24	0.23	
73213	250-yr	3003	49.63	3082.68	49.71	0.08	
73213	500-yr	3277	49.92	3364.69	50.02	0.1	
73180	2-yr	837	43.32	775.16	42.8	-0.52	
73180	5-yr	1380	46.47	1368.33	46.37	-0.1	
73180	10-yr	1729	47.4	1772.1	47.46	0.06	
73180	25-yr	2060	47.98	2113.41	48.15	0.17	
73180	50-yr	2319	48.56	2386.82	48.68	0.12	
73180	100-yr	2594	49	2663.28	49.24	0.24	
73180	250-yr	3003	49.62	3082.68	49.7	0.08	
73180	500-yr	3277	49.91	3364.69	49.97	0.06	
72989	2-yr	837	43.22	775.16	42.7	-0.52	
72989	5-yr	1380	46.43	1368.33	46.33	-0.1	
72989	10-yr	1729	47.36	1772.1	47.41	0.05	
72989	25-yr	2060	47.94	2113.41	48.11	0.17	
72989	50-yr	2319	48.52	2386.82	48.64	0.12	
72989	100-yr	2594	48.97	2663.28	49.2	0.23	
72989	250-yr	3003	49.59	3082.68	49.67	0.08	
72989	500-yr	3277	49.87	3364.69	49.93	0.06	
72940	2-yr	837	43.19	775.16	42.67	-0.52	
72940	5-yr	1380	46.42	1368.33	46.32	-0.1	
72940	10-yr	1729	47.35	1772.1	47.4	0.05	
72940	25-yr	2060	47.93	2113.41	48.1	0.17	
72940	50-yr	2319	48.51	2386.82	48.63	0.12	
72940	100-yr	2594	48.96	2663.28	49.2	0.24	
72940	250-yr	3003	49.58	3082.68	49.66	0.08	
72940	500-yr	3277	49.87	3364.69	49.93	0.06	
72914.5	LEFFINGWELL ST						Bridge
72889	2-yr	837	43.16	775.16	42.63	-0.53	
72889	5-yr	1380	46.39	1368.33	46.28	-0.11	
72889	10-yr	1729	47.3	1772.1	47.35	0.05	
72889	25-yr	2060	47.87	2113.41	48.05	0.18	
72889	50-yr	2319	48.45	2386.82	48.58	0.13	
72889	100-yr	2594	48.91	2663.28	49.16	0.25	
72889	250-yr	3003	49.54	3082.68	49.62	0.08	
72889	500-yr	3277	49.83	3364.69	49.89	0.06	
72859	2-yr	837	43.14	775.16	42.61	-0.53	
72859	5-yr	1380	46.38	1368.33	46.27	-0.11	
72859	10-yr	1729	47.29	1772.1	47.34	0.05	
72859	25-yr	2060	47.86	2113.41	48.03	0.17	
72859	50-yr	2319	48.44	2386.82	48.57	0.13	
72859	100-yr	2594	48.9	2663.28	49.14	0.24	
72859	250-yr	3003	49.53	3082.68	49.61	0.08	
72859	500-yr	3277	49.82	3364.69	49.88	0.06	
72524	2-yr	837	42.97	775.16	42.44	-0.53	
72524	5-yr	1380	46.3	1368.33	46.18	-0.12	
72524	10-yr	1729	47.23	1772.1	47.28	0.05	
72524	25-yr	2060	47.81	2113.41	47.99	0.18	
72524	50-yr	2319	48.41	2386.82	48.53	0.12	
72524	100-yr	2594	48.87	2663.28	49.12	0.25	
72524	250-yr	3003	49.51	3082.68	49.59	0.08	
72524	500-yr	3277	49.79	3364.69	49.85	0.06	
72504	2-yr	837	42.96	775.16	42.43	-0.53	
72504	5-yr	1380	46.28	1368.33	46.17	-0.11	
72504	10-yr	1729	47.23	1772.1	47.28	0.05	
72504	25-yr	2060	47.81	2113.41	47.99	0.18	
72504	50-yr	2319	48.4	2386.82	48.53	0.13	
72504	100-yr	2594	48.87	2663.28	49.12	0.25	
72504	250-yr	3003	49.51	3082.68	49.58	0.07	
72504	500-yr	3277	49.79	3364.69	49.85	0.06	
72503.5	COH WATERLINE						Bridge
72495	2-yr	837	42.96	775.16	42.43	-0.53	
72495	5-yr	1380	46.27	1368.33	46.15	-0.12	
72495	10-yr	1729	47.22	1772.1	47.27	0.05	
72495	25-yr	2060	47.8	2113.41	47.98	0.18	
72495	50-yr	2319	48.4	2386.82	48.53	0.13	
72495	100-yr	2594	48.86	2663.28	49.11	0.25	
72495	250-yr	3003	49.5	3082.68	49.58	0.08	
72495	500-yr	3277	49.79	3364.69	49.84	0.05	
72492	2-yr	837	42.96	775.16	42.43	-0.53	
72492	5-yr	1380	46.27	1368.33	46.15	-0.12	
72492	10-yr	1729	47.22	1772.1	47.27	0.05	
72492	25-yr	2060	47.8	2113.41	47.98	0.18	
72492	50-yr	2319	48.4	2386.82	48.52	0.12	
72492	100-yr	2594	48.86	2663.28	49.11	0.25	
72492	250-yr	3003	49.5	3082.68	49.58	0.08	
72492	500-yr	3277	49.78	3364.69	49.84	0.06	
72491.5	HIRSCH STREET						Bridge
72402	2-yr	837	42.89	775.16	42.36	-0.53	
72402	5-yr	1380	46.05	1368.33	45.92	-0.13	
72402	10-yr	1729	47.11	1772.1	47.16	0.05	
72402	25-yr	2060	47.72	2113.41	47.92	0.2	
72402	50-yr	2319	48.35	2386.82	48.48	0.13	
72402	100-yr	2594	48.82	2663.28	49.08	0.26	
72402	250-yr	3003	49.47	3082.68	49.55	0.08	
72402	500-yr	3277	49.76	3364.69	49.81	0.05	
72355	2-yr	837	42.87	775.16	42.33	-0.54	
72355	5-yr	1380	46.03	1368.33	45.9	-0.13	
72355	10-yr	1729	47.1	1772.1	47.15	0.05	
72355	25-yr	2060	47.72	2113.41	47.91	0.19	
72355	50-yr	2319	48.34	2386.82	48.47	0.13	
72355	100-yr	2594	48.82	2663.28	49.07	0.25	
72355	250-yr	3003	49.47	3082.68	49.54	0.07	
72355	500-yr	3277	49.75	3364.69	49.81	0.06	
72006	2-yr	837	42.73	775.16	42.2	-0.53	
72006	5-yr	1380	45.9	1368.33	45.76	-0.14	
72006	10-yr	1729	47.02	1772.1	47.07	0.05	
72006	25-yr	2060	47.64	2113.41	47.84	0.2	
72006	50-yr	2319	48.28	2386.82	48.41	0.13	
72006	100-yr	2594	48.76	2663.28	49.02	0.26	
72006	250-yr	3003	49.41	3082.68	49.49	0.08	
72006	500-yr	3277	49.7	3364.69	49.75	0.05	
71710	2-yr	837	42.67	775.16	42.12	-0.55	
71710	5-yr	1380	45.84	1368.33	45.7	-0.14	
71710	10-yr	1729	46.98	1772.1	47.03	0.05	
71710	25-yr	2060	47.6	2113.41	47.8	0.2	
71710	50-yr	2319	48.25	2386.82	48.38	0.13	
71710	100-yr	2594	48.73	2663.28	48.99	0.26	
71710	250-yr	3003	49.38	3082.68	49.46	0.08	
71710	500-yr	3277	49.67	3364.69	49.72	0.05	
71663	2-yr	837	42.66	775.16	42.11	-0.55	
71663	5-yr	1380	45.84	1368.33	45.7	-0.14	
71663	10-yr	1729	46.97	1772.1	47.02	0.05	
71663	25-yr	2060	47.6	2113.41	47.8	0.2	
71663	50-yr	2319	48.24	2386.82	48.37	0.13	
71663	100-yr	2594	48.72	2663.28	48.99	0.27	
71663	250-yr	3003	49.38	3082.68	49.46	0.08	
71663	500-yr	3277	49.66	3364.69	49.72	0.06	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
Station	Profile	Q Total (cfs)	W.S. Elev (ft)	Q Total (cfs)	W.S. Elev (ft)	W.S. Elev (ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
71657.5	WAYNE STREET						Bridge
71607	2-yr	837	42.64	775.16	42.09	-0.55	
71607	5-yr	1380	45.8	1368.33	45.66	-0.14	
71607	10-yr	1729	46.89	1772.1	46.94	0.05	
71607	25-yr	2060	47.52	2113.41	47.73	0.21	
71607	50-yr	2319	48.19	2386.82	48.32	0.13	
71607	100-yr	2594	48.68	2663.28	48.95	0.27	
71607	250-yr	3003	49.34	3082.68	49.42	0.08	
71607	500-yr	3277	49.63	3364.69	49.68	0.05	
71360	2-yr	837	42.59	775.16	42.04	-0.55	
71360	5-yr	1380	45.76	1368.33	45.62	-0.14	
71360	10-yr	1729	46.86	1772.1	46.91	0.05	
71360	25-yr	2060	47.49	2113.41	47.71	0.22	
71360	50-yr	2319	48.17	2386.82	48.3	0.13	
71360	100-yr	2594	48.66	2663.28	48.94	0.28	
71360	250-yr	3003	49.32	3082.68	49.4	0.08	
71360	500-yr	3277	49.61	3364.69	49.66	0.05	
71037	2-yr	1040	42.44	935.54	41.89	-0.55	
71037	5-yr	1672	45.68	1595.77	45.54	-0.14	
71037	10-yr	1916	46.83	1915.94	46.87	0.04	
71037	25-yr	2166	47.46	2196.29	47.68	0.22	
71037	50-yr	2374	48.14	2434.21	48.28	0.14	
71037	100-yr	2599	48.64	2677.3	48.92	0.28	
71037	250-yr	2915	49.31	2948.68	49.39	0.08	
71037	500-yr	3093	49.59	3119.09	49.65	0.06	
70520	2-yr	1040	42.34	935.54	41.78	-0.56	
70520	5-yr	1672	45.62	1595.77	45.48	-0.14	
70520	10-yr	1916	46.79	1915.94	46.84	0.05	
70520	25-yr	2166	47.44	2196.29	47.66	0.22	
70520	50-yr	2374	48.12	2434.21	48.26	0.14	
70520	100-yr	2599	48.62	2677.3	48.9	0.28	
70520	250-yr	2915	49.29	2948.68	49.37	0.08	
70520	500-yr	3093	49.58	3119.09	49.63	0.05	
70462	2-yr	1040	42.33	935.54	41.77	-0.56	
70462	5-yr	1672	45.61	1595.77	45.46	-0.15	
70462	10-yr	1916	46.78	1915.94	46.83	0.05	
70462	25-yr	2166	47.43	2196.29	47.65	0.22	
70462	50-yr	2374	48.11	2434.21	48.25	0.14	
70462	100-yr	2599	48.61	2677.3	48.9	0.29	
70462	250-yr	2915	49.29	2948.68	49.37	0.08	
70462	500-yr	3093	49.57	3119.09	49.63	0.06	
70436.5	WIPPRECHT STREET						Bridge
70411	2-yr	1040	42.31	935.54	41.76	-0.55	
70411	5-yr	1672	45.59	1595.77	45.44	-0.15	
70411	10-yr	1916	46.77	1915.94	46.82	0.05	
70411	25-yr	2166	47.42	2196.29	47.64	0.22	
70411	50-yr	2374	48.1	2434.21	48.24	0.14	
70411	100-yr	2599	48.61	2677.3	48.89	0.28	
70411	250-yr	2915	49.28	2948.68	49.36	0.08	
70411	500-yr	3093	49.57	3119.09	49.62	0.05	
70399	2-yr	1040	42.31	935.54	41.76	-0.55	
70399	5-yr	1672	45.59	1595.77	45.44	-0.15	
70399	10-yr	1916	46.77	1915.94	46.82	0.05	
70399	25-yr	2166	47.42	2196.29	47.64	0.22	
70399	50-yr	2374	48.1	2434.21	48.24	0.14	
70399	100-yr	2599	48.61	2677.3	48.89	0.28	
70399	250-yr	2915	49.28	2948.68	49.36	0.08	
70399	500-yr	3093	49.57	3119.09	49.62	0.05	
69347	2-yr	1040	42.05	935.54	41.5	-0.55	
69347	5-yr	1672	45.41	1595.77	45.27	-0.14	
69347	10-yr	1916	46.67	1915.94	46.72	0.05	
69347	25-yr	2166	47.33	2196.29	47.57	0.24	
69347	50-yr	2374	48.03	2434.21	48.17	0.14	
69347	100-yr	2599	48.55	2677.3	48.83	0.28	
69347	250-yr	2915	49.23	2948.68	49.31	0.08	
69347	500-yr	3093	49.52	3119.09	49.57	0.05	
69306	2-yr	1040	42.04	935.54	41.48	-0.56	
69306	5-yr	1672	45.4	1595.77	45.26	-0.14	
69306	10-yr	1916	46.66	1915.94	46.72	0.06	
69306	25-yr	2166	47.33	2196.29	47.56	0.23	
69306	50-yr	2374	48.03	2434.21	48.17	0.14	
69306	100-yr	2599	48.54	2677.3	48.83	0.29	
69306	250-yr	2915	49.23	2948.68	49.31	0.08	
69306	500-yr	3093	49.51	3119.09	49.57	0.06	
69305.5	PICKFAIR WALKWAY						Bridge
69290	2-yr	1040	42.03	935.54	41.47	-0.56	
69290	5-yr	1672	45.39	1595.77	45.24	-0.15	
69290	10-yr	1916	46.65	1915.94	46.7	0.05	
69290	25-yr	2166	47.31	2196.29	47.55	0.24	
69290	50-yr	2374	48.02	2434.21	48.16	0.14	
69290	100-yr	2599	48.53	2677.3	48.82	0.29	
69290	250-yr	2915	49.22	2948.68	49.3	0.08	
69290	500-yr	3093	49.5	3119.09	49.56	0.06	
69226	2-yr	1040	42.01	935.54	41.46	-0.55	
69226	5-yr	1672	45.38	1595.77	45.23	-0.15	
69226	10-yr	1916	46.64	1915.94	46.7	0.06	
69226	25-yr	2166	47.31	2196.29	47.54	0.23	
69226	50-yr	2374	48.01	2434.21	48.15	0.14	
69226	100-yr	2599	48.53	2677.3	48.81	0.28	
69226	250-yr	2915	49.21	2948.68	49.29	0.08	
69226	500-yr	3093	49.5	3119.09	49.55	0.05	
68720	2-yr	1040	41.9	935.54	41.34	-0.56	
68720	5-yr	1672	45.32	1595.77	45.17	-0.15	
68720	10-yr	1916	46.6	1915.94	46.65	0.05	
68720	25-yr	2166	47.26	2196.29	47.5	0.24	
68720	50-yr	2374	47.97	2434.21	48.11	0.14	
68720	100-yr	2599	48.49	2677.3	48.78	0.29	
68720	250-yr	2915	49.17	2948.68	49.25	0.08	
68720	500-yr	3093	49.46	3119.09	49.51	0.05	
68673	2-yr	1040	41.84	935.54	41.29	-0.55	
68673	5-yr	1672	45.27	1595.77	45.13	-0.14	
68673	10-yr	1916	46.57	1915.94	46.63	0.06	
68673	25-yr	2166	47.24	2196.29	47.49	0.25	
68673	50-yr	2374	47.96	2434.21	48.1	0.14	
68673	100-yr	2599	48.47	2677.3	48.76	0.29	
68673	250-yr	2915	49.16	2948.68	49.24	0.08	
68673	500-yr	3093	49.45	3119.09	49.5	0.05	
68665.5	LOCKWOOD STREET						Bridge
68611	2-yr	1040	41.78	935.54	41.23	-0.55	
68611	5-yr	1672	45.09	1595.77	44.97	-0.12	
68611	10-yr	1916	46.37	1915.94	46.44	0.07	
68611	25-yr	2166	47.13	2196.29	47.39	0.26	
68611	50-yr	2374	47.89	2434.21	48.04	0.15	
68611	100-yr	2599	48.42	2677.3	48.72	0.3	
68611	250-yr	2915	49.12	2948.68	49.2	0.08	
68611	500-yr	3093	49.41	3119.09	49.46	0.05	
68564	2-yr	1040	41.77	935.54	41.21	-0.56	
68564	5-yr	1672	45.07	1595.77	44.95	-0.12	
68564	10-yr	1916	46.36	1915.94	46.43	0.07	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
68564	25-yr	2166	47.12	2196.29	47.38	0.26	
68564	50-yr	2374	47.88	2434.21	48.03	0.15	
68564	100-yr	2599	48.41	2677.3	48.71	0.3	
68564	250-yr	2915	49.11	2948.68	49.19	0.08	
68564	500-yr	3093	49.4	3119.09	49.45	0.05	
67705	2-yr	1040	41.43	935.54	40.87	-0.56	
67705	5-yr	1672	44.82	1595.77	44.71	-0.11	
67705	10-yr	1916	46.19	1915.94	46.27	0.08	
67705	25-yr	2166	46.98	2196.29	47.26	0.28	
67705	50-yr	2374	47.77	2434.21	47.92	0.15	
67705	100-yr	2599	48.32	2677.3	48.63	0.31	
67705	250-yr	2915	49.03	2948.68	49.11	0.08	
67705	500-yr	3093	49.32	3119.09	49.38	0.06	
67655	2-yr	1040	41.41	935.54	40.85	-0.56	
67655	5-yr	1672	44.81	1595.77	44.69	-0.12	
67655	10-yr	1916	46.19	1915.94	46.26	0.07	
67655	25-yr	2166	46.97	2196.29	47.25	0.28	
67655	50-yr	2374	47.77	2434.21	47.92	0.15	
67655	100-yr	2599	48.31	2677.3	48.62	0.31	
67655	250-yr	2915	49.02	2948.68	49.11	0.09	
67655	500-yr	3093	49.32	3119.09	49.37	0.05	
67630	2-yr	1040	41.4	935.54	40.84	-0.56	
67630	5-yr	1672	44.8	1595.77	44.69	-0.11	
67630	10-yr	1916	46.18	1915.94	46.26	0.08	
67630	25-yr	2166	46.97	2196.29	47.25	0.28	
67630	50-yr	2374	47.76	2434.21	47.91	0.15	
67630	100-yr	2599	48.31	2677.3	48.62	0.31	
67630	250-yr	2915	49.02	2948.68	49.1	0.08	
67630	500-yr	3093	49.31	3119.09	49.37	0.06	
67605	2-yr	1040	41.4	935.54	40.83	-0.57	
67605	5-yr	1672	44.8	1595.77	44.68	-0.12	
67605	10-yr	1916	46.18	1915.94	46.25	0.07	
67605	25-yr	2166	46.96	2196.29	47.24	0.28	
67605	50-yr	2374	47.76	2434.21	47.91	0.15	
67605	100-yr	2599	48.31	2677.3	48.62	0.31	
67605	250-yr	2915	49.02	2948.68	49.1	0.08	
67605	500-yr	3093	49.31	3119.09	49.37	0.06	
67580	2-yr	1040	41.39	935.54	40.82	-0.57	
67580	5-yr	1672	44.79	1595.77	44.67	-0.12	
67580	10-yr	1916	46.17	1915.94	46.25	0.08	
67580	25-yr	2166	46.96	2196.29	47.24	0.28	
67580	50-yr	2374	47.76	2434.21	47.91	0.15	
67580	100-yr	2599	48.3	2677.3	48.62	0.32	
67580	250-yr	2915	49.02	2948.68	49.1	0.08	
67580	500-yr	3093	49.31	3119.09	49.37	0.06	
67555	2-yr	1040	41.38	935.54	40.82	-0.56	
67555	5-yr	1672	44.78	1595.77	44.67	-0.11	
67555	10-yr	1916	46.17	1915.94	46.25	0.08	
67555	25-yr	2166	46.96	2196.29	47.24	0.28	
67555	50-yr	2374	47.75	2434.21	47.91	0.16	
67555	100-yr	2599	48.3	2677.3	48.61	0.31	
67555	250-yr	2915	49.01	2948.68	49.1	0.09	
67555	500-yr	3093	49.31	3119.09	49.36	0.05	
67530	2-yr	1040	41.37	935.54	40.81	-0.56	
67530	5-yr	1672	44.78	1595.77	44.66	-0.12	
67530	10-yr	1916	46.16	1915.94	46.24	0.08	
67530	25-yr	2166	46.95	2196.29	47.23	0.28	
67530	50-yr	2374	47.75	2434.21	47.9	0.15	
67530	100-yr	2599	48.3	2677.3	48.61	0.31	
67530	250-yr	2915	49.01	2948.68	49.1	0.09	
67530	500-yr	3093	49.31	3119.09	49.36	0.05	
67505	2-yr	1040	41.39	935.54	40.83	-0.56	
67505	5-yr	1672	44.79	1595.77	44.68	-0.11	
67505	10-yr	1916	46.17	1915.94	46.25	0.08	
67505	25-yr	2166	46.96	2196.29	47.24	0.28	
67505	50-yr	2374	47.75	2434.21	47.91	0.16	
67505	100-yr	2599	48.3	2677.3	48.61	0.31	
67505	250-yr	2915	49.01	2948.68	49.1	0.09	
67505	500-yr	3093	49.31	3119.09	49.36	0.05	
67382	2-yr	1040	41.35	935.54	40.79	-0.56	
67382	5-yr	1672	44.76	1595.77	44.65	-0.11	
67382	10-yr	1916	46.15	1915.94	46.23	0.08	
67382	25-yr	2166	46.94	2196.29	47.22	0.28	
67382	50-yr	2374	47.74	2434.21	47.89	0.15	
67382	100-yr	2599	48.29	2677.3	48.6	0.31	
67382	250-yr	2915	49	2948.68	49.09	0.09	
67382	500-yr	3093	49.3	3119.09	49.35	0.05	
67351	2-yr	1040	41.33	935.54	40.77	-0.56	
67351	5-yr	1672	44.75	1595.77	44.64	-0.11	
67351	10-yr	1916	46.15	1915.94	46.23	0.08	
67351	25-yr	2166	46.94	2196.29	47.22	0.28	
67351	50-yr	2374	47.74	2434.21	47.89	0.15	
67351	100-yr	2599	48.29	2677.3	48.6	0.31	
67351	250-yr	2915	49	2948.68	49.09	0.09	
67351	500-yr	3093	49.3	3119.09	49.35	0.05	
67343.5	PEDESTRIAN BRIDG						Bridge
67336	2-yr	1040	41.32	935.54	40.76	-0.56	
67336	5-yr	1672	44.74	1595.77	44.62	-0.12	
67336	10-yr	1916	46.14	1915.94	46.22	0.08	
67336	25-yr	2166	46.93	2196.29	47.21	0.28	
67336	50-yr	2374	47.73	2434.21	47.88	0.15	
67336	100-yr	2599	48.28	2677.3	48.6	0.32	
67336	250-yr	2915	49	2948.68	49.08	0.08	
67336	500-yr	3093	49.29	3119.09	49.35	0.06	
67274	2-yr	1040	41.31	935.54	40.75	-0.56	
67274	5-yr	1672	44.73	1595.77	44.61	-0.12	
67274	10-yr	1916	46.13	1915.94	46.21	0.08	
67274	25-yr	2166	46.92	2196.29	47.21	0.29	
67274	50-yr	2374	47.73	2434.21	47.88	0.15	
67274	100-yr	2599	48.28	2677.3	48.59	0.31	
67274	250-yr	2915	48.99	2948.68	49.08	0.09	
67274	500-yr	3093	49.29	3119.09	49.34	0.05	
67074	2-yr	1040	41.27	935.54	40.71	-0.56	
67074	5-yr	1672	44.7	1595.77	44.58	-0.12	
67074	10-yr	1916	46.11	1915.94	46.19	0.08	
67074	25-yr	2166	46.9	2196.29	47.18	0.28	
67074	50-yr	2374	47.7	2434.21	47.85	0.15	
67074	100-yr	2599	48.25	2677.3	48.57	0.32	
67074	250-yr	2915	48.97	2948.68	49.05	0.08	
67074	500-yr	3093	49.26	3119.09	49.32	0.06	
66605	2-yr	1225	41.14	1098.12	40.57	-0.57	
66605	5-yr	2053	44.62	1947.57	44.51	-0.11	
66605	10-yr	2371	46.06	2365.15	46.14	0.08	
66605	25-yr	2695	46.86	2726.24	47.15	0.29	
66605	50-yr	2965	47.68	3032.35	47.83	0.15	
66605	100-yr	3261	48.23	3335.76	48.55	0.32	
66605	250-yr	3648	48.95	3674.86	49.04	0.09	
66605	500-yr	3876	49.25	3870.59	49.3	0.05	
66172	2-yr	1225	41	1098.12	40.43	-0.57	
66172	5-yr	2053	44.51	1947.57	44.4	-0.11	
66172	10-yr	2371	45.98	2365.15	46.08	0.1	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
66172	25-yr	2695	46.81	2726.24	47.11	0.3	
66172	50-yr	2965	47.64	3032.35	47.79	0.15	
66172	100-yr	3261	48.19	3335.76	48.52	0.33	
66172	250-yr	3648	48.92	3674.86	49	0.08	
66172	500-yr	3876	49.21	3870.59	49.27	0.06	
66156	2-yr	1225	40.98	1098.12	40.41	-0.57	
66156	5-yr	2053	44.49	1947.57	44.39	-0.1	
66156	10-yr	2371	45.98	2365.15	46.08	0.1	
66156	25-yr	2695	46.81	2726.24	47.1	0.29	
66156	50-yr	2965	47.63	3032.35	47.79	0.16	
66156	100-yr	3261	48.19	3335.76	48.51	0.32	
66156	250-yr	3648	48.92	3674.86	49	0.08	
66156	500-yr	3876	49.21	3870.59	49.27	0.06	
66155.5	PEDESTRIAN BRIDG						Bridge
66141	2-yr	1225	40.97	1098.12	40.4	-0.57	
66141	5-yr	2053	44.46	1947.57	44.36	-0.1	
66141	10-yr	2371	45.97	2365.15	46.07	0.1	
66141	25-yr	2695	46.8	2726.24	47.09	0.29	
66141	50-yr	2965	47.62	3032.35	47.78	0.16	
66141	100-yr	3261	48.18	3335.76	48.5	0.32	
66141	250-yr	3648	48.91	3674.86	48.99	0.08	
66141	500-yr	3876	49.2	3870.59	49.26	0.06	
66080	2-yr	1225	40.96	1098.12	40.39	-0.57	
66080	5-yr	2053	44.46	1947.57	44.36	-0.1	
66080	10-yr	2371	45.96	2365.15	46.06	0.1	
66080	25-yr	2695	46.79	2726.24	47.09	0.3	
66080	50-yr	2965	47.62	3032.35	47.77	0.15	
66080	100-yr	3261	48.18	3335.76	48.5	0.32	
66080	250-yr	3648	48.9	3674.86	48.99	0.09	
66080	500-yr	3876	49.2	3870.59	49.26	0.06	
65994	2-yr	1225	40.96	1098.12	40.38	-0.58	
65994	5-yr	2053	44.46	1947.57	44.36	-0.1	
65994	10-yr	2371	45.96	2365.15	46.06	0.1	
65994	25-yr	2695	46.79	2726.24	47.08	0.29	
65994	50-yr	2965	47.61	3032.35	47.77	0.16	
65994	100-yr	3261	48.17	3335.76	48.5	0.33	
65994	250-yr	3648	48.9	3674.86	48.98	0.08	
65994	500-yr	3876	49.19	3870.59	49.25	0.06	
65919	2-yr	1225	40.92	1098.12	40.35	-0.57	
65919	5-yr	2053	44.42	1947.57	44.32	-0.1	
65919	10-yr	2371	45.94	2365.15	46.04	0.1	
65919	25-yr	2695	46.77	2726.24	47.07	0.3	
65919	50-yr	2965	47.6	3032.35	47.76	0.16	
65919	100-yr	3261	48.16	3335.76	48.49	0.33	
65919	250-yr	3648	48.89	3674.86	48.98	0.09	
65919	500-yr	3876	49.19	3870.59	49.25	0.06	
65913.5	LOOP 610 3RD CRO						Bridge
65649	2-yr	1225	40.79	1098.12	40.22	-0.57	
65649	5-yr	2053	44.31	1947.57	44.22	-0.09	
65649	10-yr	2371	45.67	2365.15	45.76	0.09	
65649	25-yr	2695	46.43	2726.24	46.73	0.3	
65649	50-yr	2965	47.23	3032.35	47.38	0.15	
65649	100-yr	3261	47.76	3335.76	48.11	0.35	
65649	250-yr	3648	48.5	3674.86	48.59	0.09	
65649	500-yr	3876	48.79	3870.59	48.87	0.08	
65474	2-yr	1225	40.77	1098.12	40.2	-0.57	
65474	5-yr	2053	44.28	1947.57	44.2	-0.08	
65474	10-yr	2371	45.65	2365.15	45.74	0.09	
65474	25-yr	2695	46.4	2726.24	46.71	0.31	
65474	50-yr	2965	47.21	3032.35	47.36	0.15	
65474	100-yr	3261	47.75	3335.76	48.1	0.35	
65474	250-yr	3648	48.49	3674.86	48.58	0.09	
65474	500-yr	3876	48.78	3870.59	48.85	0.07	
65378	2-yr	1225	40.72	1098.12	40.15	-0.57	
65378	5-yr	2053	44.23	1947.57	44.15	-0.08	
65378	10-yr	2371	45.6	2365.15	45.7	0.1	
65378	25-yr	2695	46.37	2726.24	46.68	0.31	
65378	50-yr	2965	47.19	3032.35	47.34	0.15	
65378	100-yr	3261	47.73	3335.76	48.09	0.36	
65378	250-yr	3648	48.48	3674.86	48.57	0.09	
65378	500-yr	3876	48.77	3870.59	48.84	0.07	
65377.5	KELLEY STREET EA						Bridge
65332	2-yr	1225	40.69	1098.12	40.12	-0.57	
65332	5-yr	2053	44.19	1947.57	44.11	-0.08	
65332	10-yr	2371	45.57	2365.15	45.67	0.1	
65332	25-yr	2695	46.34	2726.24	46.66	0.32	
65332	50-yr	2965	47.17	3032.35	47.32	0.15	
65332	100-yr	3261	47.71	3335.76	48.07	0.36	
65332	250-yr	3648	48.46	3674.86	48.56	0.1	
65332	500-yr	3876	48.76	3870.59	48.83	0.07	
65286	2-yr	1225	40.7	1098.12	40.13	-0.57	
65286	5-yr	2053	44.2	1947.57	44.12	-0.08	
65286	10-yr	2371	45.58	2365.15	45.68	0.1	
65286	25-yr	2695	46.34	2726.24	46.66	0.32	
65286	50-yr	2965	47.17	3032.35	47.32	0.15	
65286	100-yr	3261	47.71	3335.76	48.07	0.36	
65286	250-yr	3648	48.46	3674.86	48.56	0.1	
65286	500-yr	3876	48.76	3870.59	48.83	0.07	
65251	2-yr	1225	40.7	1098.12	40.13	-0.57	
65251	5-yr	2053	44.2	1947.57	44.12	-0.08	
65251	10-yr	2371	45.57	2365.15	45.67	0.1	
65251	25-yr	2695	46.34	2726.24	46.66	0.32	
65251	50-yr	2965	47.17	3032.35	47.32	0.15	
65251	100-yr	3261	47.71	3335.76	48.07	0.36	
65251	250-yr	3648	48.46	3674.86	48.56	0.1	
65251	500-yr	3876	48.76	3870.59	48.83	0.07	
64923	2-yr	1225	40.64	1098.12	40.08	-0.56	
64923	5-yr	2053	44.14	1947.57	44.07	-0.07	
64923	10-yr	2371	45.53	2365.15	45.63	0.1	
64923	25-yr	2695	46.3	2726.24	46.62	0.32	
64923	50-yr	2965	47.13	3032.35	47.28	0.15	
64923	100-yr	3261	47.68	3335.76	48.04	0.36	
64923	250-yr	3648	48.43	3674.86	48.52	0.09	
64923	500-yr	3876	48.72	3870.59	48.8	0.08	
64907	2-yr	1225	40.57	1098.12	40	-0.57	
64907	5-yr	2053	44.08	1947.57	44.01	-0.07	
64907	10-yr	2371	45.49	2365.15	45.6	0.11	
64907	25-yr	2695	46.27	2726.24	46.59	0.32	
64907	50-yr	2965	47.1	3032.35	47.26	0.16	
64907	100-yr	3261	47.65	3335.76	48.01	0.36	
64907	250-yr	3648	48.4	3674.86	48.5	0.1	
64907	500-yr	3876	48.7	3870.59	48.78	0.08	
64901.5	KELLEY STREET WE						Bridge
64858	2-yr	1225	40.49	1098.12	39.93	-0.56	
64858	5-yr	2053	44.01	1947.57	43.95	-0.06	
64858	10-yr	2371	45.36	2365.15	45.46	0.1	
64858	25-yr	2695	46.08	2726.24	46.39	0.31	
64858	50-yr	2965	46.84	3032.35	47.01	0.17	
64858	100-yr	3261	47.47	3335.76	47.9	0.43	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
64858	250-yr	3648	48.32	3674.86	48.43	0.11	
64858	500-yr	3876	48.63	3870.59	48.72	0.09	
64850	2-yr	1225	40.49	1098.12	39.92	-0.57	
64850	5-yr	2053	44.01	1947.57	43.94	-0.07	
64850	10-yr	2371	45.35	2365.15	45.46	0.11	
64850	25-yr	2695	46.07	2726.24	46.39	0.32	
64850	50-yr	2965	46.83	3032.35	47.01	0.18	
64850	100-yr	3261	47.47	3335.76	47.9	0.43	
64850	250-yr	3648	48.32	3674.86	48.42	0.1	
64850	500-yr	3876	48.63	3870.59	48.71	0.08	
64775	2-yr	1225	40.48	1098.12	39.92	-0.56	
64775	5-yr	2053	44	1947.57	43.94	-0.06	
64775	10-yr	2371	45.35	2365.15	45.46	0.11	
64775	25-yr	2695	46.07	2726.24	46.39	0.32	
64775	50-yr	2965	46.83	3032.35	47.01	0.18	
64775	100-yr	3261	47.47	3335.76	47.9	0.43	
64775	250-yr	3648	48.32	3674.86	48.43	0.11	
64775	500-yr	3876	48.63	3870.59	48.72	0.09	
64773.5	COH WATERLINE CR						Bridge
64770	2-yr	1225	40.47	1098.12	39.9	-0.57	
64770	5-yr	2053	43.99	1947.57	43.93	-0.06	
64770	10-yr	2371	45.35	2365.15	45.45	0.1	
64770	25-yr	2695	46.07	2726.24	46.38	0.31	
64770	50-yr	2965	46.83	3032.35	47	0.17	
64770	100-yr	3261	47.46	3335.76	47.89	0.43	
64770	250-yr	3648	48.31	3674.86	48.42	0.11	
64770	500-yr	3876	48.63	3870.59	48.71	0.08	
64684	2-yr	1225	40.46	1098.12	39.89	-0.57	
64684	5-yr	2053	43.98	1947.57	43.92	-0.06	
64684	10-yr	2371	45.34	2365.15	45.44	0.1	
64684	25-yr	2695	46.06	2726.24	46.37	0.31	
64684	50-yr	2965	46.82	3032.35	46.99	0.17	
64684	100-yr	3261	47.45	3335.76	47.89	0.44	
64684	250-yr	3648	48.31	3674.86	48.41	0.1	
64684	500-yr	3876	48.62	3870.59	48.7	0.08	
64090	2-yr	1551	40.28	1394.84	39.71	-0.57	
64090	5-yr	2659	43.83	2537.25	43.78	-0.05	
64090	10-yr	3155	45.21	3166.5	45.32	0.11	
64090	25-yr	3667	45.95	3692.88	46.28	0.33	
64090	50-yr	4052	46.74	4125.42	46.93	0.19	
64090	100-yr	4471	47.39	4548.65	47.84	0.45	
64090	250-yr	5027	48.26	4999.23	48.37	0.11	
64090	500-yr	5329	48.58	5254.29	48.67	0.09	
63754	2-yr	1551	40.17	1394.84	39.6	-0.57	
63754	5-yr	2659	43.73	2537.25	43.69	-0.04	
63754	10-yr	3155	45.14	3166.5	45.25	0.11	
63754	25-yr	3667	45.88	3692.88	46.23	0.35	
63754	50-yr	4052	46.69	4125.42	46.88	0.19	
63754	100-yr	4471	47.35	4548.65	47.81	0.46	
63754	250-yr	5027	48.23	4999.23	48.34	0.11	
63754	500-yr	5329	48.55	5254.29	48.64	0.09	
63620	2-yr	1551	40.16	1394.84	39.58	-0.58	
63620	5-yr	2659	43.72	2537.25	43.68	-0.04	
63620	10-yr	3155	45.13	3166.5	45.24	0.11	
63620	25-yr	3667	45.87	3692.88	46.22	0.35	
63620	50-yr	4052	46.68	4125.42	46.87	0.19	
63620	100-yr	4471	47.34	4548.65	47.8	0.46	
63620	250-yr	5027	48.22	4999.23	48.34	0.12	
63620	500-yr	5329	48.54	5254.29	48.63	0.09	
63618.5	UTILITY BRIDGE						Bridge
63616	2-yr	1551	40.15	1394.84	39.58	-0.57	
63616	5-yr	2659	43.71	2537.25	43.67	-0.04	
63616	10-yr	3155	45.11	3166.5	45.23	0.12	
63616	25-yr	3667	45.85	3692.88	46.2	0.35	
63616	50-yr	4052	46.66	4125.42	46.85	0.19	
63616	100-yr	4471	47.33	4548.65	47.79	0.46	
63616	250-yr	5027	48.21	4999.23	48.33	0.12	
63616	500-yr	5329	48.54	5254.29	48.63	0.09	
63605	2-yr	1551	40.15	1394.84	39.58	-0.57	
63605	5-yr	2659	43.71	2537.25	43.67	-0.04	
63605	10-yr	3155	45.11	3166.5	45.23	0.12	
63605	25-yr	3667	45.85	3692.88	46.2	0.35	
63605	50-yr	4052	46.66	4125.42	46.85	0.19	
63605	100-yr	4471	47.33	4548.65	47.79	0.46	
63605	250-yr	5027	48.21	4999.23	48.33	0.12	
63605	500-yr	5329	48.54	5254.29	48.63	0.09	
63599.5	HOMESTEAD ROAD						Bridge
63425	2-yr	1551	40.11	1394.84	39.54	-0.57	
63425	5-yr	2659	43.67	2537.25	43.63	-0.04	
63425	10-yr	3155	45.06	3166.5	45.18	0.12	
63425	25-yr	3667	45.8	3692.88	46.15	0.35	
63425	50-yr	4052	46.61	4125.42	46.8	0.19	
63425	100-yr	4471	47.27	4548.65	47.73	0.46	
63425	250-yr	5027	48.16	4999.23	48.27	0.11	
63425	500-yr	5329	48.48	5254.29	48.58	0.1	
63253	2-yr	1551	40.06	1394.84	39.49	-0.57	
63253	5-yr	2659	43.63	2537.25	43.59	-0.04	
63253	10-yr	3155	45.03	3166.5	45.15	0.12	
63253	25-yr	3667	45.77	3692.88	46.13	0.36	
63253	50-yr	4052	46.59	4125.42	46.78	0.19	
63253	100-yr	4471	47.25	4548.65	47.72	0.47	
63253	250-yr	5027	48.14	4999.23	48.26	0.12	
63253	500-yr	5329	48.47	5254.29	48.56	0.09	
62617	2-yr	1551	39.86	1394.84	39.29	-0.57	
62617	5-yr	2659	43.48	2537.25	43.46	-0.02	
62617	10-yr	3155	44.92	3166.5	45.05	0.13	
62617	25-yr	3667	45.66	3692.88	46.04	0.38	
62617	50-yr	4052	46.53	4125.42	46.73	0.2	
62617	100-yr	4471	47.2	4548.65	47.68	0.48	
62617	250-yr	5027	48.1	4999.23	48.22	0.12	
62617	500-yr	5329	48.43	5254.29	48.53	0.1	
62067	2-yr	1551	39.7	1394.84	39.11	-0.59	
62067	5-yr	2659	43.36	2537.25	43.35	-0.01	
62067	10-yr	3155	44.82	3166.5	44.95	0.13	
62067	25-yr	3667	45.56	3692.88	45.95	0.39	
62067	50-yr	4052	46.44	4125.42	46.66	0.22	
62067	100-yr	4471	47.14	4548.65	47.63	0.49	
62067	250-yr	5027	48.05	4999.23	48.17	0.12	
62067	500-yr	5329	48.38	5254.29	48.48	0.1	
61532	2-yr	1551	39.51	1394.84	38.92	-0.59	
61532	5-yr	2659	43.17	2537.25	43.18	0.01	
61532	10-yr	3155	44.65	3166.5	44.79	0.14	
61532	25-yr	3667	45.39	3692.88	45.8	0.41	
61532	50-yr	4052	46.29	4125.42	46.53	0.24	
61532	100-yr	4471	47.01	4548.65	47.52	0.51	
61532	250-yr	5027	47.94	4999.23	48.07	0.13	
61532	500-yr	5329	48.27	5254.29	48.38	0.11	
61162	2-yr	1551	39.46	1394.84	38.87	-0.59	
61162	5-yr	2659	43.15	2537.25	43.16	0.01	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
Station	Profile	Q Total (cfs)	W.S. Elev (ft)	Q Total (cfs)	W.S. Elev (ft)	W.S. Elev (ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
61162	10-yr	3155	44.65	3166.5	44.79	0.14	
61162	25-yr	3667	45.39	3692.88	45.8	0.41	
61162	50-yr	4052	46.29	4125.42	46.53	0.24	
61162	100-yr	4471	47.01	4548.65	47.52	0.51	
61162	250-yr	5027	47.94	4999.23	48.07	0.13	
61162	500-yr	5329	48.27	5254.29	48.38	0.11	
60525	2-yr	1551	39.43	1394.84	38.83	-0.6	
60525	5-yr	2659	43.13	2537.25	43.14	0.01	
60525	10-yr	3155	44.63	3166.5	44.77	0.14	
60525	25-yr	3667	45.38	3692.88	45.79	0.41	
60525	50-yr	4052	46.28	4125.42	46.51	0.23	
60525	100-yr	4471	46.99	4548.65	47.51	0.52	
60525	250-yr	5027	47.93	4999.23	48.06	0.13	
60525	500-yr	5329	48.26	5254.29	48.37	0.11	
60280	2-yr	1854	39.41	1679.1	38.81	-0.6	
60280	5-yr	3187	43.12	3076.06	43.13	0.01	
60280	10-yr	3888	44.62	3910.85	44.76	0.14	
60280	25-yr	4399	45.37	4350.21	45.78	0.41	
60280	50-yr	4702	46.27	4720.12	46.51	0.24	
60280	100-yr	5071	46.99	5146.3	47.51	0.52	
60280	250-yr	5555	47.92	5590.3	48.05	0.13	
60280	500-yr	5856	48.25	5870.11	48.36	0.11	
60038	2-yr	1854	39.41	1679.1	38.81	-0.6	
60038	5-yr	3187	43.12	3076.06	43.13	0.01	
60038	10-yr	3888	44.61	3910.85	44.75	0.14	
60038	25-yr	4399	45.36	4350.21	45.78	0.42	
60038	50-yr	4702	46.27	4720.12	46.5	0.23	
60038	100-yr	5071	46.99	5146.3	47.5	0.51	
60038	250-yr	5555	47.92	5590.3	48.05	0.13	
60038	500-yr	5856	48.25	5870.11	48.36	0.11	
60031.5	UTILITY BRIDGE						Bridge
60025	2-yr	1854	39.41	1679.1	38.81	-0.6	
60025	5-yr	3187	43.11	3076.06	43.13	0.02	
60025	10-yr	3888	44.61	3910.85	44.75	0.14	
60025	25-yr	4399	45.36	4350.21	45.77	0.41	
60025	50-yr	4702	46.26	4720.12	46.5	0.24	
60025	100-yr	5071	46.98	5146.3	47.5	0.52	
60025	250-yr	5555	47.92	5590.3	48.05	0.13	
60025	500-yr	5856	48.25	5870.11	48.36	0.11	
60003	2-yr	1854	39.3	1679.1	38.7	-0.6	
60003	5-yr	3187	42.97	3076.06	42.99	0.02	
60003	10-yr	3888	44.44	3910.85	44.58	0.14	
60003	25-yr	4399	45.17	4350.21	45.6	0.43	
60003	50-yr	4702	46.07	4720.12	46.32	0.25	
60003	100-yr	5071	46.78	5146.3	47.35	0.57	
60003	250-yr	5555	47.77	5590.3	47.91	0.14	
60003	500-yr	5856	48.11	5870.11	48.22	0.11	
59960	2-yr	1854	39.28	1679.1	38.68	-0.6	
59960	5-yr	3187	42.95	3076.06	42.97	0.02	
59960	10-yr	3888	44.42	3910.85	44.56	0.14	
59960	25-yr	4399	45.14	4350.21	45.58	0.44	
59960	50-yr	4702	46.05	4720.12	46.3	0.25	
59960	100-yr	5071	46.76	5146.3	47.33	0.57	
59960	250-yr	5555	47.75	5590.3	47.89	0.14	
59960	500-yr	5856	48.09	5870.11	48.21	0.12	
59750.5	LOOP 610 CROSSIN						Bridge
59540	2-yr	1854	38.74	1679.1	38.15	-0.59	
59540	5-yr	3187	42.35	3076.06	42.42	0.07	
59540	10-yr	3888	43.55	3910.85	43.69	0.14	
59540	25-yr	4399	44.1	4350.21	44.24	0.14	
59540	50-yr	4702	44.48	4720.12	44.72	0.24	
59540	100-yr	5071	44.93	5146.3	45.16	0.23	
59540	250-yr	5555	45.47	5590.3	45.7	0.23	
59540	500-yr	5856	45.86	5870.11	46.07	0.21	
59497	2-yr	1854	38.71	1679.1	38.11	-0.6	
59497	5-yr	3187	42.31	3076.06	42.39	0.08	
59497	10-yr	3888	43.51	3910.85	43.66	0.15	
59497	25-yr	4399	44.05	4350.21	44.2	0.15	
59497	50-yr	4702	44.44	4720.12	44.68	0.24	
59497	100-yr	5071	44.89	5146.3	45.11	0.22	
59497	250-yr	5555	45.43	5590.3	45.66	0.23	
59497	500-yr	5856	45.81	5870.11	46.03	0.22	
59445	2-yr	1854	38.67	1679.1	38.08	-0.59	
59445	5-yr	3187	42.28	3076.06	42.36	0.08	
59445	10-yr	3888	43.47	3910.85	43.62	0.15	
59445	25-yr	4399	44.01	4350.21	44.16	0.15	
59445	50-yr	4702	44.4	4720.12	44.64	0.24	
59445	100-yr	5071	44.85	5146.3	45.07	0.22	
59445	250-yr	5555	45.38	5590.3	45.61	0.23	
59445	500-yr	5856	45.77	5870.11	45.99	0.22	
58305	2-yr	1854	38.06	1679.1	37.44	-0.62	
58305	5-yr	3187	41.76	3076.06	41.89	0.13	
58305	10-yr	3888	43.04	3910.85	43.22	0.18	
58305	25-yr	4399	43.61	4350.21	43.81	0.2	
58305	50-yr	4702	44.04	4720.12	44.34	0.3	
58305	100-yr	5071	44.54	5146.3	44.81	0.27	
58305	250-yr	5555	45.13	5590.3	45.4	0.27	
58305	500-yr	5856	45.56	5870.11	45.82	0.26	
57533	2-yr	2044	37.76	1851.48	37.14	-0.62	
57533	5-yr	3337	41.53	3327.33	41.68	0.15	
57533	10-yr	3929	42.83	4079.29	43.01	0.18	
57533	25-yr	4429	43.39	4576.57	43.6	0.21	
57533	50-yr	4778	43.83	4975.12	44.14	0.31	
57533	100-yr	5182	44.34	5349.04	44.61	0.27	
57533	250-yr	5639	44.94	5770.7	45.22	0.28	
57533	500-yr	5917	45.38	6061.45	45.64	0.26	
57306	2-yr	2044	37.61	1851.48	36.99	-0.62	
57306	5-yr	3337	41.36	3327.33	41.52	0.16	
57306	10-yr	3929	42.66	4079.29	42.84	0.18	
57306	25-yr	4429	43.2	4576.57	43.41	0.21	
57306	50-yr	4778	43.63	4975.12	43.92	0.29	
57306	100-yr	5182	44.12	5349.04	44.39	0.27	
57306	250-yr	5639	44.7	5770.7	44.99	0.29	
57306	500-yr	5917	45.14	6061.45	45.4	0.26	
57261	2-yr	2044	37.58	1851.48	36.97	-0.61	
57261	5-yr	3337	41.31	3327.33	41.46	0.15	
57261	10-yr	3929	42.6	4079.29	42.77	0.17	
57261	25-yr	4429	43.13	4576.57	43.33	0.2	
57261	50-yr	4778	43.54	4975.12	43.83	0.29	
57261	100-yr	5182	44.02	5349.04	44.29	0.27	
57261	250-yr	5639	44.6	5770.7	44.88	0.28	
57261	500-yr	5917	45.03	6061.45	45.29	0.26	
57237.5	LIBERTY ROAD						Bridge
57213	2-yr	2044	37.53	1851.48	36.92	-0.61	
57213	5-yr	3337	41.25	3327.33	41.41	0.16	
57213	10-yr	3929	42.54	4079.29	42.72	0.18	
57213	25-yr	4429	43.06	4576.57	43.27	0.21	
57213	50-yr	4778	43.48	4975.12	43.77	0.29	
57213	100-yr	5182	43.96	5349.04	44.23	0.27	
57213	250-yr	5639	44.5	5770.7	44.73	0.23	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
57213	500-yr	5917	44.86	6061.45	45.09	0.23	
57199	2-yr	2044	37.52	1851.48	36.91	-0.61	
57199	5-yr	3337	41.24	3327.33	41.4	0.16	
57199	10-yr	3929	42.53	4079.29	42.71	0.18	
57199	25-yr	4429	43.06	4576.57	43.26	0.2	
57199	50-yr	4778	43.47	4975.12	43.77	0.3	
57199	100-yr	5182	43.95	5349.04	44.22	0.27	
57199	250-yr	5639	44.49	5770.7	44.72	0.23	
57199	500-yr	5917	44.85	6061.45	45.08	0.23	
57147.5	ENGLEWOOD YARD						Bridge
57097	2-yr	2044	37.33	1851.48	36.74	-0.59	
57097	5-yr	3337	41	3327.33	41.17	0.17	
57097	10-yr	3929	42.07	4079.29	42.2	0.13	
57097	25-yr	4429	42.43	4576.57	42.58	0.15	
57097	50-yr	4778	42.72	4975.12	42.93	0.21	
57097	100-yr	5182	43.03	5349.04	43.22	0.19	
57097	250-yr	5639	43.37	5770.7	43.53	0.16	
57097	500-yr	5917	43.59	6061.45	43.75	0.16	
57090	2-yr	2044	37.33	1851.48	36.74	-0.59	
57090	5-yr	3337	41	3327.33	41.17	0.17	
57090	10-yr	3929	42.06	4079.29	42.19	0.13	
57090	25-yr	4429	42.43	4576.57	42.58	0.15	
57090	50-yr	4778	42.72	4975.12	42.93	0.21	
57090	100-yr	5182	43.03	5349.04	43.22	0.19	
57090	250-yr	5639	43.36	5770.7	43.53	0.17	
57090	500-yr	5917	43.59	6061.45	43.74	0.15	
56883	2-yr	2044	37.07	1851.48	36.44	-0.63	
56883	5-yr	3337	40.9	3327.33	41.08	0.18	
56883	10-yr	3929	41.97	4079.29	42.1	0.13	
56883	25-yr	4429	42.32	4576.57	42.46	0.14	
56883	50-yr	4778	42.6	4975.12	42.8	0.2	
56883	100-yr	5182	42.9	5349.04	43.08	0.18	
56883	250-yr	5639	43.21	5770.7	43.37	0.16	
56883	500-yr	5917	43.43	6061.45	43.58	0.15	
56848	2-yr	2044	37.06	1851.48	36.43	-0.63	
56848	5-yr	3337	40.9	3327.33	41.08	0.18	
56848	10-yr	3929	41.97	4079.29	42.09	0.12	
56848	25-yr	4429	42.32	4576.57	42.46	0.14	
56848	50-yr	4778	42.59	4975.12	42.8	0.21	
56848	100-yr	5182	42.89	5349.04	43.08	0.19	
56848	250-yr	5639	43.21	5770.7	43.37	0.16	
56848	500-yr	5917	43.43	6061.45	43.58	0.15	
56833.5	ENGLEWOOD YARD						Bridge
56818	2-yr	2044	36.95	1851.48	36.31	-0.64	
56818	5-yr	3337	40.82	3327.33	41	0.18	
56818	10-yr	3929	41.88	4079.29	42	0.12	
56818	25-yr	4429	42.22	4576.57	42.36	0.14	
56818	50-yr	4778	42.48	4975.12	42.69	0.21	
56818	100-yr	5182	42.77	5349.04	42.96	0.19	
56818	250-yr	5639	43.07	5770.7	43.23	0.16	
56818	500-yr	5917	43.28	6061.45	43.43	0.15	
56730	2-yr	2044	36.93	1851.48	36.28	-0.65	
56730	5-yr	3337	40.81	3327.33	40.99	0.18	
56730	10-yr	3929	41.87	4079.29	41.99	0.12	
56730	25-yr	4429	42.21	4576.57	42.35	0.14	
56730	50-yr	4778	42.47	4975.12	42.68	0.21	
56730	100-yr	5182	42.76	5349.04	42.94	0.18	
56730	250-yr	5639	43.06	5770.7	43.22	0.16	
56730	500-yr	5917	43.27	6061.45	43.42	0.15	
56715.5	ENGLEWOOD YARD						Bridge
56700	2-yr	2044	36.88	1851.48	36.22	-0.66	
56700	5-yr	3337	40.78	3327.33	40.96	0.18	
56700	10-yr	3929	41.84	4079.29	41.96	0.12	
56700	25-yr	4429	42.17	4576.57	42.31	0.14	
56700	50-yr	4778	42.43	4975.12	42.63	0.2	
56700	100-yr	5182	42.71	5349.04	42.9	0.19	
56700	250-yr	5639	43.01	5770.7	43.17	0.16	
56700	500-yr	5917	43.22	6061.45	43.36	0.14	
56630	2-yr	2044	36.8	1851.48	36.12	-0.68	
56630	5-yr	3337	40.75	3327.33	40.94	0.19	
56630	10-yr	3929	41.81	4079.29	41.93	0.12	
56630	25-yr	4429	42.14	4576.57	42.28	0.14	
56630	50-yr	4778	42.4	4975.12	42.6	0.2	
56630	100-yr	5182	42.68	5349.04	42.86	0.18	
56630	250-yr	5639	42.97	5770.7	43.13	0.16	
56630	500-yr	5917	43.17	6061.45	43.32	0.15	
56610.5	ENGLEWOOD YARD						Bridge
56590	2-yr	2044	36.63	1851.48	35.91	-0.72	
56590	5-yr	3337	40.66	3327.33	40.85	0.19	
56590	10-yr	3929	41.72	4079.29	41.84	0.12	
56590	25-yr	4429	42.03	4576.57	42.17	0.14	
56590	50-yr	4778	42.28	4975.12	42.48	0.2	
56590	100-yr	5182	42.55	5349.04	42.73	0.18	
56590	250-yr	5639	42.82	5770.7	42.98	0.16	
56590	500-yr	5917	43.02	6061.45	43.17	0.15	
56565	2-yr	2044	36.63	1851.48	35.91	-0.72	
56565	5-yr	3337	40.66	3327.33	40.85	0.19	
56565	10-yr	3929	41.72	4079.29	41.84	0.12	
56565	25-yr	4429	42.03	4576.57	42.17	0.14	
56565	50-yr	4778	42.28	4975.12	42.48	0.2	
56565	100-yr	5182	42.55	5349.04	42.73	0.18	
56565	250-yr	5639	42.82	5770.7	42.98	0.16	
56565	500-yr	5917	43.02	6061.45	43.17	0.15	
56555	2-yr	2044	36.63	1851.48	35.91	-0.72	
56555	5-yr	3337	40.66	3327.33	40.85	0.19	
56555	10-yr	3929	41.72	4079.29	41.84	0.12	
56555	25-yr	4429	42.03	4576.57	42.16	0.13	
56555	50-yr	4778	42.28	4975.12	42.48	0.2	
56555	100-yr	5182	42.54	5349.04	42.73	0.19	
56555	250-yr	5639	42.82	5770.7	42.98	0.16	
56555	500-yr	5917	43.02	6061.45	43.16	0.14	
56461	2-yr	2044	36.63	1851.48	35.92	-0.71	
56461	5-yr	3337	40.67	3327.33	40.86	0.19	
56461	10-yr	3929	41.74	4079.29	41.85	0.11	
56461	25-yr	4429	42.05	4576.57	42.19	0.14	
56461	50-yr	4778	42.3	4975.12	42.5	0.2	
56461	100-yr	5182	42.57	5349.04	42.76	0.19	
56461	250-yr	5639	42.85	5770.7	43.01	0.16	
56461	500-yr	5917	43.05	6061.45	43.2	0.15	
56394	2-yr	2044	36.59	1851.48	35.88	-0.71	
56394	5-yr	3337	40.65	3327.33	40.84	0.19	
56394	10-yr	3929	41.72	4079.29	41.84	0.12	
56394	25-yr	4429	42.04	4576.57	42.18	0.14	
56394	50-yr	4778	42.3	4975.12	42.5	0.2	
56394	100-yr	5182	42.57	5349.04	42.75	0.18	
56394	250-yr	5639	42.85	5770.7	43.02	0.17	
56394	500-yr	5917	43.06	6061.45	43.21	0.15	
56314.5	WAYSIDE DRIVE BR						Bridge

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
56234	2-yr	2044	36.46	1851.48	35.75	-0.71	
56234	5-yr	3337	40.04	3327.33	40.26	0.22	
56234	10-yr	3929	41.23	4079.29	41.36	0.13	
56234	25-yr	4429	41.61	4576.57	41.8	0.19	
56234	50-yr	4778	41.94	4975.12	42.26	0.32	
56234	100-yr	5182	42.34	5349.04	42.58	0.24	
56234	250-yr	5639	42.69	5770.7	42.88	0.19	
56234	500-yr	5917	42.92	6061.45	43.09	0.17	
56185	2-yr	2044	36.43	1851.48	35.72	-0.71	
56185	5-yr	3337	39.98	3327.33	40.2	0.22	
56185	10-yr	3929	41.14	4079.29	41.25	0.11	
56185	25-yr	4429	41.48	4576.57	41.65	0.17	
56185	50-yr	4778	41.78	4975.12	42.06	0.28	
56185	100-yr	5182	42.12	5349.04	42.33	0.21	
56185	250-yr	5639	42.41	5770.7	42.59	0.18	
56185	500-yr	5917	42.61	6061.45	42.77	0.16	
56165.5	HB&T RAILROAD BR						Bridge
56146	2-yr	2044	36.32	1851.48	35.61	-0.71	
56146	5-yr	3337	39.85	3327.33	40.08	0.23	
56146	10-yr	3929	41	4079.29	41.11	0.11	
56146	25-yr	4429	41.31	4576.57	41.48	0.17	
56146	50-yr	4778	41.57	4975.12	41.79	0.22	
56146	100-yr	5182	41.83	5349.04	42.02	0.19	
56146	250-yr	5639	42.05	5770.7	42.21	0.16	
56146	500-yr	5917	42.21	6061.45	42.34	0.13	
56121	2-yr	2044	36.3	1851.48	35.6	-0.7	
56121	5-yr	3337	39.84	3327.33	40.07	0.23	
56121	10-yr	3929	40.98	4079.29	41.09	0.11	
56121	25-yr	4429	41.29	4576.57	41.46	0.17	
56121	50-yr	4778	41.54	4975.12	41.77	0.23	
56121	100-yr	5182	41.8	5349.04	41.99	0.19	
56121	250-yr	5639	42.03	5770.7	42.18	0.15	
56121	500-yr	5917	42.18	6061.45	42.31	0.13	
54950	2-yr	2244	35.78	2023.85	35.07	-0.71	
54950	5-yr	3600	39.37	3657.7	39.64	0.27	
54950	10-yr	4293	40.6	4384	40.71	0.11	
54950	25-yr	4682	40.91	4946.12	41.08	0.17	
54950	50-yr	5006	41.17	5400.46	41.41	0.24	
54950	100-yr	5409	41.44	5802.46	41.63	0.19	
54950	250-yr	5922	41.65	6345.9	41.81	0.16	
54950	500-yr	6318	41.81	6758.5	41.92	0.11	
53883	2-yr	2244	35.36	2023.85	34.66	-0.7	
53883	5-yr	3600	38.94	3657.7	39.22	0.28	
53883	10-yr	4293	40.18	4384	40.31	0.13	
53883	25-yr	4682	40.51	4946.12	40.7	0.19	
53883	50-yr	5006	40.81	5400.46	41.07	0.26	
53883	100-yr	5409	41.11	5802.46	41.31	0.2	
53883	250-yr	5922	41.32	6345.9	41.46	0.14	
53883	500-yr	6318	41.47	6758.5	41.57	0.1	
53836	2-yr	2244	35.34	2023.85	34.64	-0.7	
53836	5-yr	3600	38.91	3657.7	39.19	0.28	
53836	10-yr	4293	40.15	4384	40.29	0.14	
53836	25-yr	4682	40.49	4946.12	40.68	0.19	
53836	50-yr	5006	40.79	5400.46	41.05	0.26	
53836	100-yr	5409	41.09	5802.46	41.29	0.2	
53836	250-yr	5922	41.3	6345.9	41.44	0.14	
53836	500-yr	6318	41.45	6758.5	41.55	0.1	
53820.5	TANK FARM ROAD B						Bridge
53805	2-yr	2244	35.31	2023.85	34.61	-0.7	
53805	5-yr	3600	38.86	3657.7	39.14	0.28	
53805	10-yr	4293	40.05	4384	40.19	0.14	
53805	25-yr	4682	40.42	4946.12	40.62	0.2	
53805	50-yr	5006	40.73	5400.46	40.95	0.22	
53805	100-yr	5409	40.99	5802.46	41.2	0.21	
53805	250-yr	5922	41.2	6345.9	41.35	0.15	
53805	500-yr	6318	41.35	6758.5	41.45	0.1	
53772	2-yr	2244	35.3	2023.85	34.6	-0.7	
53772	5-yr	3600	38.85	3657.7	39.13	0.28	
53772	10-yr	4293	40.03	4384	40.17	0.14	
53772	25-yr	4682	40.4	4946.12	40.6	0.2	
53772	50-yr	5006	40.72	5400.46	40.94	0.22	
53772	100-yr	5409	40.98	5802.46	41.18	0.2	
53772	250-yr	5922	41.19	6345.9	41.33	0.14	
53772	500-yr	6318	41.34	6758.5	41.43	0.09	
52267	2-yr	2244	34.83	2023.85	34.13	-0.7	
52267	5-yr	3600	38.36	3657.7	38.67	0.31	
52267	10-yr	4293	39.56	4384	39.71	0.15	
52267	25-yr	4682	39.93	4946.12	40.13	0.2	
52267	50-yr	5006	40.28	5400.46	40.52	0.24	
52267	100-yr	5409	40.57	5802.46	40.79	0.22	
52267	250-yr	5922	40.77	6345.9	40.91	0.14	
52267	500-yr	6318	40.92	6758.5	40.98	0.06	
49831	2-yr	2321	34.06	2085.15	33.37	-0.69	
49831	5-yr	3640	37.61	3746.75	37.95	0.34	
49831	10-yr	4155	38.86	4365.44	39.19	0.33	
49831	25-yr	4502	39.43	4641.68	39.64	0.21	
49831	50-yr	4808	39.76	5101.87	40.03	0.27	
49831	100-yr	5180	40.1	5567.25	40.34	0.24	
49831	250-yr	5483	40.32	5681.41	40.46	0.14	
49831	500-yr	5724	40.48	5754.97	40.54	0.06	
49781	2-yr	2321	34.04	2085.15	33.35	-0.69	
49781	5-yr	3640	37.58	3746.75	37.92	0.34	
49781	10-yr	4155	38.83	4365.44	39.18	0.35	
49781	25-yr	4502	39.42	4641.68	39.63	0.21	
49781	50-yr	4808	39.75	5101.87	40.02	0.27	
49781	100-yr	5180	40.09	5567.25	40.33	0.24	
49781	250-yr	5483	40.31	5681.41	40.45	0.14	
49781	500-yr	5724	40.47	5754.97	40.53	0.06	
49751.5	MCCARTY ROAD BRI						Bridge
49722	2-yr	2321	34	2085.15	33.31	-0.69	
49722	5-yr	3640	37.49	3746.75	37.82	0.33	
49722	10-yr	4155	38.7	4365.44	39.02	0.32	
49722	25-yr	4502	39.24	4641.68	39.45	0.21	
49722	50-yr	4808	39.57	5101.87	39.83	0.26	
49722	100-yr	5180	39.91	5567.25	40.17	0.26	
49722	250-yr	5483	40.15	5681.41	40.32	0.17	
49722	500-yr	5724	40.34	5754.97	40.41	0.07	
49712	2-yr	2321	34	2085.15	33.3	-0.7	
49712	5-yr	3640	37.49	3746.75	37.82	0.33	
49712	10-yr	4155	38.7	4365.44	39.01	0.31	
49712	25-yr	4502	39.24	4641.68	39.44	0.2	
49712	50-yr	4808	39.57	5101.87	39.83	0.26	
49712	100-yr	5180	39.9	5567.25	40.17	0.27	
49712	250-yr	5483	40.15	5681.41	40.32	0.17	
49712	500-yr	5724	40.34	5754.97	40.41	0.07	
48479	2-yr	2321	33.34	2085.15	32.64	-0.7	
48479	5-yr	3640	36.95	3746.75	37.32	0.37	
48479	10-yr	4155	38.26	4365.44	38.61	0.35	
48479	25-yr	4502	38.87	4641.68	39.1	0.23	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
Station	Profile	Q Total (cfs)	W.S. Elev (ft)	Q Total (cfs)	W.S. Elev (ft)	W.S. Elev (ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
48479	50-yr	4808	39.22	5101.87	39.5	0.28	
48479	100-yr	5180	39.58	5567.25	39.87	0.29	
48479	250-yr	5483	39.84	5681.41	40.02	0.18	
48479	500-yr	5724	40.04	5754.97	40.12	0.08	
48100	2-yr	2321	33.18	2085.15	32.47	-0.71	
48100	5-yr	3640	36.79	3746.75	37.16	0.37	
48100	10-yr	4155	38.1	4365.44	38.45	0.35	
48100	25-yr	4502	38.7	4641.68	38.93	0.23	
48100	50-yr	4808	39.14	5101.87	39.42	0.28	
48100	100-yr	5180	39.51	5567.25	39.79	0.28	
48100	250-yr	5483	39.77	5681.41	39.95	0.18	
48100	500-yr	5724	39.97	5754.97	40.06	0.09	
48040	2-yr	2321	33.16	2085.15	32.45	-0.71	
48040	5-yr	3640	36.77	3746.75	37.14	0.37	
48040	10-yr	4155	38.09	4365.44	38.43	0.34	
48040	25-yr	4502	38.69	4641.68	38.92	0.23	
48040	50-yr	4808	39.14	5101.87	39.42	0.28	
48040	100-yr	5180	39.5	5567.25	39.79	0.29	
48040	250-yr	5483	39.77	5681.41	39.95	0.18	
48040	500-yr	5724	39.97	5754.97	40.06	0.09	
47870.5	LOOP 610						Bridge
47700	2-yr	2321	32.83	2085.15	32.12	-0.71	
47700	5-yr	3640	36.42	3746.75	36.8	0.38	
47700	10-yr	4155	37.58	4365.44	37.78	0.2	
47700	25-yr	4502	37.93	4641.68	38.1	0.17	
47700	50-yr	4808	38.19	5101.87	38.38	0.19	
47700	100-yr	5180	38.46	5567.25	38.69	0.23	
47700	250-yr	5483	38.7	5681.41	38.88	0.18	
47700	500-yr	5724	38.9	5754.97	39.06	0.16	
47646	2-yr	2321	32.8	2085.15	32.1	-0.7	
47646	5-yr	3640	36.39	3746.75	36.77	0.38	
47646	10-yr	4155	37.55	4365.44	37.75	0.2	
47646	25-yr	4502	37.91	4641.68	38.08	0.17	
47646	50-yr	4808	38.17	5101.87	38.37	0.2	
47646	100-yr	5180	38.45	5567.25	38.69	0.24	
47646	250-yr	5483	38.69	5681.41	38.89	0.2	
47646	500-yr	5724	38.91	5754.97	39.04	0.13	
47641	2-yr	2321	32.8	2085.15	32.09	-0.71	
47641	5-yr	3640	36.39	3746.75	36.77	0.38	
47641	10-yr	4155	37.55	4365.44	37.76	0.21	
47641	25-yr	4502	37.91	4641.68	38.08	0.17	
47641	50-yr	4808	38.17	5101.87	38.37	0.2	
47641	100-yr	5180	38.45	5567.25	38.69	0.24	
47641	250-yr	5483	38.7	5681.41	38.89	0.19	
47641	500-yr	5724	38.91	5754.97	39.04	0.13	
47634.5	COH WATERLINE						Bridge
47628	2-yr	2321	32.77	2085.15	32.07	-0.7	
47628	5-yr	3640	36.36	3746.75	36.74	0.38	
47628	10-yr	4155	37.52	4365.44	37.72	0.2	
47628	25-yr	4502	37.86	4641.68	38.03	0.17	
47628	50-yr	4808	38.13	5101.87	38.33	0.2	
47628	100-yr	5180	38.41	5567.25	38.67	0.26	
47628	250-yr	5483	38.68	5681.41	38.86	0.18	
47628	500-yr	5724	38.88	5754.97	39.01	0.13	
47102	2-yr	2321	32.44	2085.15	31.71	-0.73	
47102	5-yr	3640	36.12	3746.75	36.52	0.4	
47102	10-yr	4155	37.33	4365.44	37.53	0.2	
47102	25-yr	4502	37.68	4641.68	37.84	0.16	
47102	50-yr	4808	37.94	5101.87	38.14	0.2	
47102	100-yr	5180	38.22	5567.25	38.48	0.26	
47102	250-yr	5483	38.49	5681.41	38.68	0.19	
47102	500-yr	5724	38.7	5754.97	38.83	0.13	
46183	2-yr	2421	31.81	2167.78	31.05	-0.76	
46183	5-yr	3795	35.59	3929.42	36.02	0.43	
46183	10-yr	4347	36.87	4523.06	37.06	0.19	
46183	25-yr	4631	37.22	4812.37	37.39	0.17	
46183	50-yr	4936	37.48	5226.72	37.67	0.19	
46183	100-yr	5309	37.75	5695.13	38	0.25	
46183	250-yr	5615	38.03	5871.73	38.23	0.2	
46183	500-yr	5830	38.25	6003.02	38.4	0.15	
46136	2-yr	2421	31.78	2167.78	31.02	-0.76	
46136	5-yr	3795	35.55	3929.42	35.99	0.44	
46136	10-yr	4347	36.84	4523.06	37.04	0.2	
46136	25-yr	4631	37.19	4812.37	37.36	0.17	
46136	50-yr	4936	37.45	5226.72	37.64	0.19	
46136	100-yr	5309	37.73	5695.13	37.97	0.24	
46136	250-yr	5615	38	5871.73	38.2	0.2	
46136	500-yr	5830	38.22	6003.02	38.37	0.15	
46118.5	MANITOU ROAD BRI						Bridge
46095	2-yr	2421	31.72	2167.78	30.96	-0.76	
46095	5-yr	3795	35.27	3929.42	35.62	0.35	
46095	10-yr	4347	36.45	4523.06	36.66	0.21	
46095	25-yr	4631	36.86	4812.37	37.05	0.19	
46095	50-yr	4936	37.17	5226.72	37.39	0.22	
46095	100-yr	5309	37.51	5695.13	37.79	0.28	
46095	250-yr	5615	37.84	5871.73	38.04	0.2	
46095	500-yr	5830	38.07	6003.02	38.22	0.15	
46074	2-yr	2421	31.7	2167.78	30.95	-0.75	
46074	5-yr	3795	35.26	3929.42	35.61	0.35	
46074	10-yr	4347	36.44	4523.06	36.65	0.21	
46074	25-yr	4631	36.84	4812.37	37.04	0.2	
46074	50-yr	4936	37.16	5226.72	37.38	0.22	
46074	100-yr	5309	37.49	5695.13	37.78	0.29	
46074	250-yr	5615	37.83	5871.73	38.03	0.2	
46074	500-yr	5830	38.06	6003.02	38.21	0.15	
44208	2-yr	2421	30.81	2167.78	30.03	-0.78	
44208	5-yr	3795	34.45	3929.42	34.81	0.36	
44208	10-yr	4347	35.62	4523.06	35.81	0.19	
44208	25-yr	4631	36.01	4812.37	36.19	0.18	
44208	50-yr	4936	36.29	5226.72	36.46	0.17	
44208	100-yr	5309	36.58	5695.13	36.81	0.23	
44208	250-yr	5615	36.91	5871.73	37.09	0.18	
44208	500-yr	5830	37.14	6003.02	37.28	0.14	
41700	2-yr	2599	29.82	2315.8	29.04	-0.78	
41700	5-yr	4063	33.52	4273.67	33.88	0.36	
41700	10-yr	4758	34.67	4922.99	34.82	0.15	
41700	25-yr	5118	35	5293.25	35.14	0.14	
41700	50-yr	5395	35.22	5563.78	35.34	0.12	
41700	100-yr	5707	35.44	5961.54	35.59	0.15	
41700	250-yr	6114	35.7	6339.48	35.82	0.12	
41700	500-yr	6428	35.88	6628.97	35.99	0.11	
39460	2-yr	2599	28.59	2315.8	27.82	-0.77	
39460	5-yr	4063	32.25	4273.67	32.67	0.42	
39460	10-yr	4758	33.6	4922.99	33.75	0.15	
39460	25-yr	5118	33.92	5293.25	34.05	0.13	
39460	50-yr	5395	34.13	5563.78	34.24	0.11	
39460	100-yr	5707	34.35	5961.54	34.49	0.14	
39460	250-yr	6114	34.6	6339.48	34.72	0.12	
39460	500-yr	6428	34.78	6628.97	34.89	0.11	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
37807	2-yr	2599	27.19	2315.8	26.43	-0.76	
37807	5-yr	4063	30.59	4273.67	31.09	0.5	
37807	10-yr	4758	32.36	4922.99	32.55	0.19	
37807	25-yr	5118	32.76	5293.25	32.91	0.15	
37807	50-yr	5395	33	5563.78	33.13	0.13	
37807	100-yr	5707	33.26	5961.54	33.41	0.15	
37807	250-yr	6114	33.55	6339.48	33.68	0.13	
37807	500-yr	6428	33.76	6628.97	33.88	0.12	
37170	2-yr	2599	26.66	2315.8	25.91	-0.75	
37170	5-yr	4063	29.93	4273.67	30.39	0.46	
37170	10-yr	4758	31.87	4922.99	32.09	0.22	
37170	25-yr	5118	32.31	5293.25	32.47	0.16	
37170	50-yr	5395	32.58	5563.78	32.7	0.12	
37170	100-yr	5707	32.85	5961.54	33	0.15	
37170	250-yr	6114	33.16	6339.48	33.29	0.13	
37170	500-yr	6428	33.38	6628.97	33.5	0.12	
37123	2-yr	2599	26.62	2315.8	25.87	-0.75	
37123	5-yr	4063	29.87	4273.67	30.32	0.45	
37123	10-yr	4758	31.83	4922.99	32.05	0.22	
37123	25-yr	5118	32.28	5293.25	32.44	0.16	
37123	50-yr	5395	32.54	5563.78	32.67	0.13	
37123	100-yr	5707	32.81	5961.54	32.97	0.16	
37123	250-yr	6114	33.13	6339.48	33.25	0.12	
37123	500-yr	6428	33.35	6628.97	33.47	0.12	
37076.5	WALLISVILLE ROAD						Bridge
37029	2-yr	2599	26.47	2315.8	25.73	-0.74	
37029	5-yr	4063	29.34	4273.67	29.7	0.36	
37029	10-yr	4758	30.97	4922.99	31.19	0.22	
37029	25-yr	5118	31.48	5293.25	31.69	0.21	
37029	50-yr	5395	31.85	5563.78	32.04	0.19	
37029	100-yr	5707	32.26	5961.54	32.47	0.21	
37029	250-yr	6114	32.71	6339.48	32.87	0.16	
37029	500-yr	6428	33	6628.97	33.14	0.14	
34658	2-yr	2599	24.76	2315.8	24.06	-0.7	
34658	5-yr	4063	27.44	4273.67	27.78	0.34	
34658	10-yr	4758	28.55	4922.99	28.8	0.25	
34658	25-yr	5118	29.19	5293.25	29.44	0.25	
34658	50-yr	5395	29.67	5563.78	29.88	0.21	
34658	100-yr	5707	30.18	5961.54	30.37	0.19	
34658	250-yr	6114	30.74	6339.48	30.87	0.13	
34658	500-yr	6428	31.07	6628.97	31.19	0.12	
32049	2-yr	2710	23	2396.81	22.31	-0.69	
32049	5-yr	4238	25.58	4488.73	25.92	0.34	
32049	10-yr	5038	26.7	5213.9	26.98	0.28	
32049	25-yr	5461	27.42	5676.03	27.68	0.26	
32049	50-yr	5820	27.95	6027	28.14	0.19	
32049	100-yr	6229	28.51	6426.75	28.64	0.13	
32049	250-yr	6759	29.08	6933.24	29.16	0.08	
32049	500-yr	7168	29.38	7332.29	29.47	0.09	
30749	2-yr	2762	22.03	2437.49	21.33	-0.7	
30749	5-yr	4354	24.7	4614.91	25.04	0.34	
30749	10-yr	5205	25.88	5405.29	26.18	0.3	
30749	25-yr	5688	26.67	5914.62	26.93	0.26	
30749	50-yr	6092	27.23	6287.53	27.43	0.2	
30749	100-yr	6558	27.84	6679.59	27.97	0.13	
30749	250-yr	7052	28.44	7139.66	28.52	0.08	
30749	500-yr	7454	28.73	7506.23	28.82	0.09	
28512	2-yr	2762	20.43	2437.49	19.73	-0.7	
28512	5-yr	4354	23.21	4614.91	23.55	0.34	
28512	10-yr	5205	24.48	5405.29	24.83	0.35	
28512	25-yr	5688	25.42	5914.62	25.7	0.28	
28512	50-yr	6092	26.06	6287.53	26.27	0.21	
28512	100-yr	6558	26.79	6679.59	27	0.21	
28512	250-yr	7052	27.71	7139.66	27.81	0.1	
28512	500-yr	7454	28.05	7506.23	28.18	0.13	
25706	2-yr	3015	18.65	2660.48	17.95	-0.7	
25706	5-yr	4815	21.47	5093.72	21.78	0.31	
25706	10-yr	5821	22.78	6126.45	23.16	0.38	
25706	25-yr	6603	23.84	6869.83	24.11	0.27	
25706	50-yr	7182	24.52	7416.17	24.72	0.2	
25706	100-yr	7842	25.41	7996.69	25.7	0.29	
25706	250-yr	8533	26.67	8707.9	26.81	0.14	
25706	500-yr	8886	27.13	9164.95	27.3	0.17	
25647	2-yr	3015	18.63	2660.48	17.94	-0.69	
25647	5-yr	4815	21.46	5093.72	21.77	0.31	
25647	10-yr	5821	22.78	6126.45	23.16	0.38	
25647	25-yr	6603	23.84	6869.83	24.12	0.28	
25647	50-yr	7182	24.54	7416.17	24.73	0.19	
25647	100-yr	7842	25.42	7996.69	25.72	0.3	
25647	250-yr	8533	26.68	8707.9	26.82	0.14	
25647	500-yr	8886	27.14	9164.95	27.31	0.17	
25645.5	UTILITY CROSSING						Bridge
25643	2-yr	3015	18.61	2660.48	17.9	-0.71	
25643	5-yr	4815	21.45	5093.72	21.75	0.3	
25643	10-yr	5821	22.75	6126.45	23.12	0.37	
25643	25-yr	6603	23.8	6869.83	24.08	0.28	
25643	50-yr	7182	24.49	7416.17	24.68	0.19	
25643	100-yr	7842	25.37	7996.69	25.67	0.3	
25643	250-yr	8533	26.62	8707.9	26.76	0.14	
25643	500-yr	8886	27.09	9164.95	27.25	0.16	
25591	2-yr	3015	18.58	2660.48	17.88	-0.7	
25591	5-yr	4815	21.42	5093.72	21.73	0.31	
25591	10-yr	5821	22.72	6126.45	23.1	0.38	
25591	25-yr	6603	23.78	6869.83	24.05	0.27	
25591	50-yr	7182	24.46	7416.17	24.65	0.19	
25591	100-yr	7842	25.35	7996.69	25.64	0.29	
25591	250-yr	8533	26.61	8707.9	26.74	0.13	
25591	500-yr	8886	27.07	9164.95	27.24	0.17	
25584.5	42" COH WATERLIN						Bridge
25577	2-yr	3015	18.53	2660.48	17.85	-0.68	
25577	5-yr	4815	21.34	5093.72	21.65	0.31	
25577	10-yr	5821	22.68	6126.45	23.05	0.37	
25577	25-yr	6603	23.72	6869.83	23.99	0.27	
25577	50-yr	7182	24.39	7416.17	24.58	0.19	
25577	100-yr	7842	25.26	7996.69	25.56	0.3	
25577	250-yr	8533	26.52	8707.9	26.65	0.13	
25577	500-yr	8886	26.99	9164.95	27.15	0.16	
25519	2-yr	3015	18.53	2660.48	17.84	-0.69	
25519	5-yr	4815	21.34	5093.72	21.64	0.3	
25519	10-yr	5821	22.67	6126.45	23.04	0.37	
25519	25-yr	6603	23.7	6869.83	23.97	0.27	
25519	50-yr	7182	24.37	7416.17	24.55	0.18	
25519	100-yr	7842	25.22	7996.69	25.51	0.29	
25519	250-yr	8533	26.5	8707.9	26.64	0.14	
25519	500-yr	8886	26.97	9164.95	27.15	0.18	
25333.5	IH-10 BRIDGE						Bridge
25152	2-yr	3015	18.13	2660.48	17.46	-0.67	
25152	5-yr	4815	20.83	5093.72	21.12	0.29	
25152	10-yr	5821	22.13	6126.45	22.48	0.35	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
Station	Profile	Q Total (cfs)	W.S. Elev (ft)	Q Total (cfs)	W.S. Elev (ft)	W.S. Elev (ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
25152	25-yr	6603	23.13	6869.83	23.38	0.25	
25152	50-yr	7182	23.78	7416.17	23.94	0.16	
25152	100-yr	7842	24.42	7996.69	24.7	0.28	
25152	250-yr	8533	25.26	8707.9	25.36	0.1	
25152	500-yr	8886	25.71	9164.95	25.91	0.2	
25105	2-yr	3015	18.1	2660.48	17.43	-0.67	
25105	5-yr	4815	20.8	5093.72	21.08	0.28	
25105	10-yr	5821	22.09	6126.45	22.44	0.35	
25105	25-yr	6603	23.1	6869.83	23.35	0.25	
25105	50-yr	7182	23.74	7416.17	23.91	0.17	
25105	100-yr	7842	24.38	7996.69	24.66	0.28	
25105	250-yr	8533	25.23	8707.9	25.33	0.1	
25105	500-yr	8886	25.67	9164.95	25.88	0.21	
24429	2-yr	3040	17.65	2676.66	16.97	-0.68	
24429	5-yr	4880	20.37	5142.32	20.65	0.28	
24429	10-yr	5910	21.67	6216.85	22.01	0.34	
24429	25-yr	6740	22.68	6995.42	22.93	0.25	
24429	50-yr	7360	23.34	7566.79	23.51	0.17	
24429	100-yr	8030	24	8179.93	24.25	0.25	
24429	250-yr	8780	24.86	8934.21	24.96	0.1	
24429	500-yr	9180	25.32	9429.48	25.54	0.22	
22389	2-yr	3072	15.01	2702.71	14.39	-0.62	
22389	5-yr	4995	17.44	5220.93	17.67	0.23	
22389	10-yr	6055	18.55	6364.02	18.82	0.27	
22389	25-yr	6957	19.44	7200.83	19.65	0.21	
22389	50-yr	7644	20.04	7813.76	20.18	0.14	
22389	100-yr	8348	20.63	8481.4	20.76	0.13	
22389	250-yr	9192	21.48	9308	21.6	0.12	
22389	500-yr	9679	22.01	9868.01	22.33	0.32	
22355	2-yr	3072	14.92	2702.71	14.31	-0.61	
22355	5-yr	4995	17.34	5220.93	17.56	0.22	
22355	10-yr	6055	18.43	6364.02	18.7	0.27	
22355	25-yr	6957	19.32	7200.83	19.53	0.21	
22355	50-yr	7644	19.9	7813.76	20.05	0.15	
22355	100-yr	8348	20.49	8481.4	20.61	0.12	
22355	250-yr	9192	21.34	9308	21.46	0.12	
22355	500-yr	9679	21.87	9868.01	22.19	0.32	
22315.5	MARKET STREET BR						Bridge
22275	2-yr	3072	14.47	2702.71	13.91	-0.56	
22275	5-yr	4995	16.65	5220.93	16.84	0.19	
22275	10-yr	6055	17.62	6364.02	17.84	0.22	
22275	25-yr	6957	18.41	7200.83	18.58	0.17	
22275	50-yr	7644	18.89	7813.76	19.02	0.13	
22275	100-yr	8348	19.39	8481.4	19.5	0.11	
22275	250-yr	9192	20.04	9308	20.14	0.1	
22275	500-yr	9679	20.45	9868.01	20.58	0.13	
22258	2-yr	3072	14.43	2702.71	13.87	-0.56	
22258	5-yr	4995	16.6	5220.93	16.78	0.18	
22258	10-yr	6055	17.55	6364.02	17.78	0.23	
22258	25-yr	6957	18.33	7200.83	18.5	0.17	
22258	50-yr	7644	18.82	7813.76	18.94	0.12	
22258	100-yr	8348	19.31	8481.4	19.42	0.11	
22258	250-yr	9192	19.95	9308	20.05	0.1	
22258	500-yr	9679	20.36	9868.01	20.49	0.13	
22170	2-yr	3072	14.53	2702.71	13.95	-0.58	
22170	5-yr	4995	16.77	5220.93	16.97	0.2	
22170	10-yr	6055	17.77	6364.02	18.01	0.24	
22170	25-yr	6957	18.59	7200.83	18.77	0.18	
22170	50-yr	7644	19.1	7813.76	19.23	0.13	
22170	100-yr	8348	19.63	8481.4	19.74	0.11	
22170	250-yr	9192	20.31	9308	20.42	0.11	
22170	500-yr	9679	20.73	9868.01	20.87	0.14	
22159.5	MISSOURI PACIFIC						Bridge
22148	2-yr	3072	14.49	2702.71	13.92	-0.57	
22148	5-yr	4995	16.72	5220.93	16.91	0.19	
22148	10-yr	6055	17.7	6364.02	17.94	0.24	
22148	25-yr	6957	18.52	7200.83	18.7	0.18	
22148	50-yr	7644	19.02	7813.76	19.15	0.13	
22148	100-yr	8348	19.54	8481.4	19.65	0.11	
22148	250-yr	9192	20.16	9308	20.26	0.1	
22148	500-yr	9679	20.56	9868.01	20.69	0.13	
22102	2-yr	3072	14.47	2702.71	13.9	-0.57	
22102	5-yr	4995	16.69	5220.93	16.88	0.19	
22102	10-yr	6055	17.67	6364.02	17.91	0.24	
22102	25-yr	6957	18.49	7200.83	18.66	0.17	
22102	50-yr	7644	18.99	7813.76	19.12	0.13	
22102	100-yr	8348	19.51	8481.4	19.62	0.11	
22102	250-yr	9192	20.13	9308	20.23	0.1	
22102	500-yr	9679	20.53	9868.01	20.66	0.13	
20985	2-yr	3072	13.64	2702.71	13.11	-0.53	
20985	5-yr	4995	15.6	5220.93	15.76	0.16	
20985	10-yr	6055	16.5	6364.02	16.7	0.2	
20985	25-yr	6957	17.23	7200.83	17.39	0.16	
20985	50-yr	7644	17.7	7813.76	17.83	0.13	
20985	100-yr	8348	18.22	8481.4	18.33	0.11	
20985	250-yr	9192	18.83	9308	18.94	0.11	
20985	500-yr	9679	19.23	9868.01	19.35	0.12	
18335	2-yr	3072	12.18	2702.71	11.74	-0.44	
18335	5-yr	4995	14.35	5220.93	14.49	0.14	
18335	10-yr	6055	15.42	6364.02	15.62	0.2	
18335	25-yr	6957	16.27	7200.83	16.47	0.2	
18335	50-yr	7644	16.85	7813.76	17.01	0.16	
18335	100-yr	8348	17.47	8481.4	17.61	0.14	
18335	250-yr	9192	18.19	9308	18.32	0.13	
18335	500-yr	9679	18.66	9868.01	18.79	0.13	
17139	2-yr	3050	11.26	2758.49	10.86	-0.4	
17139	5-yr	5250	13.86	5425.78	14.01	0.15	
17139	10-yr	6520	15.05	6793.37	15.26	0.21	
17139	25-yr	7600	15.96	7874.77	16.18	0.22	
17139	50-yr	8420	16.59	8636.89	16.76	0.17	
17139	100-yr	9330	17.24	9522.1	17.39	0.15	
17139	250-yr	10440	17.99	10605.13	18.13	0.14	
17139	500-yr	11160	18.48	11348.7	18.62	0.14	
16284	2-yr	3050	10.84	2767.69	10.43	-0.41	
16284	5-yr	5289	13.51	5459.9	13.67	0.16	
16284	10-yr	6598	14.73	6865.99	14.95	0.22	
16284	25-yr	7713	15.67	7990.35	15.89	0.22	
16284	50-yr	8553	16.31	8778.92	16.48	0.17	
16284	100-yr	9505	16.98	9703.28	17.14	0.16	
16284	250-yr	10658	17.75	10832.87	17.9	0.15	
16284	500-yr	11427	18.25	11610.05	18.4	0.15	
13551	2-yr	3050	9.87	2767.69	9.47	-0.4	
13551	5-yr	5289	12.56	5459.9	12.71	0.15	
13551	10-yr	6598	13.8	6865.99	14.03	0.23	
13551	25-yr	7713	14.77	7990.35	15	0.23	
13551	50-yr	8553	15.42	8778.92	15.61	0.19	
13551	100-yr	9505	16.11	9703.28	16.29	0.18	
13551	250-yr	10658	16.92	10832.87	17.09	0.17	
13551	500-yr	11427	17.44	11610.05	17.6	0.16	
12170	2-yr	3120	9.19	2847.03	8.83	-0.36	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
12170	5-yr	5490	11.73	5657.53	11.87	0.14	
12170	10-yr	6880	12.95	7163.14	13.17	0.22	
12170	25-yr	8080	13.91	8389.08	14.14	0.23	
12170	50-yr	8990	14.56	9255.67	14.75	0.19	
12170	100-yr	10020	15.25	10275.2	15.43	0.18	
12170	250-yr	11260	16.06	11509.23	16.22	0.16	
12170	500-yr	12110	16.58	12362.6	16.74	0.16	
9930	2-yr	3120	8.46	2847.03	8.14	-0.32	
9930	5-yr	5490	10.66	5657.53	10.79	0.13	
9930	10-yr	6880	11.76	7163.14	11.95	0.19	
9930	25-yr	8080	12.64	8389.08	12.84	0.2	
9930	50-yr	8990	13.21	9255.67	13.39	0.18	
9930	100-yr	10020	13.84	10275.2	14	0.16	
9930	250-yr	11260	14.57	11509.23	14.73	0.16	
9930	500-yr	12110	15.04	12362.6	15.19	0.15	
9888	2-yr	3154	8.36	2892.01	8.05	-0.31	
9888	5-yr	5603	10.48	5770.22	10.61	0.13	
9888	10-yr	7046	11.54	7333.48	11.71	0.17	
9888	25-yr	8293	12.38	8618.77	12.57	0.19	
9888	50-yr	9236	12.92	9531.19	13.09	0.17	
9888	100-yr	10316	13.51	10606.84	13.67	0.16	
9888	250-yr	11615	14.21	11902.44	14.35	0.14	
9888	500-yr	12508	14.64	12800.86	14.78	0.14	
9856.5	PTRA RR BRIDGES						Bridge
9824	2-yr	3154	8.22	2892.01	7.92	-0.3	
9824	5-yr	5603	10.21	5770.22	10.32	0.11	
9824	10-yr	7046	11.19	7333.48	11.35	0.16	
9824	25-yr	8293	11.97	8618.77	12.15	0.18	
9824	50-yr	9236	12.46	9531.19	12.61	0.15	
9824	100-yr	10316	13	10606.84	13.14	0.14	
9824	250-yr	11615	13.63	11902.44	13.76	0.13	
9824	500-yr	12508	14.02	12800.86	14.15	0.13	
9735	2-yr	3154	8.17	2892.01	7.87	-0.3	
9735	5-yr	5603	10.12	5770.22	10.23	0.11	
9735	10-yr	7046	11.08	7333.48	11.24	0.16	
9735	25-yr	8293	11.85	8618.77	12.02	0.17	
9735	50-yr	9236	12.34	9531.19	12.48	0.14	
9735	100-yr	10316	12.86	10606.84	13	0.14	
9735	250-yr	11615	13.49	11902.44	13.61	0.12	
9735	500-yr	12508	13.87	12800.86	14	0.13	
8375	2-yr	3154	7.2	2892.01	6.88	-0.32	
8375	5-yr	5603	9.17	5770.22	9.29	0.12	
8375	10-yr	7046	10.22	7333.48	10.38	0.16	
8375	25-yr	8293	11.07	8618.77	11.25	0.18	
8375	50-yr	9236	11.57	9531.19	11.73	0.16	
8375	100-yr	10316	12.12	10606.84	12.27	0.15	
8375	250-yr	11615	12.79	11902.44	12.92	0.13	
8375	500-yr	12508	13.2	12800.86	13.33	0.13	
6110	2-yr	3154	4.47	2892.01	4.09	-0.38	
6110	5-yr	5603	7.02	5770.22	7.17	0.15	
6110	10-yr	7046	8.47	7333.48	8.81	0.34	
6110	25-yr	8293	9.7	8618.77	9.89	0.19	
6110	50-yr	9236	10.24	9531.19	10.4	0.16	
6110	100-yr	10316	10.81	10606.84	10.96	0.15	
6110	250-yr	11615	11.5	11902.44	11.65	0.15	
6110	500-yr	12508	11.94	12800.86	12.09	0.15	
6075	2-yr	3154	4.4	2892.01	4.01	-0.39	
6075	5-yr	5603	6.89	5770.22	7.03	0.14	
6075	10-yr	7046	8.37	7333.48	8.78	0.41	
6075	25-yr	8293	9.68	8618.77	9.87	0.19	
6075	50-yr	9236	10.21	9531.19	10.38	0.17	
6075	100-yr	10316	10.79	10606.84	10.94	0.15	
6075	250-yr	11615	11.48	11902.44	11.63	0.15	
6075	500-yr	12508	11.92	12800.86	12.07	0.15	
6064.5	ABANDONED RAILRO						Bridge
6053	2-yr	3154	4.32	2892.01	3.92	-0.4	
6053	5-yr	5603	6.83	5770.22	6.98	0.15	
6053	10-yr	7046	8.07	7333.48	8.34	0.27	
6053	25-yr	8293	9.25	8618.77	9.48	0.23	
6053	50-yr	9236	9.9	9531.19	10.09	0.19	
6053	100-yr	10316	10.57	10606.84	10.74	0.17	
6053	250-yr	11615	11.34	11902.44	11.5	0.16	
6053	500-yr	12508	11.83	12800.86	11.98	0.15	
5916	2-yr	3154	3.98	2892.01	3.55	-0.43	
5916	5-yr	5603	6.68	5770.22	6.83	0.15	
5916	10-yr	7046	7.96	7333.48	8.22	0.26	
5916	25-yr	8293	9.14	8618.77	9.38	0.24	
5916	50-yr	9236	9.81	9531.19	10	0.19	
5916	100-yr	10316	10.48	10606.84	10.66	0.18	
5916	250-yr	11615	11.25	11902.44	11.42	0.17	
5916	500-yr	12508	11.75	12800.86	11.9	0.15	
5741	2-yr	3154	3.77	2892.01	3.33	-0.44	
5741	5-yr	5603	6.61	5770.22	6.77	0.16	
5741	10-yr	7046	7.96	7333.48	8.23	0.27	
5741	25-yr	8293	9.14	8618.77	9.38	0.24	
5741	50-yr	9236	9.81	9531.19	10.01	0.2	
5741	100-yr	10316	10.5	10606.84	10.67	0.17	
5741	250-yr	11615	11.27	11902.44	11.44	0.17	
5741	500-yr	12508	11.77	12800.86	11.92	0.15	
5718.5	COH WATERPLANT B						Bridge
5695	2-yr	3154	3.66	2892.01	3.22	-0.44	
5695	5-yr	5603	6.54	5770.22	6.71	0.17	
5695	10-yr	7046	7.92	7333.48	8.19	0.27	
5695	25-yr	8293	9.11	8618.77	9.35	0.24	
5695	50-yr	9236	9.78	9531.19	9.98	0.2	
5695	100-yr	10316	10.47	10606.84	10.65	0.18	
5695	250-yr	11615	11.25	11902.44	11.42	0.17	
5695	500-yr	12508	11.74	12800.86	11.9	0.16	
5691	2-yr	3154	3.53	2892.01	3.13	-0.4	
5691	5-yr	5603	6.01	5770.22	6.15	0.14	
5691	10-yr	7046	7.34	7333.48	7.59	0.25	
5691	25-yr	8293	8.43	8618.77	8.65	0.22	
5691	50-yr	9236	9.01	9531.19	9.18	0.17	
5691	100-yr	10316	9.59	10606.84	9.74	0.15	
5691	250-yr	11615	10.24	11902.44	10.39	0.15	
5691	500-yr	12508	10.66	12800.86	10.79	0.13	
5680.5	ABANDONED TIMBER						Bridge
5669	2-yr	3154	3.43	2892.01	3.04	-0.39	
5669	5-yr	5603	5.75	5770.22	5.86	0.11	
5669	10-yr	7046	6.62	7333.48	6.78	0.16	
5669	25-yr	8293	7.45	8618.77	7.66	0.21	
5669	50-yr	9236	8.01	9531.19	8.16	0.15	
5669	100-yr	10316	8.55	10606.84	8.69	0.14	
5669	250-yr	11615	9.17	11902.44	9.31	0.14	
5669	500-yr	12508	9.57	12800.86	9.69	0.12	
5597	2-yr	3154	3.42	2892.01	3.03	-0.39	
5597	5-yr	5603	5.75	5770.22	5.87	0.12	
5597	10-yr	7046	6.64	7333.48	6.81	0.17	
5597	25-yr	8293	7.37	8618.77	7.57	0.2	

Table 5. Comparison of WSEL with HEC-RAS 3.1.1 and HEC-1 Flows and HEC-RAS 4.1.0 and Flows from HEC-HMS with Updated Routing Data

		HEC-1 / RAS 3.1.1		HEC-HMS with HEC-1		Difference	
			W.S. Elev		W.S. Elev	W.S. Elev	
Station	Profile	Q Total (cfs)	(ft)	Q Total (cfs)	(ft)	(ft)	
76752	2-yr	320	44.58	294.37	44.09	-0.49	
5597	50-yr	9236	7.92	9531.19	8.07	0.15	
5597	100-yr	10316	8.46	10606.84	8.6	0.14	
5597	250-yr	11615	9.08	11902.44	9.22	0.14	
5597	500-yr	12508	9.49	12800.86	9.62	0.13	
5585	2-yr	3154	3.42	2892.01	3.02	-0.4	
5585	5-yr	5603	5.74	5770.22	5.86	0.12	
5585	10-yr	7046	6.63	7333.48	6.79	0.16	
5585	25-yr	8293	7.35	8618.77	7.55	0.2	
5585	50-yr	9236	7.89	9531.19	8.04	0.15	
5585	100-yr	10316	8.43	10606.84	8.56	0.13	
5585	250-yr	11615	9.04	11902.44	9.17	0.13	
5585	500-yr	12508	9.44	12800.86	9.56	0.12	
5543	2-yr	3154	3.39	2892.01	3	-0.39	
5543	5-yr	5603	5.7	5770.22	5.81	0.11	
5543	10-yr	7046	6.58	7333.48	6.73	0.15	
5543	25-yr	8293	7.27	8618.77	7.46	0.19	
5543	50-yr	9236	7.79	9531.19	7.93	0.14	
5543	100-yr	10316	8.3	10606.84	8.43	0.13	
5543	250-yr	11615	8.87	11902.44	9	0.13	
5543	500-yr	12508	9.25	12800.86	9.36	0.11	
4062	2-yr	3154	1.72	2892.01	1.38	-0.34	
4062	5-yr	5603	4.21	5770.22	4.35	0.14	
4062	10-yr	7046	5.29	7333.48	5.49	0.2	
4062	25-yr	8293	6.14	8618.77	6.36	0.22	
4062	50-yr	9236	6.74	9531.19	6.9	0.16	
4062	100-yr	10316	7.32	10606.84	7.47	0.15	
4062	250-yr	11615	7.97	11902.44	8.11	0.14	
4062	500-yr	12508	8.39	12800.86	8.52	0.13	
3171	2-yr	3154	1.39	2892.01	1.06	-0.33	
3171	5-yr	5603	3.72	5770.22	3.85	0.13	
3171	10-yr	7046	4.74	7333.48	4.94	0.2	
3171	25-yr	8293	5.58	8618.77	5.81	0.23	
3171	50-yr	9236	6.21	9531.19	6.39	0.18	
3171	100-yr	10316	6.84	10606.84	7	0.16	
3171	250-yr	11615	7.54	11902.44	7.69	0.15	
3171	500-yr	12508	7.98	12800.86	8.12	0.14	
3116	2-yr	3154	1.37	2892.01	1.04	-0.33	
3116	5-yr	5603	3.7	5770.22	3.82	0.12	
3116	10-yr	7046	4.71	7333.48	4.91	0.2	
3116	25-yr	8293	5.55	8618.77	5.77	0.22	
3116	50-yr	9236	6.16	9531.19	6.33	0.17	
3116	100-yr	10316	6.77	10606.84	6.92	0.15	
3116	250-yr	11615	7.44	11902.44	7.58	0.14	
3116	500-yr	12508	7.87	12800.86	8	0.13	
3113.5	COH WATERLINE						Bridge
3110	2-yr	3154	1.35	2892.01	1.03	-0.32	
3110	5-yr	5603	3.67	5770.22	3.8	0.13	
3110	10-yr	7046	4.66	7333.48	4.84	0.18	
3110	25-yr	8293	5.44	8618.77	5.65	0.21	
3110	50-yr	9236	6.02	9531.19	6.18	0.16	
3110	100-yr	10316	6.61	10606.84	6.76	0.15	
3110	250-yr	11615	7.28	11902.44	7.43	0.15	
3110	500-yr	12508	7.73	12800.86	7.88	0.15	
3105	2-yr	3154	1.29	2892.01	0.97	-0.32	
3105	5-yr	5603	3.56	5770.22	3.68	0.12	
3105	10-yr	7046	4.52	7333.48	4.69	0.17	
3105	25-yr	8293	5.27	8618.77	5.47	0.2	
3105	50-yr	9236	5.82	9531.19	5.98	0.16	
3105	100-yr	10316	6.37	10606.84	6.51	0.14	
3105	250-yr	11615	6.99	11902.44	7.12	0.13	
3105	500-yr	12508	7.4	12800.86	7.53	0.13	
3015.5	FEDERAL RD BRIDG						Bridge
2985	2-yr	3154	1.19	2892.01	0.88	-0.31	
2985	5-yr	5603	3.4	5770.22	3.51	0.11	
2985	10-yr	7046	4.32	7333.48	4.5	0.18	
2985	25-yr	8293	5.04	8618.77	5.23	0.19	
2985	50-yr	9236	5.56	9531.19	5.72	0.16	
2985	100-yr	10316	6.11	10606.84	6.25	0.14	
2985	250-yr	11615	6.73	11902.44	6.86	0.13	
2985	500-yr	12508	7.13	12800.86	7.26	0.13	
2942	2-yr	3154	1.18	2892.01	0.87	-0.31	
2942	5-yr	5603	3.38	5770.22	3.5	0.12	
2942	10-yr	7046	4.31	7333.48	4.48	0.17	
2942	25-yr	8293	5.03	8618.77	5.21	0.18	
2942	50-yr	9236	5.54	9531.19	5.69	0.15	
2942	100-yr	10316	6.09	10606.84	6.23	0.14	
2942	250-yr	11615	6.71	11902.44	6.85	0.14	
2942	500-yr	12508	7.12	12800.86	7.25	0.13	
2140	2-yr	3154	0.43	2892.01	0.14	-0.29	
2140	5-yr	5603	2.53	5770.22	2.65	0.12	
2140	10-yr	7046	3.42	7333.48	3.58	0.16	
2140	25-yr	8293	4.11	8618.77	4.29	0.18	
2140	50-yr	9236	4.61	9531.19	4.77	0.16	
2140	100-yr	10316	5.16	10606.84	5.3	0.14	
2140	250-yr	11615	5.78	11902.44	5.91	0.13	
2140	500-yr	12508	6.19	12800.86	6.32	0.13	

Table 6				
	2010 EAD using HEC-1 / HEC-RAS 3.1.1 (x$1,000)	2010 EAD using HEC-1 / HEC-RAS 4.1.0 (x$1,000)	2010 EAD using HEC-HMS / HEC-RAS 4.1.0 (x$1,000)	2010 EAD using HEC-HMS / HEC-RAS 4.1.0 (x$1,000)
Without Project Conditions	$22,419.79	$22,420.07	$24,351.81	$24,351.81