Project Design Report:

Whitewater Preserve Flood Protection Improvements

Whitewater Preserve, Riverside County, CA

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1 INTRODUCTION

1.1 Project Overview

The Whitewater Preserve is a 2,851-acre site surrounded by the Bureau of Land Management's San Gorgonio Wilderness. The visitor facilities and ranger station for the Whitewater Preserve (Preserve) lies at the end of Whitewater Canyon Road, northeast of Palm Springs off of Interstate 10. The Preserve is owned and maintained by The Wildlands Conservancy.

The Wildlands Conservancy (TWC) is the largest nonprofit nature preserve system in California, currently with seventeen (17) preserves, it is dedicated to preserving the beauty and biodiversity of the earth and providing programs so that children may know the wonder and joy of nature.

The Preserve is located along the Whitewater River. The Whitewater River through the Preserve is a natural river that flows year-round. The river flows freely from the summit of Mount San Gorgonio in the San Bernardino Mountains to the floor of the Coachella Valley and eventually to its terminus at the Salton Sea. The visitor facilities, ranger station, and critical habitat within the Preserve has long been protected from severe flooding associated with the Whitewater River by a series of temporary levee systems along the eastern boundary of the river. The eroding levee system is in a constant need of repair in order to protect the visitor facilities, ranger station, and critical habitats.

In October 2019, TWC received a Proposition 1 Grant from the Coachella Valley Mountains Conservancy for the *Permitting Feasibility and Planning for Whitewater River Flood Improvements Project* to undertake the design, environmental review and permitting work for a replacement flood control structure to protect the Whitewater Preserve's visitor facilities and the current configuration of the wetlands habitat.

See Figure 1-1, Regional Location Map, and Figure 1-2, Whitewater Preserve Vicinity Map for the location of the river system and the Preserve facilities.

1.2 The Goals and Objectives

The goal of this project is to evaluate flood protection alternatives and provide the basis of design for the recommended facility improvements needed to provide up to a 500-year level of protection for The Preserve visitor facilities and critical habitats. The purpose of this report is to present the detailed engineering design used for the recommended flood protection improvements. The document will provide a detailed assessment of Whitewater River including the hydrology, hydraulics, sedimentation and scour, along with a detailed assessment of the existing conditions. Together, the in-depth understanding of the watershed and project reach conditions will guide the development of appropriate, long-term solutions for improved flood protection along the project reach.

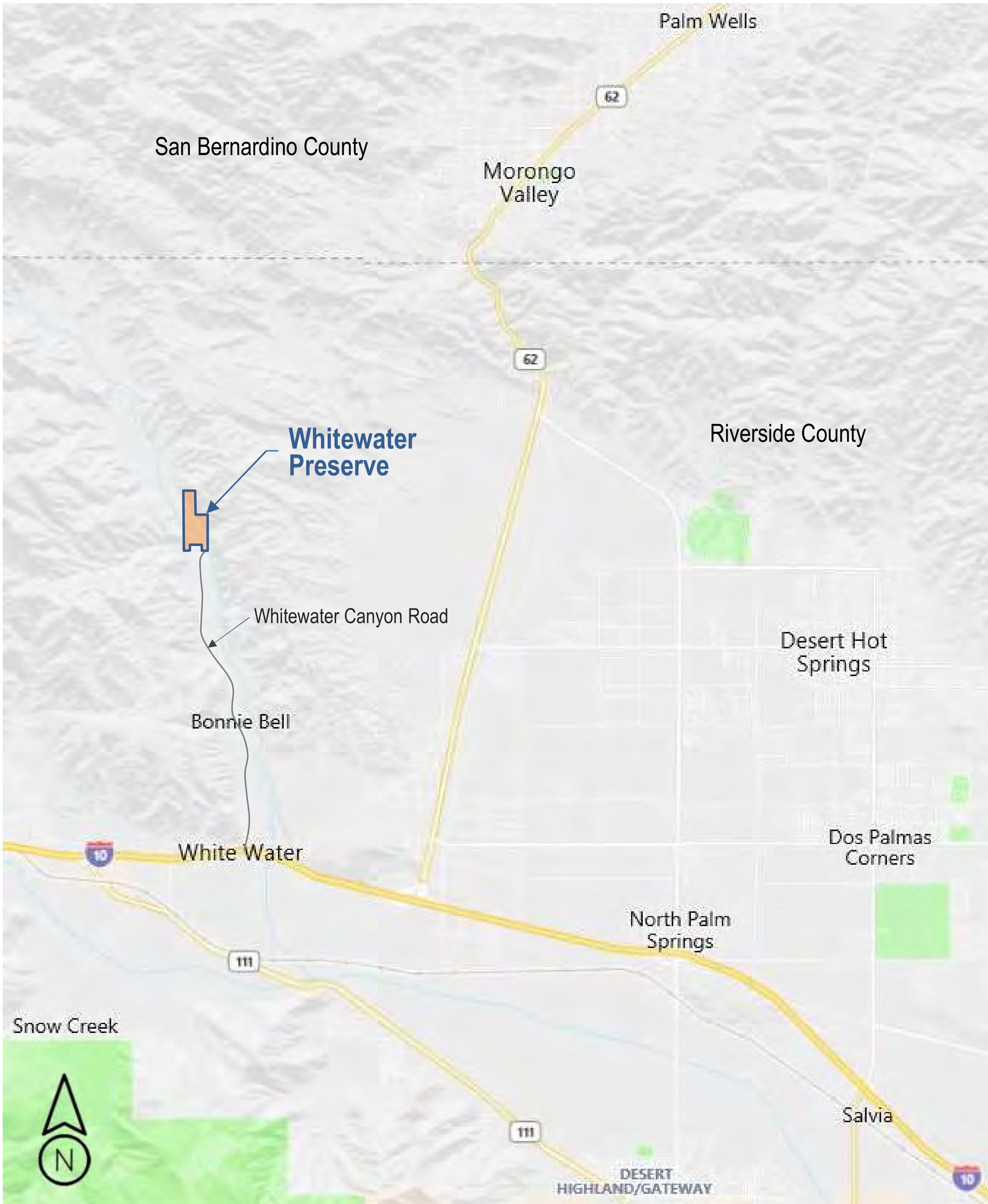
The primary objectives of this study include the following:

- Research, collect, and review previous studies completed in the watershed and along the study reach
- Establish the design criteria and requirements to be used for the development of the proposed flood protection improvements

- Establish the design hydrology and flow rates that will be used for the river analysis.
- Complete a hydraulic analysis of the river for the existing and project conditions to verify the operation of the proposed improvements and determine the facility requirements
- Prepare a geomorphic assessment and sedimentation and scour analyses to establish parameters for the facility design
- Review and identify recommendations for the bank protection requirements
- Provide detailed recommendations for the final design of the recommended improvements
- Prepare a basis of design report to document and support the recommended improvements along the Whitewater River
- Provide supporting documentation for the preparation of an environmental document and processing of the regulatory permits.

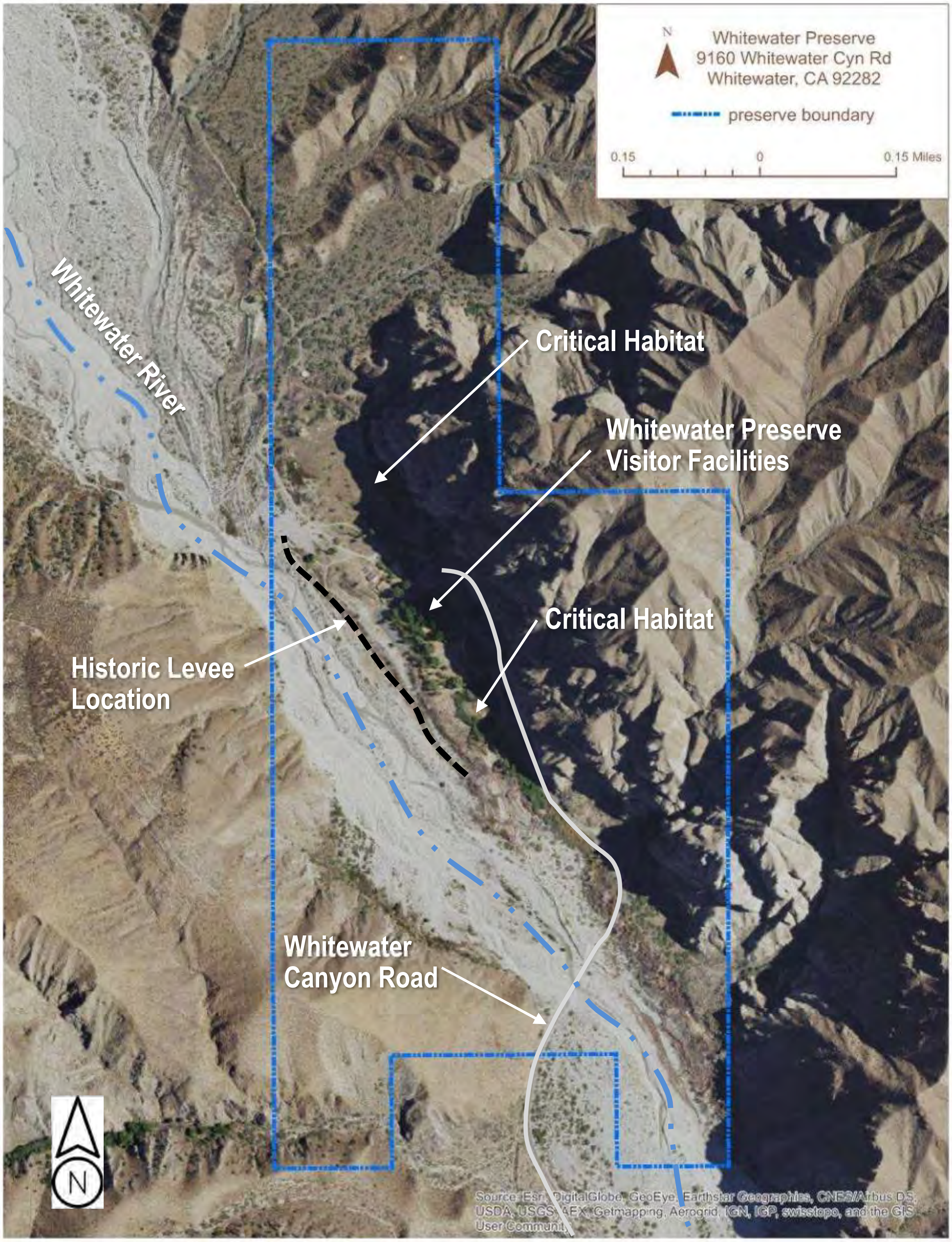
The project shall be developed in coordination with the TWC and The Whitewater Preserve to establish the appropriate levels of flood protection and resiliency in accordance with intended goals for the project.

Figure 1-1. Regional Location Map



Ref: Bing Maps

Figure 1-2. Whitewater Preserve Vicinity Map



2 Existing Conditions

The Preserve visitor facilities, ranger station, and critical habitat are located adjacent to the eastern bank of the Whitewater River. The river is a dynamic system with a wide floodplain, high flow rates in response to storm events, and a meandering flow path. The Preserve facilities and previous fish hatchery have historically been protected from flooding by a series of levees along the riverbank. The levees have historically been constructed by pushing dirt and river rocks into a raised bank long the rivers edge. In some cases, the rock has been grouted with concrete to provide additional protection. As the levee erodes or is damaged by large storm events, it has been repaired in the same fashion as it was initially constructed. An engineered levee system designed to handle the dynamic conditions of the river has not been previously developed.

The Whitewater River adjacent to the Preserve has a watershed area of almost 58 square miles. The large watershed, step terrain, and rocky conditions can rapidly change the dynamics of the river in response to storm events. The tranquil low flow conditions can quickly change into a raging river with destructive force. These conditions have resulted in significant damage to the current levee system. Much of the previous levee system has been eroded since its last repairs and the Preserve facilities and habitats are in danger of being damaged or destroyed as a result of a large storm event. Remnants of the exiting levee system and erosion of the bank protection along the Whitewater River are shown in Figure 2-1. The existing levee and bank protection are in need of being reconstructed and upgraded to an engineered system designed to handle the river conditions.

Figure 2-1. Whitewater River at Preserve (looking downstream)

2.1 FEMA Floodplain Mapping

The project site is not located within a Special Flood Hazard Area (SFHA) as shown on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs). The proposed project area is covered by FIRM Panel Number 06065C0860G, effective August 28, 2008, which indicates the project area lies within Zone X (Unshaded) which is defined as areas having moderate or minimal risk of flooding. While the area is not defined by FEMA as a SFHA, it does not mean that there is not the potential for flooding. In this location it is more likely that the area has not been mapped by FEMA due to its rural location.

2.2 Flood History and Damage

The recent storm events have resulted in erosion of the existing levee system and significant damage to the Whitewater Canyon Road including the low water crossing which was washed out in the February 2019 storm event. Riverside County completed reconstructed the low water crossing in late 2019. The crossing is significant in that it provides the only access to the Preserve visitor facilities and it acts as a grade control structure along the Whitewater River which helps maintain the vertical profile of the river along the project reach. The photographs in the figures below show the Whitewater River during storm flow events and the recently reconstructed low water crossing at Whitewater Canyon Road.

Figure 2-2. Whitewater Canyon Road low water crossing

Figure 2-3. Moderate storm flows in Whitewater River adjacent to the Preserve

Figure 2-4. Whitewater Canyon Road Low Water Crossing (January 2020)

3 Hydrology Analysis

The hydrologic analysis performed herein is intended to serve as the hydrologic basis to be used in the planning and design of the proposed flood protection improvements, including the determination of impacts, mitigation requirements, and engineering constraints. The hydrologic basis supports the analysis of hydraulics, sedimentation, and scour through model development and simulation as well as the use of spreadsheet calculations.

3.1 Hydrologic goals objectives

The hydrologic basis was formulated being mindful of the following goals:

- Conveyance of floodwaters along the edge conditions and near vicinity of the proposed improvements as it relates to stream stability, flood and erosion protection, and consequences to adjacent properties and existing infrastructure
- Increased runoff volume and/or flow redistribution attributed to the improvements

The hydrologic objectives focused on the determination of the following for the portion of the Whitewater River watershed that is relevant to the Whitewater Preserve Area:

- *Regional flood frequency curves*. A regional flood frequency analysis was performed based on most current available streamflow data to determine peak flow rates using stochastic methods based on recorded observations to provide a metric for evaluating the reasonableness of peak flow rates computed based on deterministic methods
- *Regional peak flow rates and flood hydrographs*. Peak flow rates and flood hydrographs were determined for selected combinations of frequencies and durations to support the development, simulation, and analysis of steady- and unsteady-flow hydraulic models and supplementary calculations, which contribute to the basis of design formulated for the proposed levee improvements.

3.2 General approach and assumptions

The following general approach and assumptions were employed herein:

- Flood frequency analysis were performed based on the method of *L*-moments (Hosking and Wallis, 1997)
- The Riverside County Hydrology Manual (RCHM; RCFCWCD, 1978) Synthetic Unit Hydrograph Method (SUHM) was used as the framework for the deterministic computation of peak flow rates and flood hydrographs
- The relevant Whitewater River watershed was identified as the area tributary to the historic USGS streamflow gage site at Whitewater (USGS ID 10256000), located between Interstate 10 and the Whitewater Preserve Area
- The 50-, 20-, 10-, 2-, 1-, 0.5, and 0.2-percent annual chance storm events were evaluated
- Parameter development was performed using a combination of GIS and spreadsheet applications

3.3 Regional flood frequency analysis

A regional flood frequency analysis based on the method of *L*-moments (Hosking and Wallis, 1997) was adopted herein to determine frequency distributions of annual maximum discharges for selected gauges in the Salton Basin with a focus on the Whitewater River and its tributaries.

3.3.1 Data screening

There are 45 combined available active and historic streamflow gauging stations (sites) located in the Salton Basin as shown in Figure 3-1. Site information is also presented in Table 3-1, which includes drainage area, elevation, location (latitude and longitude), length of record, and range of water years covered where a water year is considered to span from October 1st to September 30th of the following calendar year.

The available 45 sites were screened for their potential use in regional frequency analysis. Characteristics of the recorded dataset for each of these sites were inventoried as shown in Table 3-2, which was subsequently used to narrow the list potential sites suitable for regional frequency analysis. Of the available 45 sites, seven (7) were excluded due to climatic dissimilarities and another 21 sites were discarded due to limitations in the type, quantity, and/or quality of observed data, resulting in 17 sites highlighted in Table 3-2 that remain available for further evaluation.

The tributary drainage areas associated with the remaining 17 sites range from four (4) square miles to 1,073 square miles with elevations varying from -220 feet below sea level to 2,370 feet above sea level. The water years covered span from 1930 to 2019.

Data records of the remaining 17 sites were evaluated further and adjusted, as necessary to resolve issues related to the following:

- *Missing data*. There are 16 data points missing from a total of 802 recorded observations resulting in an effective dataset of 786 recorded observations
- *Historic peaks*. The data record for the 10256000 Whitewater River site at Whitewater identifies a historic peak of 42,000 *cfs* occurring on March 2, 1938, which precedes the operational period of the site and represents the only historic peak on record for the remaining of 17 sites; this historical peak was added to the record because of its significance despite its unknown basis of determination
- *Maximum daily averages*. There are 15 data points annotated as maximum daily averages. These observations were generally assumed to reflect the maximum flow conditions for the affected sites and water years; and thus, were retained in the dataset
- *Zero values*. There are 19 data points with zero values. Zero values are deemed consistent with the climatic conditions of an arid region such as the Salton Basin. Accordingly, these data points were included in the dataset
- *Estimated values*. There are 20 data points annotated as estimates. There is no apparent reason to suspect any of these data points are erroneous and thus, were retained in the dataset
- *Affects related to regulation or diversion*. The following four (4) sites were identified as potentially being affected by either regulation or diversion: (1) 10256500 Whitewater River at Whitewater, (2) 10256500 Snow Creek near Whitewater, (3) 10257550 Whitewater River at Windy Point, and (4) 1025772 Chino Canyon near Palm Springs. It has been demonstrated that *L*-moments are negligibly affected by regulation (Azquith, 2002); and thus, the affected data points for these four (4) sites were retained in the dataset
- *Unknown dates*. The data record for 10256500 Snow Creek near Whitewater has two (2) data points identified as having an unknown month or day, but otherwise, there is no apparent reason to suspect these data points are erroneous; and thus, were retained in the dataset
- *Affects related to urbanization, mining, agricultural activities, channelization*. There are 10 data points identified as being potentially influenced by land management or development practices associated with the following sites: (1) 10259100 Whitewater River at Rancho Mirage and (2) 10259300 Whitewater River at Indio; these types of influences were not viewed as being significant; and thus, the affected data points were retained in the dataset
- *Change in base discharge*. There are no data points affected by a change in the base discharge

The resolved 17-site dataset contains a total of 786 streamflow observations, with effective sample record lengths varying from 17 to 85 years. The at-site sample *L*-CV ranges from 0.63 to 0.89, the at-site sample *L*-skewness ranges from 0.45 to 0.81, and the L-Kurtosis ranges from 0.18 to 0.63. The average value for *L*-CV, *L*-skewness, and L-kurtosis are 0.74, 0.62, and 0.39, respectively. The unbiased at-site sample L-moments for the selected group of 17 sites are presented in Table 3-3.

Figure 3-1. USGS streamflow gauge location map

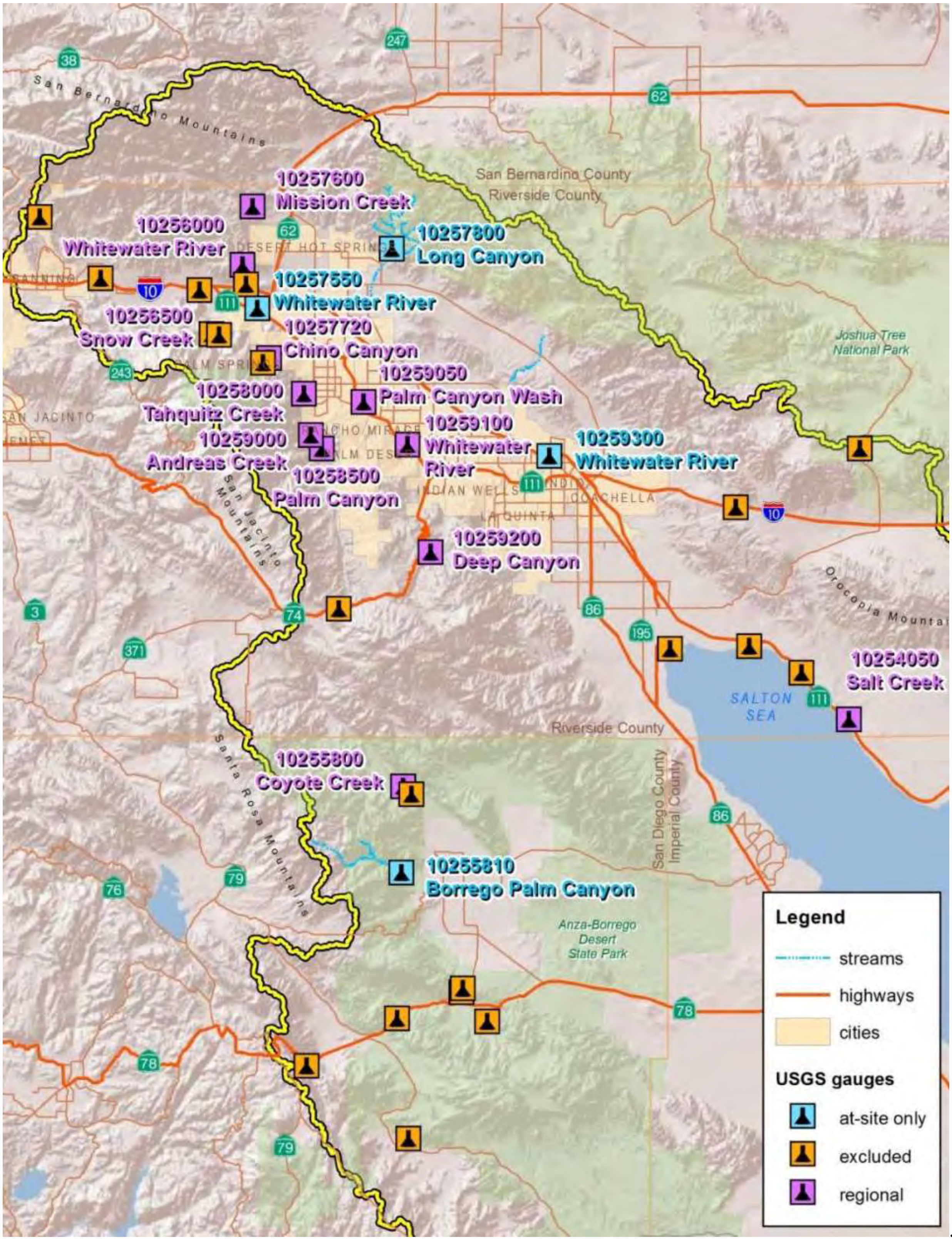


Table 3-1. Gauged sites located within the Salton Basin

USGS ID	description	latitude	longitude	drainage area {sq mi}	elevation {feet}	record length {years}	recorded water years
10254020	Betz Wash near Salton Sea	33.4981	-115.9053	5.95		14	1960-73
10254050	Salt Creek near Mecca	33.4470	-115.8433	269	-220	31	1961-91
10254475	Glamis Wash at Glamis	32.9981	-115.0702	0.60	340	15	1960-74
10254670	Alamo River at Drop 3 near Calipatria	33.1044	-115.5442		-190	24	1980-2003
10254730	Alamo River near Niland	33.1989	-115.5969			58	1961-2018
10254970	New River at international boundary at Calexico	32.6659	-115.5031		-30	37	1982-2018
10255200	Myer Creek Tributary near Jacumba	32.6737	-116.0814	0.11	1880	14	1960-73
10255230	Myer Creek Tributary #2 near Coyote Wells	32.7206	-116.0453	0.08	820	14	1960-73
10255550	New River near Westmorland	33.1048	-115.6644			57	1962-2018
10255650	Chariot Creek near Julian	33.0662	-116.5531	7.95	2820	12	1962-73
10255700	San Felipe Creek near Julian	33.1187	-116.4353	89.2		25	1959-83
10255730	Pinyon Wash near Borrego	33.1153	-116.3175	19.6	1400	14	1960-73
10255800	Coyote Creek near Borrego Springs	33.3736	-116.4275	144	1200	36	1951-84, 1985-86
10255805	Coyote Creek below Box Canyon near Borrego Springs	33.3650	-116.4167	154	1100	10	1984-90, 1992
10255810	Borrego Palm Canyon near Borrego Springs	33.2789	-116.4300	21.8	1200	53	1951-93, 1995-2003
10255820	Yaqui Pass Wash near Borrego	33.1473	-116.3508	0.04	1720	14	1960-73
10255825	Yaqui Pass Wash No. 2 near Borrego	33.1514	-116.3495	0.03	1680	14	1960-73
10255850	Vallecito Creek near Julian	32.9862	-116.4203	39.7	1860	20	1964-83
10255885	San Felipe Creek near Westmorland	33.1239	-115.8531	1693	-180	28	1961-88
10256000	Whitewater River at Whitewater	33.9467	-116.6408	57.5	1610	30	1950-79
10256060	Whitewater River at diversion	33.9253	-116.6361	59.1	1360	5	1986-87, 1989-90
10256200	San Gorgonio River near Banning	33.9983	-116.9089	14.8		2	1976-77
10256300	San Gorgonio River at Banning	33.9311	-116.8278	44.2		3	1981, 1983
10256400	San Gorgonio River near Whitewater	33.9189	-116.6978	154	1320	14	1966-79
10256500	Snow Creek near Whitewater	33.8706	-116.6811	10.9	2000	68	1923-31, 1961-2019
10256501	Snow Creek and diversion combined	33.8706	-116.6811	10.9		27	1992-2018
10257500	Falls Creek near Whitewater	33.8695	-116.6717	4.14	1940	25	1995-2019
10257501	Falls Creek and diversion combined	33.8695	-116.6717		1940	24	1995-2018
10257550	Whitewater River at Windy Point	33.8989	-116.6211	264	1040	35	1985-87, 1990-2019
10257600	Mission Creek near Desert Hot Springs	34.0111	-116.6281	35.6	2370	52	1968-92, 1994-2019
10257710	Chino Canyon Creek near Palm Springs	33.8392	-116.6133	3.82	2260	10	1975-84
10257720	Chino Canyon near Palm Springs	33.8442	-116.6053	4.71	2100	32	1987-2018
10257800	Long Creek near Desert Hot Springs	33.9647	-116.4439	19.6	1560	17	1963-79
10258000	Tahquitz Creek near Palm Springs	33.8050	-116.5592	16.9	763	75	1948-82, 1984-89, 1991-93, 1995-2019
10258100	Palm Canyon Creek tributary near Anza	33.5689	-116.5128	0.47		12	1962-73
10258500	Palm Canyon Creek near Palm Springs	33.7450	-116.5356	93.1	700	90	1930-42, 1948-2019
10259000	Andreas Creek near Palm Springs	33.7600	-116.5500	8.65	800	71	1949-2019
10259050	Palm Canyon Wash near Cathedral City	33.7964	-116.4808			31	1989-2019
10259100	Whitewater River at Rancho Mirage	33.7495	-116.4228	588		31	1989-2019
10259200	Deep Canyon near Palm Desert	33.6311	-116.3922	30.6	1440	58	1962-2019
10259300	Whitewater River at Indio	33.7372	-116.2361	1073	0	54	1966-84, 1986-91, 1994-2019
10259500	Thermal Canyon tributary near Mecca	33.6806	-115.9911	0.18	1640	14	1960-73
10259540	Whitewater River near Mecca	33.5247	-116.0775	1495	-225	32	1961-97, 2006-11
10259600	Cottonwood Wash	33.7445	-115.8272	0.65	3080	14	1960-73
10259920	Wasteway #1 near Mecca	33.5278	-115.9739			6	1966-71

Table 3-2. Initial screening of gauged sites considered for regional flood frequency analysis

USGS ID	description	hydrologic zone	record length {years}	missing records	zero records	USGS qualification code									exclusion code		
						1	2	5	6	7	B	C	D	E	1	2	3
10254020	Betz Wash near Salton Sea	Salton Sea	14	0	5	0	6	0	0	0	0	0	0	0			x
10254050	Salt Creek near Mecca	Chocolate	31	0	0	1	0	0	0	0	0	5	0	0			
10254475	Glamis Wash at Glamis	Chocolate	15	0	4	0	0	0	0	0	0	0	0	0			x
10254670	Alamo River at Drop 3 near Calipatria	Salton Sea	24	0	0	0	2	0	0	0	0	20	0	0		x	
10254730	Alamo River near Niland	Salton Sea	58	0	0	58	0	0	0	0	0	35	0	0		x	
10254970	New River at international boundary at Calexico	Salton Sea	37	0	0	5	0	0	0	0	0	35	0	0		x	
10255200	Myer Creek Tributary near Jacumba	Anza-Borrego	14	0	3	0	5	0	0	0	0	0	0	0			x
10255230	Myer Creek Tributary #2 near Coyote Wells	Anza-Borrego	14	0	6	0	0	0	0	0	0	0	0	0			x
10255550	New River near Westmorland	Salton Sea	57	0	0	57	1	0	0	0	0	35	0	0		x	
10255650	Chariot Creek near Julian	Anza-Borrego	12	0	0	0	1	0	0	0	0	0	0	0			x
10255700	San Felipe Creek near Julian	Cleveland	25	0	0	0	0	0	0	0	0	0	0	0	x		
10255730	Pinyon Wash near Borrego	Anza-Borrego	14	0	6	0	6	0	0	0	0	0	0	0			x
10255800	Coyote Creek near Borrego Springs	Anza-Borrego	36	1	0	1	2	0	0	0	0	0	0	0			
10255805	Coyote Creek below Box Canyon near Borrego Springs	Anza-Borrego	10	1	0	1	2	0	0	0	0	0	0	0			x
10255810	Borrego Palm Canyon near Borrego Springs	Anza-Borrego	53	1	0	0	0	0	0	0	0	0	0	0			
10255820	Yaqui Pass Wash near Borrego	Anza-Borrego	14	0	3	0	2	0	0	0	0	0	0	0			x
10255825	Yaqui Pass Wash No. 2 near Borrego	Anza-Borrego	14	0	1	0	4	0	0	0	0	0	0	0			x
10255850	Vallecito Creek near Julian	Cleveland	20	0	0	0	0	0	0	0	0	0	0	0	x		
10255885	San Felipe Creek near Westmorland	Cleveland	28	0	0	0	0	0	0	0	0	0	0	0	x		
10256000	Whitewater River at Whitewater	San Bernardino	30	0	0	0	1	30	0	1	0	0	0	0			
10256060	Whitewater River at diversion	San Bernardino	5	1	0	2	1	0	2	0	0	0	0	0			x
10256200	San Gorgonio River near Banning	San Bernardino	2	0	0	0	0	0	0	0	0	0	0	0			x
10256300	San Gorgonio River at Banning	San Bernardino	3	1	0	0	1	0	0	0	0	0	0	0			x
10256400	San Gorgonio River near Whitewater	San Bernardino	14	0	0	0	0	0	0	0	0	0	0	0			x
10256500	Snow Creek near Whitewater	San Jacinto	68	0	0	9	2	0	68	0	0	0	0	0			
10256501	Snow Creek and diversion combined	San Jacinto	27	0	0	0	0	0	0	0	0	0	0	0			
10257500	Falls Creek near Whitewater	San Jacinto	25	0	0	0	0	0	25	0	0	0	0	0			
10257501	Falls Creek and diversion combined	San Jacinto	24	0	0	0	0	0	0	0	0	0	0	0			
10257550	Whitewater River at Windy Point	San Bernardino	35	2	2	0	4	0	32	0	0	0	0	0			
10257600	Mission Creek near Desert Hot Springs	San Bernardino	52	1	1	1	5	0	0	0	0	0	0	0			
10257710	Chino Canyon Creek near Palm Springs	San Jacinto	10	0	0	2	1	0	0	0	0	0	0	0			x
10257720	Chino Canyon near Palm Springs	San Jacinto	32	0	0	0	0	32	0	0	0	0	0	0			
10257800	Long Creek near Desert Hot Springs	Little San Bernardino	17	0	4	0	1	0	0	0	0	0	0	0			
10258000	Tahquitz Creek near Palm Springs	San Jacinto	74	3	0	1	1	0	0	0	0	0	0	1			
10258100	Palm Canyon Creek tributary near Anza	San Jacinto	12	0	3	0	1	0	0	0	0	0	0	0			x
10258500	Palm Canyon Creek near Palm Springs	San Jacinto	90	5	4	0	6	0	0	0	0	0	0	0			
10259000	Andreas Creek near Palm Springs	San Jacinto	70	0	0	1	0	0	0	0	0	0	0	0			
10259050	Palm Canyon Wash near Cathedral City	San Jacinto	30	0	2	1	2	0	0	0	0	0	0	0			
10259100	Whitewater River at Rancho Mirage	San Bernardino	30	0	3	0	1	0	0	0	0	13	0	0		x	
10259200	Deep Canyon near Palm Desert	Santa Rosa	57	0	1	0	1	0	0	0	0	0	0	0			
10259300	Whitewater River at Indio	San Bernardino	54	3	7	0	2	0	0	0	0	17	0	0		x	
10259500	Thermal Canyon tributary near Mecca	Little San Bernardino	14	0	5	0	2	0	0	0	0	0	0	0			x
10259540	Whitewater River near Mecca	San Bernardino	51	7	0	34	3	0	0	0	0	18	0	0		x	
10259600	Cottonwood Wash	Little San Bernardino	14	0	4	0	5	0	0	0	0	0	0	0			x
10259920	Wasteway #1 near Mecca	Little San Bernardino	6	0	0	6	0	0	0	0	0	0	0	0			x

qualification code key:
- 1 - discharge is a maximum daily average
- 2 - discharge is an estimate
- 5 - discharge affected to unknown degree by regulation or diversion
- 6 - discharge affected by regulation or diversion
- 7 - discharge is a historic peak
- B - month or day of occurrence is unknown or not exact
- C - all or part of the record affected by urbanization, mining, agricultural changes, channelization, or other
- D - base discharge changed during this year
- E - only annual maximum peak available for this year

exclusion code key:
- 1 - governing clmate zone considered too dissimilar
- 2 - significantly influenced by urbanization
- 3 - limited by useable record years

[shaded box] selected potential sites for regional analysis

Table 3-3. Unbiased sample L-moments, 17 sites

site i	USGS ID	description	n_i	l_1	l_2	$t^{(i)}$	$t_3^{(i)}$	$t_4^{(i)}$
1	10254050	Salt Creek	30	1132.77	832.94	0.7353	0.6727	0.4952
2	10255800	Coyote Creek	35	863.66	544.94	0.6310	0.4506	0.2058
3	10255810	Borrego Palm Canyon	56	240.30	206.48	0.8593	0.7841	0.5795
4	10256000	Whitewater River at Whitewater	31	3403.19	2890.28	0.8493	0.8063	0.6302
5	10256500	Snow Creek	68	641.32	468.77	0.7309	0.6534	0.4594
6	10257500	Falls Creek	25	160.76	116.78	0.7264	0.6458	0.5021
7	10257550	Whitewater River at Windy Point	32	1849.34	1174.87	0.6353	0.6852	0.5561
8	10257600	Mission Creek	52	249.13	196.01	0.7868	0.6396	0.3322
9	10257720	Chino Canyon	42	30.88	22.83	0.7392	0.6352	0.4035
10	10257800	Long Canyon	17	933.59	835.19	0.8946	0.8138	0.6245
11	10258000	Tahquitz Creek	71	321.61	248.66	0.7732	0.6547	0.3951
12	10258500	Palm Canyon Creek	85	1054.42	692.49	0.6568	0.4581	0.1806
13	10259000	Andreas Creek	71	178.69	126.87	0.7100	0.6288	0.4060
14	10259050	Palm Canyon Wash	32	1327.97	908.04	0.6838	0.5428	0.3014
15	10259100	Whitewater at Rancho Mirage	30	2427.77	1902.57	0.7837	0.6765	0.4756
16	10259200	Deep Canyon	58	730.17	513.34	0.7030	0.5284	0.2825
17	10259300	Whitewater at Indo	51	2261.04	1747.92	0.7731	0.5974	0.2770
			weighted means:	1.0000		0.7388	0.6234	0.3908

n_i - effective record length of site i

sample L-moments:

l_1 - mean

l_2 - L-scale

L-moment ratios:

t - coefficient of L-variation

t_3 - L-skewness

t_4 - L-kurtosis

3.3.2 Application of discordancy and heterogeneity measures

Discordancy and heterogeneity measures, as presented by Hosking and Wallis (1997), were applied to the group of sites initially selected to form a statistically homogeneous region:

- *Discordancy*. It is difficult choosing a discordancy measure, D_i, as a criterion for identifying discordant sites; Hosking and Wallis (1997) recommended that sites with $D_i > 3$ be regarded as discordant.
- *Heterogeneity*. A region is considered heterogeneous if the heterogeneity measure, H, is sufficiently large. Hosking and Wallis (1997) suggested that a region be regarded as "acceptably homogenous" if $H < 1$, "possibly heterogeneous" if $1 \leq H < 2$, and "definitely heterogeneous" if $H \geq 2$.

For the region evaluated herein, a heterogeneity measure less than one was targeted. Discordancy and heterogeneity measures were computed for the initial group of 17 sites. The site with the largest computed discordancy measure was eliminated from the group and the discordancy and heterogeneity measures were recomputed. This cycle continued until a heterogeneity measure of less than one was attained for the remaining sites. This process ultimately resulted in narrowing the initial group of 17 sites down to the 12 sites, which satisfied both discordancy and heterogeneity measures. This final group of 12 sites and their discordancy and heterogeneity statistics are presented in Table 3-4 and Table 3-5, respectively. The following five (5) sites were eliminated during this process: (1) Salt Creek near Mecca, (2) Coyote Creek near Borrego Springs, (3) Borrego Palm Canyon near Borrego Springs, (4) Whitewater River at Windy Point, and (5) Long Canyon near Desert Hot Springs.

Table 3-4. Unbiased sample L-moments and discordancy, final 12 sites

site i	USGS ID		n_i	$t^{(i)}$	$t_3^{(i)}$	$t_4^{(i)}$	D_i
1	10256000	Whitewater River at Whitewater	31	0.8493	0.8063	0.6302	1.78
2	10256500	Snow Creek	68	0.7309	0.6534	0.4594	0.58
3	10257500	Falls Creek	25	0.7264	0.6458	0.5021	1.42
4	10257600	Mission Creek	52	0.7868	0.6396	0.3322	1.08
5	10257720	Chino Canyon	42	0.7392	0.6352	0.4035	0.21
6	10258000	Tahquitz Creek	71	0.7732	0.6547	0.3951	0.27
7	10258500	Palm Canyon Creek	85	0.6568	0.4581	0.1806	1.36
8	10259000	Andreas Creek	71	0.7100	0.6288	0.4060	1.71
9	10259050	Palm Canyon Wash	32	0.6838	0.5428	0.3014	0.49
10	10259100	Whitewater at Rancho Mirage	30	0.7837	0.6765	0.4756	0.84
11	10259200	Deep Canyon	58	0.7030	0.5284	0.2825	1.03
12	10259300	Whitewater at Indio	51	0.7731	0.5974	0.2770	1.23
			weighted means:	0.7352	0.6077	0.3640	

Table 3-5. Heterogeneity measures, final 12 sites

H_1	observed standard deviation of group t	0.0494
	simulated mean of standard deviation of group t	0.0460
	simulated standard deviation of standard deviation of group t	0.0100
	standardized test value	0.34
H_2	observed average of t/t_3 distance	0.0790
	simulated mean of average t/t_3 distance	0.0738
	simulated standard deviation of average t/t_3 distance	0.0165
	standardized test value	0.32
H_3	observed average of t_3/t_4 distance	0.1149
	simulated mean of average t_3/t_4 distance	0.1084
	simulated standard deviation of average t_3/t_4 distance	0.0245
	standardized test value	0.26

*Parameters of regional kappa distribution: $\xi = -1.07131$, $\alpha = 1.3711$, $k = -0.2346$, and $h = 3.0129$

3.3.3 L-moment Ratio Diagrams

L-moment ratio diagrams are based on the relationships between *L*-moment ratios, which can be used to identify appropriate distributions. For the region, the sample *L*-moment ratios *L*-skewness, t_3, and *L*-kurtosis, t_4, for each site as well as their regional average are plotted as depicted in Figure 3-2. A distribution may be considered suitable if the distribution averages the scattered data and the data is spread consistently around the distribution; however, a certain degree of homogeneity must be satisfied in order to obtain a suitable regional distribution. Also, *L*-moment ratios *L*-skewness, t_3, and *L*-CV, t, for each site, including their regional average are plotted as shown in Figure 3-3. The more the data is scattered, the more likely the selected region is heterogeneous. The use of such a test is subjective.

Figure 3-2. *L*-moment ratio diagram: *L*-skewness (t_3) versus *L*-kurtosis (t_4)

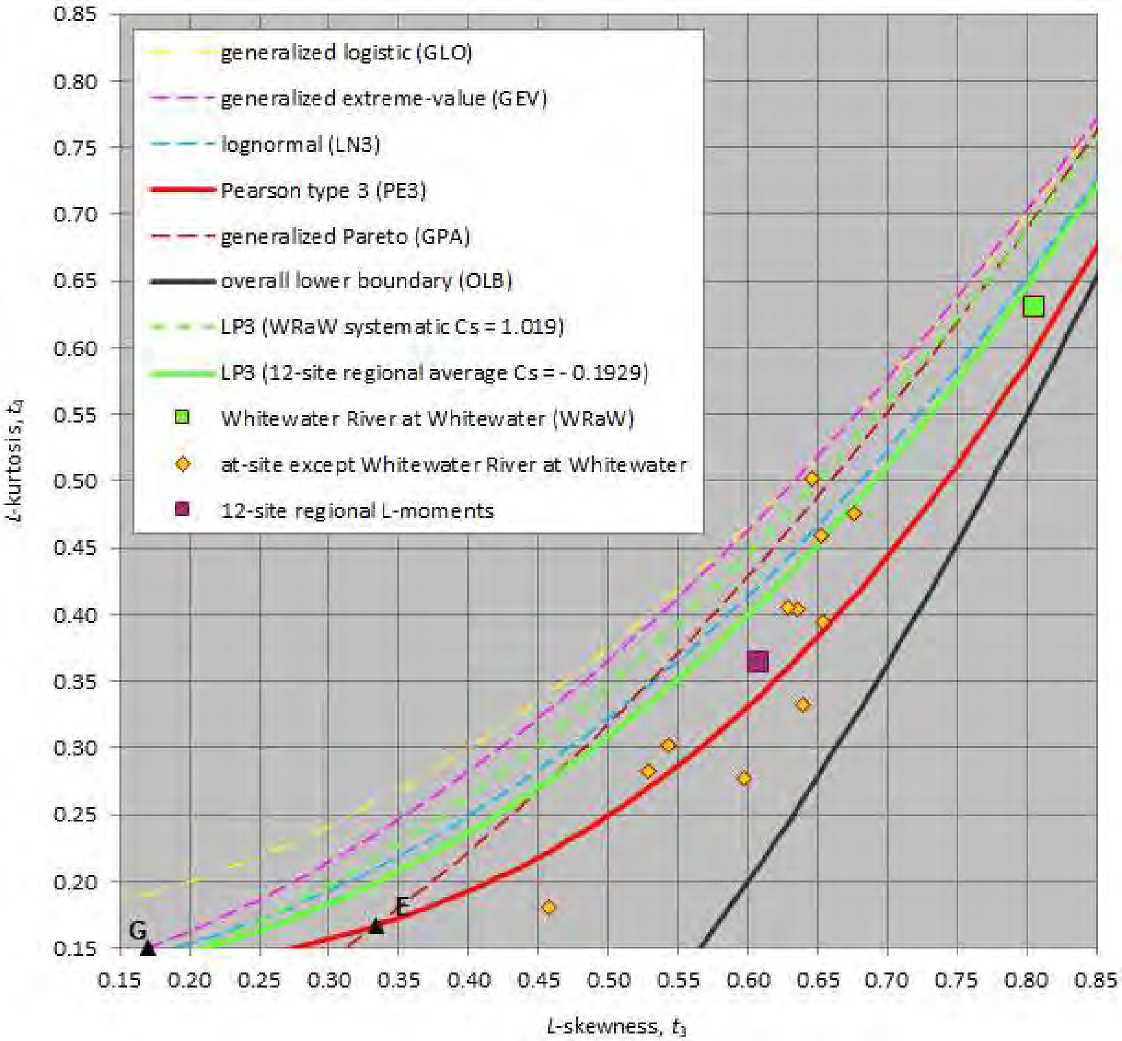
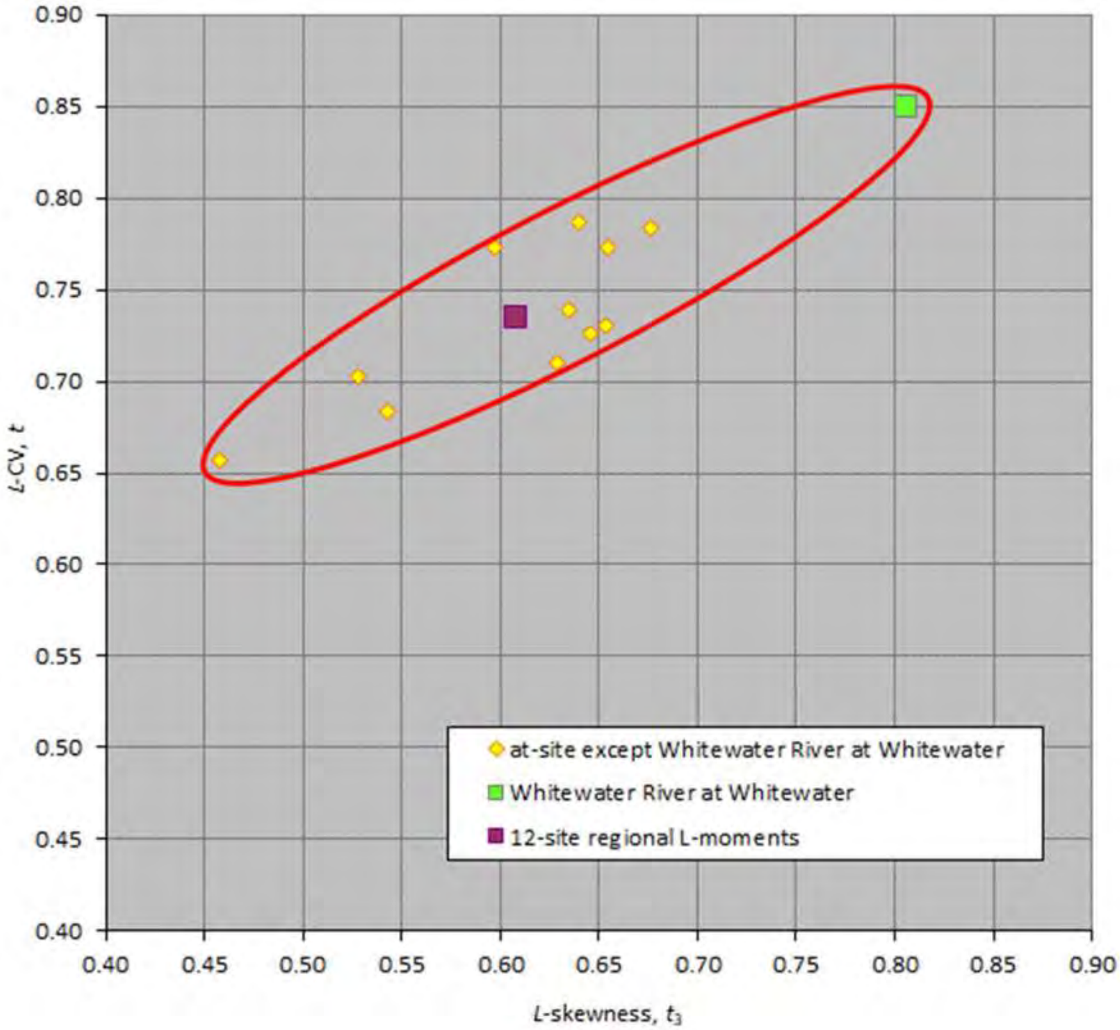


Figure 3-3. *L*-moment ratio diagram: *L*-skewness (t_3) versus *L*-CV (t)



3.3.4 Application of the Z^{DIST} goodness-of-fit measure

The Z^{DIST} goodness-of-fit measure was determined by means of Monte Carlo simulations. Data were synthesized from homogeneous regions with one of four 3-parameter frequency distributions: generalized logistic (GLO), generalized extreme-value (GEV), lognormal (LN3), Pearson type 3 (PE3), and generalized Pareto (GPA); 10,000 replications of the region were simulated.

The generalized normal and Pearson type 3 distributions demonstrate an acceptable fit in accordance with the criteron suggested by Hosking and Wallis (1997), $|Z^{DIST}| \leq 1.64$, with the generalized normal distribution providing the best fit to the available data. The Z^{DIST} results are presented in Table 3-6.

Table 3-6. Z^{DIST} goodness-of-fit measure test, 12 sites

DIST	*L*-CK	Z^{DIST}	$\leq$ |1.64|	parameter estimates for distributions accepted at the 90% level		
				location	scale	shape
GLO	0.474	2.77		-	-	-
GEV	0.472	2.70		-	-	-
GNO	0.421	1.18	✔	0.327	0.584	-1.379
PE3	0.339	-1.28	✔	1.000	1.931	3.947
GPA	0.437	1.67		-	-	-

According to Hosking and Wallis (1997), the criterion $|Z^{DIST}| \leq 1.64$ is somewhat arbitrary; therefore, it should only serve as a rough indicator of goodness-of-fit and is not recommended as a formal test. The *Z* statistic has the form of a significance test of goodness-of-fit and has approximately a standard normal distribution under suitable conditions. This criterion then corresponds to acceptance of the hypothesized distribution at a confidence of 90 percent; however the assumptions necessary for *Z* to be standard normal include two that are unlikely to be exactly satisfied in practice: (1) the region is exactly homogeneous; and (2) the region has no inter-site dependence.

Furthermore, the criterion $|Z^{DIST}| \leq 1.64$ is particularly unreliable if serial correlation or cross-correlation is present in the data. Correlation tends to increase the variability of $t_4^{\mathbf{R}}$, and because there is no correlation in the simulated kappa region, the resulting estimate of σ_4 is too small and the *Z* values are too large. Thus, a false indication of poor fit may be given. To overcome this problem, it is possible to generate simulated data that are correlated via Monte Carlo simulation.

3.3.5 Application of Intersite dependence

The computed average intersite dependence between each pair of sites is 0.48. While the proposed region may not be exactly homogeneous, its heterogeneity measure indicates a high degree of homogeneity. However, the intersite correlation among the sites is significant. Accordingly, a goodness-of-fit measure based on the simulated population is strongly recommended to attain a more reliable measure of goodness-of-fit because of the ZDIST reliability is lessened with serial/cross-correlation.

3.3.6 Application of the Regional *L*-moment algorithm

The regional *L*-moment algorithm was applied to the generalized normal (LN3) and Pearson type 3 distributions, which demonstrated an adequate goodness-of-fit based loosely on the ZDIST test. The Generalized Pareto distribution was marginally outside the ZDIST criterion Hosking and Wallis (1997) had suggested; and therefore, was included as part of the evaluation. A total of 1,000 replications of the region were simulated. The resultant goodness-of-fit measures for the simulated populations, based on the 12 selected sites, are summarized in Table 3-7.

Table 3-7. Simulated population goodness-of-fit measures, 12 sites

true distribution		candidate distribution					heterogeneity measure		
		GLO	GEV	GNO	PE3	GPA	H_1	H_2	H_3
GNO	accepted	86.4%	90.9%	89.2%	1.5%	97.6%	0.46	0.13	-0.08
	best fit	20.8%	26.8%	17.7%	0.5%	34.2%			
PE3	accepted	0.1%	0.1%	9.1%	99.4%	1.0%	1.07	0.31	-0.20
	best fit	0.0%	0.0%	2.1%	97.9%	0.0%			
GPA	accepted	89.3%	94.2%	80.7%	0.9%	89.5%	0.67	0.43	0.28
	best fit	32.4%	30.5%	15.0%	0.2%	21.0%			

The Pearson Type 3 distribution provides the best fit to the observed data having a 99.4 percent acceptance and demonstrating the best fit in 97.9 percent of the simulations. The accuracy of the selected distribution relative to the simulated population of the observed data was evaluated and the confidence limits of the distribution approximated. The results for these statistics are presented in Table 3-8. The estimated flood discharge quantiles for the final regional group of 12 sites based on selected distribution are shown in Table 3-9.

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Table 3-8. Simulated population accuracy measures for regional PE3 frequency distribution

		nonexceedance probability, *F*								
		0.5	0.8	0.9	0.95	0.98	0.99	0.995	0.998	0.999
average for all sites {arithmetic}	abs rel bias	0.154	0.011	0.023	0.028	0.031	0.032	0.033	0.034	0.034
	relative bias	0.068	0.001	-0.006	-0.010	-0.012	-0.013	-0.013	-0.014	-0.014
	RMSE	0.464	0.300	0.283	0.280	0.280	0.281	0.283	0.284	0.285
	0.05 PT.	0.585	0.713	0.743	0.745	0.741	0.739	0.737	0.733	0.732
	0.95 PT.	1.740	1.344	1.283	1.268	1.265	1.265	1.265	1.270	1.269
regional growth curve {harmonic}	abs rel bias	0.150	0.011	0.023	0.028	0.031	0.032	0.032	0.033	0.033
	relative bias	0.062	0.004	-0.001	-0.002	-0.003	-0.004	-0.004	-0.004	-0.004
	RMSE	0.291	0.053	0.026	0.050	0.072	0.084	0.092	0.100	0.105
	0.05 PT.	0.691	0.908	0.982	0.933	0.896	0.878	0.864	0.852	0.844
	0.95 PT.	1.474	1.079	1.012	1.062	1.109	1.129	1.148	1.166	1.176

Table 3-9. Regional flood discharge quantiles in cubic feet per second

USGS ID	desciption	n_i	nonexceedance probability, F								
			0.5	0.8	0.9	0.95	0.98	0.99	0.995	0.998	0.999
10256000	Whitewater River at Whitewater	31	712	4,940	9,987	15,946	24,694	31,751	39,072	49,053	56,778
10256500	Snow Creek	68	134	931	1,882	3,005	4,654	5,983	7,363	9,244	10,700
10257500	Falls Creek	25	34	233	472	753	1,167	1,500	1,846	2,317	2,682
10257600	Mission Creek	52	52	362	731	1,167	1,808	2,324	2,860	3,591	4,157
10257720	Chino Canyon	42	6	45	91	145	224	288	355	445	515
10258000	Tahquitz Creek	71	67	467	944	1,507	2,334	3,000	3,692	4,636	5,366
10258500	Palm Canyon	85	221	1,531	3,094	4,941	7,651	9,837	12,106	15,198	17,592
10259000	Andreas Creek	71	37	259	524	837	1,297	1,667	2,052	2,576	2,981
10259050	Palm Canywn Wash	32	278	1,928	3,897	6,222	9,636	12,390	15,246	19,141	22,156
10259100	Whitewater River at Rancho Mirage	30	508	3,524	7,124	11,376	17,617	22,650	27,873	34,993	40,504
10259200	Deep Canyon	58	153	1,060	2,143	3,421	5,298	6,812	8,383	10,525	12,182
10259300	Whitewater River at Indio	51	473	3,282	6,635	10,594	16,407	21,095	25,959	32,590	37,723

3.3.7 Adopted regional flood frequency curve based on *L*-moments

The regional flood discharge quantiles and corresponding confidence limits for the relevant Whitewater River watershed are shown in Table 3-10. The accompanying regional flood frequency curve, confidence limits, and plotting positions are presented in Figure 3-4. A plotting position is a distribution-free estimator. Calculations specified in Bulletin 17C (USGS, 2019) do not require designation of plotting positions; however, they do provide a non-probability-based graphical depiction of the sample data for a given site, which may be useful in evaluating historical events as well as the relative positioning of all data with respect to the selected distribution. A general formula for computing plotting positions is

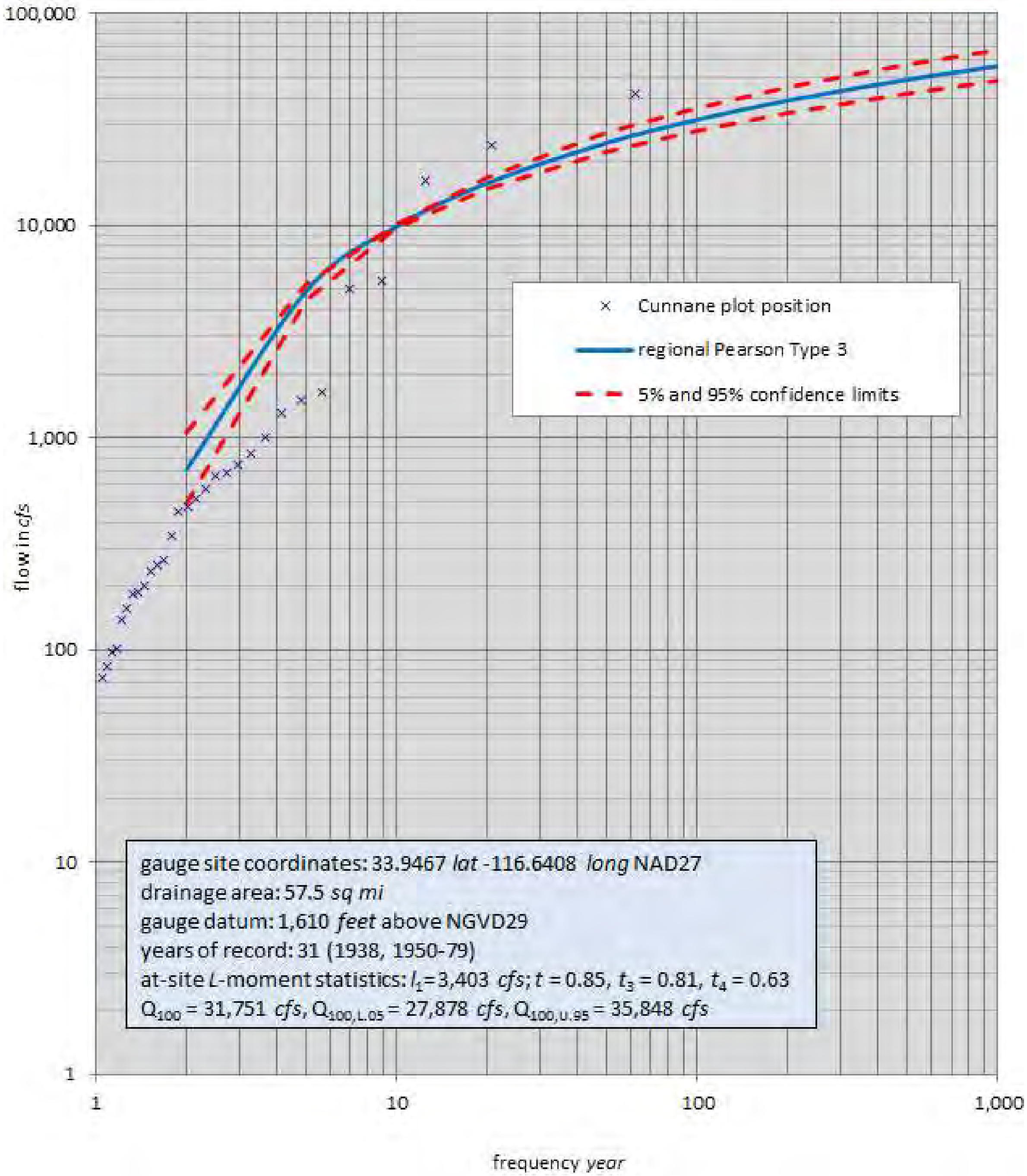
$$p_{j:n} = (j + \gamma) / (n + \delta) \text{ for } \delta > \gamma > -1,$$

where j equals the ordered sequence of flood values with the largest assigned a value of one; and n equal to the size of the sample data set; and γ and δ dependent upon the distribution. A modified Cunnane plotting position formula was used herein assuming $\gamma = 0.2$ and $\delta = 0.5$.

Table 3-10. Whitewater River regional flood discharge quantiles, in *cubic feet per second*

	nonexceedance probability, *F*								
	0.5	0.8	0.9	0.95	0.98	0.99	0.995	0.998	0.999
$q(F)$	0.209	1.452	2.930	4.686	7.260	9.330	11.481	14.414	16.684
$Q(F)$	712	4940	9971	15946	24707	31751	39072	49053	56778
5%	0.691	0.908	0.982	0.933	0.896	0.878	0.864	0.852	0.844
95%	1.474	1.079	1.012	1.062	1.109	1.129	1.148	1.166	1.176
$Q(F)_{5\%}$	492	4485	9792	14877	22138	27878	33758	41793	47921
$Q(F)_{95\%}$	1050	5330	10091	16934	27401	35847	44855	57195	66771

Figure 3-4. Whitewater River regional flood frequency curve



3.4 Regional Flood Hydrograph Development

Peak flow rates and corresponding flood hydrographs for the 50-, 10-, 1-, 0.5-, and 02-percent annual chance (i.e., 2-, 10-, 100-, 200-, and 500-year) storm events were determined for the relevant Whitewater River watershed in accordance with the standards prescribed in the Riverside County Hydrology Manual (RCFCWCD, 1978). These standards were implemented using the HEC-HMS Hydrologic Modeling System, Version 4.3 (USACE, 2018) in conjunction with supplemental GIS and spreadsheet applications.

3.4.1 Data resources

The following are a list of data resources applied herein:

- NOAA Atlas 14 spatial dataset of precipitation frequency-duration depths (NWS, 2014)
- SoCal Wildfires 1-meter resolution LiDAR (USGS, 2018)
- 2016 National Land Cover Database (USGS, 2019)
- NRCS soil surveys

3.4.2 General procedure for developing hydrologic models

The following outlines the general procedure used to develop hydrologic models for simulation and analysis:

- Delineate the watershed, subbasins, and define the stream network and related characteristics to support the concentration points required to satisfy the hydrologic objectives
- Determine frequency-duration precipitation depths and areal adjustments for selected frequency-duration combinations
- Determine loss rate characteristics for selected conditions and scenarios
- Determine the effective rainfall and related pattern for selected durations
- Determine unit hydrograph transform parameters
- Determine applicable channel and reservoir routing parameters
- Configure the hydrologic model, including catchments, processes, and their ordered connectivity, and assign relevant parameters, including time-series and paired datasets

The following assumptions were considered herein:

- Precipitation areal effects were considered regionally, but not locally where contributing drainage is less than 10 square miles.
- The regional hydrology is expected to remain substantially unchanged between the baseline (“without project”) and project conditions.
- The 3-, 6-, and 24-hour storm patterns were evaluated to determine governing duration
- Frequency-duration point precipitation depths were estimated from the NOAA Atlas 14 (NWS, 2014)
- Areal effects were estimated using the NOAA Atlas 2 depth-area-duration curves (Plate E-5.8; RCFCWCD, 1978) for contributing drainage areas exceeding 10 square miles
- The low loss fraction of 0.9 was assumed, given that the relevant watershed is mostly undeveloped
- Loss rates were determined based on the combination of land cover characteristics from the 2016 NLCD (USGS, 2019) and the soil characteristics published by the NRCS
- Topographic-based parameters were determined using the SoCal Wildfire 1-meter resolution LiDAR (USGS, 2018).
- The only concentration point considered is located at the historic streamflow gage (USGS ID 10256000)

3.4.3 Watershed delineation

The Whitewater Preserve is located along the lower reach of the Whitewater River north of Interstate 10. The watershed tributary to the historic USGS streamflow station, 10256000, defines the downstream limits of the relevant watershed and provides a means to correlate to recorded historical observations.

The watershed was delineated, including the boundary extents, longest watercourse, and centroid, based on the SoCal Wildfire 1-meter resolution LiDAR (USGS, 2018); also, the elevation profile along the longest watercourse was determined to facilitate the analysis of the representative slope required as part unit hydrograph transform procedure.

The delineated watershed encompasses approximately 58 square miles as shown in Figure 3-5.

3.4.4 Precipitation

The Riverside County Hydrology Manual (RCFCWCD, 1978), which has not been updated since it was first published in 1978, provides NOAA Atlas 2 frequency-duration isopluvials of precipitation depths (NA2; NWS, 1973) for use in hydrologic analysis; however, the current practice in Riverside County typically requires the application of NOAA Atlas 14 spatial dataset of frequency-duration maximum point precipitation depths (NA14; NWS, 2014), which was used herein.

Area-weighted average maximum precipitation depths for selected frequencies (50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual chance) and durations (3-, 6-, and 24-hour) were determined from NOAA Atlas 14 (NWS, 2014) for the relevant portion of the Whitewater River watershed.

Precipitation depth-areal reduction factors were determined for the watershed from Plate E-5.8 (RCFCWCD, 1978).

Area-weighted average maximum and areal-reduced frequency-duration precipitation depths are listed in Table 3-11.

Table 3-11. Whitewater River watershed frequency-duration precipitation depths

duration {hours}	DAR*	precipitation depth, in *inches*, for selected *n*-year frequencies							
		2	5	10	25	50	100	200	500
3	0.887	1.55	2.08	2.53	3.16	3.69	4.26	4.86	5.73
		1.37	1.84	2.24	2.80	3.28	3.78	4.31	5.08
6	0.920	2.20	2.93	3.55	4.44	5.18	5.97	6.82	8.05
		2.02	2.69	3.27	4.08	4.77	5.49	6.27	7.41
24	0.949	4.04	5.47	6.73	8.56	10.14	11.86	13.75	16.52
		4.99	6.42	7.68	9.51	11.08	12.80	14.70	17.47

*depth-areal reduction (DAR) factors were determined from Plate E-5.8 (RCFCWCD, 1978) based on a total drainage area of 58 square miles; values in **red** represented the areal-reduced depths

3.4.5 Land use, cover, and soil characteristics

In Riverside County, the NRCS detailed soil survey maps are typically used to estimate the spatial variation of hydrologic soil groups within the drainage basin of interest. The detailed soil maps, which provide coverage for the Whitewater River watershed above Interstate 10 are the Coachella Valley Area Soil Survey (CA680; NRCS, 2018) and the San Bernardino National Forest Soil Survey Area (CA777; NRCS, 2018), roughly encompassing a combined 62 percent of the total watershed. The U.S Generalized Soils Map (NRCS, 2018) was used to supplement soil information for the remainder of the watershed. The watershed composition of NRCS soils map units is presented in Figure 3-6 as well as in Table 3-12, which also lists the breakdown of hydrologic soil groups. The map unit hydrologic soil group definitions are listed in Table 3-13.

The 2016 National Land Cover Database (USGS, 2019) was used to approximate the composition of land use and cover in the Whitewater River Watershed as presented in Figure 3-7.

The combined land use, cover, and soil definitions used to parameterize the loss rate characteristics are shown in Table 3-14.

Figure 3-5. Whitewater River watershed delineation

Figure 3-6. Whitewater River watershed NRCS soils map units

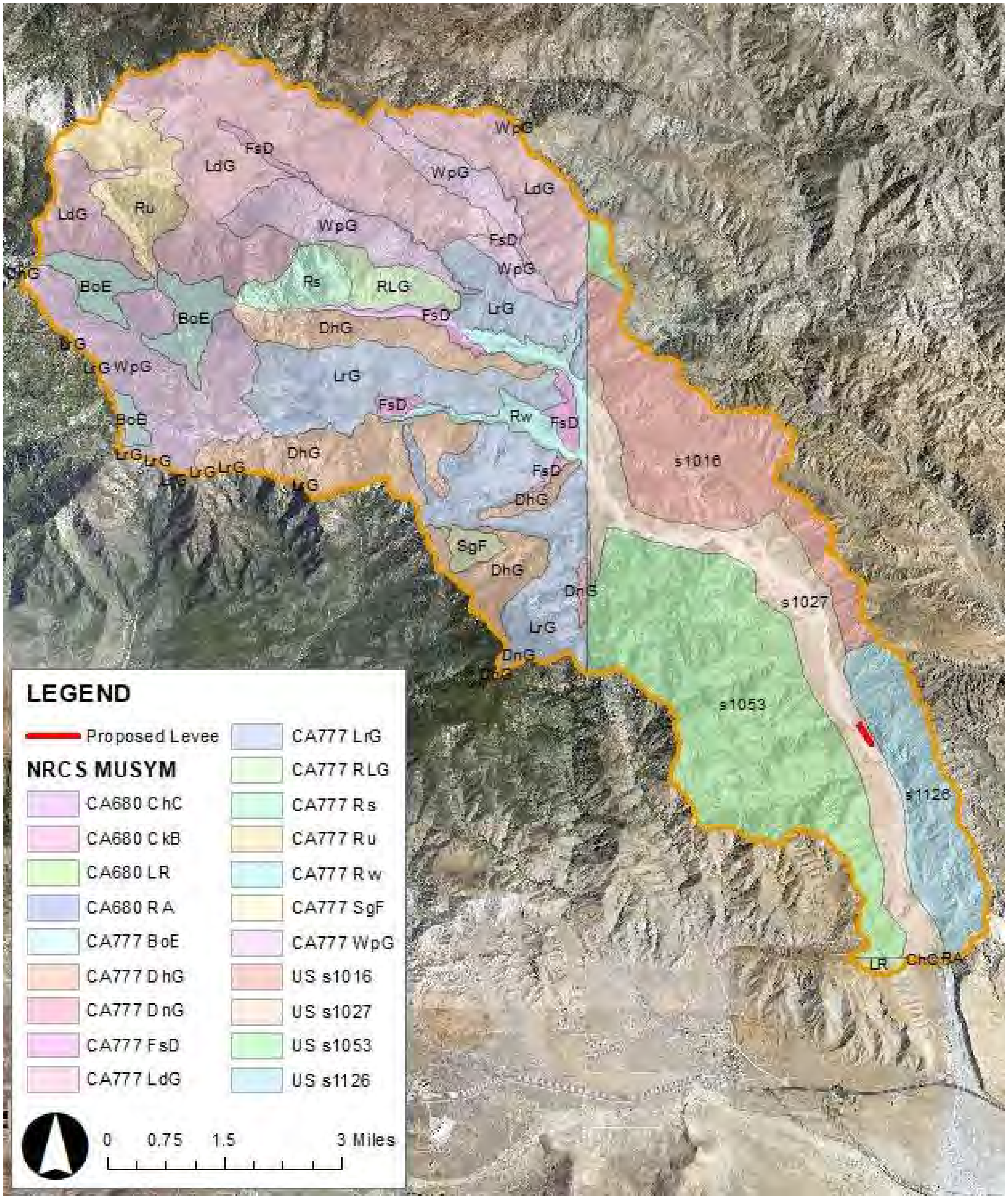


Figure 3-7. Whitewater River watershed 2016 NLCD land cover mapping

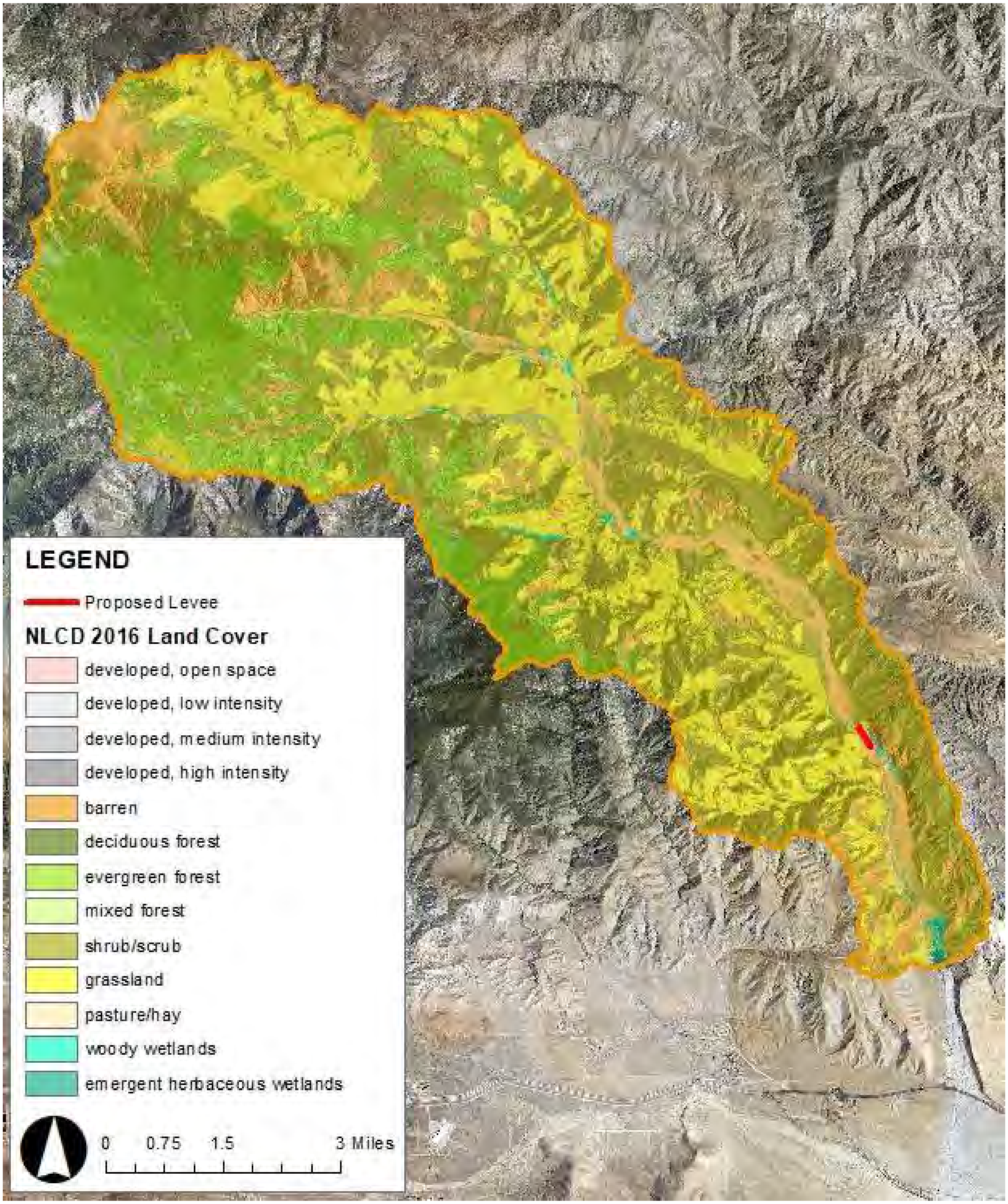


Table 3-12. Whitewater River watershed soil composition

NRCS soil survey	area, in *acres*	hydrologic soil group area composition, in *acres*			
		A	B	C	D
CA777	23,067	643	5,262	65	17,097
CA680	90	80	0	0	11
US	13,951	0	2,807	3,229	7,915
total	37,108	722	8,069	3,293	25,023

Table 3-13. NRCS map unit hydrologic soil group designations

NRCS soil		HSG
survey	MUSYM	
CA680	ChC	D
CA680	CkB	D
CA680	LR	A
CA680	RA	A
CA777	BoE	B
CA777	DhG	D
CA777	DnG	C
CA777	FsD	A
CA777	LdG	D
CA777	LrG	D
CA777	RLG	D
CA777	Rs	D
CA777	Ru	D
CA777	Rw	D
CA777	SgF	B
CA777	WpG	B
US	s1016	C
US	s1027	B
US	s1053	D
US	s1126	D

Table 3-14. 2016 NLCD land cover definitions

2016 NLCD land cover		area {acres}	RTIMP {%}	runoff indexes of hydrologic soil-cover complexes for pervious areas					
code	land cover identifier			cover	quality	A	B	C	D
21	developed, open space	115	10	landscaping	good	32	56	69	75
22	developed, low intensity	42	35	landscaping	good	32	56	69	75
23	developed, medium intensity	15	65	landscaping	good	32	56	69	75
24	developed, high intensity	0	90	landscaping	good	32	56	69	75
31	barren land (rock/sand/clay)	3818	0	barren	-	78	86	91	93
41	deciduous forest	3	0	woodland	fair	36	60	73	79
42	evergreen forest	7511	0	woodland	fair	36	60	73	79
43	mixed forest	312	0	woodland, grass	fair	44	65	77	82
52	shrub/scrub	15749	0	open brush	fair	46	66	77	83
71	grassland	9313	0	grass, annual or perennial	fair	50	69	79	84
81	pasture/hay	2	0	pasture, dryland	fair	50	69	79	84
82	cultivated crops	0	1	row crops	good	67	78	85	89
90	woody wetlands	111	0	meadows or cienegas	fair	51	70	80	84
95	emergent herbaceous wetlands	62	0	meadows or cienegas	fair	51	70	80	84

3.4.6 Loss rate determination procedure

The following process was implemented to determine the precipitation losses (constant and variable loss rates) for the delineated Whitewater River watershed:

- The land cover and hydrologic soils spatial datasets were intersected to determine the composition of land use, cover, and hydrologic soil-group (land-soil) combinations within the watershed
- An imperviousness fraction, A_i, for each land-soil combination was assigned based on the land cover definitions listed in Table 3-14.
- The adjusted constant loss rate, F, for each land-soil combination was computed using the following equation:

$$F = F_p (1 - 0.9A_i)$$

- The adjusted constant loss rate computed for each land-soil combination within the delineated watershed was area weighted and averaged to determine the average adjusted constant loss rate for the watershed
- A "good" cover quality was assumed where irrigation and maintenance is expected; otherwise, unmaintained pervious areas were assume to be of "fair" quality
- A pervious area runoff index, RI (Plate E-6.2; RCFCWCD, 1978) was assigned to each land-soil combination in the watershed
- The pervious area loss rate, F_p, in *inches per hour*, was determined for each land-soil combination (Plate E-6.2; RCFCWCD, 1978);
- Land cover definitions were defined based on standardized pervious area runoff indexes (Plate D-6.1; RCFCWCD, 1978)
- The land-soil combination adjusted loss rates were area-weighted to determine the representative adjusted loss rate for the watershed
- For short-duration storms (3- and 6-hour storm durations), the loss rate was assumed to remain constant throughout the entire storm event
- For 24-hour events, the loss rate was applied to a function of time where the adjusted loss rate defines the maximum value on the loss curve, which occurs at the beginning of the storm; and the minimum value, F_m, on the loss curve, which occurs at the end of a storm is typically assumed to be equal to 50 percent of the adjusted loss rate; the variable loss rate (F_T) is defined as follows:

$$F_T = C(24\text{-}T)1.55 + F_m \text{ where } C = (F - F_m)/54$$

- In the early and late stages of a storm the adjusted loss rate (constant or variable) will generally exceed the rainfall intensity on a unit time basis, indicating a zero runoff condition; to ensure runoff occurs during such periods, a low loss rate is used, which was assumed to be 90 percent of precipitation for any unit time period where the loss would otherwise exceed the precipitation

The loss rate parameterization worksheet for the Whitewater River watershed is summarized in Tables 3-15 through 3-19.

3.4.7 Effective rainfall pattern determination

The following process was implemented to determine the effective rainfall and related pattern:

- The average maximum precipitation depth for each subbasin is determined and adjusted for areal effects
- The time distribution of rainfall was determined on a unit time basis using the appropriate pattern percentages multiplied by the adjusted rainfall, in inches, for the selected subbasin

- The effective rainfall was computed by subtracting the selected rainfall loss for each unit time period from the rainfall for that unit time period
- This process was utilized to determine the effective rainfall and related pattern for each delineated subbasin and for each set of land-use conditions (existing and ultimate) given that there are minor variations in the computed loss rates for each set of conditions, which is expected to translate into minor differences in the computed flood hydrographs

This process was applied to the standardized 3-, 6-, and 24-hour storm patterns (Plate D-5; RCFCWCD, 1978) using the appropriate frequency-duration precipitation depth from Table 3-19.

Table 3-15. Precipitation loss determination (1 of 5)

	NRCS soil				2016 NLCD land cover		Riverside County precipitation losses {RCFCWCD, 1978}						
							cover		AMC 2			AMC 1	
line item	survey	MUSYM	area {acres}	HSG	land cover identifier	RTIMP	type	quality	runoff index	F_p {in/h}	F {in/h}	F_p {in/h}	F {in/h}
1	CA680	ChC	1	D	developed, low intensity	35	landscaping	good	75	0.304	0.208	0.499	0.342
2	CA680	ChC	3	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
3	CA680	ChC	6	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
4	CA680	CkB	1	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
5	CA680	LR	25	A	barren land (rock/sand/clay)	0	barren	-	78	0.269	0.269	0.468	0.468
6	CA680	LR	38	A	shrub/scrub	0	open brush	fair	46	0.609	0.609	0.782	0.782
7	CA680	LR	10	A	grassland	0	grass, annual or perennial	fair	50	0.570	0.570	0.747	0.747
8	CA680	RA	1	A	developed, low intensity	35	landscaping	good	32	0.739	0.506	0.872	0.597
9	CA680	RA	0	A	shrub/scrub	0	open brush	fair	46	0.609	0.609	0.782	0.782
10	CA680	RA	4	A	emergent herbaceous wetlands	0	meadows or cienegas	fair	51	0.560	0.560	0.747	0.747
11	CA777	BoE	29	B	developed, open space	10	landscaping	good	56	0.510	0.464	0.703	0.640
12	CA777	BoE	1	B	developed, low intensity	35	landscaping	good	56	0.510	0.349	0.703	0.481
13	CA777	BoE	0	B	developed, medium intensity	65	landscaping	good	56	0.510	0.211	0.703	0.292
14	CA777	BoE	1	B	barren land (rock/sand/clay)	0	barren	-	86	0.175	0.175	0.338	0.338
15	CA777	BoE	2	B	deciduous forest	0	woodland	fair	60	0.468	0.468	0.666	0.666
16	CA777	BoE	918	B	evergreen forest	0	woodland	fair	60	0.468	0.468	0.666	0.666
17	CA777	BoE	33	B	mixed forest	0	woodland, grass	fair	65	0.415	0.415	0.619	0.619
18	CA777	BoE	12	B	shrub/scrub	0	open brush	fair	66	0.404	0.404	0.609	0.609
19	CA777	BoE	14	B	grassland	0	grass, annual or perennial	fair	69	0.371	0.371	0.570	0.570
20	CA777	DhG	32	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
21	CA777	DhG	1,568	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
22	CA777	DhG	5	D	mixed forest	0	woodland, grass	fair	82	0.223	0.223	0.404	0.404
23	CA777	DhG	1,145	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
24	CA777	DhG	369	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
25	CA777	DhG	0	D	woody wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382

Table 3-16. Precipitation loss determination (2 of 5)

line item	NRCS soil				2016 NLCD land cover		Riverside County precipitation losses {RCFCWCD, 1978}						
							cover		AMC 2			AMC 1	
	survey	MUSYM	area {acres}	HSG	land cover identifier	RTIMP	type	quality	runoff index	F_p {in/h}	F {in/h}	F_p {in/h}	F {in/h}
26	CA777	DnG	0	C	barren land (rock/sand/clay)	0	barren	-	91	0.114	0.114	0.246	0.246
27	CA777	DnG	1	C	evergreen forest	0	woodland	fair	73	0.327	0.327	0.530	0.530
28	CA777	DnG	42	C	shrub/scrub	0	open brush	fair	77	0.281	0.281	0.479	0.479
29	CA777	DnG	21	C	grassland	0	grass, annual or perennial	fair	79	0.258	0.258	0.447	0.447
30	CA777	FsD	67	A	barren land (rock/sand/clay)	0	barren	-	78	0.269	0.269	0.468	0.468
31	CA777	FsD	17	A	evergreen forest	0	woodland	fair	36	0.703	0.703	0.848	0.848
32	CA777	FsD	2	A	mixed forest	0	woodland, grass	fair	44	0.628	0.628	0.799	0.799
33	CA777	FsD	118	A	shrub/scrub	0	open brush	fair	46	0.609	0.609	0.782	0.782
34	CA777	FsD	384	A	grassland	0	grass, annual or perennial	fair	50	0.570	0.570	0.747	0.747
35	CA777	FsD	1	A	woody wetlands	0	meadows or cienegas	fair	51	0.560	0.560	0.747	0.747
36	CA777	FsD	0	A	emergent herbaceous wetlands	0	meadows or cienegas	fair	51	0.560	0.560	0.747	0.747
37	CA777	LdG	252	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
38	CA777	LdG	1,185	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
39	CA777	LdG	113	D	mixed forest	0	woodland, grass	fair	82	0.223	0.223	0.404	0.404
40	CA777	LdG	2,461	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
41	CA777	LdG	2,291	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
42	CA777	LdG	2	D	cultivated crops	0	row crops	good	89	0.138	0.138	0.292	0.292
43	CA777	LdG	11	D	woody wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
44	CA777	LdG	2	D	emergent herbaceous wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
45	CA777	LrG	2	D	developed, open space	10	landscaping	good	75	0.304	0.277	0.499	0.454
46	CA777	LrG	333	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
47	CA777	LrG	931	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
48	CA777	LrG	61	D	mixed forest	0	woodland, grass	fair	82	0.223	0.223	0.404	0.404
49	CA777	LrG	1,780	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
50	CA777	LrG	1,727	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
51	CA777	LrG	24	D	woody wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
52	CA777	LrG	0	D	emergent herbaceous wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382

Table 3-17. Precipitation loss determination (3 of 5)

line item	NRCS soil				2016 NLCD land cover		Riverside County precipitation losses {RCFCWCD, 1978}						
							cover		AMC 2			AMC 1	
	survey	MUSYM	area {acres}	HSG	land cover identifier	RTIMP	type	quality	runoff index	F_p {in/h}	F {in/h}	F_p {in/h}	F {in/h}
53	CA777	RLG	147	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
54	CA777	RLG	45	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
55	CA777	RLG	2	D	mixed forest	0	woodland, grass	fair	82	0.223	0.223	0.404	0.404
56	CA777	RLG	219	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
57	CA777	RLG	99	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
58	CA777	Rs	356	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
59	CA777	Rs	18	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
60	CA777	Rs	2	D	mixed forest	0	woodland, grass	fair	82	0.223	0.223	0.404	0.404
61	CA777	Rs	125	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
62	CA777	Ru	617	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
63	CA777	Ru	82	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
64	CA777	Ru	3	D	mixed forest	0	woodland, grass	fair	82	0.223	0.223	0.404	0.404
65	CA777	Ru	388	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
66	CA777	Ru	45	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
67	CA777	Rw	152	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
68	CA777	Rw	1	D	deciduous forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
69	CA777	Rw	2	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
70	CA777	Rw	280	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
71	CA777	Rw	178	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
72	CA777	Rw	20	D	woody wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
73	CA777	Rw	26	D	emergent herbaceous wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
74	CA777	SgF	91	B	evergreen forest	0	woodland	fair	60	0.468	0.468	0.666	0.666
75	CA777	SgF	6	B	mixed forest	0	woodland, grass	fair	65	0.415	0.415	0.619	0.619
76	CA777	SgF	81	B	shrub/scrub	0	open brush	fair	66	0.404	0.404	0.609	0.609
77	CA777	SgF	1	B	grassland	0	grass, annual or perennial	fair	69	0.371	0.371	0.570	0.570
78	CA777	SgF	4	B	woody wetlands	0	meadows or cienegas	fair	70	0.360	0.360	0.560	0.560

Table 3-18. Precipitation loss determination (4 of 5)

line item	NRCS soil: survey	NRCS soil: MUSYM	NRCS soil: area {acres}	NRCS soil: HSG	2016 NLCD land cover: land cover identifier	2016 NLCD land cover: RTIMP	Riverside County precipitation losses {RCFCWCD, 1978}: cover: type	cover: quality	AMC 2: runoff index	AMC 2: F_p {in/h}	AMC 2: F {in/h}	AMC 1: F_p {in/h}	AMC 1: F {in/h}
79	CA777	WpG	49	B	developed, open space	10	landscaping	good	56	0.510	0.464	0.703	0.640
80	CA777	WpG	61	B	barren land (rock/sand/clay)	0	barren	-	86	0.175	0.175	0.338	0.338
81	CA777	WpG	0	B	deciduous forest	0	woodland	fair	60	0.468	0.468	0.666	0.666
82	CA777	WpG	2,548	B	evergreen forest	0	woodland	fair	60	0.468	0.468	0.666	0.666
83	CA777	WpG	85	B	mixed forest	0	woodland, grass	fair	65	0.415	0.415	0.619	0.619
84	CA777	WpG	797	B	shrub/scrub	0	open brush	fair	66	0.404	0.404	0.609	0.609
85	CA777	WpG	526	B	grassland	0	grass, annual or perennial	fair	69	0.371	0.371	0.570	0.570
86	CA777	WpG	2	B	woody wetlands	0	meadows or cienegas	fair	70	0.360	0.360	0.560	0.560
87	CA777	WpG	0	B	emergent herbaceous wetlands	0	meadows or cienegas	fair	70	0.360	0.360	0.560	0.560
88	US	s1016	226	C	barren land (rock/sand/clay)	0	barren	-	91	0.114	0.114	0.246	0.246
89	US	s1016	22	C	evergreen forest	0	woodland	fair	73	0.327	0.327	0.530	0.530
90	US	s1016	2,239	C	shrub/scrub	0	open brush	fair	77	0.281	0.281	0.479	0.479
91	US	s1016	741	C	grassland	0	grass, annual or perennial	fair	79	0.258	0.258	0.447	0.447
92	US	s1027	15	B	developed, open space	10	landscaping	good	56	0.510	0.464	0.703	0.640
93	US	s1027	33	B	developed, low intensity	35	landscaping	good	56	0.510	0.349	0.703	0.481
94	US	s1027	9	B	developed, medium intensity	65	landscaping	good	56	0.510	0.211	0.703	0.292
95	US	s1027	0	B	developed, high intensity	90	landscaping	good	56	0.510	0.097	0.703	0.134
96	US	s1027	836	B	barren land (rock/sand/clay)	0	barren	-	86	0.175	0.175	0.338	0.338
97	US	s1027	1,384	B	shrub/scrub	0	open brush	fair	66	0.404	0.404	0.609	0.609
98	US	s1027	486	B	grassland	0	grass, annual or perennial	fair	69	0.371	0.371	0.570	0.570
99	US	s1027	25	B	woody wetlands	0	meadows or cienegas	fair	70	0.360	0.360	0.560	0.560
100	US	s1027	20	B	emergent herbaceous wetlands	0	meadows or cienegas	fair	70	0.360	0.360	0.560	0.560

Table 3-19. Precipitation loss determination (5 of 5)

line item	NRCS soil				2016 NLCD land cover		Riverside County precipitation losses {RCFCWCD, 1978}						
							cover		AMC 2			AMC 1	
	survey	MUSYM	area {acres}	HSG	land cover identifier	RTIMP	type	quality	runoff index	F_p {in/h}	F {in/h}	F_p {in/h}	F {in/h}
101	US	s1053	21	D	developed, open space	10	landscaping	good	75	0.304	0.277	0.499	0.454
102	US	s1053	376	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
103	US	s1053	82	D	evergreen forest	0	woodland	fair	79	0.258	0.258	0.447	0.447
104	US	s1053	1	D	mixed forest	0	woodland, grass	fair	82	0.223	0.223	0.404	0.404
105	US	s1053	3,125	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
106	US	s1053	2,392	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
107	US	s1053	2	D	woody wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
108	US	s1053	2	D	emergent herbaceous wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
109	US	s1126	6	D	developed, low intensity	35	landscaping	good	75	0.304	0.208	0.499	0.342
110	US	s1126	6	D	developed, medium intensity	65	landscaping	good	75	0.304	0.126	0.499	0.207
111	US	s1126	337	D	barren land (rock/sand/clay)	0	barren	-	93	0.089	0.089	0.211	0.211
112	US	s1126	1,514	D	shrub/scrub	0	open brush	fair	83	0.211	0.211	0.393	0.393
113	US	s1126	22	D	grassland	0	grass, annual or perennial	fair	84	0.199	0.199	0.382	0.382
114	US	s1126	22	D	woody wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
115	US	s1126	9	D	emergent herbaceous wetlands	0	meadows or cienegas	fair	84	0.199	0.199	0.382	0.382
			37,054			0.10			79	0.258	0.257	0.441	0.440

3.4.8 Unit-hydrograph transform

The Synthetic Unit Hydrograph Method (SUHM; RCFCWCD, 1978) was used to compute peak flow rates and develop flood hydrographs for the relevant watershed. The SUHM assumes the watershed discharge is related to the total volume of runoff. The time factors affecting the shape of the SUHM are dominant. The watershed rainfall-runoff relationships are characterized by watershed area, slope, and shape factors. The SUHM is used to estimate the time distribution of watershed runoff in drainage basins where stream gauge information is not available. In Riverside County, the SUHM is normally used to evaluate individual drainage areas in excess of 300 to 500 acres.

Synthetic unit hydrographs were developed for 5-minute and 15-minute intervals to support the analysis 6-hour and 24-hour duration storms, respectively, based on a computed lag transform and Whitewater S-graph (USACE, 1980), also known as the Desert S-graph (Plate E-4.4, RCFCWCD, 1978).

The transformation of unit hydrographs is a process that is integrated into the HEC-HMS model definition. The lag formula used for Southern California watersheds (USACE, 1962; RCFCWCD, 1978) is as follows:

$$\text{lag}\ (hours) = C\left[\frac{LL_{CA}}{S^{0.5}}\right]^{0.38}$$

where

C	=	$24\overline{n}$ = basin factor or correlation coefficient
$\overline{n}$	=	"n-bar" = mean hydraulic roughness of all collection streams and channels within a watershed (dimensionless)
L	=	length of longest watercourse, in *miles*
L_{CA}	=	length along longest watercourse, measured upstream to a point opposite the centroid of the area, in *miles*
S	=	overall slope of the longest watercourse between the headwaters and the collection point, in *feet per mile*

The unit hydrograph transform lag parameters were determined as follows subsequent to the delineation of the watershed and topographic-based hydrologic parameters:

Watercourse length. The length of the longest watercourse (L), in *miles*, and the length along the longest watercourse from downstream to a line that intersects the area centroid and longest watercourse and is perpendicular to the longest watercourse (LCA), in *miles*, were determined based on the SoCal Wildfires 1-meter LiDAR (USGS, 2018).

Representative slope. The representative slope of the longest watercourse (S), in *feet per mile*, was determined for the watershed by balancing the area above and below a constant slope (representative slope) formed between the longitudinal profile and the constant slope as shown in Figure 3-8.

Basin factor. The basin factor (*C*) by extension of the mean hydraulic roughness ($\overline{n}$) was determined from Plate E-3 (RCFCWCD, 1978) based on the observed terrain of the relevant watershed

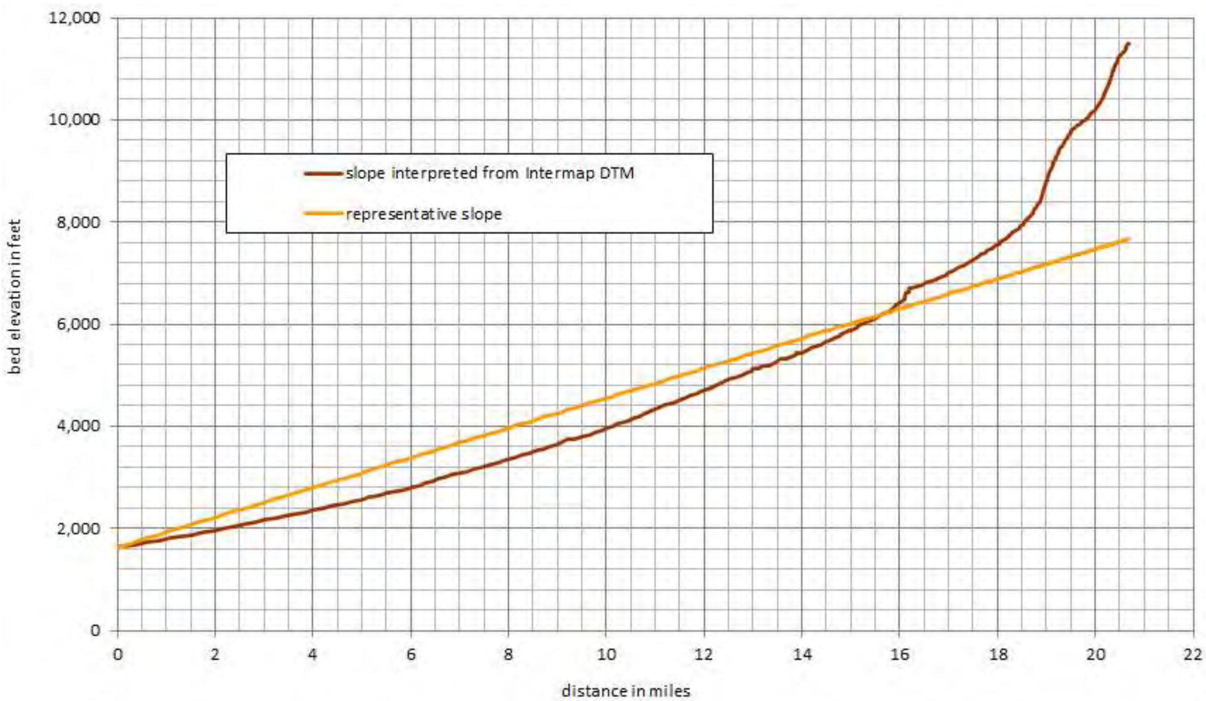
S-graph. The Whitewater S-graph was assumed to represent the runoff response of the relevant watershed. The Whitewater S-graph was developed by the USACE Los Angeles District by averaging the S-graphs constructed for nine gauged watersheds located in southern California.

The resultant lag is 2.886 hours based on the following parameter assignment summary:

- basin factor terrain ($\overline{n}$) of 0.05 (Plate E-3; RCFCWCD, 1978) based on the observed mountainous and undeveloped nature of the relevant watershed

- watercourse length (L) of 20.86 miles based on SoCal Wildfires 1-meter LiDAR (USGS, 2018)
- length from centroid intersect to outlet (LCA) of 8.32 miles based on SoCal Wildfires 1-meter LiDAR (USGS, 2018)
- representative slope (S) of 291.84 feet per mile, as shown in Figure 3-8, based on SoCal Wildfires 1-meter LiDAR (USGS, 2018)

Figure 3-8. Representative slope determination



3.4.9 HEC-HMS model development summary

A summary of model development using the HEC-HMS model platform (USACE, 2018) is as follows:

- The watershed boundary, main stem, and centroid were determined from USGS topographic mapping for the coverage area depicted in Figure 3-4.
- Since there are no subbasins defined within the watershed, the model schematic consists of a single watershed outlet (concentration point) defined at the historical USGS gage site
- The effective rainfall and related pattern for each frequency-duration event analyzed were determined external to the model and defined as a specified hyetograph linked with assigned precipitation gauge time-series data for each subbasin-frequency-duration combination analyzed
- The Whitewater S-graph (USACE, 1980), also referred to the Desert S-graph (RCFCWCD, 1978), was applied to the entire watershed, defined as paired data percentage curves and linked as a user-specified S-graph for the unit hydrograph transformation in conjunction with the lag parameters and coefficients
- Channel routing was not required
- There are no recognized natural or man-made impoundments located within the watershed; therefore, no reservoir routing was required

3.4.10 Summary of model simulation results

The resultant peak flow rates and corresponding runoff volumes for each simulated storm event are presented in Table 3-20. The regional frequency analysis flood quantile discharges were included as a measure of comparison.

Analysis of the 3-hour duration was ultimately not considered applicable for design, and as such, was not analyzed herein. Precipitation depths were previously determined for the 5-, 25, and 50-year storm events; however, absent of need, model simulations were not conducted for these frequency events.

Table 3-20. Whitewater River watershed model simulation results and comparison

method	parameter	results for selected *n*-year and duration storm event combinations									
		2		10		100		200		500	
		6h	24h	6h	24h	6h	24h	6h	24h	6h	24h
Riverside County	P_{excess}, in *inches*	0.48	0.42	1.79	2.72	3.97	6.47	4.74	7.99	5.88	10.34
	Q_p, in *cfs*	4,836	1,816	15,893	13,076	31,368	28,737	36,781	34,624	44,809	43,279
	volume, in *acre-feet*	1,467	1,293	5,476	8,383	12,157	19,946	14,517	24,631	18,011	31,870
regional frequency analysis	$Q_{5\%}$ in *cfs*	712		9,971		31,751		39,072		49,053	
	Q_{EV}, in *cfs*	492		9,792		27,878		33,758		41,793	
	$Q_{95\%}$ in *cfs*	1,050		10,091		35,847		44,855		57,195	

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4 HYDRAULIC ANALYSES

4.1 General

A detailed hydraulic model was developed to analyze Whitewater River along the study reach for a range of discharges. The analysis was prepared for the existing and proposed project conditions and was used to develop the design for the proposed improvements and evaluate impacts to the existing upstream and downstream river reaches and existing facilities.

4.2 One-Dimensional Hydraulic Model Development

A steady-state hydraulic model was developed for the project condition based on the best available data, using the computer application, HEC-RAS Version 5.0.7 (USACE, 2019), in conjunction with the companion ArcGIS-based pre-processor, HEC-GeoRAS10.2 (USACE, 2012). Cross sections, hydraulic structures, and relevant parameters were defined and updated as needed in the models.

The following model is included:

1. **Existing condition.** Based on available topographic mapping to represent the current conditions of the river and bank protection.
2. **Project condition.** The project condition includes the construction of the proposed levee/bank protection improvements. This model reflects the design condition with the proposed grading. The existing channel improvements are used for the reaches upstream and downstream of the proposed improvements.

4.2.1 Model Geometry and Topographic Mapping

The base model geometry was developed based on the USGS 2018 Southern California Wildfire topographic mapping. Once the base model geometry was established, the Whitewater Canyon Road crossing was defined based on field measurements and observations. No other features were added to the topography for the existing condition.

Modifications for the project condition analysis were based on the grading plans for the proposed improvements.

4.2.2 Design Flow Rates

The design flow rates for the Whitewater River were developed as part of this study. A summary of the estimated discharges for a range of storm events is included in Table 4-1. Summary of Design discharges.

Table 4-1. Summary of Design discharges

Storm Event (return frequency)	Design Discharge (cfs)
100	31,400
200	37,000
500	45,000

4.2.3 Expansion and Contraction Coefficients

Irregularities in the channelized section of the floodplain are limited and gradual and bridge abutments generally conform to the banks, therefore, expansion and contraction coefficients were limited to 0.1 and 0.3, respectively, except immediately upstream and downstream of bridges and culverts, where they were increased to 0.3 and 0.5, respectively.

4.2.4 Ineffective Flow Areas

Ineffective flow areas were defined where overbank areas were not considered to be directly contributing to the conveyance characteristics of the Whitewater River.

4.2.5 Hydraulic Roughness

The hydraulic roughness characteristics of the river channel and floodplain were delineated based on the existing condition of the river and vegetation within the central channel and the overbank areas. The ground conditions were categorized and assigned representative n-values consistent with FEMA guidelines. The following categories and their associated n-values were applied:

- channel bed (sand and rock), 0.030
- channel overbank/floodplain with some weeds/minor vegetation, 0.045
- channel overbank/floodplain with light brush and trees, 0.070
- soil cement, 0.020
- rock riprap, 0.035

4.2.6 One-Dimensional Hydraulic Results

The results of the HEC-RAS hydraulic analysis were used to evaluate the hydraulic characteristics and floodplain associated with the design storm event; and subsequently used to establish the levee/bank protection heights required in order to provide the desired level of flood protection. The results of the project condition hydraulic analysis were also used to evaluate the scour conditions along the project reach to determine the toe down requirements for the levee/bank protection.

The results of the hydraulic modeling are summarized in Tables 4-2 and 4-3. The model cross sections locations and floodplain for the existing and project conditions are illustrated on Figures 4-1 and 4-2. The profile for the project condition is shown on Figure 4-3. The full HEC-RAS output results for all the storm events are included in Appendix A.

Figure 4-1. Whitewater River HEC-RAS Model Layout, Existing Condition

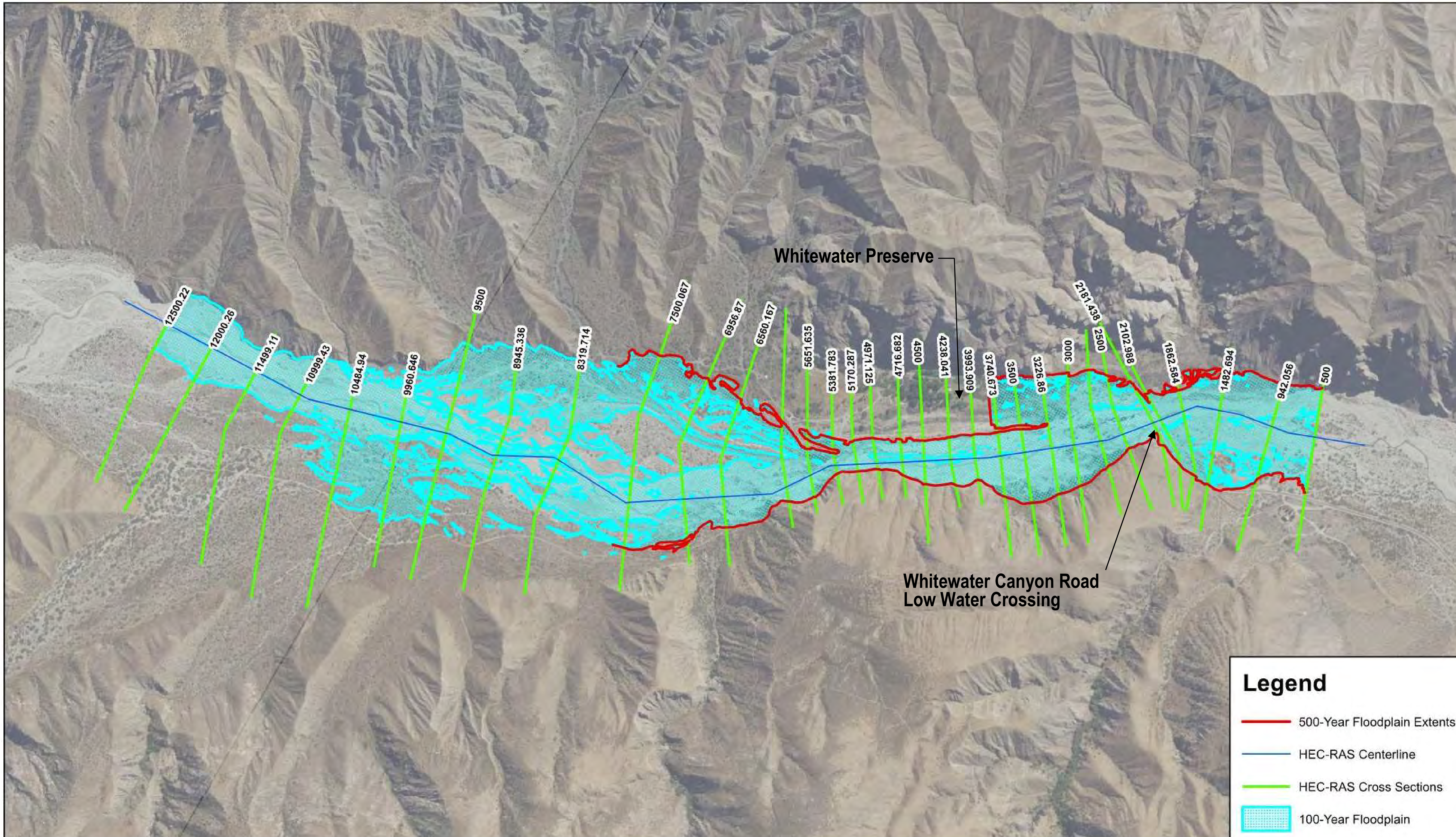

Figure 4-2. Whitewater River HEC-RAS Model Layout, Project Condition

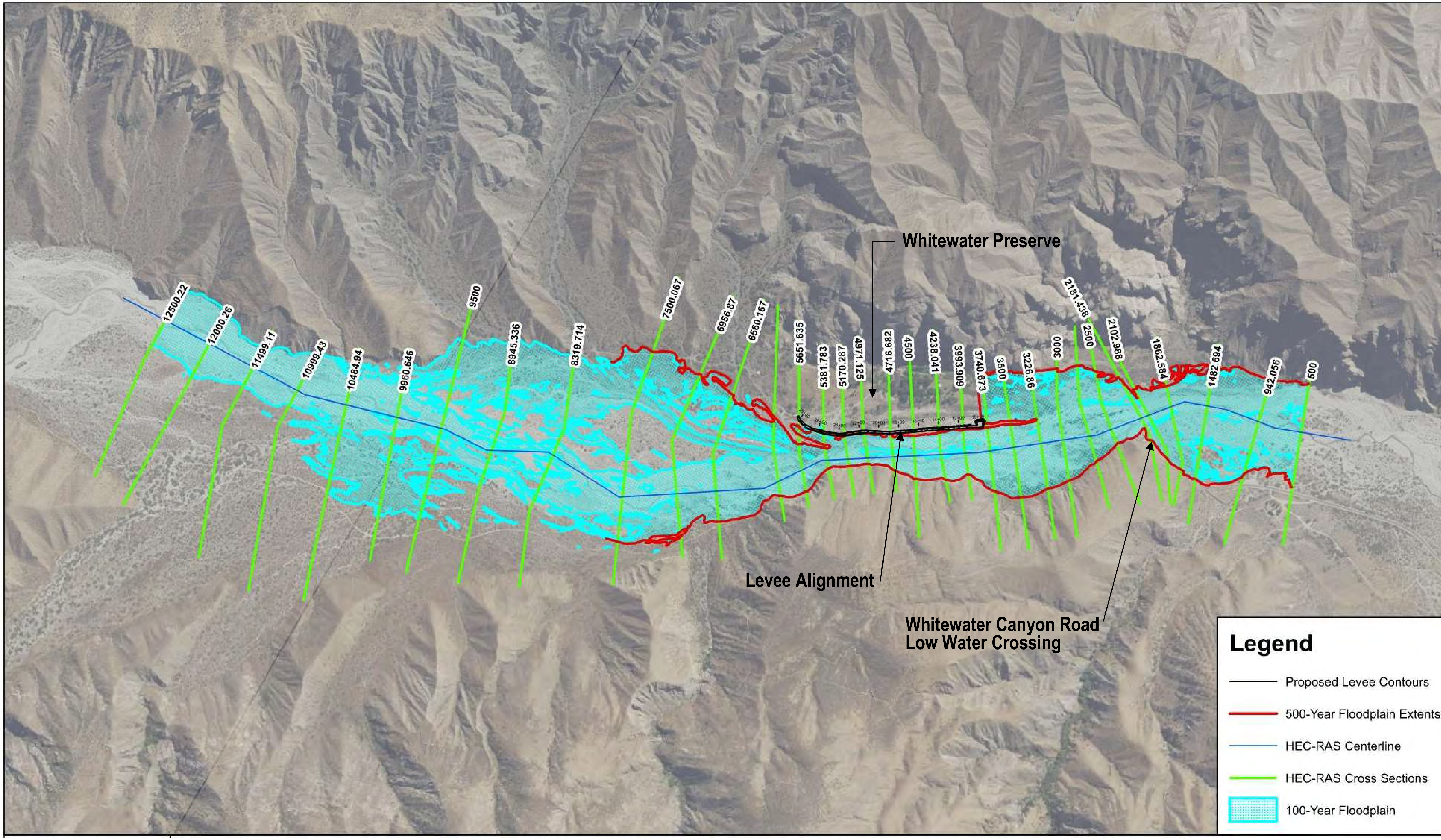

Figure 4-3. Whitewater River HEC-RAS Profile, Project Condition

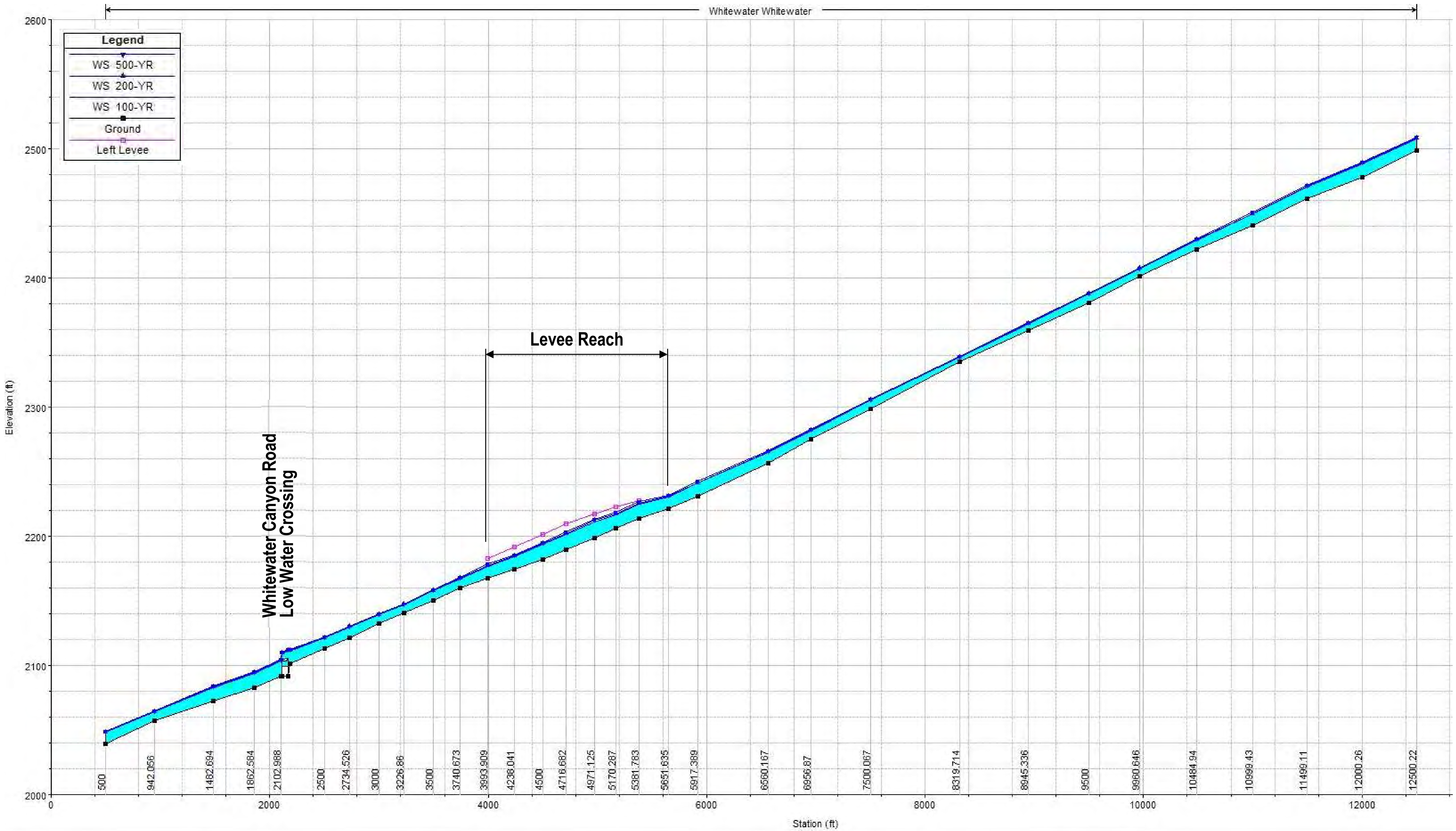

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Table 4-2. Whitewater River Hydraulics, 100-Year Storm Event (Baseline and Project Conditions)

river station {feet}	100-yr flow rate {ft^3/s}	Baseline Condition Floodplain Model				Project Condition Floodplain Model				Delta WSE {ft}
		EL_{bed} {feet}	WSE {feet}	flow depth {feet}	velocity {ft/s}	EL_{bed} {feet}	WSE {feet}	flow depth {feet}	velocity {ft/s}	
125+00	31400	2498.53	2507.70	9.17	11.95	2498.57	2507.77	9.20	11.96	0.07
120+00	31400	2477.63	2488.55	10.92	11.15	2477.64	2488.61	10.97	11.15	0.06
114+99	31400	2461.02	2470.49	9.47	13.09	2461.11	2470.54	9.43	13.10	0.05
109+99	31400	2440.33	2449.40	9.07	12.20	2440.40	2449.46	9.06	12.14	0.06
104+85	31400	2421.95	2429.10	7.15	10.69	2421.97	2429.15	7.18	10.62	0.05
99+61	31400	2401.03	2407.13	6.30	9.31	2401.07	2407.15	6.31	9.32	0.02
95+00	31400	2380.38	2387.30	9.55	8.53	2380.44	2387.34	9.57	8.51	0.04
89+45	31400	2359.59	2364.49	9.05	6.38	2359.64	2364.44	8.99	6.45	-0.05
83+20	31400	2334.85	2338.53	13.33	5.39	2334.96	2338.54	13.32	5.36	0.01
75+00	31400	2298.96	2305.24	10.45	8.14	2298.88	2305.20	10.39	8.15	-0.04
69+57	31400	2274.96	2281.70	9.14	9.55	2274.97	2281.68	9.10	9.83	-0.02
65+60	31400	2256.69	2265.04	8.68	10.86	2256.73	2265.03	8.63	10.84	-0.01
59+17	31400	2231.28	2241.12	9.83	12.37	2231.27	2241.09	9.82	12.36	-0.03
56+52	31400	2221.61	2230.23	8.62	12.62	2221.63	2230.22	8.59	12.62	-0.01
53+82	31400	2213.46	2224.78	11.32	15.39	2213.45	2224.59	11.14	15.78	-0.19
51+70	31400	2206.27	2216.72	10.45	15.18	2206.29	2216.70	10.41	15.11	-0.02
49+71	31400	2198.91	2211.24	12.33	15.58	2198.89	2211.21	12.32	15.63	-0.03
47+17	31400	2189.96	2201.52	13.92	14.40	2189.95	2201.51	13.95	14.35	-0.01
45+00	31400	2181.96	2193.86	11.90	13.70	2181.93	2193.84	11.91	13.65	-0.02
42+38	31400	2174.72	2184.19	9.47	13.56	2174.70	2184.18	9.48	13.52	-0.01
39+94	31400	2167.53	2176.86	9.36	13.23	2167.49	2176.81	9.32	13.21	-0.05
37+41	31400	2159.81	2167.07	7.26	11.63	2159.79	2167.02	7.23	11.61	-0.05
35+00	31400	2150.35	2157.77	7.42	11.09	2150.27	2157.72	7.45	11.09	-0.05
32+27	31400	2140.60	2147.79	7.19	11.19	2140.47	2146.93	6.46	9.80	-0.86
30+00	31400	2132.74	2139.21	6.47	9.79	2132.60	2139.17	6.57	9.82	-0.04
27+35	31400	2121.71	2129.80	8.09	10.16	2121.69	2129.80	8.11	9.99	0.00
25+00	31400	2112.95	2121.24	8.29	11.42	2112.87	2121.19	8.32	11.38	-0.05
21+81	31400	2101.57	2111.29	9.72	11.51	2101.57	2111.21	9.64	11.49	-0.08
21+50	Culvert	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21+03	31400	2091.39	2103.45	12.06	7.62	2091.39	2103.22	11.83	7.81	-0.23
18+63	31400	2082.47	2093.87	11.40	8.03	2082.49	2093.83	11.34	7.97	-0.04
14+83	31400	2072.52	2082.70	10.18	11.20	2072.50	2082.69	10.19	11.17	-0.01
9+42	31400	2056.93	2063.94	7.25	10.57	2056.91	2063.90	7.32	10.60	-0.04
5+00	31400	2039.25	2048.11	8.86	10.50	2039.26	2048.07	8.81	10.51	-0.04

Table 4-3. Whitewater River Hydraulics, Project Condition along Levee (100, 200, and 500-Year Events)

river station {feet}	Storm Event	Flow rate {ft^3/s}	Project Condition - Top of Bank Summary						Notes
			EL_{bed} {feet}	WSE {feet}	flow depth {feet}	velocity {ft/s}	top of bank {feet}	Freeboard {feet}	
65+60	100-YR	31,400	2256.7	2265.0	8.6	10.8	0.0	0.0	
65+60	200-YR	37,000	2256.7	2265.4	9.0	11.4	0.0	0.0	
65+60	500-YR	45,000	2256.7	2266.0	9.5	12.3	0.0	0.0	
59+17	100-YR	31,400	2231.3	2241.1	9.8	12.4	0.0	0.0	
59+17	200-YR	37,000	2231.3	2241.6	10.3	13.2	0.0	0.0	
59+17	500-YR	45,000	2231.3	2242.5	11.2	13.6	0.0	0.0	
56+52	100-YR	31,400	2221.6	2230.2	8.6	12.6	2237.1	6.9	Levee Station 28+39
56+52	200-YR	37,000	2221.6	2230.8	9.2	13.2	2237.1	6.3	
56+52	500-YR	45,000	2221.6	2231.6	9.9	14.1	2237.1	5.5	
53+82	100-YR	31,400	2213.5	2224.6	11.1	15.8	2227.6	3.0	Levee Station 25+48
53+82	200-YR	37,000	2213.5	2225.3	11.8	17.0	2227.6	2.3	
53+82	500-YR	45,000	2213.5	2226.8	13.4	17.3	2227.6	0.8	
51+70	100-YR	31,400	2206.3	2216.7	10.4	15.1	2222.6	5.9	Levee Station 23+47
51+70	200-YR	37,000	2206.3	2217.6	11.3	15.9	2222.6	5.1	
51+70	500-YR	45,000	2206.3	2218.7	12.4	16.8	2222.6	3.9	
49+71	100-YR	31,400	2198.9	2211.2	12.3	15.6	2217.2	6.0	Levee Station 21+48
49+71	200-YR	37,000	2198.9	2212.2	13.3	16.3	2217.2	5.1	
49+71	500-YR	45,000	2198.9	2213.4	14.5	17.3	2217.2	3.8	
47+17	100-YR	31,400	2190.0	2201.5	14.0	14.4	2209.8	8.3	Levee Station 18+76
47+17	200-YR	37,000	2190.0	2202.3	14.7	15.1	2209.8	7.5	
47+17	500-YR	45,000	2190.0	2203.3	15.8	16.0	2209.8	6.4	
45+00	100-YR	31,400	2181.9	2193.8	11.9	13.7	2201.2	7.4	Levee Station 16+47
45+00	200-YR	37,000	2181.9	2194.5	12.6	14.4	2201.2	6.7	
45+00	500-YR	45,000	2181.9	2195.5	13.6	15.2	2201.2	5.7	
42+38	100-YR	31,400	2174.7	2184.2	9.5	13.5	2191.6	7.4	Levee Station 13+86
42+38	200-YR	37,000	2174.7	2184.8	10.1	14.3	2191.6	6.8	
42+38	500-YR	45,000	2174.7	2185.9	11.2	14.9	2191.6	5.8	
39+94	100-YR	31,400	2167.5	2176.8	9.3	13.2	2183.0	6.2	Levee Station 11+46
39+94	200-YR	37,000	2167.5	2177.5	10.0	13.9	2183.0	5.5	
39+94	500-YR	45,000	2167.5	2178.3	10.8	14.8	2183.0	4.7	
37+41	100-YR	31,400	2159.8	2167.0	7.2	11.6	2180.3	13.3	End levee
37+41	200-YR	37,000	2159.8	2167.5	7.7	12.3	2180.3	12.8	
37+41	500-YR	45,000	2159.8	2168.2	8.4	13.1	2180.3	12.1	

4.3 Two-Dimensional Hydraulic Analysis

The Whitewater River floodplain is wide and deeply braided in some parts, including upstream and downstream of the Preserve, with independent terraced flood processes, which marginalize the applicability of a 1-dimensional hydraulic model. The only part of the lower Whitewater that is not significantly braided is the reach immediately adjacent to the Preserve where the conveyance transitions to a narrow gap bisected by an existing levee aligned in the middle of the flood corridor.

Given the nature of the flood environment, a 2-dimensional flood routing model was used to supplement the 1-dimensional hydraulic model to identify and resolve analytical disparities resulting from the flood process complexities that persist in this environment.

The non-bulked standard 1-percent annual chance 6-hour flood hydrograph was used to evaluate the flood pattern behavior along the study reach of the Whitewater using FLO-2D PRO v19.07.21 (FLO-2D, Inc., 2019), a 2-dimensional, finite-difference scheme, flood-routing computer model.

Model development typically includes the following aspects:

- General model definitions
- Topographic features
- Levees
- Hydraulic structures
- Infiltration and transmission losses
- Inflow boundary conditions

4.3.1 General model definitions

The following general definitions were applied in the development of the 2-dimensional hydraulic model:

- domain of 311,013 (main-stem model) and 171,562 (Preserve local drainage model) grid elements
- 24-hour simulation time
- 10' x 10' grid element size; grid element elevations were interpolated from the 1-meter California Wildfire LiDAR (USGS, 2018)
- A constant floodplain n-value of 0.065 was assigned to the entire domain; given the steepness of the Whitewater combined with the sediment-laden floodwater, the hydraulic regime is expected to trend toward critical depth.
- A shallow n-value of 0.100 was assigned to the entire domain to account for the larger bed material that persists in the Whitewater and the greater influence it will have on shallow flooding at depths less than 0.5 feet.
- Given persistence of sediment-laden floodwaters, particularly at higher stages, the supercritical regime that one might expect due to the steepness of this conveyance is expected to be suppressed; a limiting Froude number of 0.95 was assigned to the entire domain to prevent supercritical flow

4.3.2 Topographic features

The 1-meter California Wildfire LiDAR (USGS, 2018) dataset used to interpolate the grid element elevations, in some measure, captures the influence of natural and anthropogenic features and disturbance in the active floodplain given its resolution and assume grid element size.

4.3.3 Levees

Existing levees and berms were not formally defined as it is expected that the influence of these features will be captured by the selected grid element size.

4.3.4 Hydraulic structures

The culverts associated with the access road downstream were not defined, assuming this feature is not expected to influence the hydraulics and sediment transport behavior within the proposed levee reach.

4.3.5 Infiltration and transmission losses

While transmission losses are likely naturally occurring in this environment, they were not considered important toward the objective of this modeling application; and therefore, were ignored.

4.3.6 Inflow boundary conditions

The standard 1-percent annual chance 6-hour flood hydrograph was distributed within the active floodplain at the upstream boundary of the model domain.

4.3.7 Precipitation

The local drainage tributary to the Preserve was modeled using the rainfall component, which allows for either the definition of a single depth and pattern applied throughout the domain or the implementation of spatially and temporally varied rainfall. Given the limited size and rainfall variance of the local drainage, a single depth and pattern was applied.

4.3.8 Model scenarios

The Whitewater main stem and local drainage of the Preserve were modeled separately, and the results composited in presentation. The local drainage models simulated runoff using an effective rainfall pattern determine externally, maintaining consistency with the assumptions and parameterizations applied in the determination of the hydrology for the overall watershed. Baseline main stem and local drainage 1-percent annual chance 6-hour duration flood results are presented in Figure 4-3 (depths) and Figure 4-4 (velocities). Proposed main stem 1-percent annual chance 6-hour duration flood results are shown in Figure 4-5 (depths) and Figure 4-6 (velocities).

Due to the complexity of the flow patterns adjacent to the proposed levee elevation, the required top of levee heights were evaluating using both the FLO-2D PRO and the one-dimensional HEC-RAS analysis results.

Figure 4-4. Baseline 1-percent annual chance flood depths (main stem and local drainage)

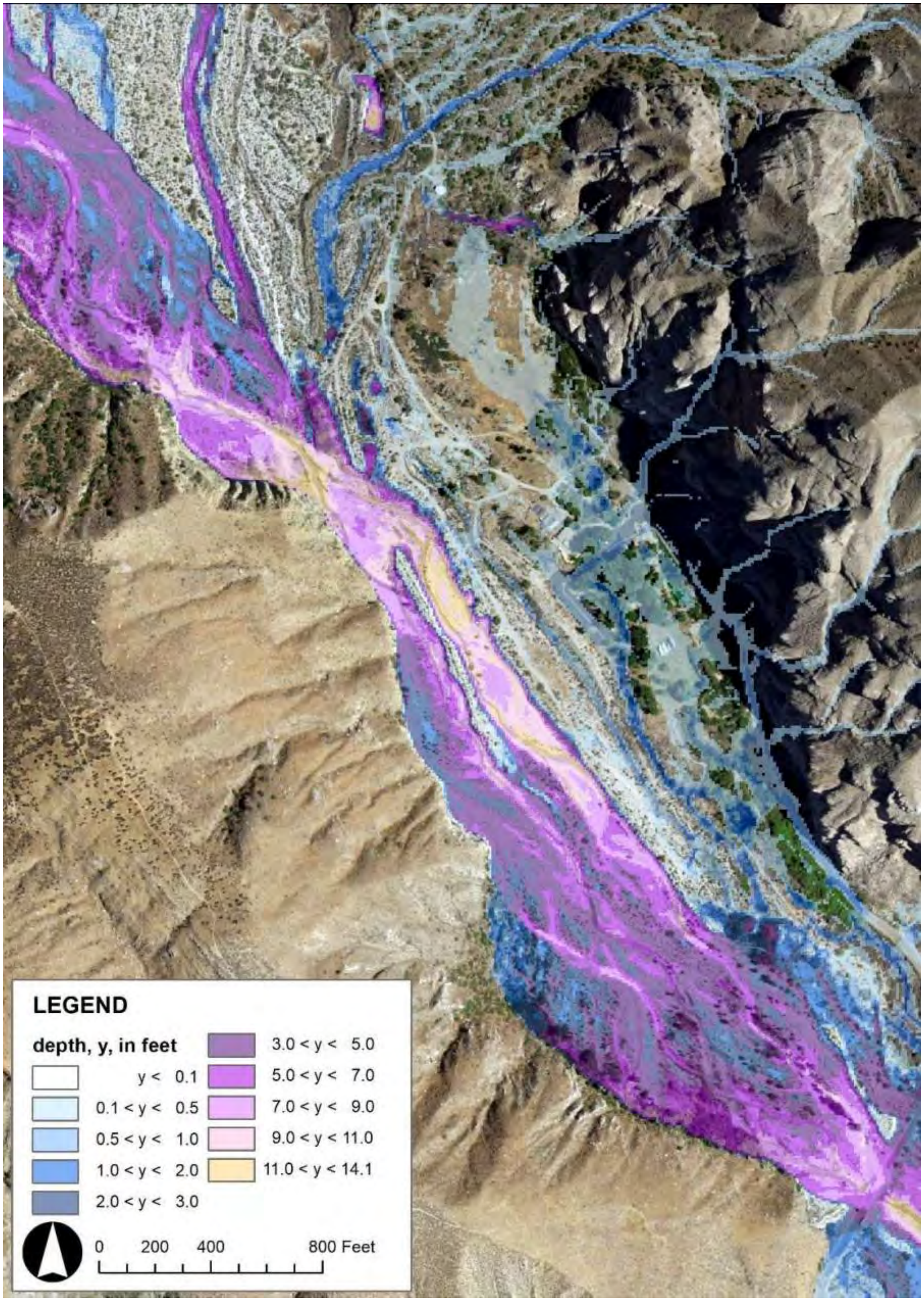


Figure 4-5. Baseline 1-percent annual chance flood velocities (main stem and local drainage)

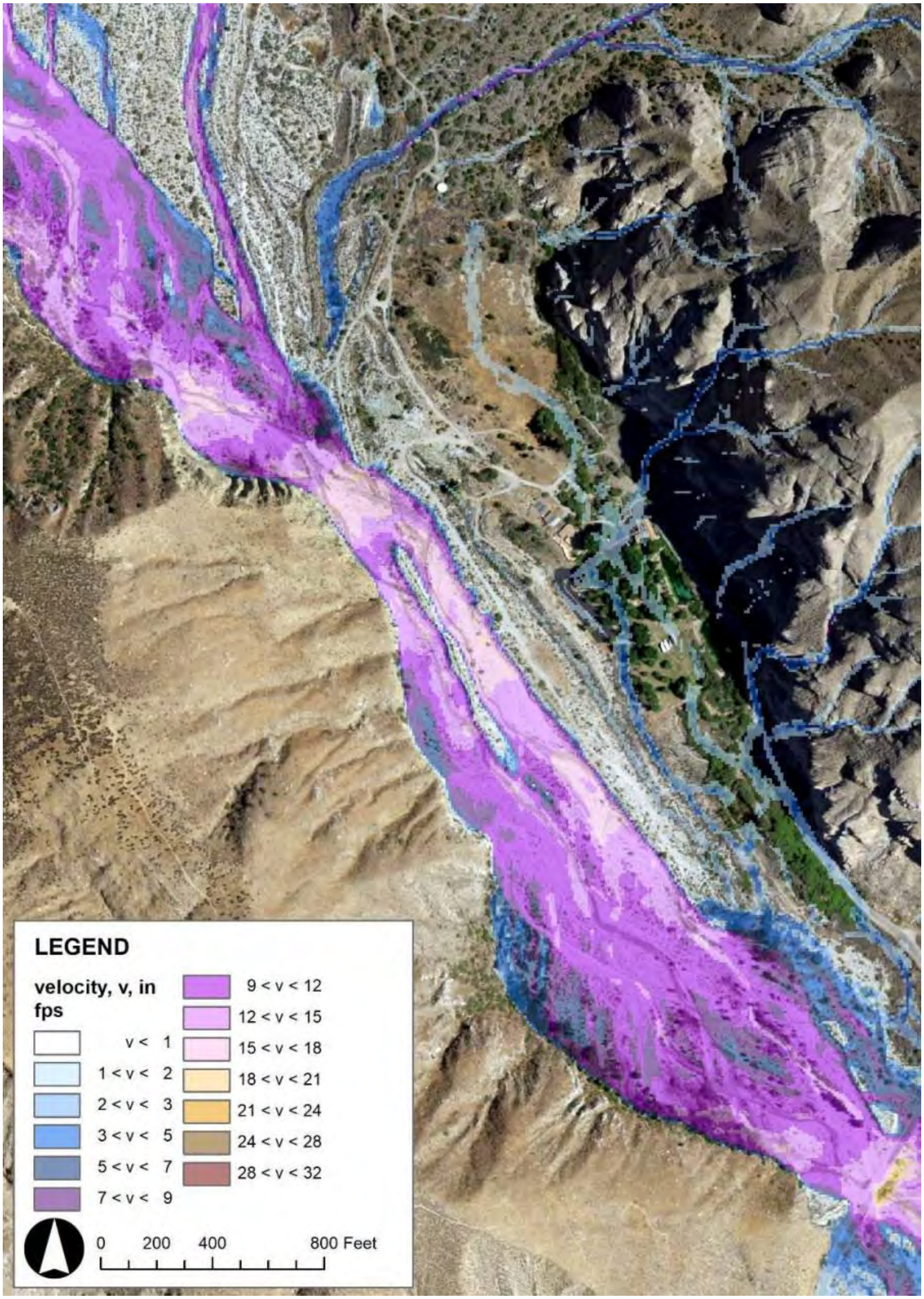


Figure 4-6. Proposed 1-percent annual chance flood depths (main stem only)

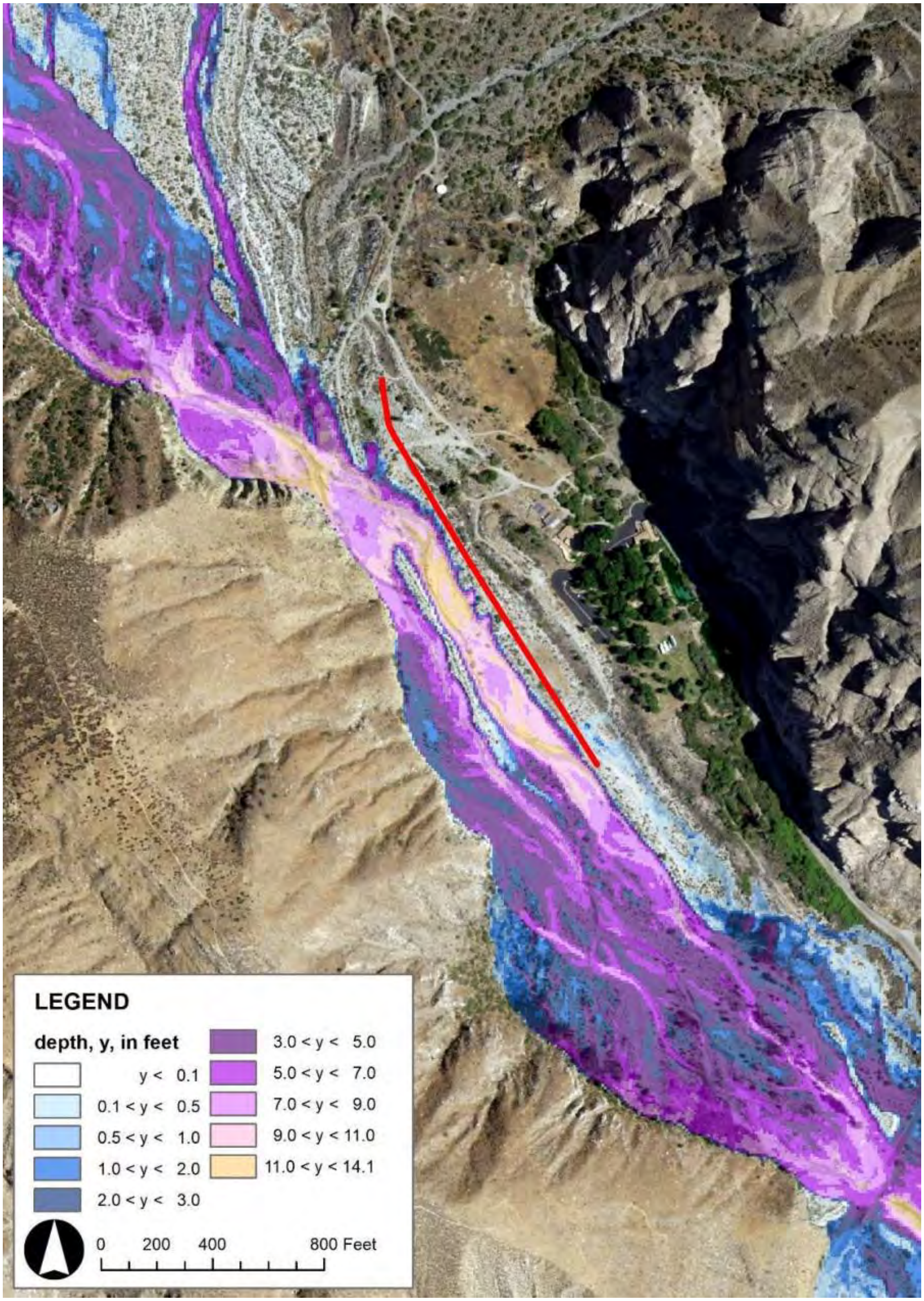
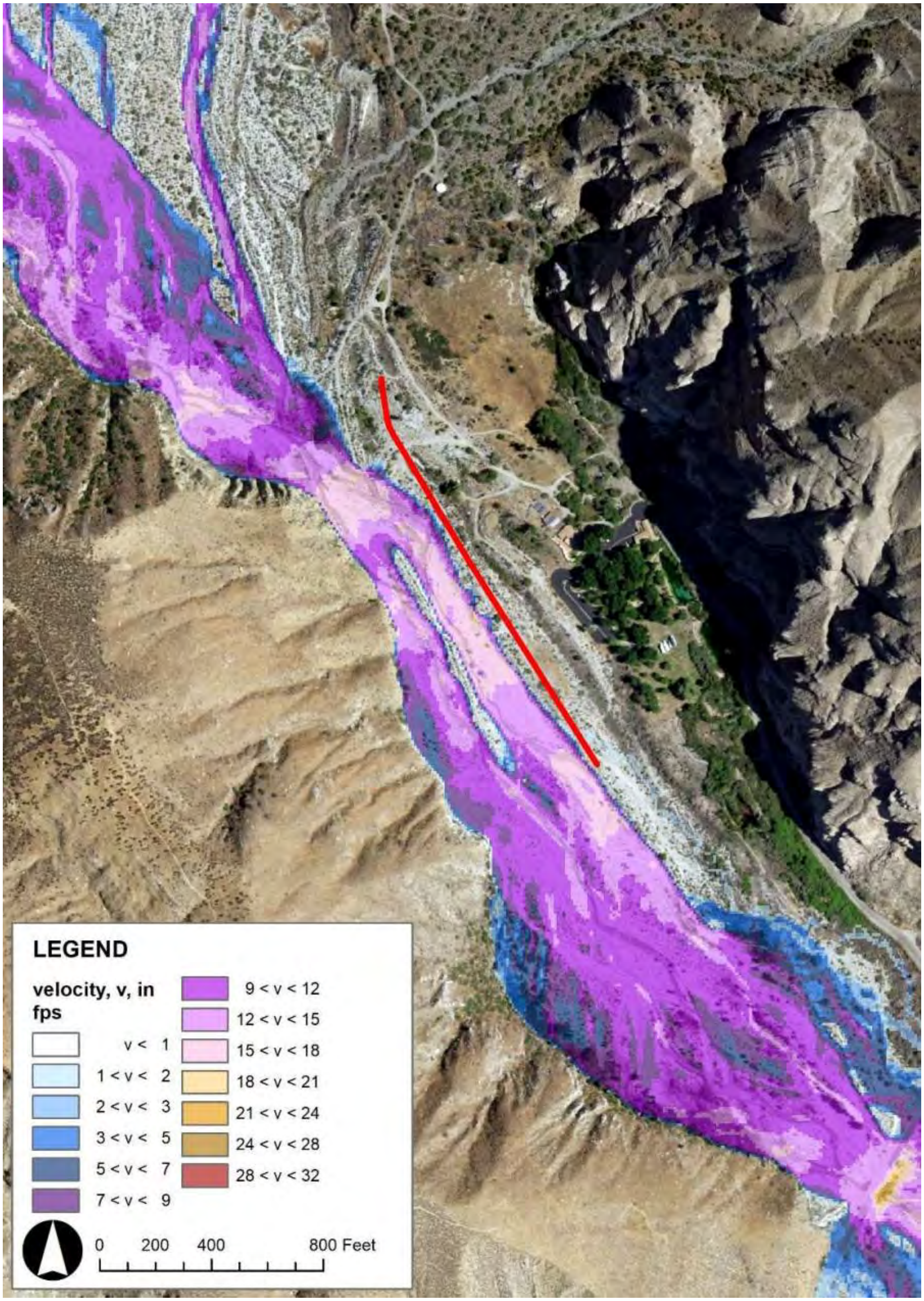


Figure 4-7. Proposed 1-percent annual chance flood velocities (main stem only)



5 SEDIMENTATION AND SCOUR ANALYSIS

5.1 Overview

Scour along the conveyance side of the proposed levee improvements was evaluated for the purpose of determining the required design of toe-down protection. The three scour types expected to occur along the proposed levee alignment includes the following:

- long term vertical adjustments (channel incision)
- event-based general scour
- local scour in the form of low-flow incisement (thalweg formation)

5.2 Methodology

Sediment transport was evaluated along the proposed levee alignment reach of the Whitewater to estimate the event-based and long-term vertical changes to the bed elevation profile. Appropriate methodologies for evaluating sediment transport were screened, taking into consideration their implementation by available modeling platforms, including an assessment of their related assumptions, limitations, and procedural framework.

5.2.1 Sediment transport model selection

Available 1-dimensional mobile boundary hydraulic and sediment transport numerical models include HEC6 (USACE, 1993), HEC6T (MBH, 2017), HEC-RAS (USACE, 2019), and SRH-1D (formerly known as GSTARS-1D; Bureau of Reclamation, 2018).

HEC6T is a proprietary version of HEC6 v4.1 (USACE, 1993) and includes additional features. HEC6 was integrated into HEC-RAS beginning with Version 4 (USACE, 2010). HEC-RAS Version 5.0.7 (USACE, 2019) represents the most current release/update at the time of this study.

SRH-1D was not considered for this study. HEC-RAS sediment transport modeling continues to improve, but there are some relative performance concerns when compared to HEC6T; and therefore, HEC6T was selected to provide modeling support for this study.

The Sedimentation in Stream Networks (HEC6T) v5.13.22.08ab (MBH, 2017) computer application was ultimately selected to develop and simulate numerical model iterations of the Whitewater study reach given its longstanding familiarity of its successful implementation on numerous other studies in the past.

5.2.1.1 HEC6T theoretical assumptions and limitations

As stated previously, HEC6T is a proprietary version of HEC6 v4.1 (USACE, 1993), which was developed based on the HEC2 (predecessor to HEC-RAS) platform; however, HEC6T does not use all of the capabilities implemented in HEC2 (e.g., special bridge routines and split flow analysis). HEC6T applies a sequence of steady flows to represent a flood hydrograph (quasi-unsteady). The cross section is subdivided into two parts; that part which has a moveable bed, and that which does not. The moveable bed is constrained within the limits of the wetted perimeter. The entire wetted part of the cross section is normally moved uniformly up or down; alternatively, HEC6T can be directed to adjust the bed elevation in horizontal layers when deposition occurs.

Secondary currents, transverse movement, transverse variation, lateral diffusion, and transmission losses are ignored; therefore, the model cannot simulate phenomena such as river meandering, point bar formation, pool-riffle formation, and many other planform changes. Bed forms cannot be simulated directly; however, they can be emulated indirectly by assigning n-values as functions of discharge. Local erosion and deposition caused by water diversions, bridges, and other in-stream structures may not be simulated. Only one closed loop and one distributary can be defined.

5.2.1.2 HEC6T sedimentation model procedural framework

HEC6T is a fully coupled explicit model; at each time step, the hydraulics are computed first, followed by sediment transport calculations. The following briefly describes the general computational procedure exercised by HEC6T:

- Compute the water surface profile using the standard step backwater procedure
- Compute the sediment transport potential at each cross section
- Compute the volume of material eroded or deposited between cross sections by solving the sediment continuity equation
- Compute the associated change in bed surface and modify cross-section geometry
- Read inflowing water discharge, sediment load by particle size, temperature, and boundary conditions for the next event
- Repeat steps 1 through 5

5.2.2 Additional limitations and constraints related to sediment transport modeling

In addition to the general limitations that are specific to HEC6T, there are potential limitations and constraints related to model processes, which affect the erosion and deposition potential:

1. If a size fraction does not move it detracts from the overall capacity in the control volume.
2. Increases in the percentage of one size fraction will reduce the capacity of other size fractions.
3. If material does not exist in the bed, it has zero transport capacity.
4. Erosion and deposition of a size class cannot occur at the same time in a control volume.
5. Bed material is assumed to be evenly distributed throughout the zone at the beginning of each time step.
6. Three limiters are used to modify the amount of material eroded or deposited during a time step:
    a. Temporal deposition (physically takes time to deposit)
    b. Temporal erosion (physically takes time to entrain)
    c. Bed armoring (supply reduction)
7. The deposition limiter works by comparing how far a particle can fall in a time step versus the distance available for it to travel
8. Sediment can travel through each control volume in a single time step
9. Both erosion and deposition potentials are also constrained by the following model processes:
    a. The actual continuous sequence of flows is, for modeling purposes, segmented into a series of steady state flow events
    b. Volumes of sediment are classified by size classes in each reach between cross sections
    c. Erosion or deposition computed for each reach and cross section geometry are adjusted after each flow event
    d. Sediment calculations are performed based on grain size fraction
    e. Allowance for hydraulic sorting and armoring

5.3 HEC6T model development

5.3.1 Procedure

The following steps outline the general procedure used to evaluate the sediment transport behavior tendencies within the Whitewater study reach:

1. Identify the conditions and permutations for sediment transport model development and simulation
2. Develop the baseline conditions hydraulic model using HEC-RAS v5.0.7 (USACE, 2019) or equivalent computer application
3. Transform the hydraulic model channel geometry to the HEC6T-supported format
4. Select and develop the event-based on long-term hydrologic regimes for sediment transport model simulation; the 1-percent annual chance events will be used to evaluate short-term (event-based) general scour and will also be used in conjunction with a long-term continuous record of mean daily flows to evaluate channel incision (profile degradation); this long-term flow record will be based on the dataset recorded at the streamflow gaging station located on the Whitewater River between Interstate 10 and the Preserve (USGS ID 10256000), which is currently inactive, but was active for 31 water years from 1949 through 1979
5. Determine the hydraulic controls based on developed hydraulic model
6. Identify and process relevant sediment gradation(s) for sediment transport model simulation
7. Estimate sediment inflow boundary conditions based on watershed debris production and delivery analysis and previously determined gradations
8. Construct sediment transport models to represent the baseline conditions as well as selected variations and permutations to support sensitivity analyses and desired alternative evaluations
9. Determine the most applicable sediment transport function(s) through a prescreening process and additional sensitivity testing
10. Evaluate the performance and sensitivity of selected parameters and processes
11. Conduct simulations and process results for evaluation and discussion

5.3.2 Hydraulic model development and synthesis of mean-bed geometry

A geometric model based on the 1-meter resolution LiDAR (USGS, 2018) was first developed and analyzed hydraulically using the River Analysis System (HEC-RAS) v5.0.7 (USACE, 2019) computer application. The existing geometry associated with the cross sections shown in Figure 5-1 was converted to equivalent rectangular sections based on a mean bed elevation profile to counter the 1-dimensional modeling issues associated terraced braided patterns within the floodplain as evidenced by the depicted flood depths and related cross sections in Figure 5-2. An example of the transformation from topographic-based cross section to its rectangular equivalent is presented in Figure 5-3. The resultant mean bed elevation profile in comparison to the topographic thalweg profile is shown in Figure 5-4. Using the 1-percent annual chance event hydraulics, the mean bed elevation at each defined cross section was computed by subtracting the hydraulic (mean) depth from the water surface elevation. The top width, which represents the consolidation of active multiple channels across the floodplain, was assumed as the equivalent width. The difference between the top width and the wetted perimeter is considered insignificant due to the low depth to width ratio.

Figure 5-1. Geometry schematic of cross sections

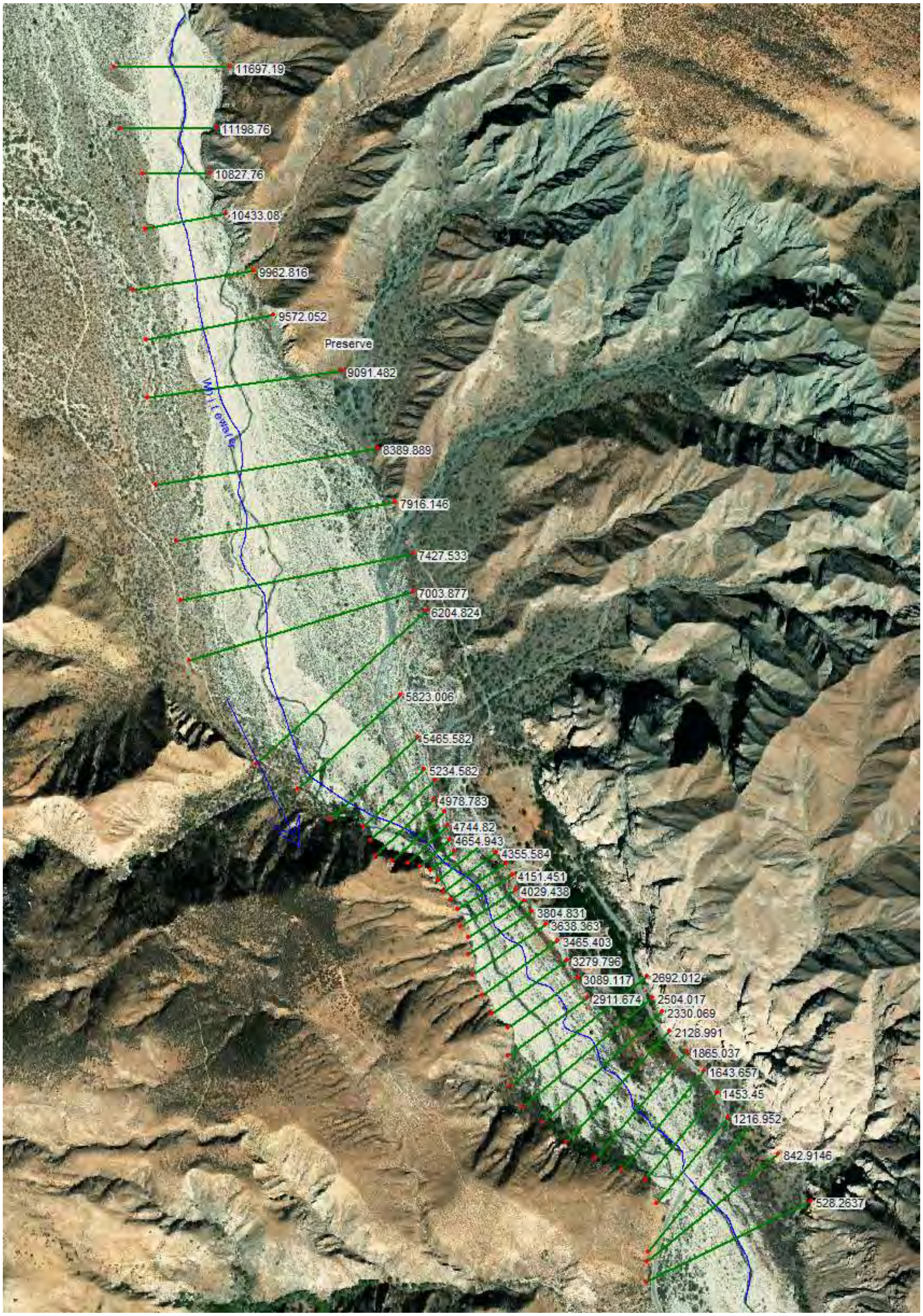


Figure 5-2. Comparison of cross sections versus braided flood pattern behavior

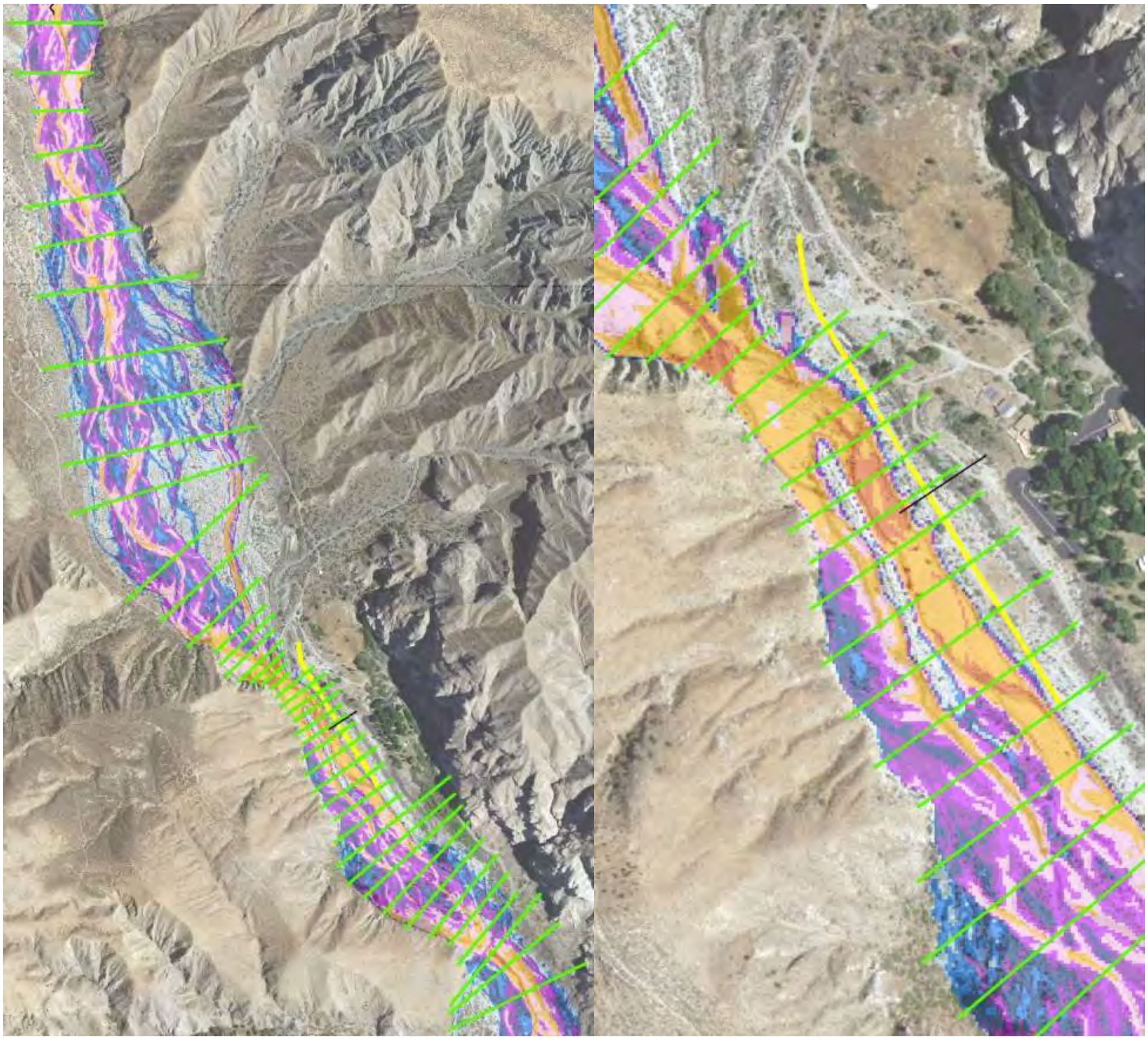


Figure 5-3. Mean bed equivalent rectangular section example

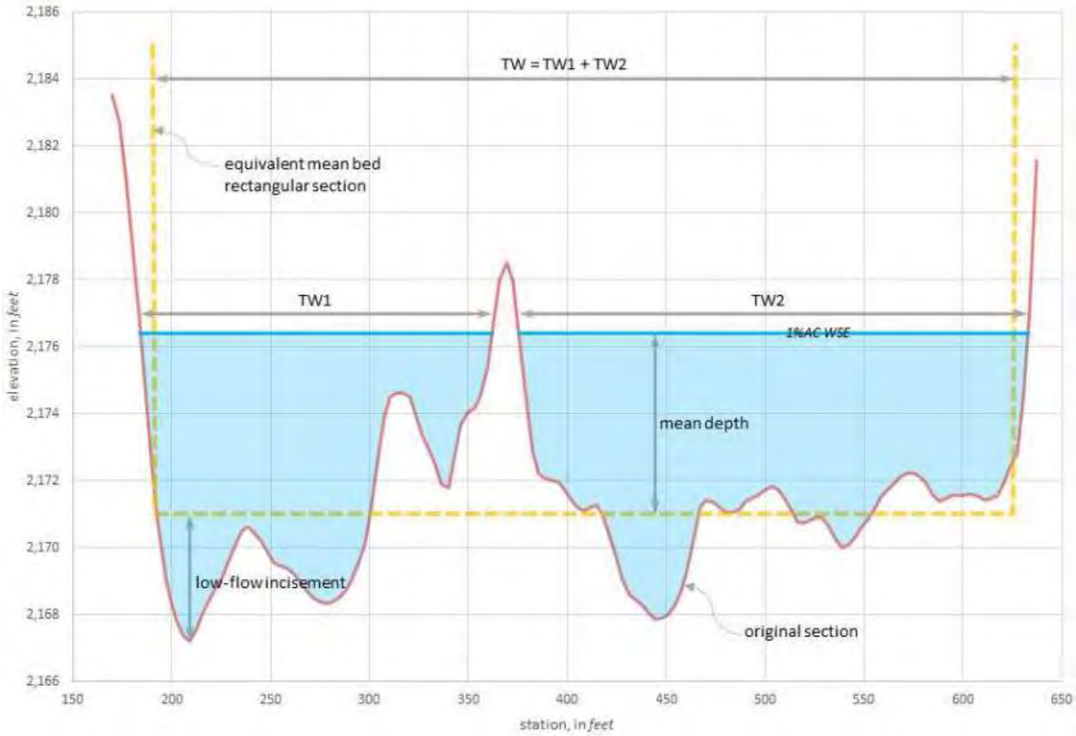
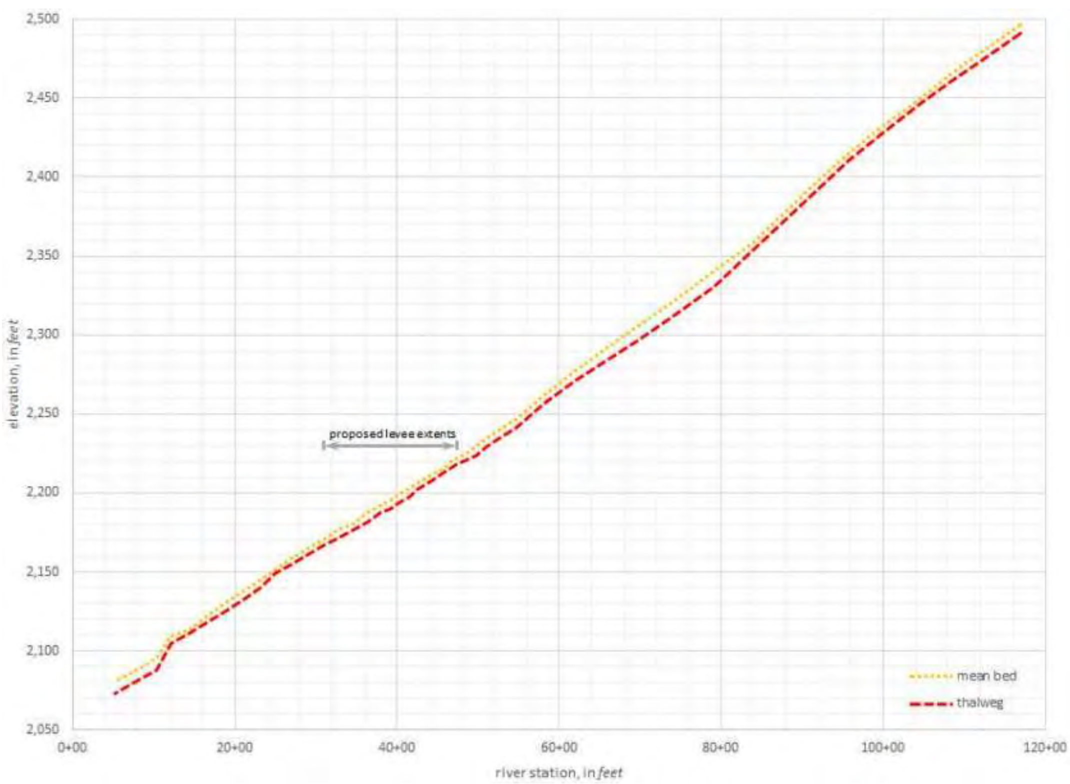


Figure 5-4. Derived mean bed versus thalweg profile



5.3.3 Hydrologic regime

The hydrology used to evaluate sediment transport includes the following:

- RCFCWCD standard 1%AC 6-hour and 24-hour storm events based on the NOAA Atlas 14 precipitation dataset (NWS, 2014) as shown in Figure 5-5
- Continuous mean daily flow record for the inactive streamflow gaging station on the Whitewater, located between Interstate 10 and the Preserve (USGS ID 10256000); the record includes 31 water years of recorded flows from 1949 through 1979, as presented in Figure 5-6

Long-term continuous simulations were performed based on the mean daily flow record.

The 1-percent annual chance flood hydrographs were transformed to quasi-unsteady flow ordinates. A minimum flow threshold of 5 cfs was applied to both event-based on long-term hydrologic regimes.

Durations and time steps related to the individual flow ordinates were adjusted in conjunction with other parameterizations to minimize erratic numerical behavior and assimilate toward a reasonable model simulation response to the applied processes and parameter set.

Figure 5-5. Whitewater River standard 1-percent annual chance flood hydrographs

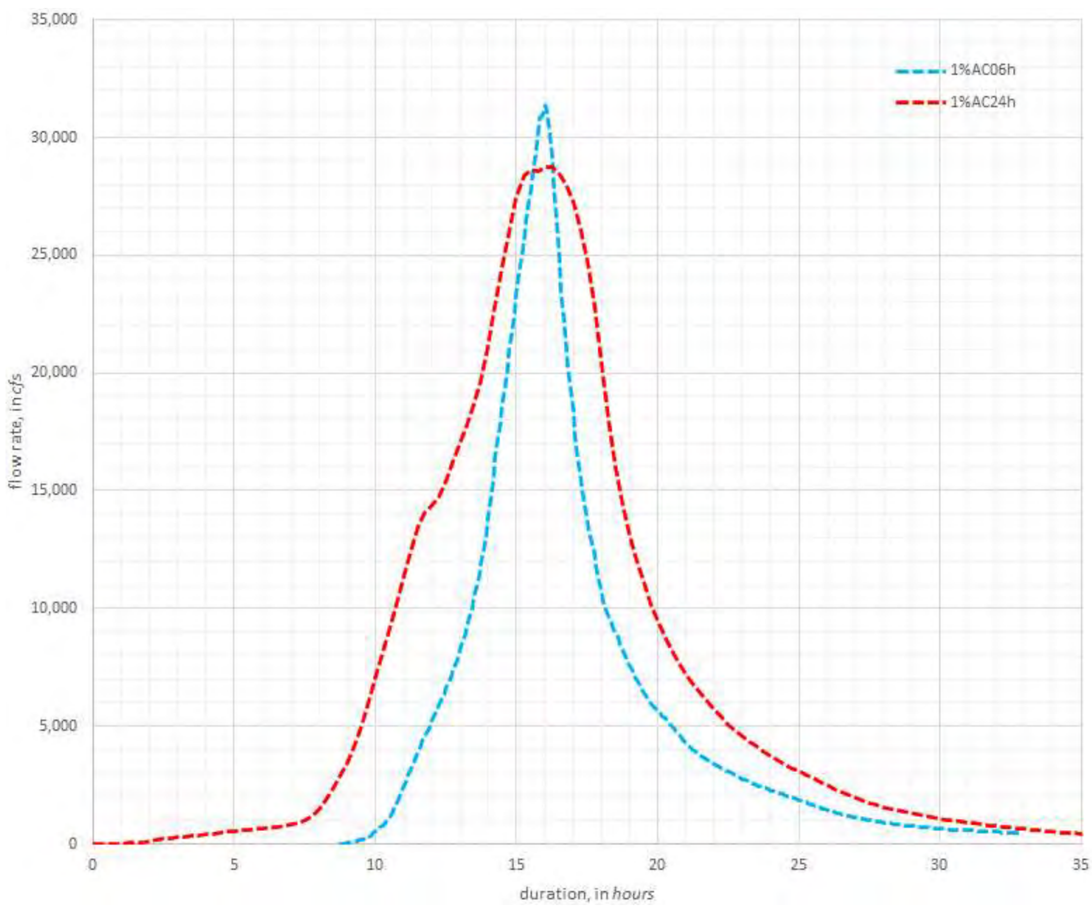
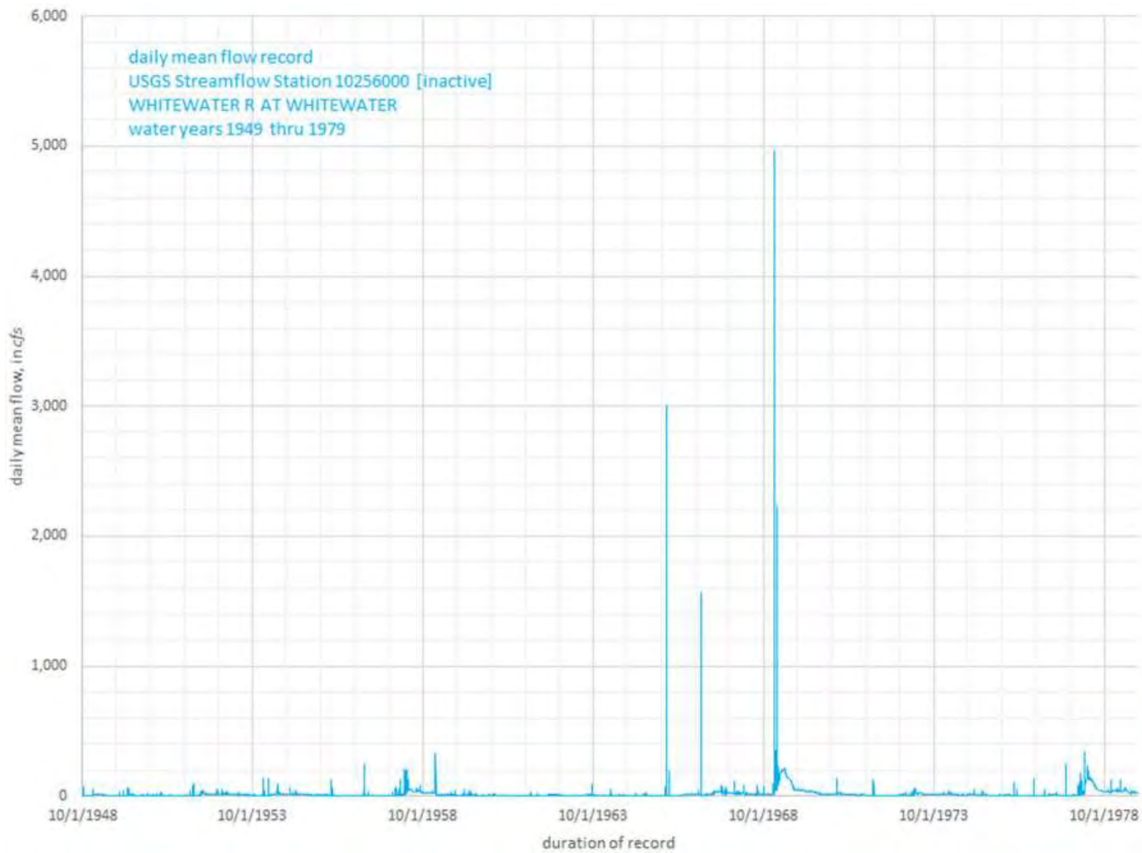


Figure 5-6. Whitewater River streamflow record of daily mean flows



5.3.4 Downstream hydraulic controls

The hydraulic controls were defined downstream based on critical depth, as previously determined from HEC-RAS model results.

5.3.5 Sediment inflow boundary conditions

The amount of debris by volume delivered to the outfall of the computed watershed was estimated using the method prescribed by the USACE Los Angeles District (2000). The appropriate regression formula for the size of the Whitewater River watershed is as follows for watersheds of 50 to 200 square miles in area:

$$logDy = 1.02log(Q) + 0.23log(RR) + 0.16log(A) + 0.13(FF)$$

where

Dy = unit debris yield, in cubic yards per square mile =

Q = unit peak runoff, in cfs per square mile

RR = relief ratio (slope), in feet per mile

A = drainage area, in acres

FF = non-dimensional Fire Factor

An Adjustment-Transposition (A-T) factor of 0.47 was approximated relative to reference watersheds used to derived the regression equations prescribed in the USACE (2000), taking into consideration the differences in relevant characteristics, including the soils and geology as well as the channel and hillslope morphology. Tectonic influence in the upper part of the watershed is expected to be minor to moderate. Soils are predominantly loamy in nature with some cohesive behavior in its undisturbed state (outside the active floodplain). There is not a substantial amount of evidence related to rills, gullies, bank erosion, and head cuts. The Whitewater River watershed consists of roughly 20 percent of bedrock and is substantially vegetated in the upper portions of the watershed with limited evidence of mass movement and eroding debris deposits. A summary of the debris yield analysis as prescribed by the USACE (2000) is shown in Table 5-7 for selected storm events for the purpose of developing the sediment inflow rating curve for the sediment transport model.

Table 5-1. Debris yield analysis for sediment transport sediment inflow boundary conditions

parameter	*n*-percent annual chance 24-hour storm event				
	50	10	1	0.5	0.2
Q, in *cfs*	1,816	13,076	28,737	34,624	43,279
A, in *sq mi*	57.90	57.90	57.90	57.90	57.90
q, in *cfs/sq mi*	31.37	225.85	496.35	598.03	747.52
RR, in *feet/mile*	291.84	291.84	291.84	291.84	291.84
A, in *acres*	37,054	37,054	37,054	37,054	37,054
FF	3	3	3	3	3
Dy, in *cy/sq mi*	1,638	12,271	27,397	33,132	41,600
D, in *acre-feet*	59	440	983	1,189	1,493
A-T	0.47	0.47	0.47	0.47	0.47
D_{A-T}, in *acre-feet*	28	207	462	559	702
$1.00D_{A-T}$, in *tons/day*	55,961	419,171	935,829	1,131,752	1,420,984
$0.75D_{A-T}$, in *tons/day*	41,971	314,378	701,872	848,814	1,065,738
$0.50D_{A-T}$, in *tons/day*	27,980	209,585	467,915	565,876	710,492

5.3.6 Bed-material gradation

The sediment gradation for use in the determination of scour was developed from a combination of a pebble count survey for coarse material (greater than 2 millimeters) and sieve analysis for fine material (less than 2 millimeters). The pebble count survey evaluated 160 sample points over a grid, which extended longitudinally approximately 100 feet within the Project reach and spanned across the floodway immediately adjacent to the proposed levee alignment. with spacing. Fine bed-material was sampled at 3 locations with the grid, generally located the upstream terminus, midpoint, and downstream terminus of the grid. A sieve analysis was performed by Petra (2020) on each fine bed-material sample (3 in total).

The results of the pebble count and sieve analyses are presented in Table 5-1 (pebble count) and Table 5-2 (sieve analysis). The composite sediment gradation for the Project reach is shown in Table 5-3.

Table 5-2. Pebble count analysis results

sediment classification		sediment size, in *mm* minimum	sediment size, in *mm* maximum	pebble count samples	pebble count percent of total	pebble count cumulative percent
sand	sand	0.0625	2	61	38.13	38.13
gravel	very fine	2	2.8	16	10.00	48.13
		3	4	17	10.63	58.75
	fine	4	5.6	1	0.63	59.38
		6	6	2	1.25	60.63
		6	8	2	1.25	61.88
	medium	8	11	0	0.00	61.88
		11	16	5	3.13	65.00
	coarse	16	22	8	5.00	70.00
		22	32	4	2.50	72.50
	very coarse	32	45	4	2.50	75.00
		45	64	3	1.88	76.88
cobble	small	64	90	9	5.63	82.50
		90	128	3	1.88	84.38
	large	128	180	7	4.38	88.75
		180	256	6	3.75	92.50
boulder	small	256	512	1	0.63	93.13
	medium	512	1,024	2	1.25	94.38
	large	1,024	2,048	3	1.88	96.25
	very large	2,048	4,096	6	3.75	100.00
		total sample count:		160		

Table 5-3. Sieve analysis results

ASTM sieve no.	sediment size, in *mm*	percent finer for selected samples			
		1	2	3	average
200	0.075	1.60	3.20	6.70	3.83
100	0.15	9.70	14.80	19.60	14.70
50	0.3	38.40	48.10	45.40	43.97
30	0.6	69.30	73.90	71.50	71.57
16	1.18	79.40	80.80	84.00	81.40
interpolated	2.00	82.22	83.16	88.03	84.47
8	2.36	83.10	83.90	89.30	85.43
4	4.75	85.60	85.90	93.50	88.33
3/8"	9.53	88.20	89.40	97.10	91.57
3/4"	19.05	88.70	92.80	100.00	93.83
1"	25.4	100.00	100.00	100.00	100.00
3"	76.2	100.00	100.00	100.00	100.00
gradation statistics	D_{84}, in *mm*	3.04	2.44	1.18	1.84
	D_{50}, in *mm*	0.39	0.32	0.34	0.35
	D_{16}, in *mm*	0.17	0.15	0.12	0.15
	G	5.01	4.90	3.11	3.77

Table 5-4. Composite sediment gradation results

analysis	sediment size, in *mm*	percent finer: pebble count	percent finer: sieve analysis raw	percent finer: sieve analysis adjusted	percent finer: combined
sieve analysis	0.075	-	3.83	1.73	1.73
	0.15	-	14.70	6.63	6.63
	0.3	-	43.97	19.84	19.84
	0.6	-	71.57	32.30	32.30
	1.18	-	81.40	36.74	36.74
intersect	2	38.13	84.47	38.13	38.13
pebble count	2.8	48.13	-	-	48.13
	4	58.75	-	-	58.75
	5.6	59.38	-	-	59.38
	6	60.63	-	-	60.63
	8	61.88	-	-	61.88
	11	61.88	-	-	61.88
	16	65.00	-	-	65.00
	22	70.00	-	-	70.00
	32	72.50	-	-	72.50
	45	75.00	-	-	75.00
	64	76.88	-	-	76.88
	90	82.50	-	-	82.50
	128	84.38	-	-	84.38
	180	88.75	-	-	88.75
	256	92.50	-	-	92.50
	512	93.13	-	-	93.13
	1,024	94.38	-	-	94.38
	2,048	96.25	-	-	96.25
	4,096	100.00	-	-	100.00
gradation statistics	D_{84}, in *mm*	119.29	-	-	119.29
	D_{50}, in *mm*	2.98	-	-	2.98
	D_{16}, in *mm*	-	0.15	0.25	0.25
	G	-	-	-	26.08

5.3.7 Prescreening and evaluation of sediment transport functions

The following sand- and gravel-based sediment transport functions were evaluated using a baseline 1-percent annual chance flood model scheme, also considering the range and applicability of parameters used in their development:

- Toffaleti (1969)
- Yang stream power for sand (1973) and gravel (1984)
- Einstein (1950)
- Ackers and White (1973)
- Schoklitsch (1962) gravel transport
- Toffaleti (1969) and Schoklitsch (1962) combined
- Meyer-Peter and Muller (MPM; 1948) gravel transport
- Toffaleti (1969) and MPM (1948) combined
- Laursen (1958) modified by Madden (1963)
- Laursen (1958) modified by Madden (1985)
- Engelund and Hansen (1967)
- Laursen (1958) modified by Copeland and Thomas (1989)
- Engelund and Hansen (1967)
- Parker gravel transport (1990)
- Wilcock and Crowe (2003)

From the limited testing, it was determined that the combined use of Toffaleti (1969) and Schoklitsch (1962) provided the reasonable response to the modeled environment as any of the available functions and appeared to be transporting all bed-material sizes in concentrations that were of the same order of magnitude as the debris volumes estimated in the determination of the sediment inflow boundary conditions.

5.3.8 Sensitivity analysis

The sensitivity of the model performance was evaluated considering changes to the follow parameters and/or processes:

- *transport function*. Further sensitivity testing demonstrated, given the extreme range of bed-material sizes from fines to boulders, available transport functions are limited in their capability of emulating the Whitewater environment; it was concluded that the combined methods of Toffaleti (1969) and Schoklitsch (1962) provided the best opportunity for success; other transport function alternatives were generally more limited by parameter and/or process constraints
- *hydraulic roughness*. The hydraulic regime of floodwaters transporting a significant bed-material load is generally assumed to trend toward critical depth; however, some intermittent divergence is expected, where hydraulic roughness may have a significant influence on the transport behavior; also, numerical anomalies may persist as a consequence of the geometric synthesis, consequently resulting in minor mismatches between the hydraulic parameters; three scenarios of hydraulic roughness were evaluated where a constant value of 0.035, 0.050, or 0.065 was applied to all define sections
- *sediment inflow*. Three different definitions of the sediment inflow rating curve were implemented to evaluate predictive response to changes in sediment supply. The variation in sediment inflow considered was based on assuming 50, 75, or 100 percent of the debris volume estimated based on the method prescribed in USACE (2000) was being transported into the modeled study reach
- *bed sorting*. There are three available bed sorting and armoring schemes available, which were all tested. The Exner 7 scheme developed by Copeland (1995) was the least problematic, consistently producing results within the envelope of reasonable expectations

Ultimately, the combined set of assumptions adopted to construct the models used to estimate the worst-case composite bed elevation profile are as follows:

- Toffaleti (1969) and Schoklitsch (1932) combined transport functions
- Critical flow regime
- Hydraulic roughness (Manning's n-value) equal to 0.050
- Sediment inflow rating curve based on 75 percent of the adjusted debris yield computed based on the method prescribed in USACE (2000)
- Bed sorting and armoring based on Exner 7 (Copeland, 1995)

5.4 Final model simulations and results

The long-term mean daily flow record and the County standard 1-percent annual chance storm events were evaluated independently, starting from a mean bed geometry based on the 1-meter California Wildfire LiDAR (LiDAR).

The County standard 1-percent annual chance storm events were also evaluated, starting from a geometry based on the final mean bed profile resulting from the simulation of the long-term daily mean flow record.

The following sediment transport model scenarios were simulated, assuming, a (1) critical flow regime, (2) constant hydraulic roughness of 0.05 and (3) sediment inflow rating curve, which reflects 75 percent of the computed adjusted debris volume for the Whitewater watershed:

- Long-term mean daily flow record, consisting of 31 water years from 1949 through 1979, starting from a mean-bed rectangular equivalent geometry based on the 1-meter California Wildfire LiDAR (USGS, 2018)
- RCFCWCD standard 1-percent annual chance 6-hour (1%AC06h) flood hydrograph, starting from a mean-bed rectangular equivalent geometry based on the 1-meter California Wildfire LiDAR (USGS, 2018)
- RCFCWCD standard 1-percent annual chance 24-hour (1%AC24h) flood hydrograph, starting from a mean-bed rectangular equivalent geometry based on the 1-meter California Wildfire LiDAR (USGS, 2018)
- RCFCWCD standard 1-percent annual chance 6-hour (1%AC06h) flood hydrograph, starting from a mean-bed rectangular equivalent geometry based on the long-term final bed profile
- RCFCWCD standard 1-percent annual chance 24-hour (1%AC24h) flood hydrograph, starting from a mean-bed rectangular equivalent geometry based on the long-term final bed profile

All simulations relied on the combination Toffaleti (1969) and Schoklitsch (1962) sediment transport functions for computing the transport of sand and gravel, respectively. The composite bed-material gradation determined from a pebble count and sieve analyses performed in 2020, was consistently used in all models and is directly representative of the contracted conveyance adjacent to the proposed levee alignment.

The long-term simulation results shown in Figure 5-7, demonstrated progressive degradation for the given set of implemented processes, assumptions, and parameterization. It is worth noting the assumed sediment inflow rating curve is less than the computed potential based on the USACE (2000) methodology, to error conservatively in the determination of scour.

The independently simulated event-based flood results presented in Figure 5-8 (1-percent annual chance 6-hour storm event) and Figure 5-9 (1-percent annual chance 24-hour storm event) show the formation of a scour hole at the downstream terminus of the contracted section near the proposed levee alignment upstream extents. In both cases (6-hour and 24-hour duration events), the scour hole fills in on the receding limb of the flood as suggested by the final bed profile. Overall, the final bed profile depicts some measure of recovery, with the 24-hour duration event demonstrating less success than the 6-hour duration event for this aspect.

The simulated event-based flood results following simulated long-term vertical adjustments, as shown in Figure 5-10 (1-percent annual chance 6-hour storm event) and Figure 5-11 (1-percent annual chance 24-hour storm event), demonstrated that the scour hole formations at the downstream terminus of the contracted section are muted in both cases relative to their outcomes when analyzed based on the most recent topographic conditions (USGS, 2018).

A comparison of minimum mean-bed profiles from all five (5) sediment transport model simulated results is presented in Figure 5-12. The composite worst-case bed profiles derived from all five (5) sediment transport model simulated results is shown in Figure 5-13. Tabulation results corresponding to the profiles displayed in Figures 5-7 through 5-13 are listed in Table 5-5 and Table 5-6, a continuation of Table 5-5.

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Figure 5-7. Sediment transport model long-term (31-year) simulated bed profile results

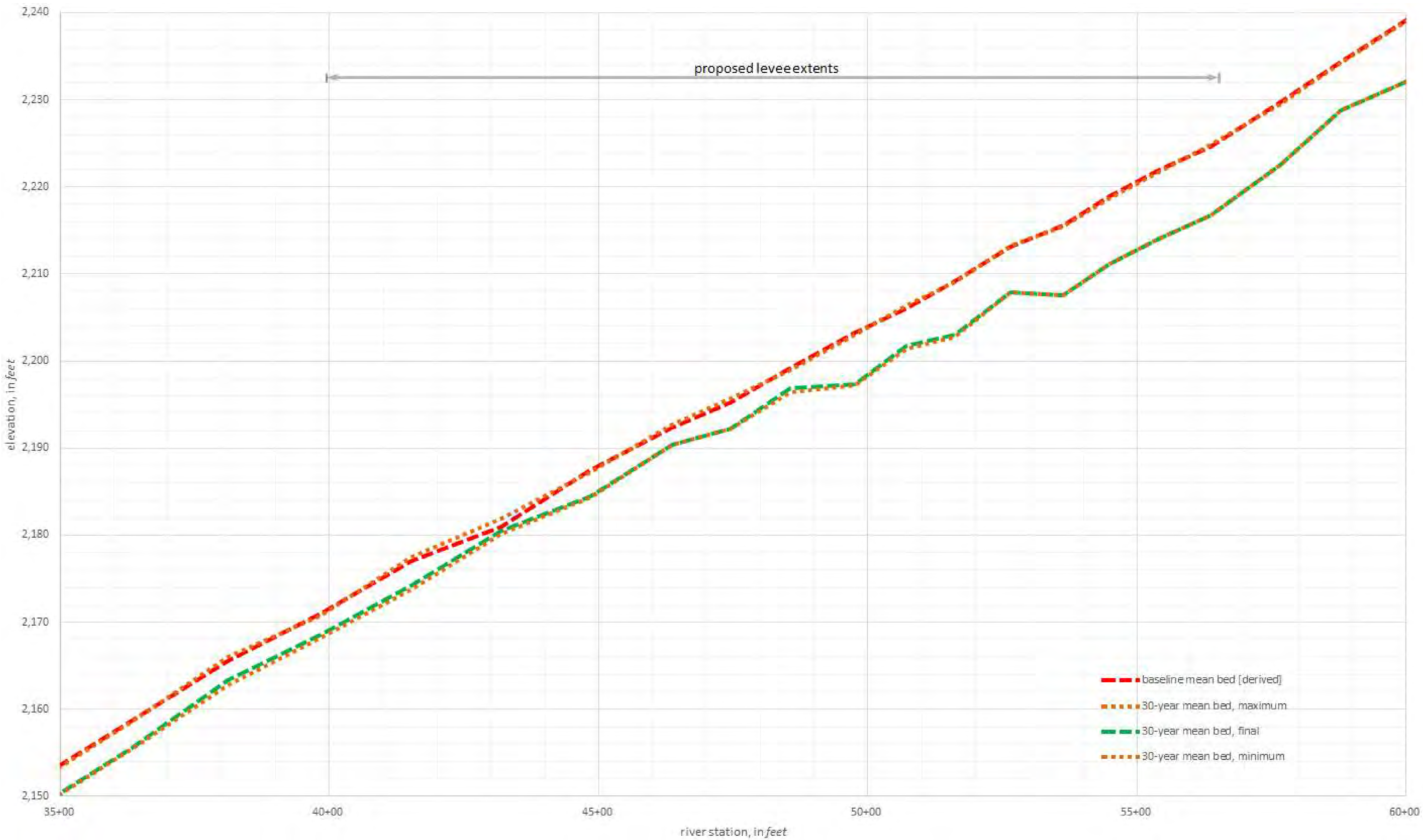

Figure 5-8. Sediment transport model 1-percent annual chance 6-hour event simulated bed profile results

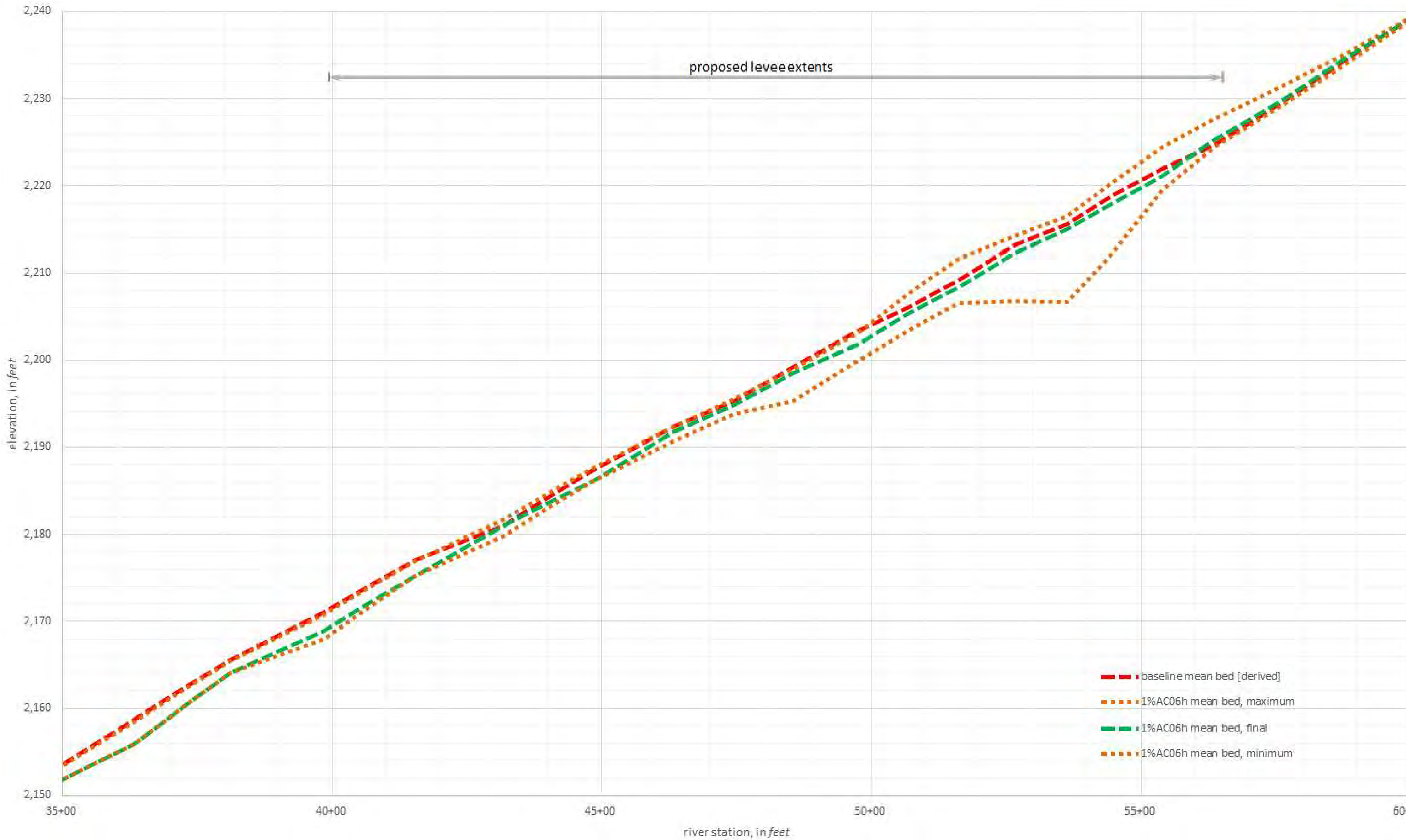

Figure 5-9. Sediment transport model 1-percent annual chance 24-hour event simulated bed profile results

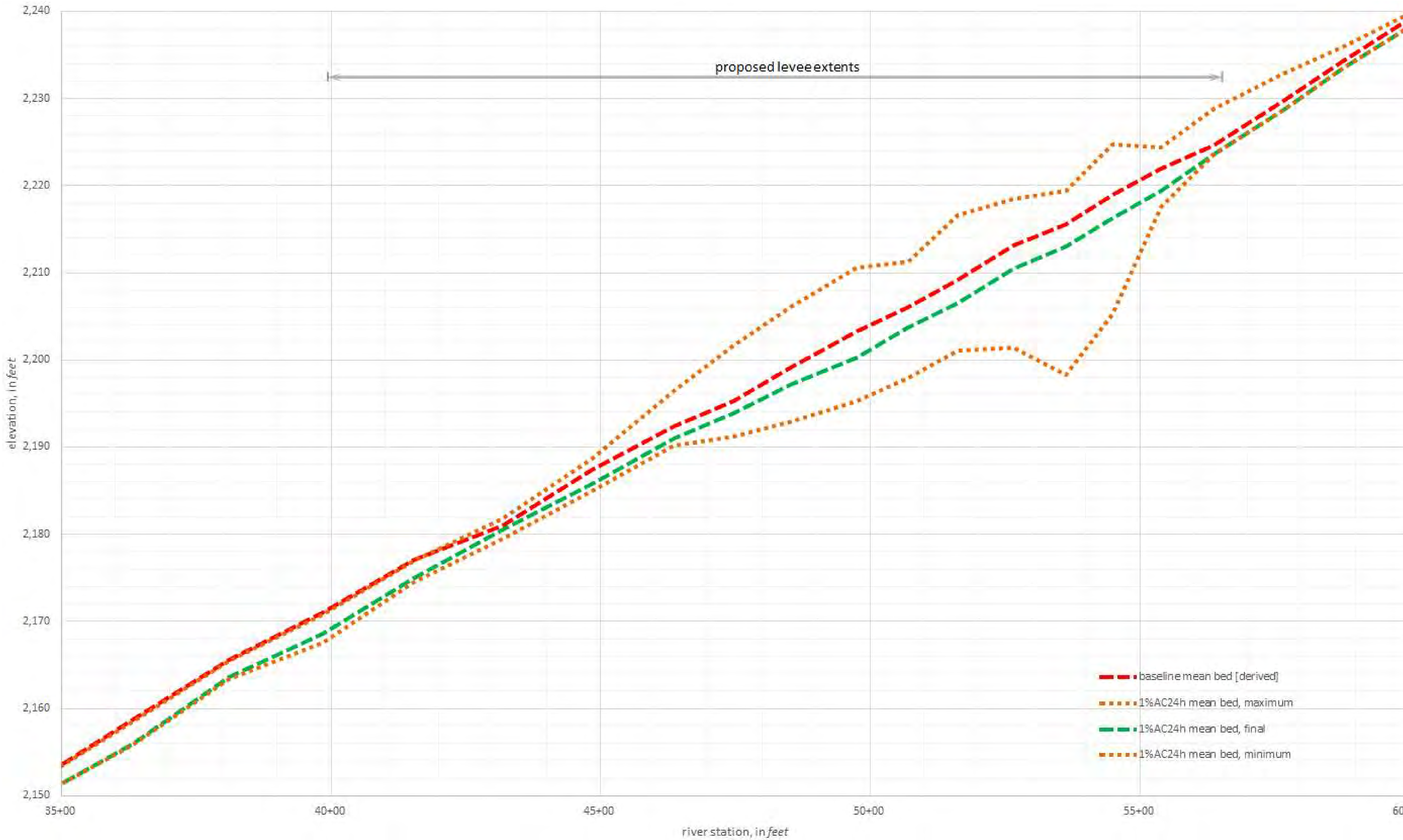

Figure 5-10. Sediment transport model long-term + 1-percent annual chance 6-hour event simulated bed profile results

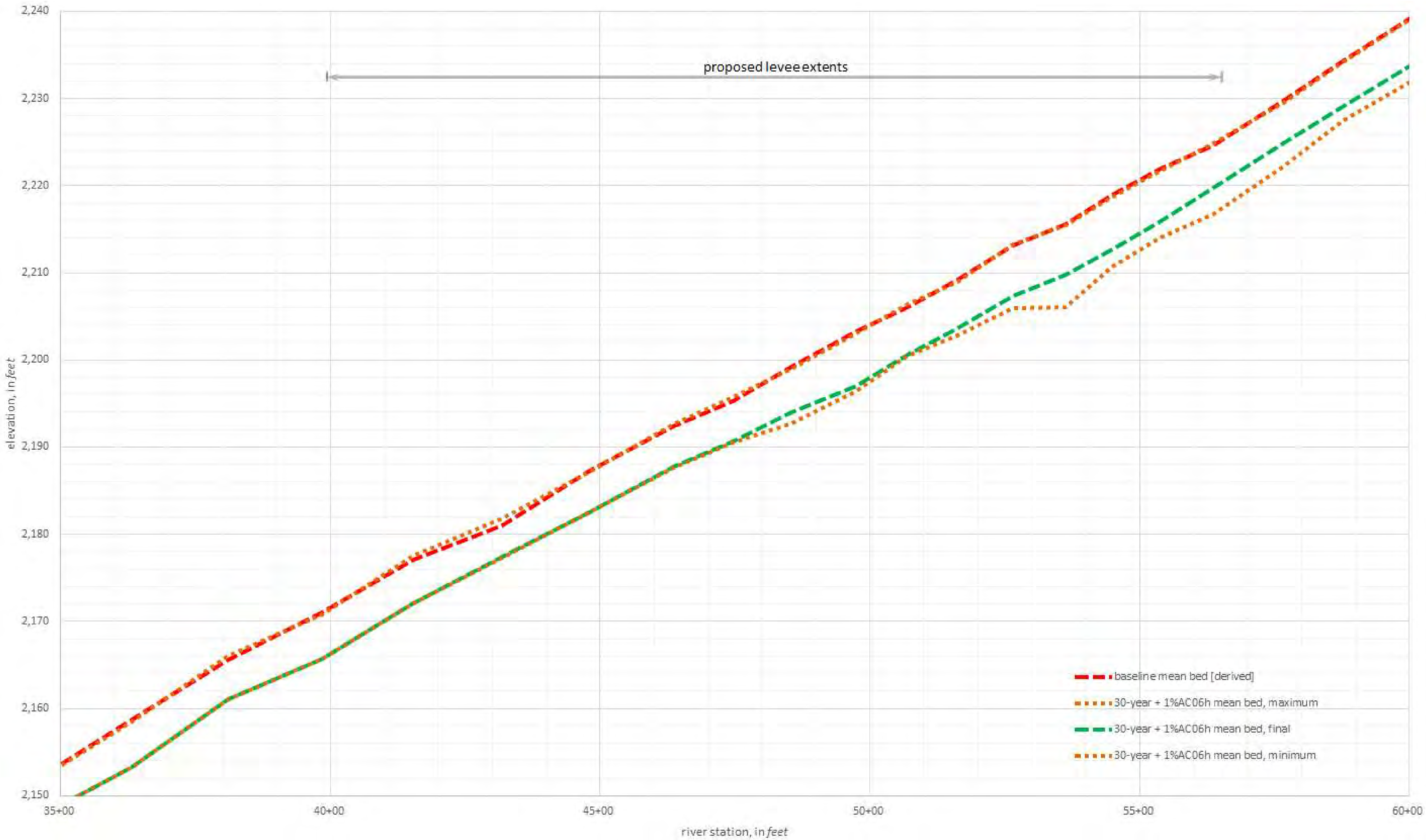

Figure 5-11. Sediment transport model long-term + 1-percent annual chance 24-hour event simulated bed profile results

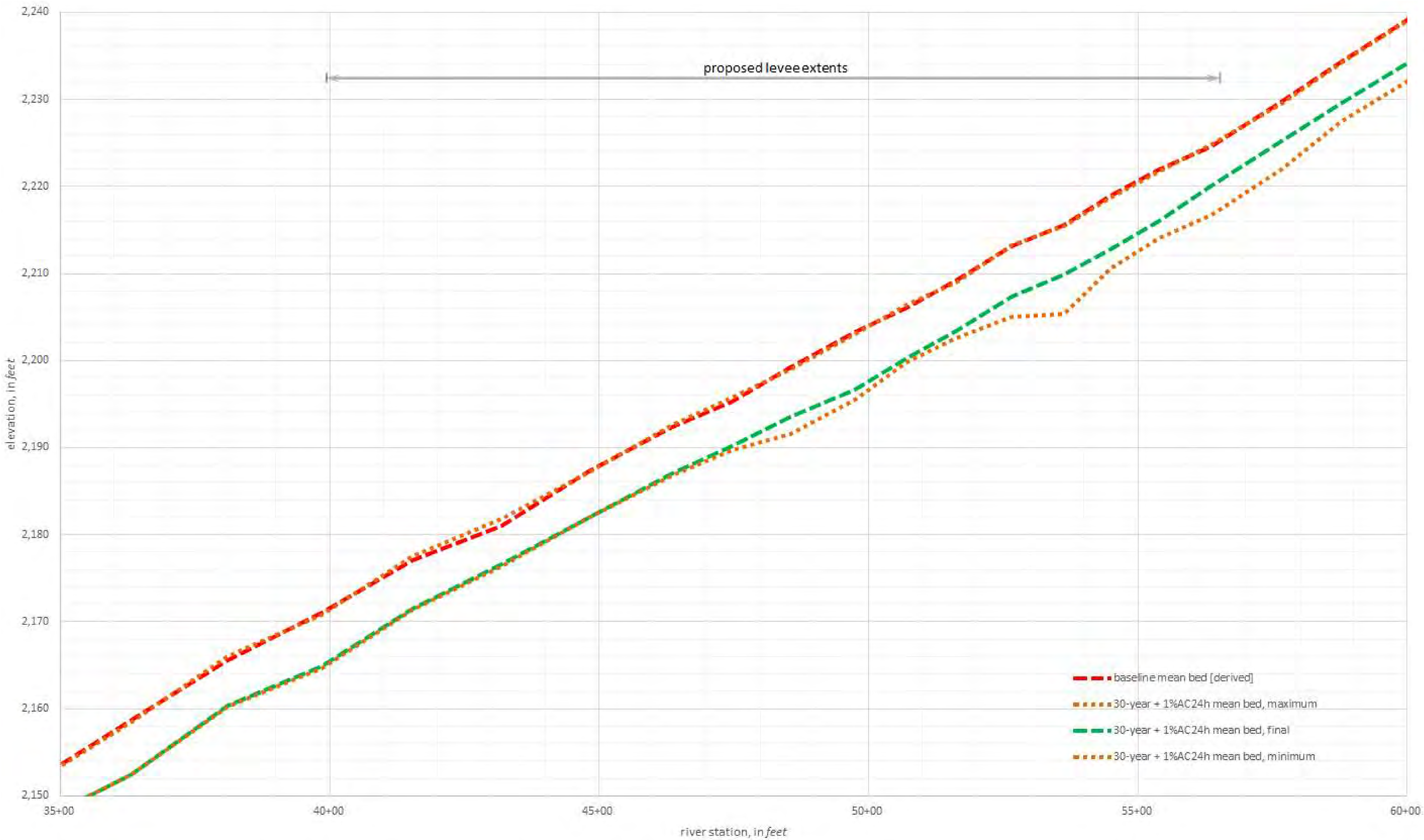

Figure 5-12. Comparison of sediment transport model simulated minimum bed profile results

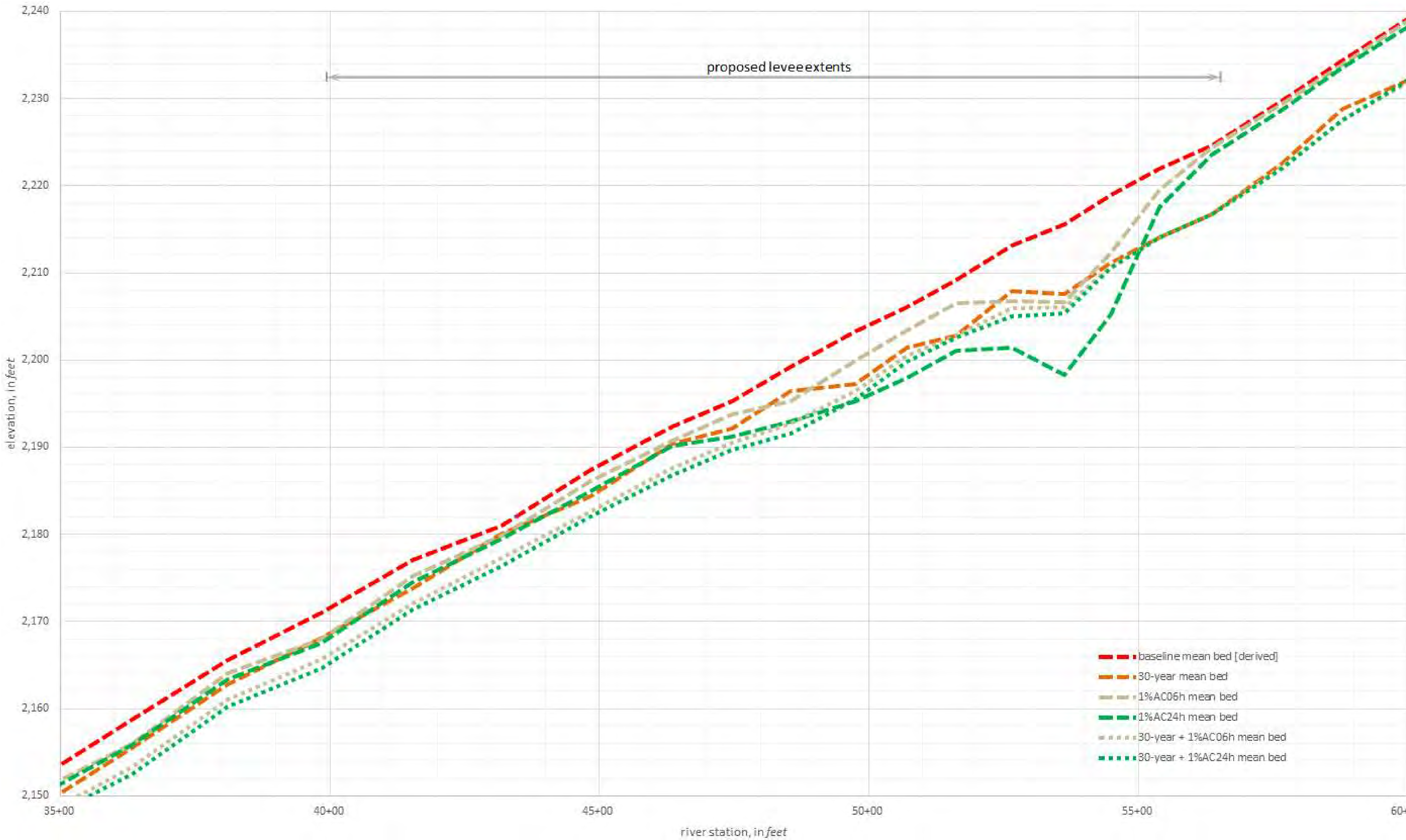

Figure 5-13. Worst-case composite bed profiles based on evaluated long-term and event-based event outcomes

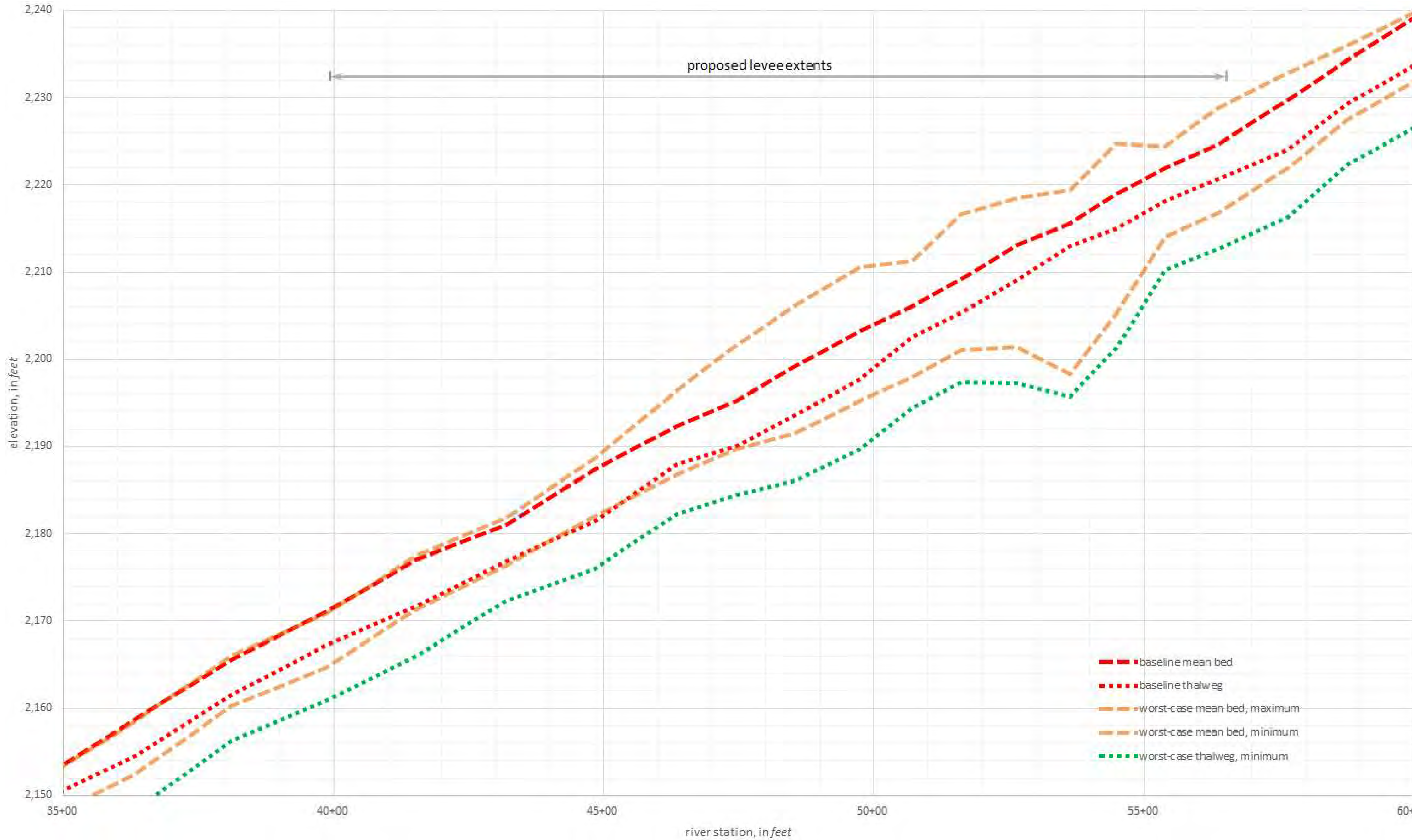

Table 5-5. Sediment transport model simulation results

				long-term daily mean flow record [31 years]								Standard 1-percent annual chance 6-hour flood hydrograph								Standard 1-percent annual chance 24-hour event							
				mean bed elevation, in *feet*			final bed, in *feet*			maximum depth of scour, in *feet*		mean bed elevation, in *feet*			final bed, in *feet*			maximum depth of scour, in *feet*		mean bed elevation, in *feet*			final bed, in *feet*			maximum depth of scour, in *feet*	
station, *feet*	thalweg, in *feet*	mean bed, in *feet*	low-flow incisement, in *feet*	maximum	minimum	maximum mean deposition, in *feet*	mean change	mean elevation	thalweg elevation	mean	thalweg	maximum	minimum	maximum mean deposition, in *feet*	mean change	mean elevation	thalweg elevation	mean	thalweg	maximum	minimum	maximum mean deposition, in *feet*	mean change	mean elevation	thalweg elevation	mean	thalweg
123+17	2490.54	2496.17	5.63	2495.95	2491.01	0.00	-1.57	2494.60	2488.97	5.16	10.79	2495.94	2489.51	0.00	-6.50	2489.67	2484.04	6.66	12.29	2495.95	2487.99	0.00	-7.99	2488.18	2482.55	8.18	13.81
118+37	2473.37	2478.32	4.95	2478.10	2469.52	0.00	-8.80	2469.52	2464.57	8.80	13.75	2478.10	2471.56	0.00	-6.76	2471.56	2466.61	6.76	11.71	2478.10	2470.04	0.00	-8.28	2470.04	2465.09	8.28	13.23
114+78	2460.39	2464.47	4.08	2464.25	2453.89	0.00	-10.58	2453.89	2449.81	10.58	14.66	2464.25	2456.83	0.00	-7.64	2456.83	2452.75	7.64	11.72	2464.25	2455.19	0.00	-9.28	2455.19	2451.11	9.28	13.36
110+85	2445.29	2448.90	3.61	2448.69	2442.24	0.00	-6.41	2442.49	2438.88	6.66	10.27	2448.68	2443.68	0.00	-5.22	2443.68	2440.07	5.22	8.83	2448.68	2442.31	0.00	-6.59	2442.31	2438.70	6.59	10.20
106+14	2426.42	2431.27	4.85	2431.08	2423.59	0.00	-7.68	2423.59	2418.74	7.68	12.53	2431.05	2426.29	0.00	-4.98	2426.29	2421.44	4.98	9.83	2431.06	2424.55	0.00	-6.72	2424.55	2419.70	6.72	11.57
102+22	2410.34	2415.05	4.71	2414.83	2405.43	0.00	-9.62	2405.43	2400.72	9.62	14.33	2414.83	2410.00	0.00	-5.05	2410.00	2405.29	5.05	9.76	2414.83	2408.69	0.00	-6.36	2408.69	2403.98	6.36	11.07
97+39	2387.20	2392.47	5.27	2392.25	2383.75	0.00	-8.72	2383.75	2378.48	8.72	13.99	2392.25	2388.74	0.00	-3.73	2388.74	2383.47	3.73	9.00	2392.25	2387.91	0.00	-4.56	2387.91	2382.64	4.56	9.83
90+57	2353.45	2358.26	4.81	2358.06	2352.54	0.00	-5.72	2352.54	2347.73	5.72	10.53	2358.08	2357.45	0.00	-0.81	2357.45	2352.64	0.81	5.62	2358.07	2357.13	0.00	-1.13	2357.13	2352.32	1.13	5.94
85+75	2330.34	2340.41	10.07	2341.28	2338.56	0.87	-1.85	2338.56	2328.49	1.85	11.92	2340.47	2339.57	0.06	-0.79	2339.62	2329.55	0.84	10.91	2340.47	2338.81	0.06	-1.39	2339.02	2328.95	1.60	11.67
81+09	2312.67	2322.35	9.68	2322.53	2319.64	0.18	-2.27	2320.08	2310.40	2.71	12.39	2322.22	2321.55	0.00	-0.80	2321.55	2311.87	0.80	10.48	2322.22	2321.26	0.00	-0.98	2321.37	2311.69	1.09	10.77
76+87	2297.64	2307.01	9.37	2306.79	2303.83	0.00	-3.18	2303.83	2294.46	3.18	12.55	2306.82	2305.88	0.00	-1.13	2305.88	2296.51	1.13	10.50	2306.82	2305.21	0.00	-1.80	2305.21	2295.84	1.80	11.17
69+40	2271.71	2277.53	5.82	2277.31	2270.44	0.00	-7.09	2270.44	2264.62	7.09	12.91	2277.31	2274.94	0.00	-2.59	2274.94	2269.12	2.59	8.41	2277.31	2274.18	0.00	-3.35	2274.18	2268.36	3.35	9.17
65+77	2256.91	2261.86	4.95	2261.64	2257.58	0.00	-4.28	2257.58	2252.63	4.28	9.23	2261.64	2260.56	0.00	-0.95	2260.91	2255.96	1.30	6.25	2261.64	2260.49	0.00	-1.02	2260.84	2255.89	1.37	6.32
62+25	2241.71	2246.94	5.23	2246.91	2242.35	0.00	-4.59	2242.35	2237.12	4.59	9.82	2248.21	2246.72	1.27	1.01	2247.95	2242.72	0.22	5.45	2248.59	2246.72	1.65	0.54	2247.48	2242.25	0.22	5.45
60+03	2233.83	2239.25	5.42	2239.10	2232.11	0.00	-7.14	2232.11	2226.69	7.14	12.56	2239.29	2238.96	0.04	-0.19	2239.06	2233.64	0.29	5.71	2239.85	2238.30	0.60	-0.95	2238.30	2232.88	0.95	6.37
58+79	2229.38	2234.41	5.03	2234.19	2228.79	0.00	-5.62	2228.79	2223.76	5.62	10.65	2235.07	2233.84	0.66	0.17	2234.58	2229.55	0.57	5.60	2236.02	2233.58	1.61	-0.83	2233.58	2228.55	0.83	5.86
57+65	2224.00	2229.69	5.69	2229.49	2222.53	0.00	-7.16	2222.53	2216.84	7.16	12.85	2231.58	2229.41	1.89	0.25	2229.94	2224.25	0.28	5.97	2232.80	2228.72	3.11	-0.97	2228.72	2223.03	0.97	6.66
56+36	2220.67	2224.66	3.99	2224.81	2216.70	0.15	-7.96	2216.70	2212.71	7.96	11.95	2227.62	2224.44	2.96	0.49	2225.15	2221.16	0.22	4.21	2228.78	2223.63	4.12	-1.03	2223.63	2219.64	1.03	5.02
55+40	2218.12	2221.90	3.78	2221.68	2214.01	0.00	-7.89	2214.01	2210.23	7.89	11.67	2224.37	2219.46	2.47	-0.78	2221.12	2217.34	2.44	6.22	2224.41	2217.58	2.51	-2.52	2219.38	2215.60	4.32	8.10
54+49	2214.96	2218.88	3.92	2218.65	2211.20	0.00	-7.68	2211.20	2207.28	7.68	11.60	2220.47	2212.36	1.59	-0.85	2218.03	2214.11	6.52	10.44	2224.79	2205.25	5.91	-2.67	2216.21	2212.29	13.63	17.55
53+62	2212.99	2215.52	2.53	2215.43	2207.53	0.00	-7.99	2207.53	2205.00	7.99	10.52	2216.46	2206.60	0.94	-0.58	2214.94	2212.41	8.92	11.45	2219.45	2198.26	3.93	-2.50	2213.02	2210.49	17.26	19.79
52+64	2209.04	2213.12	4.08	2213.25	2207.86	0.13	-5.17	2207.95	2203.87	5.26	9.34	2214.21	2206.70	1.09	-0.92	2212.20	2208.12	6.42	10.50	2218.48	2201.36	5.36	-2.65	2210.47	2206.39	11.76	15.84
51+62	2205.40	2209.14	3.74	2209.01	2202.85	0.00	-6.07	2203.07	2199.33	6.29	10.03	2211.65	2206.52	2.51	-0.80	2208.34	2204.60	2.62	6.36	2216.56	2201.09	7.42	-2.63	2206.51	2202.77	8.05	11.79
50+71	2202.52	2206.06	3.54	2206.36	2201.43	0.30	-4.30	2201.76	2198.22	4.63	8.17	2207.72	2203.41	1.66	-0.72	2205.34	2201.80	2.65	6.19	2211.24	2197.95	5.18	-2.33	2203.73	2200.19	8.11	11.65
49+75	2197.73	2203.30	5.57	2203.07	2197.23	0.00	-5.99	2197.31	2191.74	6.07	11.64	2203.07	2199.90	0.00	-1.57	2201.73	2196.16	3.40	8.97	2210.61	2195.22	7.31	-3.08	2200.22	2194.65	8.08	13.65
48+55	2193.70	2199.18	5.48	2198.99	2196.43	0.00	-2.35	2196.83	2191.35	2.75	8.23	2198.96	2195.27	0.00	-0.67	2198.51	2193.03	3.91	9.39	2206.13	2192.93	6.95	-1.90	2197.28	2191.80	6.25	11.73
47+46	2190.03	2195.30	5.27	2195.75	2192.19	0.45	-3.11	2192.19	2186.92	3.11	8.38	2195.56	2193.79	0.26	-0.50	2194.80	2189.53	1.51	6.78	2201.64	2191.17	6.34	-1.40	2193.90	2188.63	4.13	9.40
46+36	2187.91	2192.39	4.48	2192.66	2190.39	0.27	-1.97	2190.42	2185.94	2.00	6.48	2192.33	2190.77	0.00	-0.59	2191.80	2187.32	1.62	6.10	2196.45	2190.14	4.06	-1.38	2191.01	2186.53	2.25	6.73
44+83	2181.49	2187.43	5.94	2187.24	2184.40	0.00	-2.92	2184.51	2178.57	3.03	8.97	2187.67	2186.12	0.24	-1.29	2186.14	2180.20	1.31	7.25	2188.69	2184.92	1.26	-1.62	2185.81	2179.87	2.51	8.45
43+19	2176.84	2181.00	4.16	2181.85	2180.12	0.85	-0.48	2180.52	2176.36	0.88	5.04	2181.67	2179.84	0.67	0.06	2181.06	2176.90	1.16	5.32	2181.86	2179.46	0.86	-0.42	2180.58	2176.42	1.54	5.70
41+53	2171.77	2177.09	5.32	2177.50	2173.77	0.41	-2.86	2174.23	2168.91	3.32	8.64	2176.93	2175.17	0.00	-1.91	2175.18	2169.86	1.92	7.24	2176.97	2174.56	0.00	-2.16	2174.93	2169.61	2.53	7.85
39+84	2167.21	2171.00	3.79	2170.78	2168.16	0.00	-2.38	2168.62	2164.83	2.84	6.63	2170.78	2168.00	0.00	-2.03	2168.97	2165.18	3.00	6.79	2170.78	2167.51	0.00	-2.44	2168.56	2164.77	3.49	7.28
38+11	2161.55	2165.60	4.05	2166.03	2162.76	0.43	-2.30	2163.30	2159.25	2.84	6.89	2165.43	2164.02	0.00	-1.58	2164.02	2159.97	1.58	5.63	2165.46	2163.38	0.00	-2.03	2163.57	2159.52	2.22	6.27
36+32	2154.53	2158.68	4.15	2158.53	2155.46	0.00	-3.08	2155.60	2151.45	3.22	7.37	2158.46	2155.90	0.00	-2.71	2155.97	2151.82	2.78	6.93	2158.46	2155.87	0.00	-2.69	2155.99	2151.84	2.81	6.96
34+54	2149.24	2151.82	2.58	2151.60	2148.53	0.00	-3.21	2148.61	2146.03	3.29	5.87	2151.60	2150.36	0.00	-1.46	2150.36	2147.78	1.46	4.04	2151.60	2149.79	0.00	-2.03	2149.79	2147.21	2.03	4.61
32+85	2141.20	2145.42	4.22	2145.34	2142.71	0.00	-2.69	2142.73	2138.51	2.71	6.93	2145.21	2143.55	0.00	-1.86	2143.56	2139.34	1.87	6.09	2145.21	2143.22	0.00	-1.77	2143.65	2139.43	2.20	6.42
30+75	2133.36	2138.65	5.29	2139.44	2135.90	0.79	-2.59	2136.06	2130.77	2.75	8.04	2138.55	2137.88	0.00	-0.77	2137.88	2132.59	0.77	6.06	2138.58	2137.37	0.00	-1.27	2137.38	2132.09	1.28	6.57
28+30	2124.56	2129.95	5.39	2129.73	2124.89	0.00	-5.06	2124.89	2119.50	5.06	10.45	2129.73	2127.02	0.00	-2.93	2127.02	2121.63	2.93	8.32	2129.73	2126.90	0.00	-3.05	2126.90	2121.51	3.05	8.44
26+09	2117.85	2121.83	3.98	2121.61	2116.09	0.00	-5.74	2116.09	2112.11	5.74	9.72	2121.61	2119.54	0.00	-2.29	2119.54	2115.56	2.29	6.27	2121.61	2119.62	0.00	-2.18	2119.65	2115.67	2.21	6.19
24+20	2111.42	2113.78	2.36	2113.76	2109.32	0.00	-4.43	2109.35	2106.99	4.46	6.82	2114.03	2111.75	0.25	-2.03	2111.75	2109.39	2.03	4.39	2114.06	2111.39	0.28	-1.75	2112.03	2109.67	2.39	4.75
22+34	2104.90	2108.96	4.06	2108.73	2104.25	0.00	-4.50	2104.46	2100.40	4.71	8.77	2108.73	2103.45	0.00	-4.27	2104.69	2100.63	5.51	9.57	2108.74	2103.52	0.00	-3.39	2105.57	2101.51	5.44	9.50
20+49	2087.81	2095.18	7.37	2098.71	2094.17	3.53	2.99	2098.17	2090.80	1.01	8.38	2098.15	2094.71	2.97	2.97	2098.15	2090.78	0.47	7.84	2098.91	2094.70	3.73	3.73	2098.91	2091.54	0.48	7.85
18+67	2082.53	2089.74	7.21	2095.00	2089.52	5.26	2.48	2092.22	2085.01	0.22	7.43	2092.42	2089.52	2.68	2.52	2092.26	2085.05	0.22	7.43	2093.68	2089.52	3.94	3.74	2093.48	2086.27	0.22	7.43
15+46	2073.64	2081.18	7.54	2082.38	2080.83	1.20	-0.03	2081.15	2073.61	0.35	7.89	2084.19	2080.96	3.01	-0.04	2081.14	2073.60	0.22	7.76	2085.45	2080.96	4.27	-0.05	2081.13	2073.59	0.22	7.76

Table 5-6. Sediment transport model simulation results (continued)

station, *feet*	thalweg, in *feet*	mean bed, in *feet*	low-flow incisement, in *feet*	long-term recored + 1-percent annual chance 6-hour flood hydrograph								long term + 1-percent annual chance 24-hour flood hydrograph								worst-case composite profiles								minimum thalweg, in *feet*
				mean bed elevation, in *feet*		maximum mean deposition, in *feet*	final bed, in *feet*			maximum depth of scour, in *feet*		mean bed elevation, in *feet*		maximum mean deposition, in *feet*	final bed, in *feet*			maximum depth of scour, in *feet*		mean bed elevation, in *feet*		maximum mean deposition, in *feet*	final bed, in *feet*			maximum depth of scour, in *feet*		
				maximum	minimum		mean change	mean elevation	thalweg elevation	mean	thalweg	maximum	minimum		mean change	mean elevation	thalweg elevation	mean	thalweg	maximum	minimum		mean change	mean elevation	thalweg elevation	mean	thalweg	
123+17	2490.54	2496.17	5.63	2495.95	2487.76	0.00	-8.26	2487.91	2482.28	8.41	14.04	2495.95	2486.57	0.00	-9.44	2486.73	2481.10	9.60	15.23	2495.95	2486.57	0.00	-9.44	2486.73	2481.10	9.60	15.23	2480.94
118+37	2473.37	2478.32	4.95	2478.10	2469.52	0.00	-8.59	2469.73	2464.78	8.80	13.75	2478.10	2469.20	0.00	-9.12	2469.20	2464.25	9.12	14.07	2478.10	2469.20	0.00	-9.12	2469.20	2464.25	9.12	14.07	2464.25
114+78	2460.39	2464.47	4.08	2464.25	2453.89	0.00	-9.88	2454.59	2450.51	10.58	14.66	2464.25	2453.74	0.00	-10.73	2453.74	2449.66	10.73	14.81	2464.25	2453.74	0.00	-10.73	2453.74	2449.66	10.73	14.81	2449.66
110+85	2445.29	2448.90	3.61	2448.69	2440.65	0.00	-8.25	2440.65	2437.04	8.25	11.86	2448.69	2439.10	0.00	-9.77	2439.13	2435.52	9.80	13.41	2448.69	2439.10	0.00	-9.77	2439.13	2435.52	9.80	13.41	2435.49
106+14	2426.42	2431.27	4.85	2431.08	2421.19	0.00	-10.08	2421.19	2416.34	10.08	14.93	2431.08	2420.67	0.00	-10.57	2420.70	2415.85	10.60	15.45	2431.08	2420.67	0.00	-10.57	2420.70	2415.85	10.60	15.45	2415.82
102+22	2410.34	2415.05	4.71	2414.83	2405.00	0.00	-10.05	2405.00	2400.29	10.05	14.76	2414.83	2404.80	0.00	-10.24	2404.81	2400.10	10.25	14.96	2414.83	2404.80	0.00	-10.24	2404.81	2400.10	10.25	14.96	2400.09
97+39	2387.20	2392.47	5.27	2392.25	2383.37	0.00	-9.10	2383.37	2378.10	9.10	14.37	2392.25	2383.30	0.00	-9.17	2383.30	2378.03	9.17	14.44	2392.25	2383.30	0.00	-9.17	2383.30	2378.03	9.17	14.44	2378.03
90+57	2353.45	2358.26	4.81	2358.06	2352.38	0.00	-4.68	2353.58	2348.77	5.88	10.69	2358.06	2352.36	0.00	-4.44	2353.82	2349.01	5.90	10.71	2358.08	2352.36	0.00	-5.72	2352.54	2347.73	5.90	10.71	2347.55
85+75	2330.34	2340.41	10.07	2341.28	2337.71	0.87	-2.68	2337.73	2327.66	2.70	12.77	2341.28	2336.65	0.87	-3.73	2336.68	2326.61	3.76	13.83	2341.28	2336.65	0.87	-3.73	2336.68	2326.61	3.76	13.83	2326.58
81+09	2312.67	2322.35	9.68	2322.53	2318.65	0.18	-3.64	2318.71	2309.03	3.70	13.38	2322.53	2318.45	0.18	-3.77	2318.58	2308.90	3.90	13.58	2322.53	2318.45	0.18	-3.77	2318.58	2308.90	3.90	13.58	2308.77
76+87	2297.64	2307.01	9.37	2306.79	2302.88	0.00	-4.13	2302.88	2293.51	4.13	13.50	2306.79	2302.78	0.00	-4.23	2302.78	2293.41	4.23	13.60	2306.82	2302.78	0.00	-4.23	2302.78	2293.41	4.23	13.60	2293.41
69+40	2271.71	2277.53	5.82	2277.31	2270.09	0.00	-7.44	2270.09	2264.27	7.44	13.26	2277.31	2269.89	0.00	-7.64	2269.89	2264.07	7.64	13.46	2277.31	2269.89	0.00	-7.64	2269.89	2264.07	7.64	13.46	2264.07
65+77	2256.91	2261.86	4.95	2261.64	2256.25	0.00	-5.61	2256.25	2251.30	5.61	10.56	2261.64	2256.35	0.00	-5.36	2256.50	2251.55	5.51	10.46	2261.64	2256.25	0.00	-5.61	2256.25	2251.30	5.61	10.56	2251.30
62+25	2241.71	2246.94	5.23	2246.91	2241.98	0.00	-4.71	2242.23	2237.00	4.96	10.19	2246.91	2241.94	0.00	-4.34	2242.60	2237.37	5.00	10.23	2248.59	2241.94	1.65	-4.71	2242.23	2237.00	5.00	10.23	2236.71
60+03	2233.83	2239.25	5.42	2239.10	2231.97	0.00	-5.48	2233.77	2228.35	7.28	12.70	2239.10	2232.11	0.00	-5.06	2234.19	2228.77	7.14	12.56	2239.85	2231.97	0.60	-7.14	2232.11	2226.69	7.28	12.70	2226.55
58+79	2229.38	2234.41	5.03	2234.19	2227.57	0.00	-5.24	2229.17	2224.14	6.84	11.87	2234.19	2227.48	0.00	-4.83	2229.58	2224.55	6.93	11.96	2236.02	2227.48	1.61	-5.62	2228.79	2223.76	6.93	11.96	2222.45
57+65	2224.00	2229.69	5.69	2229.49	2222.14	0.00	-4.87	2224.82	2219.13	7.55	13.24	2229.49	2221.99	0.00	-4.50	2225.19	2219.50	7.70	13.39	2232.80	2221.99	3.11	-7.16	2222.53	2216.84	7.70	13.39	2216.30
56+36	2220.67	2224.66	3.99	2224.81	2216.70	0.15	-4.87	2219.79	2215.80	7.96	11.95	2224.81	2216.70	0.15	-4.61	2220.05	2216.06	7.96	11.95	2228.78	2216.70	4.12	-7.96	2216.70	2212.71	7.96	11.95	2212.71
55+40	2218.12	2221.90	3.78	2221.68	2214.01	0.00	-5.99	2215.91	2212.13	7.89	11.67	2221.68	2214.01	0.00	-5.81	2216.09	2212.31	7.89	11.67	2224.41	2214.01	2.51	-7.89	2214.01	2210.23	7.89	11.67	2210.23
54+49	2214.96	2218.88	3.92	2218.65	2210.75	0.00	-6.17	2212.71	2208.79	8.13	12.05	2218.65	2210.54	0.00	-6.10	2212.78	2208.86	8.34	12.26	2224.79	2205.25	5.91	-7.68	2211.20	2207.28	13.63	17.55	2201.33
53+62	2212.99	2215.52	2.53	2215.43	2206.10	0.00	-5.74	2209.78	2207.25	9.42	11.95	2215.43	2205.41	0.00	-5.67	2209.85	2207.32	10.11	12.64	2219.45	2198.26	3.93	-7.99	2207.53	2205.00	17.26	19.79	2195.73
52+64	2209.04	2213.12	4.08	2213.25	2205.97	0.13	-5.80	2207.32	2203.24	7.15	11.23	2213.25	2205.00	0.13	-5.84	2207.28	2203.20	8.12	12.20	2218.48	2201.36	5.36	-5.84	2207.28	2203.20	11.76	15.84	2197.28
51+62	2205.40	2209.14	3.74	2209.01	2202.83	0.00	-5.57	2203.57	2199.83	6.31	10.05	2209.01	2202.63	0.00	-5.71	2203.43	2199.69	6.51	10.25	2216.56	2201.09	7.42	-6.07	2203.07	2199.33	8.05	11.79	2197.35
50+71	2202.52	2206.06	3.54	2206.36	2200.48	0.30	-5.50	2200.56	2197.02	5.58	9.12	2206.36	2199.81	0.30	-5.79	2200.27	2196.73	6.25	9.79	2211.24	2197.95	5.18	-5.79	2200.27	2196.73	8.11	11.65	2194.41
49+75	2197.73	2203.30	5.57	2203.07	2196.44	0.00	-6.27	2197.03	2191.46	6.86	12.43	2203.07	2195.52	0.00	-6.59	2196.71	2191.14	7.78	13.35	2210.61	2195.22	7.31	-6.59	2196.71	2191.14	8.08	13.65	2189.65
48+55	2193.70	2199.18	5.48	2198.99	2192.72	0.00	-5.18	2194.00	2188.52	6.46	11.94	2198.99	2191.58	0.00	-5.68	2193.50	2188.02	7.60	13.08	2206.13	2191.58	6.95	-5.68	2193.50	2188.02	7.60	13.08	2186.10
47+46	2190.03	2195.30	5.27	2195.75	2190.48	0.45	-4.64	2190.66	2185.39	4.82	10.09	2195.75	2189.73	0.45	-5.16	2190.14	2184.87	5.57	10.84	2201.64	2189.73	6.34	-5.16	2190.14	2184.87	5.57	10.84	2184.46
46+36	2187.91	2192.39	4.48	2192.66	2187.61	0.27	-4.67	2187.72	2183.24	4.78	9.26	2192.66	2186.79	0.27	-5.32	2187.07	2182.59	5.60	10.08	2196.45	2186.79	4.06	-5.32	2187.07	2182.59	5.60	10.08	2182.31
44+83	2181.49	2187.43	5.94	2187.24	2182.58	0.00	-4.85	2182.58	2176.64	4.85	10.79	2187.24	2182.01	0.00	-5.42	2182.01	2176.07	5.42	11.36	2188.69	2182.01	1.26	-5.42	2182.01	2176.07	5.42	11.36	2176.07
43+19	2176.84	2181.00	4.16	2181.85	2177.32	0.85	-3.63	2177.37	2173.21	3.68	7.84	2181.85	2176.42	0.85	-4.46	2176.54	2172.38	4.58	8.74	2181.86	2176.42	0.86	-4.46	2176.54	2172.38	4.58	8.74	2172.26
41+53	2171.77	2177.09	5.32	2177.50	2172.02	0.41	-5.06	2172.03	2166.71	5.07	10.39	2177.50	2171.40	0.41	-5.64	2171.45	2166.13	5.69	11.01	2177.50	2171.40	0.41	-5.64	2171.45	2166.13	5.69	11.01	2166.08
39+84	2167.21	2171.00	3.79	2170.78	2165.64	0.00	-5.25	2165.75	2161.96	5.36	9.15	2170.78	2164.63	0.00	-6.13	2164.87	2161.08	6.37	10.16	2170.78	2164.63	0.00	-6.13	2164.87	2161.08	6.37	10.16	2160.84
38+11	2161.55	2165.60	4.05	2166.03	2161.02	0.43	-4.55	2161.05	2157.00	4.58	8.63	2166.03	2160.29	0.43	-5.22	2160.38	2156.33	5.31	9.36	2166.03	2160.29	0.43	-5.22	2160.38	2156.33	5.31	9.36	2156.24
36+32	2154.53	2158.68	4.15	2158.53	2153.27	0.00	-5.41	2153.27	2149.12	5.41	9.56	2158.53	2152.50	0.00	-6.18	2152.50	2148.35	6.18	10.33	2158.53	2152.50	0.00	-6.18	2152.50	2148.35	6.18	10.33	2148.35
34+54	2149.24	2151.82	2.58	2151.60	2147.31	0.00	-4.51	2147.31	2144.73	4.51	7.09	2151.60	2146.88	0.00	-4.94	2146.88	2144.30	4.94	7.52	2151.60	2146.88	0.00	-4.94	2146.88	2144.30	4.94	7.52	2144.30
32+85	2141.20	2145.42	4.22	2145.34	2140.85	0.00	-4.57	2140.85	2136.63	4.57	8.79	2145.34	2140.36	0.00	-5.05	2140.37	2136.15	5.06	9.28	2145.34	2140.36	0.00	-5.05	2140.37	2136.15	5.06	9.28	2136.14
30+75	2133.36	2138.65	5.29	2139.44	2134.62	0.79	-3.83	2134.82	2129.53	4.03	9.32	2139.44	2134.48	0.79	-3.71	2134.94	2129.65	4.17	9.46	2139.44	2134.48	0.79	-3.83	2134.82	2129.53	4.17	9.46	2129.19
28+30	2124.56	2129.95	5.39	2129.73	2124.89	0.00	-4.78	2125.17	2119.78	5.06	10.45	2129.73	2124.70	0.00	-5.25	2124.70	2119.31	5.25	10.64	2129.73	2124.70	0.00	-5.25	2124.70	2119.31	5.25	10.64	2119.31
26+09	2117.85	2121.83	3.98	2121.61	2116.09	0.00	-4.54	2117.29	2113.31	5.74	9.72	2121.61	2116.09	0.00	-4.36	2117.47	2113.49	5.74	9.72	2121.61	2116.09	0.00	-5.74	2116.09	2112.11	5.74	9.72	2112.11
24+20	2111.42	2113.78	2.36	2113.76	2109.28	0.00	-3.30	2110.48	2108.12	4.50	6.86	2113.76	2109.32	0.00	-3.54	2110.24	2107.88	4.46	6.82	2114.06	2109.28	0.28	-4.43	2109.35	2106.99	4.50	6.86	2106.92
22+34	2104.90	2108.96	4.06	2108.73	2102.33	0.00	-5.59	2103.37	2099.31	6.63	10.69	2108.73	2102.45	0.00	-5.16	2103.80	2099.74	6.51	10.57	2108.74	2102.33	0.00	-5.59	2103.37	2099.31	6.63	10.69	2098.27
20+49	2087.81	2095.18	7.37	2098.71	2094.17	3.53	2.73	2097.91	2090.54	1.01	8.38	2098.71	2094.17	3.53	2.86	2098.04	2090.67	1.01	8.38	2098.91	2094.17	3.73	2.73	2097.91	2090.54	1.01	8.38	2086.80
18+67	2082.53	2089.74	7.21	2095.00	2089.52	5.26	2.04	2091.78	2084.57	0.22	7.43	2095.00	2089.52	5.26	2.70	2092.44	2085.23	0.22	7.43	2095.00	2089.52	5.26	2.04	2091.78	2084.57	0.22	7.43	2082.31
15+46	2073.64	2081.18	7.54	2083.89	2080.83	2.71	-0.03	2081.15	2073.61	0.35	7.89	2085.05	2080.83	3.87	-0.04	2081.14	2073.60	0.35	7.89	2085.45	2080.83	4.27	-0.05	2081.13	2073.59	0.35	7.89	2073.29

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5.5 Summary of scour analysis and related levee design considerations

The maximum depth of scour (to thalweg) and corresponding minimum bed elevation for RAS and selected levee stations are presented in Table 5-7.

In general, the minimum design toe-down elevation should assume the maximum scoured thalweg formation from Table 5-7 can potentially migrate laterally to a point adjacent to the proposed levee. This is a reasonable assumption, in large part, for the length of the proposed alignment, except for the upstream extent, which diverges from what can be considered the active floodplain, reaching a point at its most upstream extent that is nearly 200 feet from the active floodplain. For such a case, it would be appropriate to determine the volume displacement of bed/bank material required to reach the point of divergence to estimate the volume offset from original displaced volume reflective of the estimated composite scour determined from sediment transport modeling results. This may even result in the elimination of any scour occurring adjacent to the upstream terminus of the proposed levee alignment.

Table 5-7. Proposed levee minimum toe-down requirements at selected stations

station, in *feet*		maximum depth of thalweg scour, in *feet*	minimum thalweg elevation, in *feet*
RAS	levee		
60+02.76	-	12.70	2,226.55
58+79.09	-	11.96	2,222.45
57+65.09	-	13.39	2,216.30
56+51.64	28+38.65	12.13	2,213.15
56+35.94	-	11.95	2,212.71
55+39.67	-	11.67	2,210.23
54+48.76	-	17.55	2,201.33
53+81.78	25+48.00	19.28	2,196.99
53+62.24	-	19.79	2,195.73
52+64.37	-	15.84	2,197.28
51+70.29	23+47.30	12.13	2,197.34
51+61.60	-	11.79	2,197.35
50+70.80	-	11.65	2,194.41
49+75.36	-	13.65	2,189.65
49+71.13	21+48.08	13.63	2,189.53
48+55.01	-	13.08	2,186.10
47+45.93	-	10.84	2,184.46
47+16.68	47+16.68	10.64	2,183.89
46+35.81	-	10.08	2,182.31
45+00.00	16+46.53	11.22	2,176.75
44+83.50	-	11.36	2,176.07
43+19.22	-	8.74	2,172.26
42+38.04	13+86.30	9.85	2,169.24
41+52.95	-	11.01	2,166.08
39+93.91	11+46.44	10.21	2,161.14
39+84.20	-	10.16	2,160.84
38+10.92	-	9.36	2,156.24

6 DESIGN REQUIREMENTS AND ALTERNATIVE ANALYSIS

6.1 Design Goals and Requirements

The goal of the project is to develop a levee and bank protection system to protect the visitor facilities and critical habitats located within the Whitewater Preserve. The project is not located in a FEMA mapped Special Flood Hazard Area and the levee is not intended to be designed in accordance with the requirements for the National Flood Insurance Program (NFIP) as outlined in Title 44 of the Code of Federal Regulations, Part 65.10, Mapping of areas protected by levee systems (44 CFR §65.10). However, some of the requirements in the regulations will be incorporated into the system design. Other design criteria and goals were developed in conjunction with The Wildlands Conservancy and The Whitewater Preserve.

The following summarizes the main criteria used for the design of the levee and bank protection system:

- **Design Flow Rate:** The 100-and 500-year storm events shall be used for the design of the recommended flood protection improvements.
- **Freeboard:** The top of the levee and bank protection shall be 3-foot above the 100- water surface profile and above the 500-year water surface elevation. The higher of the 2 shall control the design.
- **Scour Protection:** Toe of the levee and bank protection to extend to the calculated scour depths
- **Access Road:** An all-weather access road shall be provided along the top of the proposed improvements. Adequate turn around shall be included at the downstream limits of the improvements
- **Environmental Impacts:** Minimize impacts to environmentally sensitive areas and delineated waters of the U.S.
- **Aesthetics:** Minimize the visual impacts to the visitor facilities and surrounding trails
- **Economics:** Minimize the project cost where possible while still providing the appropriate flood protection

6.2 Formulation of Preliminary Plans

A series of conceptual alternatives were developed to meet the general design criteria and goals identified for the project. The alternative plans were generated and reviewed in coordination with TWC and The Preserve. The plans consisted of a range of options which considered alternative alignments, lengths, and materials.

Four (4) alternative plans were developed and reviewed. The plans included two different plan alignments and two different plan lengths for each alignment.

- Alternative 1 – This alternative is located on an alignment closest to the visitor facilities and away from the Whitewater River. Alternative 1 is a full-length plan which extended from approximately the existing water tank to the north and all the way to Whitewater Canyon Road to the south. This alternative provided full protection for the visitor facilities and the critical habitats on both the north and south side of the visitor facilities. The alignment impacted a secondary flow channel for the local drainages which was identified to include jurisdictional waters of the U.S. The alignment is also the most visible from the visitor facilities and would have the greatest visual impact.

- Alternative 2 – This is a reduced version of Alternative 1. The project limits on the downstream side of the improvements were terminated near the area of critical habitat. While the limited improvements had a lower cost than Alternative 1, the project issues of impacts to jurisdictional waters and aesthetics remained.

- Alternative 3 - This alternative is a full-length plan similar to Alternative 1 which extends from approximately the existing water tank to the north and all the way to Whitewater Canyon Road to the south. This alternative differs from Alternative 1 in that it is located further from the visitor center along an alignment similar to the existing levee/bank protection. This alignment has a reduced environmental impact compared to Alternative 1 and also has less visibility from the visitor center. This alignment is mostly located along the disturbed area of the existing levee/bank protection.

- Alternative 4 - This is a reduced version of Alternative 3. The project limits on the downstream side of the improvements were terminated near the area of critical habitat. This alignment has the least environmental and aesthetic impacts compared to the other 3.

Conceptual layout plans for each of the alternatives are included on Exhibits A through D. An evaluation of the preliminary alternatives in relation to project goals and environmental impacts was prepared by the team. The primary goals are flood protection of the visitor center and protection of critical habitat.

6.3 Evaluation of Preliminary Alternatives and Recommendations

The team reviewed the hydraulic profiles for the 100-, 200-, and 500-year storm events and determined that there was only a minor increase in cost to obtain a 500-year level of protection as compared to the more typical 100-year standard. It was determined that the flood protection system shall be designed to contain the 500-year storm event (without freeboard) to provide additional protection and to provide resiliency to combat the effects of climate change.

The required length of the levee was evaluated to determine the benefits of the long alignments (Alternative 1 and 3) compared to the shorter alignments (Alternatives 2 and 4). The shorter alignments provided the same level of protection to the visitor center and upper habitat areas but allowed some flooding of the lower habitat area during the larger storm events. The potential impacts to the lower habitat with the shorter levees was evaluated by reviewing the potential flooding depths and velocities in the habitat areas. The 2-dimensional flood routing models were used for the analysis. An artificial breach was included in the existing bank just below the limits of the proposed levee. The breach was located at a low point along the existing bank, a location with a high potential for failure.

The 2-dimensional analysis provides a graphical display of the potential flood water depths and velocities for any storm event modeled. The results of the analysis showed the flow velocities to be generally less than 5 feet per second in the critical habitat areas. These velocities are typically considered non-erosion and were determined to have a minimal impact to the habitat. As a result of the analysis, it was recommended that the shorter levees are preferred over the longer alternative. The results of the breach analysis for the 500-year storm event are illustrated on Figures 6-1 (depth) and 6-2 (velocity).

The alignments for Alternatives 2 and 4 were then evaluated for their environmental and aesthetic impacts. Alternative 2 is closer to the visitor center and impacts an internal drainage channel with environmental impacts. Alternative 4 is located on the disturbed area of the existing bank protection and minimizes the environmental impacts. The further distance from the visitor center also provides aesthetic benefits as it can be screened from the heavily uses areas of the park.

Based on the evaluation of numerous factors discussed, Alternative 4 was selected as the preferred alternative to be designed for a 500-year storm event.

Figure 6-1. Proposed Levee with Downstream Breach – Flow Depth

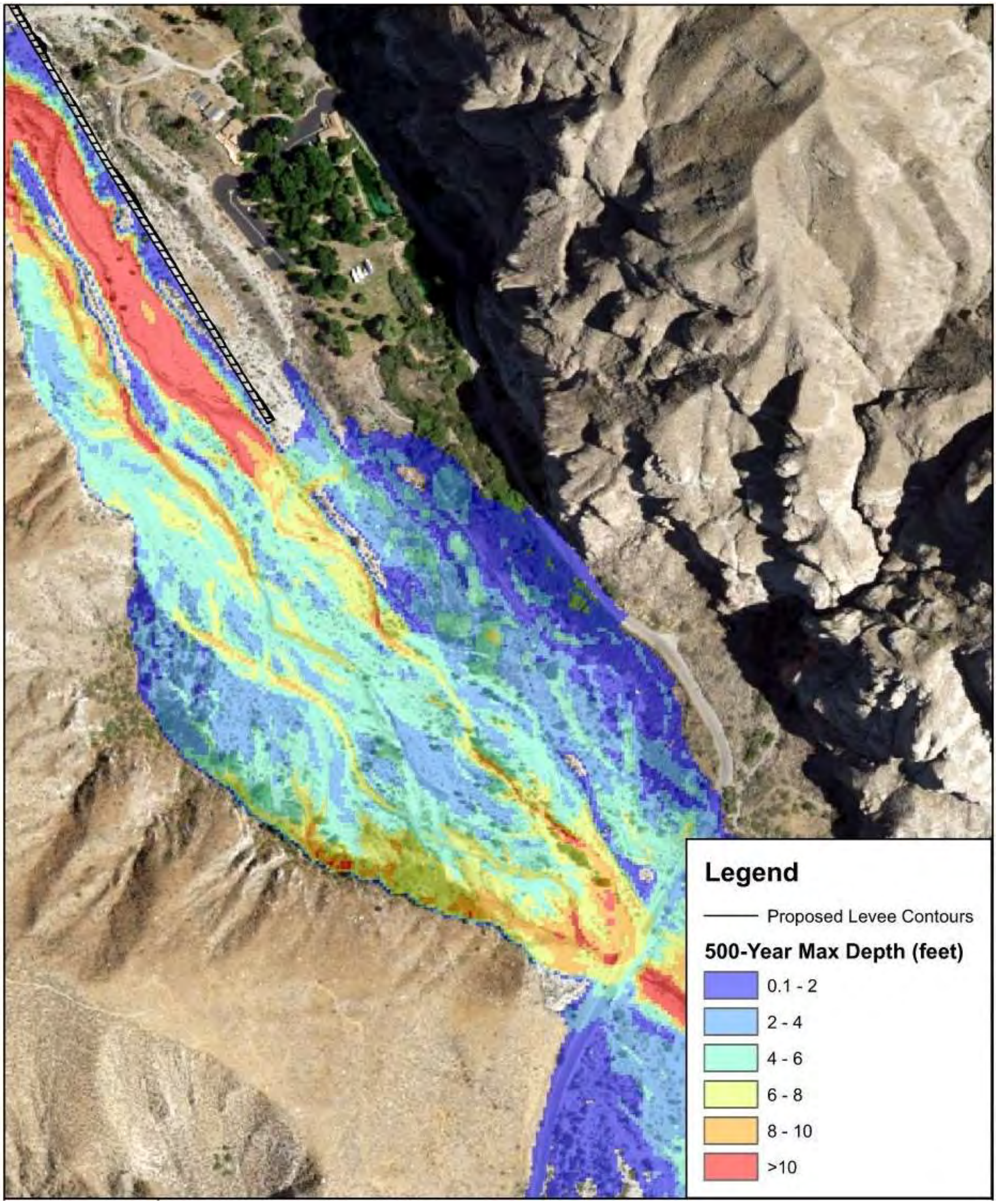
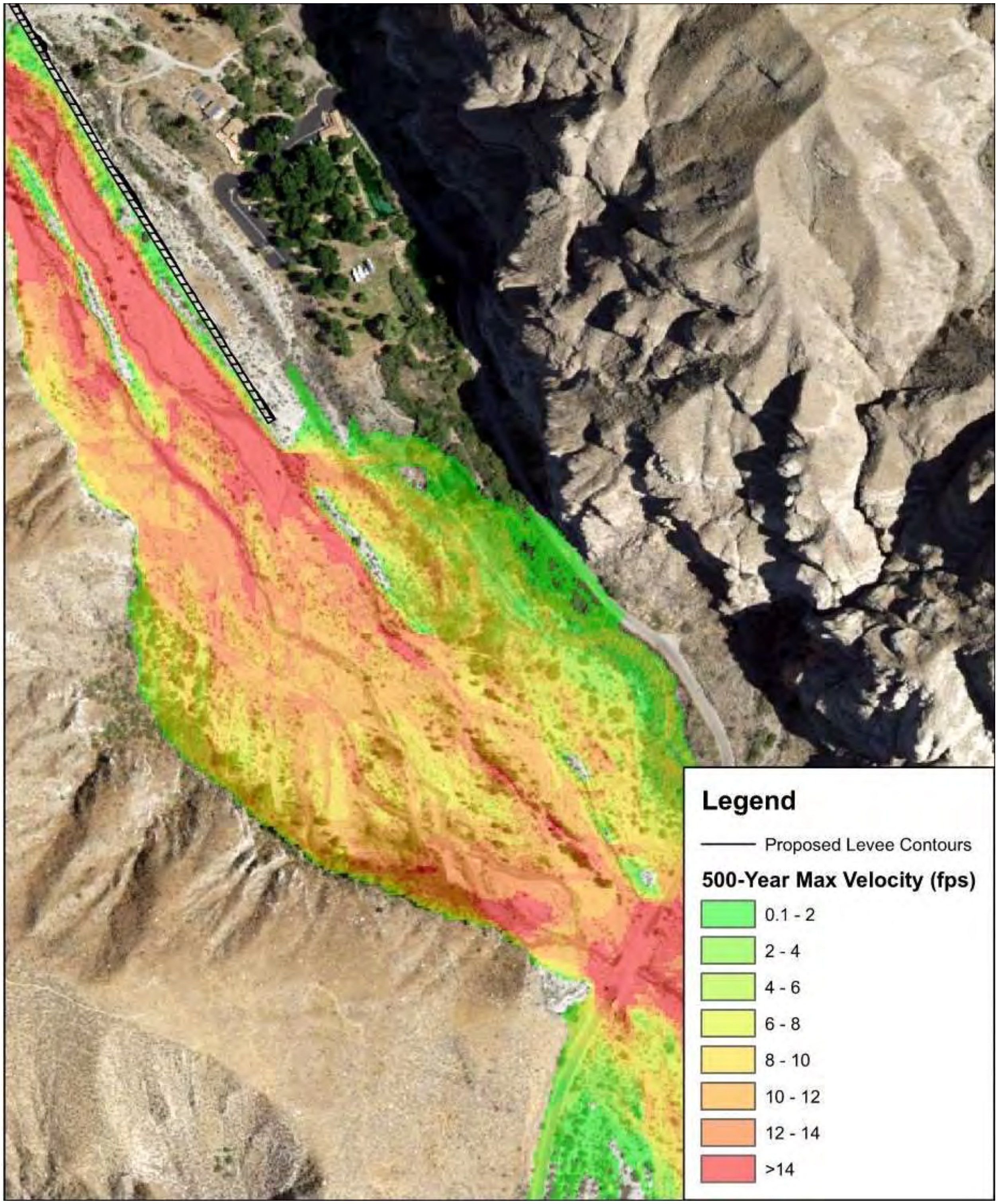


Figure 6-2. Proposed Levee with Downstream Breach – Flow Velocity



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7 RECOMMENDED IMPROVEMENTS

7.1 General

The technical analyses completed as part of this study were prepared to identify the flood protection requirements and provide documentation for the development of the final design improvements along the Whitewater River at the Whitewater Preserve. The technical analyses included hydrology, hydraulic, and sedimentation analyses, along with a detailed assessment of the existing conditions and prior studies completed along the project reach. The final design improvements were developed for the recommended Alternative No. 4 configuration.

7.2 Top of Levee/Bank Elevations

The proposed levee and bank protection were designed to contain the 100-year storm event with a minimum of 3-feet of freeboard and a 500-year storm event below the top of the levee banks. The design water surface elevations and proposed top of bank elevations for the improvements are summarized in Table 4-3.

7.3 Scour Protection and Toe Down Depths

A sedimentation evaluation and scour calculations were prepared to determine the required toe down elevations for the proposed bank protection. The results of the analysis determined the depth below the Whitewater River thalweg elevations to be used for the toe down of the bank protection. The results of the analysis indicate that the toe of the bank protection shall be located from 10 to 20-feet below the adjacent thalweg elevation of the Whitewater River. A summary of the thalweg elevations and required toe elevations are provided in Table 5-7.

7.4 Bank Protection Design

The proposed levee requires a bank protection system to prevent erosion and failure due to storm events. Rock riprap and soil cement were reviewed as potential alternatives for the bank protection. Due to the high velocities and significant amount of bed material moved by the river in a large storm event, soil cement was chosen the recommended method for the bank protection. Previous construction of the bank protection at this location using loose and grouted riprap has shown susceptibility to failure due to the conditions in the river during large storm events. Soil-cement has proven to be an effective and economical construction material for use in water resource applications including streambank protection and slope protection (Richards & Hadley, 2006). For applications exposed to debris carrying rapid flowing water the soil-cement is typically placed in horizontal layers approximately 80-feet wide and 6-12-inches thick along the face of the slope. The soil-cement should have a minimum 7-day compressive strength of at least 750 psi.

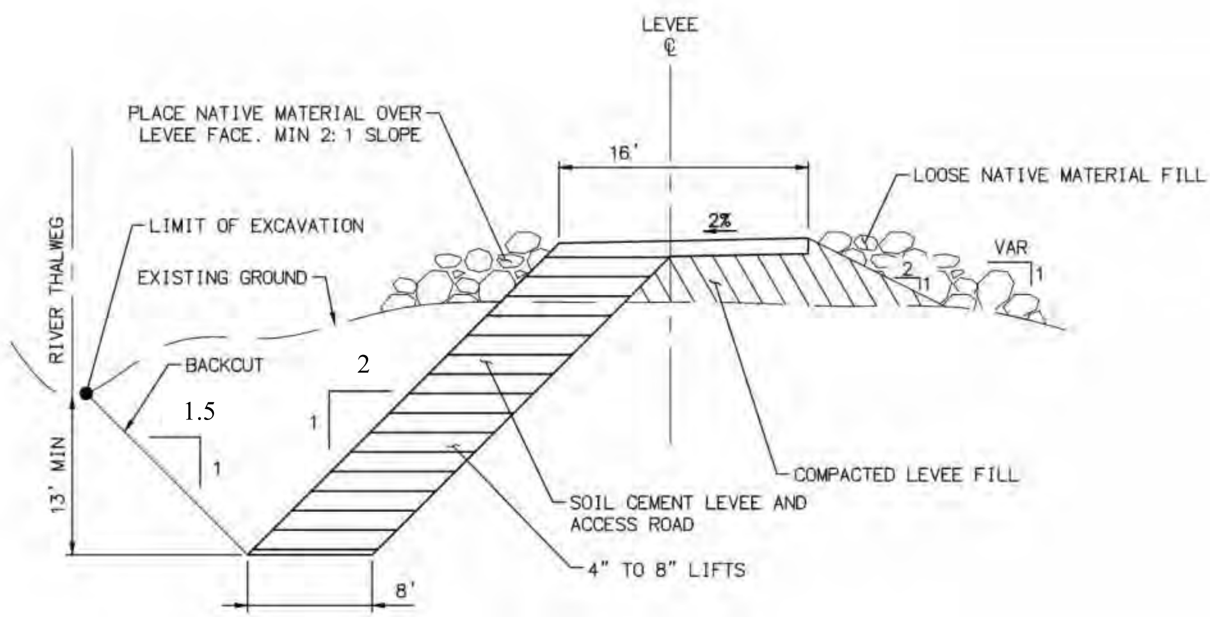
The on-site soils were reviewed as part of the geotechnical analysis to determine their suitability for use in a soil cement bank. The on-site materials were determined to be suitable. The evaluation is included in a separate geotechnical report prepared by Petra Geosciences, Inc.

7.5 Cross Section Geometry and Grading

The proposed cross section was designed to meet the required elevations for the top and toe of the bank protection based on the results of the technical analysis. The bank protection was determined to be a soil-cement lining. In addition to the requirements for the top, toe, and lining, additional features were added to minimize the aesthetic impact on the natural surroundings. On the river side of the levee, native rock materials displaced during construction are proposed to be placed in front of the soil-cement lining. The rock material will screen the soil-cement from view and provide an additional level of scour protection. The native rock materials are for aesthetics and will not influence the required design for the soil-cement bank protection.

On the land side of the levee, native soils and plant material are proposed outside of the levee prism to blend the engineered improvements into the natural surroundings. The native soils will be used to provide a more natural grade to the existing ground. A typical section for the proposed improvements is included in Figure 7-1.

Figure 7-1. Levee and bank protection typical section



7.6 Temporary Construction Limits

The proposed improvements are located along the bank of the Whitewater River and near environmentally sensitivity habitats and jurisdictional waters of the State. The work area on the river side of the levee is proposed to be limited to reduce temporary impacts to the waters for the State. Additional area will be provided along the levee on the landside to provide sufficient work areas and for the soil cement operations and construction of the proposed improvements. The temporary construction limits will be provided on the final improvement plans.

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Exhibits

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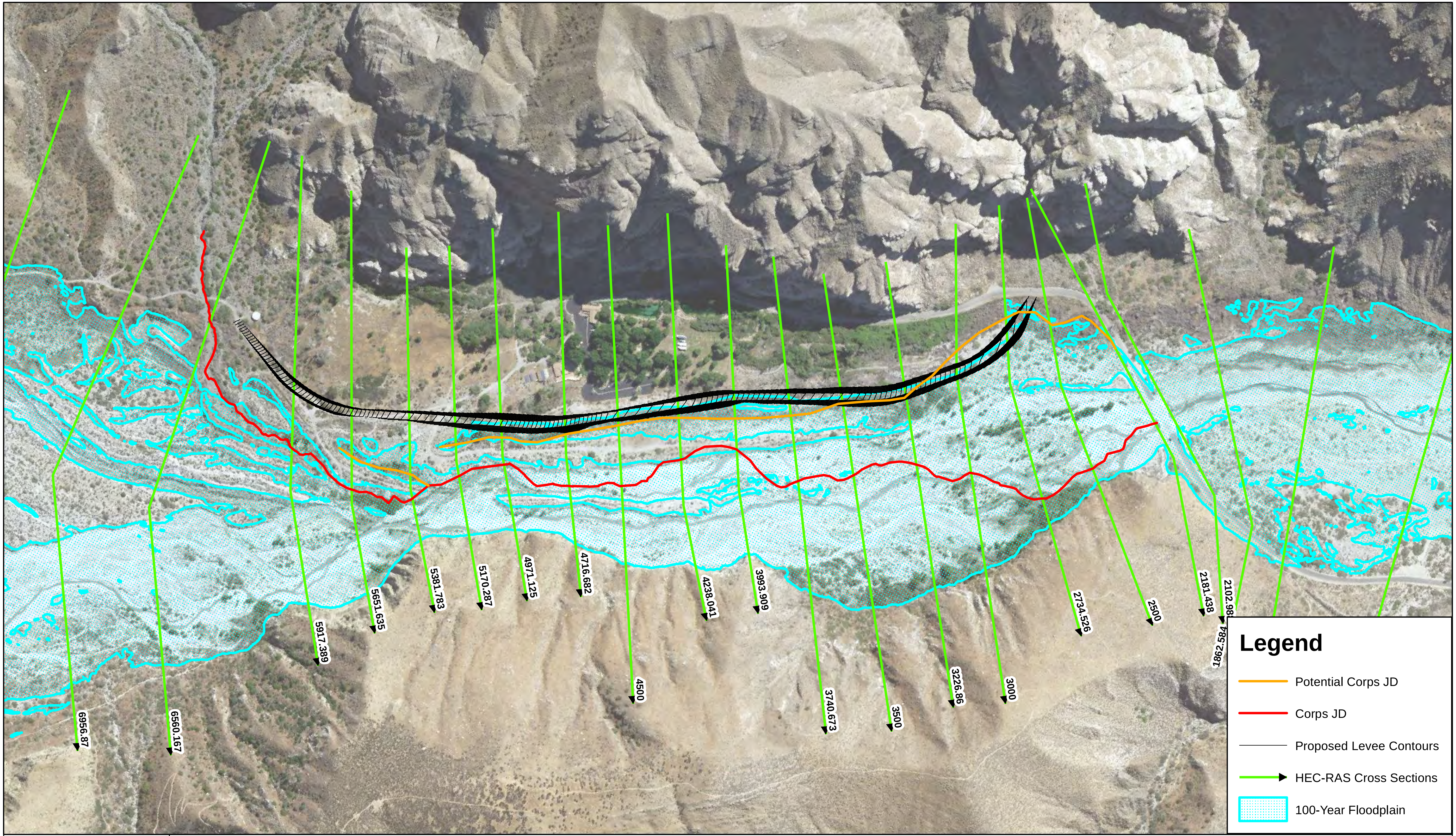


Q3 Consulting

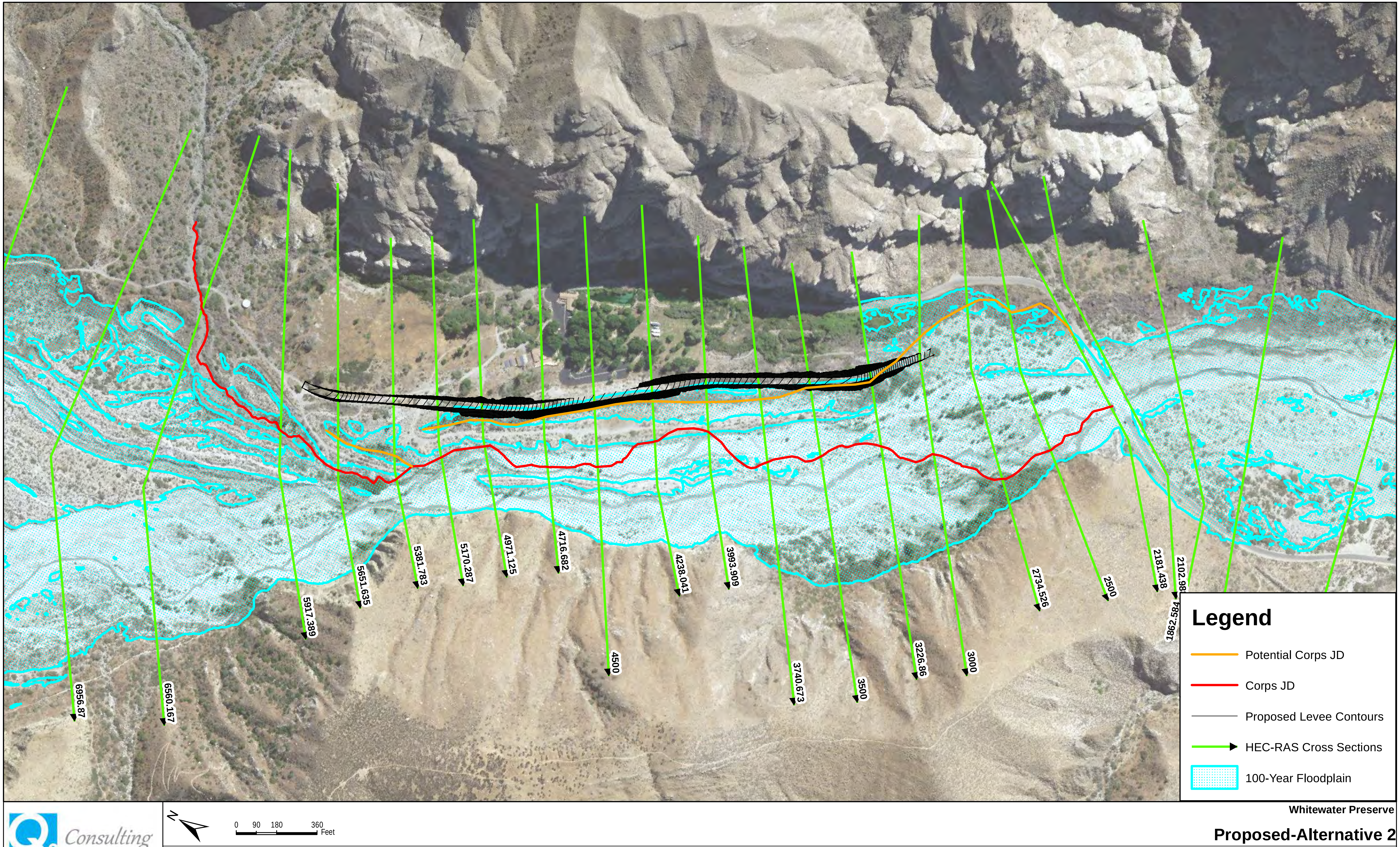
N

0 90 180 360 Feet

Whitewater Preserve

Proposed-Alternative 1

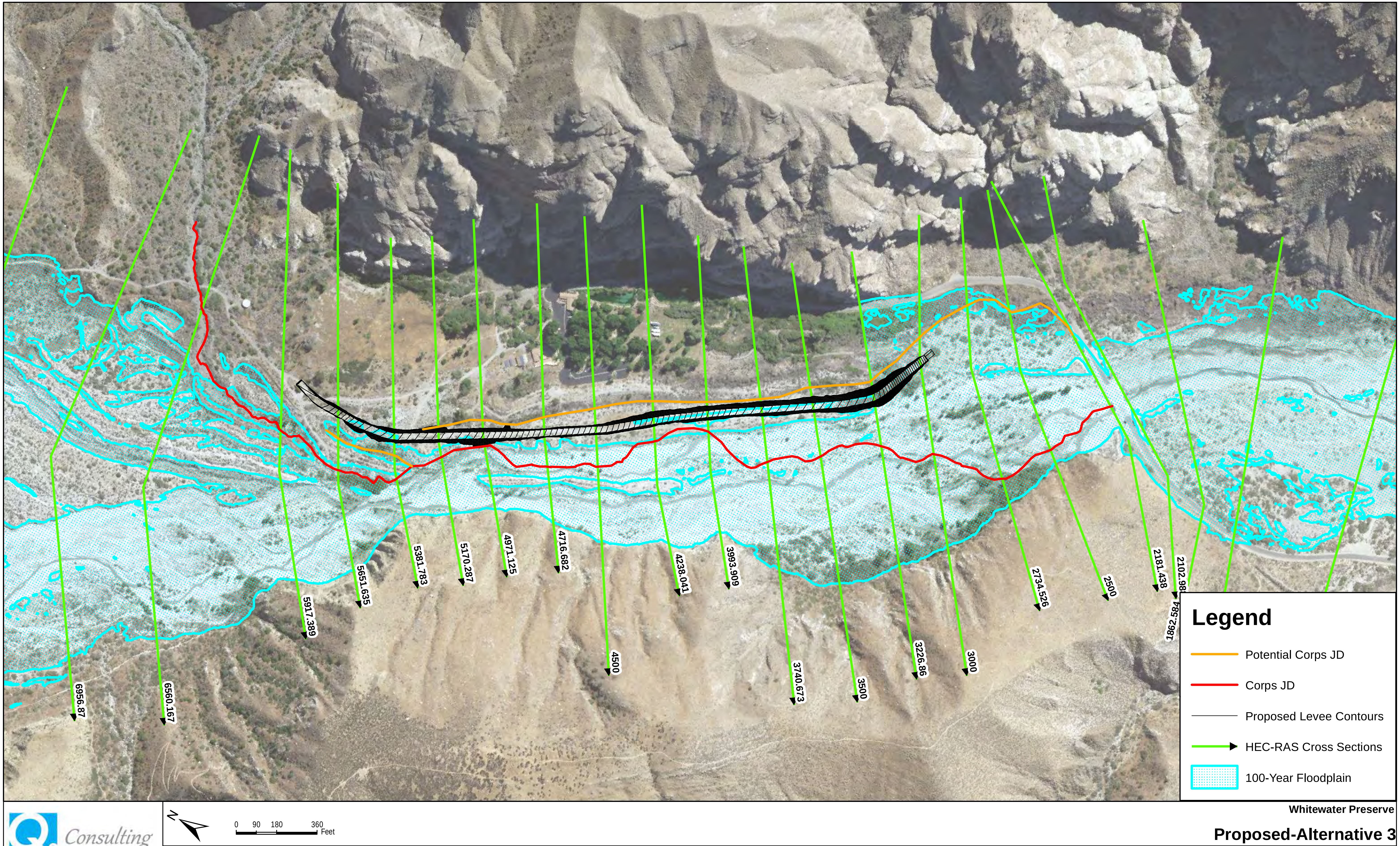
Exhibit A



Whitewater Preserve

Proposed-Alternative 2

Exhibit B

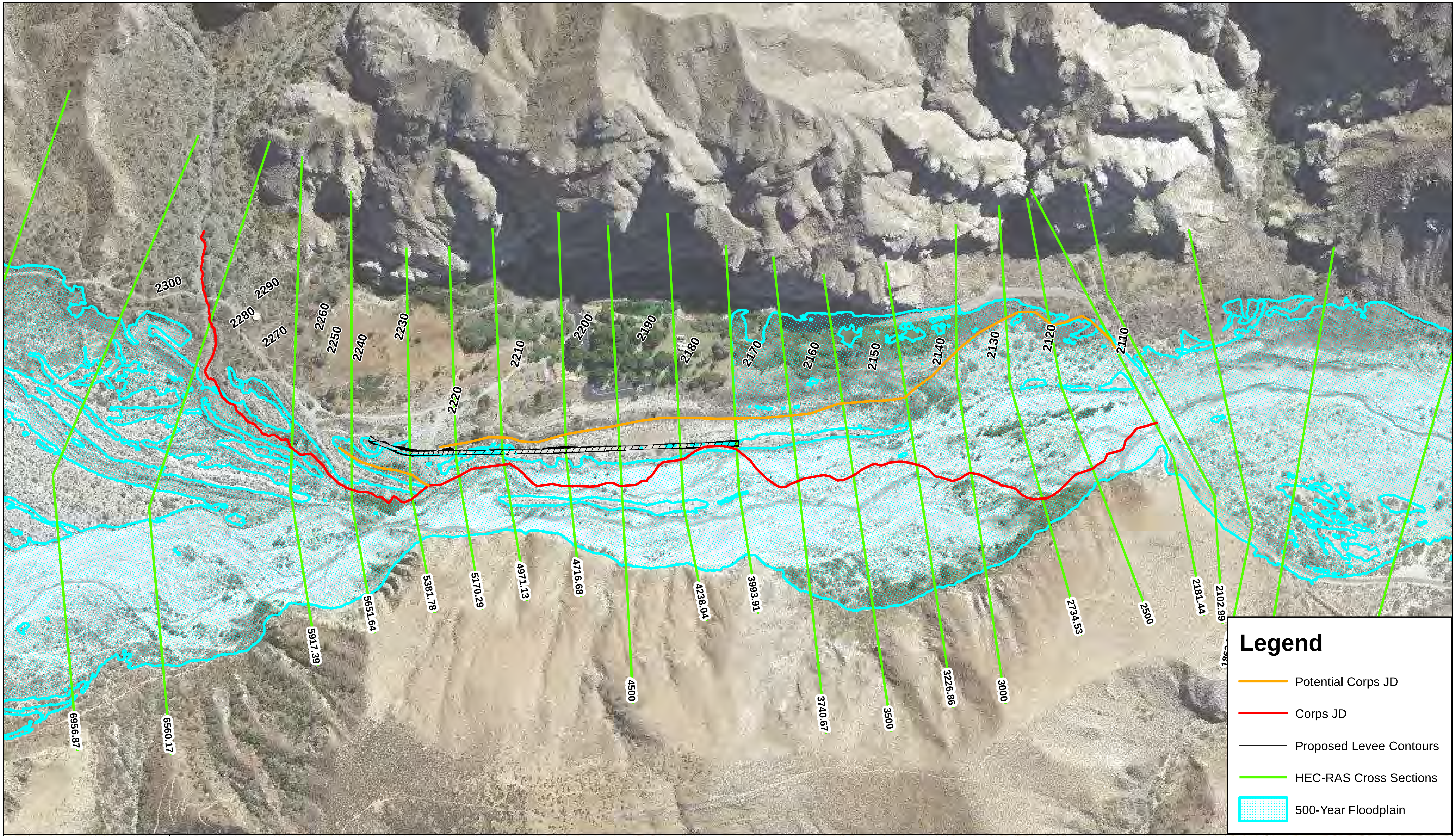


Q3 Consulting

Whitewater Preserve

Proposed-Alternative 3

Exhibit C



Q3 Consulting

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Whitewater Preserve

Proposed-Alternative 4

Exhibit D

Technical Appendix

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Appendix A

Hydraulic Analysis

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A.1 – Existing Condition

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HEC-RAS Plan: Baseline River: Whitewater Reach: Whitewater

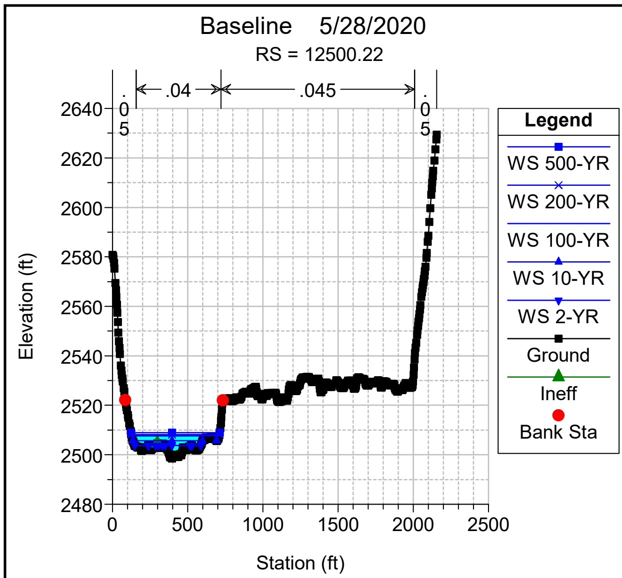
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Max Chl Dpth	Vel Chnl	Flow Area	Top Width	Froude # Chl	Top W Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)
Whitewater	12500.22	100-YR	31400.00	2498.53	2507.70	2507.70	2509.92	0.014421	9.17	11.95	2627.12	583.42	0.99	583.42
Whitewater	12500.22	10-YR	15900.00	2498.53	2505.69	2505.69	2507.32	0.016064	7.15	10.26	1550.44	470.47	1.00	470.47
Whitewater	12500.22	2-YR	4900.00	2498.53	2503.77	2503.77	2504.92	0.017862	5.24	8.62	568.76	380.87	1.00	380.87
Whitewater	12500.22	200-YR	37000.00	2498.53	2508.21	2508.21	2510.69	0.014063	9.68	12.64	2928.01	586.34	1.00	586.34
Whitewater	12500.22	500-YR	45000.00	2498.53	2508.91	2508.91	2511.73	0.013536	10.38	13.47	3341.62	590.19	1.00	590.19
Whitewater	12000.26	100-YR	31400.00	2477.63	2488.55	2488.55	2490.48	0.015636	10.92	11.15	2816.05	718.54	0.99	718.54
Whitewater	12000.26	10-YR	15900.00	2477.63	2487.05	2487.05	2488.50	0.016827	9.42	9.65	1647.84	655.30	1.00	655.30
Whitewater	12000.26	2-YR	4900.00	2477.63	2486.15	2486.15	2487.02	0.019561	8.52	7.50	653.15	581.92	1.00	581.92
Whitewater	12000.26	200-YR	37000.00	2477.63	2489.01	2489.01	2491.15	0.015310	11.38	11.74	3150.51	730.06	1.00	730.06
Whitewater	12000.26	500-YR	45000.00	2477.63	2489.63	2489.63	2492.05	0.014635	12.00	12.50	3600.48	733.72	0.99	733.72
Whitewater	11499.11	100-YR	31400.00	2461.02	2470.49	2470.49	2473.16	0.014152	9.47	13.09	2398.14	454.87	1.01	454.87
Whitewater	11499.11	10-YR	15900.00	2461.02	2468.54	2468.54	2470.25	0.016430	7.52	10.50	1513.91	449.28	1.01	449.28
Whitewater	11499.11	2-YR	4900.00	2461.02	2466.48	2466.48	2467.41	0.019809	5.46	7.73	634.00	342.37	1.00	342.37
Whitewater	11499.11	200-YR	37000.00	2461.02	2471.11	2471.11	2474.07	0.013673	10.09	13.81	2679.33	456.31	1.00	456.31
Whitewater	11499.11	500-YR	45000.00	2461.02	2471.94	2471.94	2475.30	0.013143	10.92	14.72	3057.19	458.04	1.00	458.04
Whitewater	10999.43	100-YR	31400.00	2440.33	2449.40	2449.40	2451.71	0.016169	9.07	12.20	2573.75	575.17	1.02	575.17
Whitewater	10999.43	10-YR	15900.00	2440.33	2447.59	2447.59	2449.16	0.018109	7.26	10.05	1581.70	519.95	1.02	519.95
Whitewater	10999.43	2-YR	4900.00	2440.33	2445.65	2445.65	2446.52	0.020857	5.32	7.47	656.10	378.43	1.00	378.43
Whitewater	10999.43	200-YR	37000.00	2440.33	2449.93	2449.93	2452.49	0.015542	9.60	12.85	2878.86	577.19	1.01	577.19
Whitewater	10999.43	500-YR	45000.00	2440.33	2450.66	2450.66	2453.54	0.014629	10.33	13.62	3303.62	581.15	1.01	579.32
Whitewater	10484.94	100-YR	31400.00	2421.95	2429.10	2429.10	2430.67	0.017112	7.15	10.69	3185.24	1026.28	1.02	615.81
Whitewater	10484.94	10-YR	15900.00	2421.95	2427.70	2427.70	2428.89	0.018909	5.75	9.28	1878.71	839.49	1.02	517.98
Whitewater	10484.94	2-YR	4900.00	2421.95	2425.80	2425.80	2426.61	0.019409	3.85	7.48	692.84	436.82	0.99	308.38
Whitewater	10484.94	200-YR	37000.00	2421.95	2429.48	2429.48	2431.20	0.017069	7.53	11.17	3590.96	1085.69	1.02	637.98
Whitewater	10484.94	500-YR	45000.00	2421.95	2430.13	2430.13	2431.84	0.016350	8.18	11.13	4363.83	1290.11	1.00	726.51
Whitewater	9960.646	100-YR	31400.00	2401.03	2407.13	2407.13	2408.42	0.020288	6.30	9.31	3441.69	1348.09	1.04	624.82
Whitewater	9960.646	10-YR	15900.00	2401.03	2405.92	2405.92	2406.91	0.020726	5.09	8.29	1996.77	1022.84	1.04	443.97
Whitewater	9960.646	2-YR	4900.00	2401.03	2404.44	2404.44	2405.08	0.023086	3.61	6.99	781.71	630.06	1.04	263.99
Whitewater	9960.646	200-YR	37000.00	2401.03	2407.44	2407.44	2408.87	0.019835	6.60	9.81	3859.97	1374.69	1.05	638.25
Whitewater	9960.646	500-YR	45000.00	2401.03	2407.86	2407.86	2409.45	0.018836	7.03	10.31	4457.88	1411.54	1.04	658.78
Whitewater	9500	100-YR	31400.00	2380.38	2387.30	2387.30	2388.95	0.013210	9.55	8.53	3233.67	1103.90	0.89	300.73
Whitewater	9500	10-YR	15900.00	2380.38	2385.28	2385.28	2386.76	0.016597	7.53	7.94	1658.78	566.42	0.95	174.00
Whitewater	9500	2-YR	4900.00	2380.38	2382.98	2382.98	2384.03	0.021788	5.23	4.97	609.01	318.27	0.94	69.98
Whitewater	9500	200-YR	37000.00	2380.38	2387.89	2387.89	2389.48	0.012196	10.14	8.26	3959.95	1327.05	0.86	367.51
Whitewater	9500	500-YR	45000.00	2380.38	2388.48	2388.48	2390.12	0.011996	10.73	8.54	4791.10	1538.93	0.87	432.20
Whitewater	8945.336	100-YR	31400.00	2359.59	2364.49	2364.49	2366.16	0.012908	9.05	6.38	3171.07	946.29	0.84	341.43
Whitewater	8945.336	10-YR	15900.00	2359.59	2362.52	2362.52	2363.98	0.013038	7.08	5.02	1690.68	581.51	0.78	126.78
Whitewater	8945.336	2-YR	4900.00	2359.59	2359.58	2359.58	2360.72	0.021993	4.14		572.37	252.11	0.00	
Whitewater	8945.336	200-YR	37000.00	2359.59	2364.92	2364.92	2366.66	0.016562	9.48	7.47	3616.35	1092.90	0.94	394.76
Whitewater	8945.336	500-YR	45000.00	2359.59	2365.63	2365.63	2367.34	0.014219	10.19	7.61	4439.90	1270.36	0.88	466.75
Whitewater	8319.714	100-YR	31400.00	2334.85	2338.53	2338.53	2340.04	0.015397	13.33	5.39	3300.69	1102.22	0.85	337.76
Whitewater	8319.714	10-YR	15900.00	2334.85	2336.47	2336.47	2338.03	0.017093	11.27	3.38	1603.82	542.64	0.78	58.32
Whitewater	8319.714	2-YR	4900.00	2334.85	2333.56	2333.56	2334.71	0.016669	8.36		569.00	257.35	0.00	
Whitewater	8319.714	200-YR	37000.00	2334.85	2338.91	2338.91	2340.55	0.015178	13.71	5.96	3732.84	1161.16	0.87	385.58
Whitewater	8319.714	500-YR	45000.00	2334.85	2339.39	2339.39	2341.19	0.016664	14.19	6.98	4308.40	1260.35	0.93	439.24
Whitewater	7500.067	100-YR	31400.00	2298.96	2305.24	2305.24	2306.65	0.012823	10.45	8.14	3371.09	1088.19	0.87	505.91
Whitewater	7500.067	10-YR	15900.00	2298.96	2303.62	2303.62	2304.86	0.013218	8.83	6.32	1875.30	758.38	0.82	362.88
Whitewater	7500.067	2-YR	4900.00	2298.96	2300.39	2300.39	2301.88	0.016539	5.60	3.88	518.42	187.20	0.80	58.86
Whitewater	7500.067	200-YR	37000.00	2298.96	2305.58	2305.58	2307.14	0.013588	10.79	8.99	3750.02	1134.58	0.91	513.68
Whitewater	7500.067	500-YR	45000.00	2298.96	2305.96	2305.96	2307.77	0.017051	11.17	10.82	4188.00	1195.44	1.04	517.13
Whitewater	6956.87	100-YR	31400.00	2274.96	2281.70	2281.70	2283.31	0.016148	9.14	9.55	3112.75	959.58	0.95	615.20
Whitewater	6956.87	10-YR	15900.00	2274.96	2280.42	2280.42	2281.52	0.013450	7.86	6.76	1986.53	795.85	0.81	550.45
Whitewater	6956.87	2-YR	4900.00	2274.96	2278.04	2278.04	2279.35	0.017886	5.48	5.61	575.87	299.42	0.96	179.10
Whitewater	6956.87	200-YR	37000.00	2274.96	2282.09	2282.09	2283.84	0.017153	9.53	10.52	3489.98	1006.00	1.00	626.04
Whitewater	6956.87	500-YR	45000.00	2274.96	2282.61	2282.61	2284.55	0.017373	10.05	11.45	4038.01	1097.53	1.02	641.21
Whitewater	6560.167	100-YR	31400.00	2256.69	2265.04	2265.04	2266.69	0.014406	8.68	10.86	3108.36	944.85	0.97	575.82
Whitewater	6560.167	10-YR	15900.00	2256.69	2263.29	2263.29	2264.61	0.017046	6.92	9.26	1722.09	665.25	1.01	495.68
Whitewater	6560.167	2-YR	4900.00	2256.69	2261.21	2261.21	2262.09	0.018104	4.85	7.07	657.09	358.97	0.95	276.99
Whitewater	6560.167	200-YR	37000.00	2256.69	2265.44	2265.44	2267.25	0.015186	9.08	11.42	3496.47	1028.99	1.01	616.64
Whitewater	6560.167	500-YR	45000.00	2256.69	2265.96	2265.96	2268.02	0.015384	9.60	12.33	4048.29	1080.88	1.03	623.01
Whitewater	5917.389	100-YR	31400.00	2231.28	2241.12	2241.12	2243.38	0.012473	9.83	12.37	2711.87	630.60	0.95	447.67
Whitewater	5917.389	10-YR	15900.00	2231.28	2238.86	2238.86	2240.69	0.015410	7.58	10.94	1482.97	421.00	0.99	379.14
Whitewater	5917.389	2-YR	4900.00	2231.28	2236.35	2236.35	2237.44	0.018846	5.07	8.38	584.48	269.82	1.00	269.82
Whitewater	5917.389	200-YR	37000.00	2231.28	2241.61	2241.61	2244.15	0.012658	10.33	13.16	3029.55	653.17	0.97	450.30
Whitewater	5917.389	500-YR	45000.00	2231.28	2242.48	2242.48	2245.15	0.011368	11.20	13.58	3616.94	685.49	0.93	454.81
Whitewater	5651.635	100-YR	31400.00	2221.61	2230.23	2230.23	2232.63	0.015084	8.62	12.62	2556.71	541.41	1.00	474.17
Whitewater	5651.635	10-YR	15900.00	2221.61	2228.39	2228.39	2229.98	0.017218	6.78	10.22	1590.60	511.06	1.00	459.82
Whitewater	5651.635	2-YR	4900.00	2221.61	2226.52	2226.52	2227.33	0.020699	4.91	7.25	685.26	427.72	0.99	398.02
Whitewater	5651.635	200-YR	37000.00	2221.61	2230.81	2230.81	2233.45	0.014574	9.20	13.26	2871.12	550.17	1.00	478.10
Whitewater	5651.635	500-YR	45000.00	2221.61	2231.56	2231.56	2234.54	0.014072	9.95	14.09	3291.07	560.58	1.00	482.69
Whitewater	5381.783	100-YR	31400.00	2213.46	2224.78	2224.78	2228.14	0.010779	11.32	15.38	2244.38	347.92	0.92	206.00
Whitewater	5381.783	10-YR	15900.00	2213.46	2221.33	2221.33	2224.00	0.013848	7.87	13.42	1241.22	236.13	0.98	190.28
Whitewater	5381.783	2-YR	4900.00	2213.46	2218.18	2218.18	2219.50	0.016963	4.72	9.33	539.63	206.49	0.98	181.19
Whitewater	5381.783	200-YR	37000.00	2213.46	2225.42	2225.42	2229.30	0.011634	11.96	16.62	2473.47	368.81	0.96	207.94
Whitewater	5381.783	500-YR	45000.00	2213.46	2227.08	2227.08	2230.81	0.009550	13.62	16.50	3125.80	401.32	0.89	212.65
Whitewater	5170.287	100-YR	31400.00	2206.27	2216.74	2216.74	2220.03	0.011946	10.47	14.68	2172.17	337.88	0.97	290.33
Whitewater	5170.287	10-YR	15900.00	2206.27	2214.00	2214.00	2216.29	0.013863	7.73	12.15	1318.23	291.36	0.98	272.69

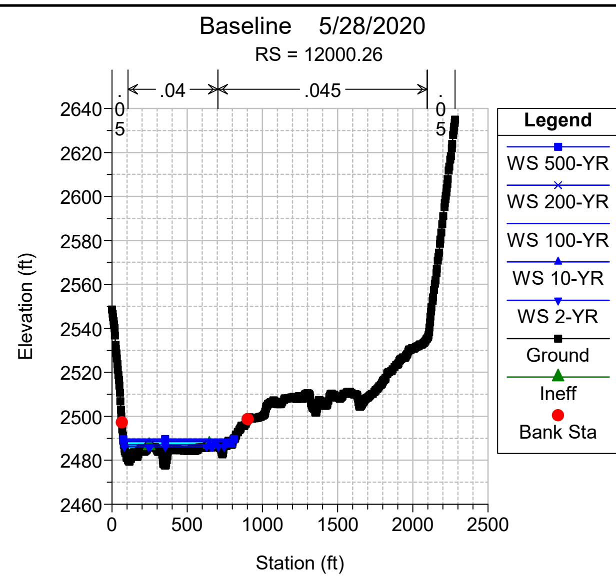
HEC-RAS Plan: Baseline River: Whitewater Reach: Whitewater (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Max Chl Dpth	Vel Chnl	Flow Area	Top Width	Froude # Chl	Top W Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)
Whitewater	5170.287	2-YR	4900.00	2206.27	2211.24	2211.24	2212.37	0.018296	4.97	8.56	572.48	252.58	1.00	252.58
Whitewater	5170.287	200-YR	37000.00	2206.27	2217.71	2217.71	2221.14	0.010887	11.44	15.05	2525.42	393.71	0.94	295.69
Whitewater	5170.287	500-YR	45000.00	2206.27	2219.60	2219.60	2222.46	0.007522	13.33	14.05	3517.05	672.72	0.80	306.24
Whitewater	4971.125	100-YR	31400.00	2198.91	2210.49	2210.49	2213.22	0.010455	11.58	13.79	2394.93	433.85	0.91	255.72
Whitewater	4971.125	10-YR	15900.00	2198.91	2207.77	2207.77	2209.88	0.011951	8.85	11.97	1375.10	325.98	0.93	225.78
Whitewater	4971.125	2-YR	4900.00	2198.91	2204.50	2204.50	2205.92	0.015100	5.59	9.64	515.93	180.92	0.97	160.61
Whitewater	4971.125	200-YR	37000.00	2198.91	2211.39	2211.39	2214.13	0.009612	12.48	13.92	2828.77	543.70	0.88	266.57
Whitewater	4971.125	500-YR	45000.00	2198.91	2212.73	2212.73	2215.10	0.007529	13.82	13.20	3736.33	756.19	0.79	282.09
Whitewater	4716.682	100-YR	31400.00	2189.96	2199.67	2199.67	2202.03	0.008723	12.06	9.86	2680.65	531.98	0.79	321.80
Whitewater	4716.682	10-YR	15900.00	2189.96	2197.19	2197.19	2199.06	0.008919	9.59	8.63	1530.86	387.59	0.77	224.30
Whitewater	4716.682	2-YR	4900.00	2189.96	2194.28	2194.28	2195.45	0.006919	6.68	6.34	615.63	226.50	0.65	121.54
Whitewater	4716.682	200-YR	37000.00	2189.96	2200.26	2200.26	2202.84	0.008787	12.66	10.55	3001.27	546.95	0.80	327.68
Whitewater	4716.682	500-YR	45000.00	2189.96	2201.29	2201.29	2203.75	0.009273	13.69	11.98	3592.46	637.75	0.84	336.12
Whitewater	4500	100-YR	31400.00	2181.96	2191.71	2191.71	2194.31	0.010570	9.75	10.35	2553.55	598.13	0.86	325.96
Whitewater	4500	10-YR	15900.00	2181.96	2189.71	2189.71	2191.45	0.011359	7.75	10.02	1510.97	461.80	0.87	229.51
Whitewater	4500	2-YR	4900.00	2181.96	2187.14	2187.14	2188.33	0.013423	5.18	8.02	569.17	236.06	0.88	162.75
Whitewater	4500	200-YR	37000.00	2181.96	2192.75	2192.75	2195.11	0.007722	10.79	9.25	3229.26	675.82	0.74	383.35
Whitewater	4500	500-YR	45000.00	2181.96	2193.76	2193.76	2195.93	0.006849	11.80	9.73	3961.98	792.93	0.72	391.52
Whitewater	4238.041	100-YR	31400.00	2174.72	2182.42	2182.42	2184.39	0.012819	7.70	10.70	2802.90	710.48	0.92	386.11
Whitewater	4238.041	10-YR	15900.00	2174.72	2180.49	2180.49	2182.10	0.015115	5.77	9.36	1578.54	521.36	0.95	305.68
Whitewater	4238.041	2-YR	4900.00	2174.72	2178.32	2178.32	2179.22	0.017654	3.60	7.73	643.56	358.25	0.97	198.71
Whitewater	4238.041	200-YR	37000.00	2174.72	2182.93	2182.93	2185.06	0.012445	8.21	11.27	3168.20	741.51	0.92	391.44
Whitewater	4238.041	500-YR	45000.00	2174.72	2183.66	2183.66	2185.90	0.011987	8.94	12.02	3745.55	846.45	0.92	399.39
Whitewater	3993.909	100-YR	31400.00	2167.53	2175.09	2175.09	2176.87	0.012492	7.58	10.47	2935.23	814.64	0.92	400.27
Whitewater	3993.909	10-YR	15900.00	2167.53	2173.53	2173.53	2174.80	0.014502	6.03	8.91	1764.13	709.25	0.93	364.16
Whitewater	3993.909	2-YR	4900.00	2167.53	2171.41	2171.41	2172.53	0.015712	3.91	6.51	613.56	318.59	0.89	205.66
Whitewater	3993.909	200-YR	37000.00	2167.53	2175.57	2175.57	2177.47	0.012347	8.07	11.00	3351.23	887.67	0.92	412.84
Whitewater	3993.909	500-YR	45000.00	2167.53	2176.12	2176.12	2178.25	0.012161	8.62	11.55	3850.82	925.34	0.93	427.50
Whitewater	3740.673	100-YR	31400.00	2159.81	2165.98	2165.98	2167.46	0.014065	6.17	9.53	3222.17	1109.95	0.93	618.56
Whitewater	3740.673	10-YR	15900.00	2159.81	2164.84	2164.84	2165.83	0.016067	5.03	7.94	1997.23	1025.15	0.94	594.13
Whitewater	3740.673	2-YR	4900.00	2159.81	2163.50	2163.50	2164.10	0.019188	3.69	6.14	792.13	678.37	0.95	456.39
Whitewater	3740.673	200-YR	37000.00	2159.81	2166.33	2166.33	2167.97	0.013573	6.51	9.94	3605.45	1119.89	0.93	623.32
Whitewater	3740.673	500-YR	45000.00	2159.81	2166.79	2166.79	2168.65	0.012958	6.98	10.43	4132.27	1135.15	0.92	632.14
Whitewater	3500	100-YR	31400.00	2150.35	2156.92	2156.92	2158.44	0.015266	6.57	9.20	3209.46	1069.08	0.93	722.90
Whitewater	3500	10-YR	15900.00	2150.35	2155.76	2155.76	2156.75	0.017289	5.41	7.59	1999.77	999.62	0.93	664.99
Whitewater	3500	2-YR	4900.00	2150.35	2154.25	2154.25	2154.87	0.020756	3.90	6.49	774.12	622.54	0.95	407.27
Whitewater	3500	200-YR	37000.00	2150.35	2157.31	2157.31	2158.97	0.014369	6.96	9.56	3629.77	1087.53	0.92	737.16
Whitewater	3500	500-YR	45000.00	2150.35	2157.88	2157.88	2159.66	0.012718	7.53	9.96	4252.71	1120.61	0.88	738.57
Whitewater	3226.86	100-YR	31400.00	2140.60	2146.91	2146.91	2148.40	0.015781	6.31	9.70	3214.75	1109.41	0.97	703.82
Whitewater	3226.86	10-YR	15900.00	2140.60	2145.78	2145.78	2146.77	0.017876	5.18	7.92	1995.24	1015.43	0.98	681.14
Whitewater	3226.86	2-YR	4900.00	2140.60	2144.22	2144.22	2144.89	0.022667	3.62	6.21	749.13	575.99	0.99	411.89
Whitewater	3226.86	200-YR	37000.00	2140.60	2147.29	2147.29	2148.90	0.014946	6.69	10.06	3633.67	1139.45	0.96	715.58
Whitewater	3226.86	500-YR	45000.00	2140.60	2147.75	2147.75	2149.56	0.014196	7.15	10.64	4166.70	1158.48	0.95	716.69
Whitewater	3000	100-YR	31400.00	2132.74	2139.21	2139.21	2140.67	0.015498	6.47	9.79	3254.99	1098.28	0.99	718.16
Whitewater	3000	10-YR	15900.00	2132.74	2138.10	2138.10	2139.05	0.016265	5.36	7.84	2061.33	1037.05	0.98	694.73
Whitewater	3000	2-YR	4900.00	2132.74	2136.52	2136.52	2137.19	0.017335	3.78	6.62	773.09	572.90	0.98	373.03
Whitewater	3000	200-YR	37000.00	2132.74	2139.58	2139.58	2141.17	0.014826	6.84	10.27	3664.67	1128.34	0.98	718.16
Whitewater	3000	500-YR	45000.00	2132.74	2140.03	2140.03	2141.84	0.014427	7.29	10.96	4181.51	1133.48	0.98	718.16
Whitewater	2734.526	100-YR	31400.00	2121.71	2129.80	2129.80	2131.34	0.013366	8.09	10.16	3222.79	981.86	0.93	776.35
Whitewater	2734.526	10-YR	15900.00	2121.71	2128.35	2128.35	2129.49	0.016294	6.64	8.64	1882.76	843.87	0.98	740.94
Whitewater	2734.526	2-YR	4900.00	2121.71	2126.74	2126.74	2127.40	0.021178	5.03	6.52	752.95	566.11	0.98	550.12
Whitewater	2734.526	200-YR	37000.00	2121.71	2130.14	2130.14	2131.89	0.013645	8.43	10.84	3556.05	983.62	0.95	776.82
Whitewater	2734.526	500-YR	45000.00	2121.71	2130.64	2130.64	2132.62	0.013350	8.93	11.55	4051.38	986.01	0.95	777.37
Whitewater	2500	100-YR	31400.00	2112.95	2121.24	2121.24	2123.21	0.014613	8.29	11.42	2807.46	716.21	0.97	603.09
Whitewater	2500	10-YR	15900.00	2112.95	2119.67	2119.67	2121.01	0.016885	6.72	9.34	1723.64	662.59	0.97	586.00
Whitewater	2500	2-YR	4900.00	2112.95	2117.94	2117.94	2118.69	0.022858	4.99	6.94	706.39	483.05	1.01	483.05
Whitewater	2500	200-YR	37000.00	2112.95	2121.66	2121.66	2123.89	0.014725	8.71	12.15	3108.89	725.80	0.99	605.33
Whitewater	2500	500-YR	45000.00	2112.95	2122.37	2122.37	2124.78	0.013344	9.42	12.65	3643.02	751.80	0.96	609.47
Whitewater	2181.438	100-YR	31400.00	2101.57	2111.29	2111.29	2113.35	0.002588	9.72	11.51	2728.70	676.81	1.01	676.81
Whitewater	2181.438	10-YR	15900.00	2101.57	2109.38	2109.38	2110.93	0.002855	7.81	9.99	1592.25	515.38	1.00	515.38
Whitewater	2181.438	2-YR	4900.00	2101.57	2107.27	2107.27	2108.19	0.003750	5.70	7.68	637.73	364.85	1.02	364.85
Whitewater	2181.438	200-YR	37000.00	2101.57	2112.07	2111.78	2114.08	0.002023	10.50	11.35	3259.84	681.55	0.91	681.55
Whitewater	2181.438	500-YR	45000.00	2101.57	2113.05	2112.39	2115.09	0.001651	11.48	11.46	3926.03	689.49	0.85	689.49
Whitewater	2150		Culvert											
Whitewater	2102.988	100-YR	31400.00	2091.39	2103.45	2103.45	2105.77	0.004478	12.06	7.62	2940.05	662.87	0.62	343.84
Whitewater	2102.988	10-YR	15900.00	2091.39	2101.13	2101.13	2102.95	0.004204	9.74	6.87	1693.55	441.51	0.54	202.24
Whitewater	2102.988	2-YR	4900.00	2091.39	2097.07	2097.07	2098.60	0.009489	5.68	9.79	493.87	165.08	0.81	89.01
Whitewater	2102.988	200-YR	37000.00	2091.39	2104.03	2104.03	2106.57	0.004687	12.64	7.78	3338.54	697.23	0.62	371.15
Whitewater	2102.988	500-YR	45000.00	2091.39	2104.96	2104.96	2107.54	0.004408	13.57	7.88	4021.17	750.42	0.60	414.52
Whitewater	1862.584	100-YR	31400.00	2082.47	2093.87	2093.87	2095.67	0.005778	11.40	8.03	3254.84	833.39	0.70	583.94
Whitewater	1862.584	10-YR	15900.00	2082.47	2091.99	2091.99	2093.45	0.004930	9.52	6.76	1906.44	581.54	0.64	411.31
Whitewater	1862.584	2-YR	4900.00	2082.47	2089.18	2089.18	2090.27	0.005029	6.71	5.31	735.78	291.91	0.55	203.37
Whitewater	1862.584	200-YR	37000.00	2082.47	2094.26	2094.26	2096.28	0.006331	11.79	8.68	3580.29	853.67	0.73	596.33
Whitewater	1862.584	500-YR	45000.00	2082.47	2094.78	2094.78	2097.10	0.006858	12.31	9.46	4027.81	855.59	0.76	597.39
Whitewater	1482.694	100-YR	31400.00	2072.52	2082.70	2082.70	2084.61	0.012697	10.18	11.20	2874.99	758.91	0.95	636.86
Whitewater	1482.694	10-YR	15900.00	2072.52	2080.70	2080.70	2082.30	0.016048	8.18	10.15	1566.40	510.03	1.02	507.42

HEC-RAS Plan: Baseline River: Whitewater Reach: Whitewater (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Max Chl Dpth	Vel Chnl	Flow Area	Top Width	Froude # Chl	Top W Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)
Whitewater	1482.694	2-YR	4900.00	2072.52	2078.59	2078.59	2079.55	0.013905	6.07	7.84	625.04	332.33	1.01	332.33
Whitewater	1482.694	200-YR	37000.00	2072.52	2083.26	2083.26	2085.25	0.011959	10.73	11.47	3321.55	831.57	0.93	660.07
Whitewater	1482.694	500-YR	45000.00	2072.52	2083.98	2083.98	2086.04	0.011076	11.46	11.73	3981.30	997.69	0.91	694.33
Whitewater	942.056	100-YR	31400.00	2056.93	2063.94	2063.94	2065.77	0.014694	7.25	10.57	2910.71	799.97	1.00	741.46
Whitewater	942.056	10-YR	15900.00	2056.93	2062.29	2062.29	2063.63	0.015918	5.60	8.98	1726.49	643.57	0.99	587.32
Whitewater	942.056	2-YR	4900.00	2056.93	2060.13	2060.13	2061.00	0.021401	3.43	7.34	653.51	372.79	1.00	320.14
Whitewater	942.056	200-YR	37000.00	2056.93	2064.44	2064.44	2066.38	0.014122	7.75	10.92	3327.14	862.62	1.00	803.44
Whitewater	942.056	500-YR	45000.00	2056.93	2065.07	2065.07	2067.16	0.013623	8.38	11.35	3896.78	941.14	1.00	881.11
Whitewater	500	100-YR	31400.00	2039.25	2048.11	2048.11	2049.82	0.016044	8.86	10.50	2991.22	889.69	1.01	888.33
Whitewater	500	10-YR	15900.00	2039.25	2046.65	2046.65	2047.89	0.016600	7.39	8.94	1778.28	727.43	1.01	727.43
Whitewater	500	2-YR	4900.00	2039.25	2044.82	2044.82	2045.59	0.019188	5.57	7.07	693.50	469.65	1.03	469.65
Whitewater	500	200-YR	37000.00	2039.25	2048.55	2048.55	2050.39	0.015797	9.30	10.89	3397.31	936.32	1.01	934.07
Whitewater	500	500-YR	45000.00	2039.25	2049.14	2049.14	2051.14	0.015317	9.89	11.35	3967.20	1004.97	1.01	1001.17


Baseline 5/28/2020
RS = 12500.22
.04
.045
Elevation (ft)
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta


Baseline 5/28/2020
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Elevation (ft)
Station (ft)
Legend
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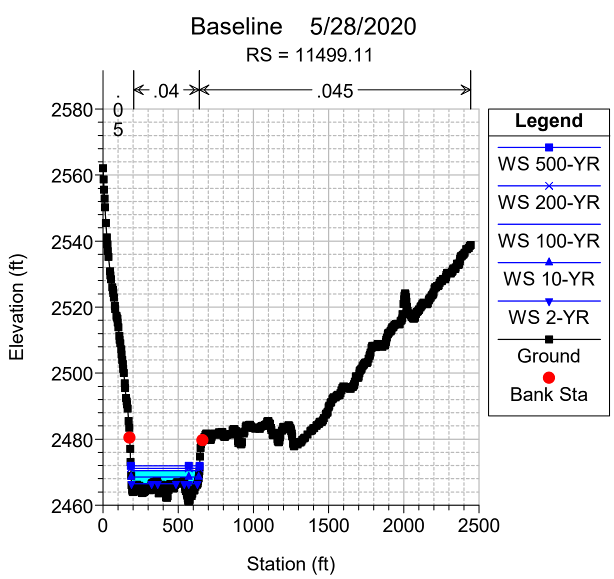
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta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Elevation (ft)
Station (ft)
Legend
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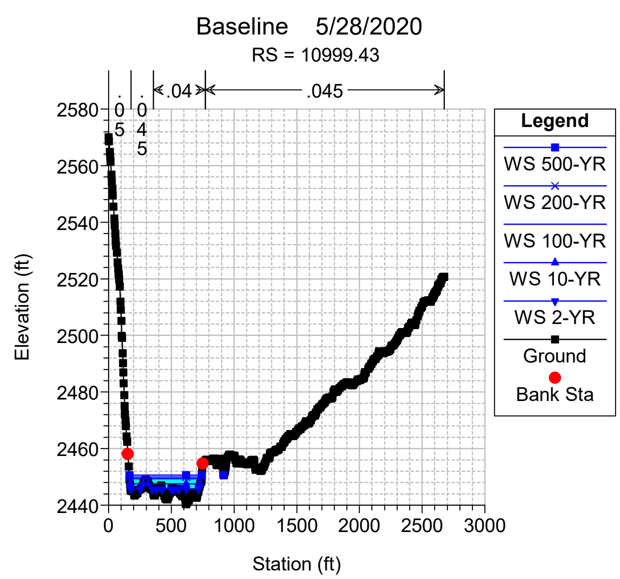
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta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Station (ft)
Legend
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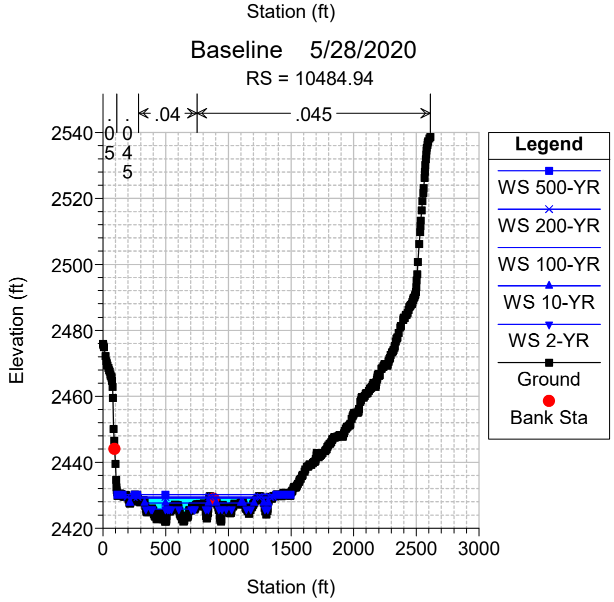
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta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Elevation (ft)
Station (ft)
Legend
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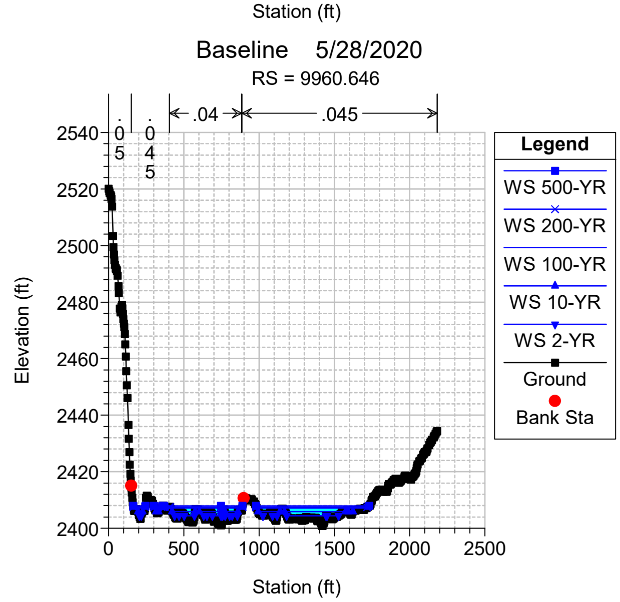
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta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Elevation (ft)
Station (ft)
Legend
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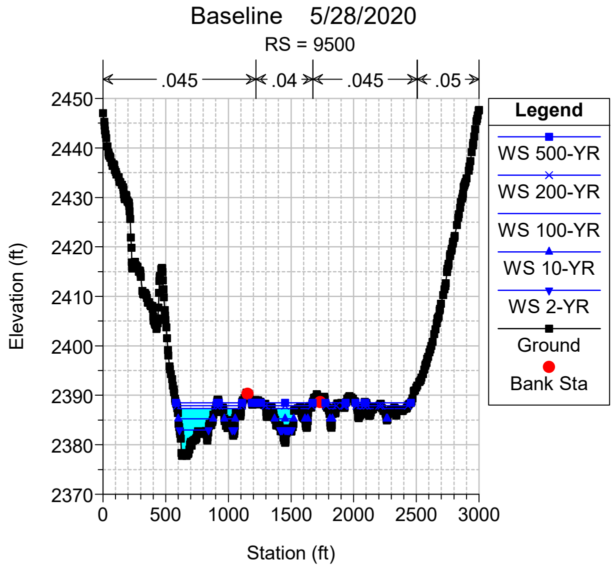
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta


Baseline 5/28/2020
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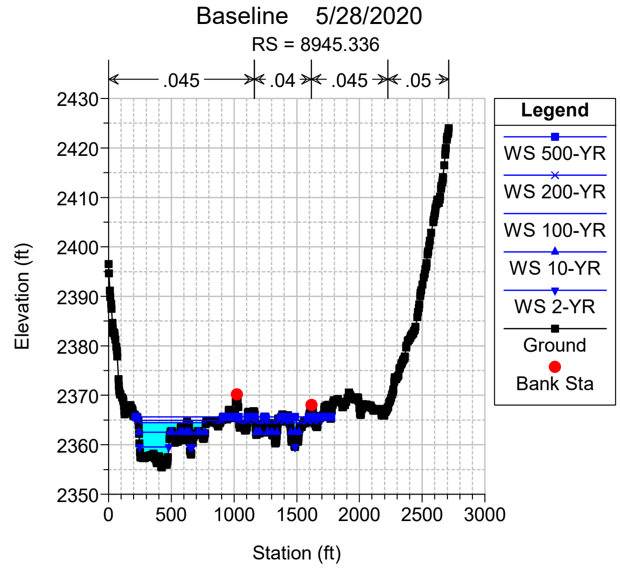
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)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.04
.045
.05
Legend
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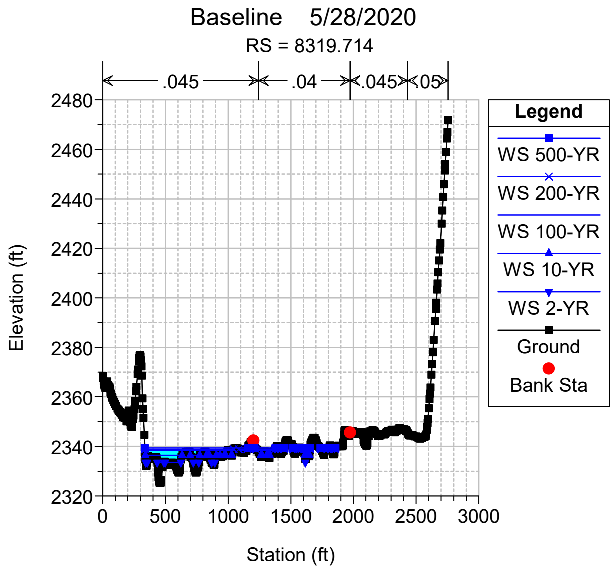
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
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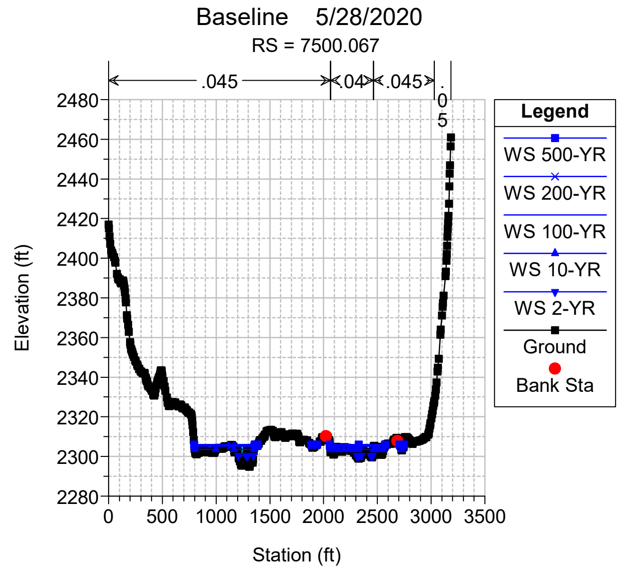
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)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Legend
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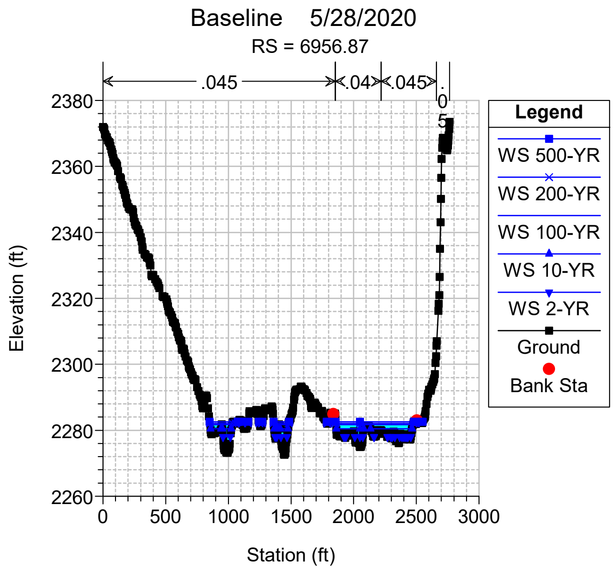
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
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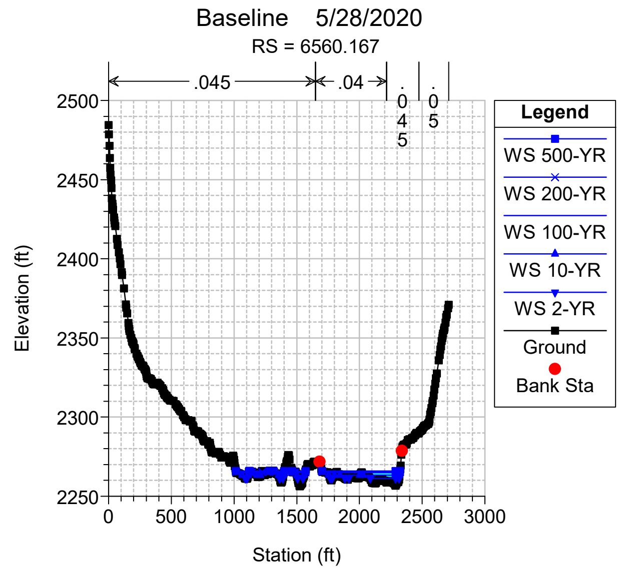
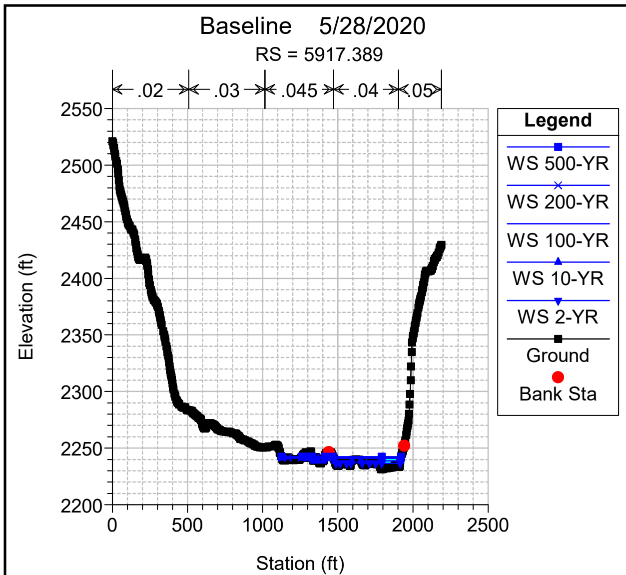
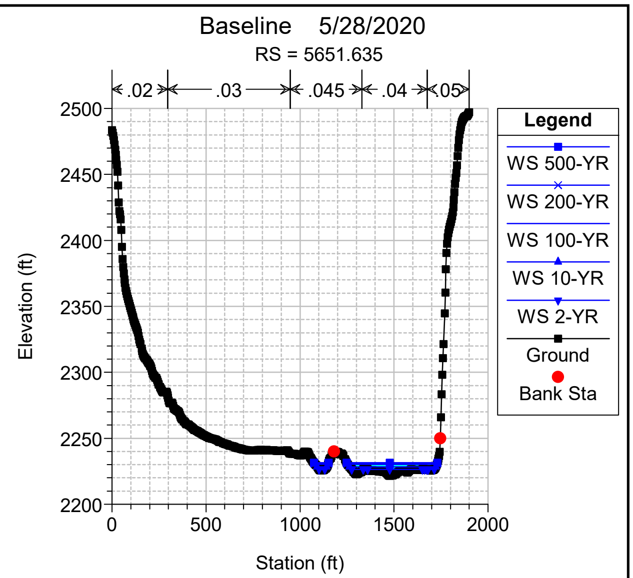
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
RS = 6560.167
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
RS = 5917.389
.02
.03
.045
.04
.05
Elevation (ft)
2550
2500
2450
2400
2350
2300
2250
2200
0
500
1000
1500
2000
2500
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta


Baseline 5/28/2020
RS = 5651.635
.02
.03
.045
.04
.05
Elevation (ft)
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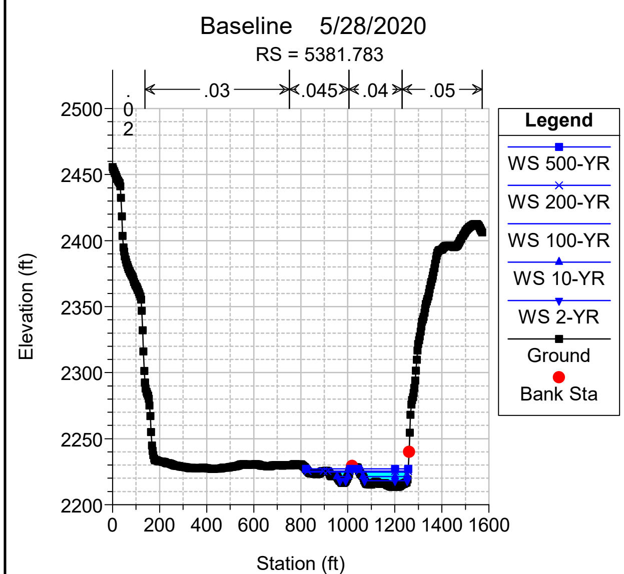
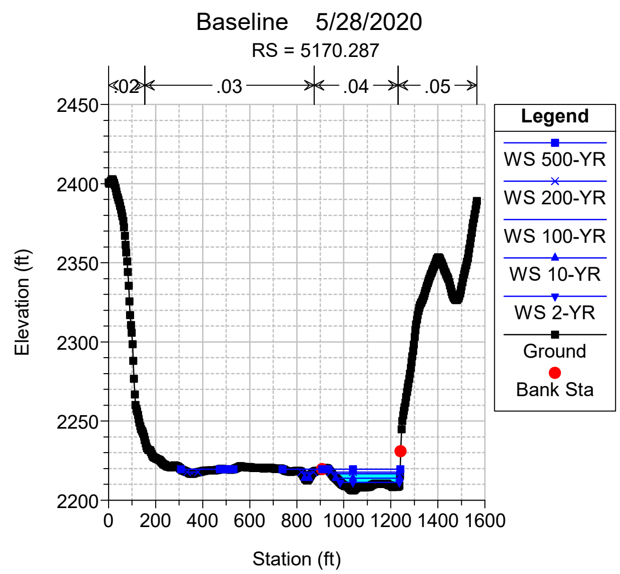
2450
2400
2350
2300
2250
2200
0
500
1000
1500
2000
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta


Baseline 5/28/2020
RS = 5381.783
.
0
2
.03
.045
.04
.05
Elevation (ft)
2500
2450
2400
2350
2300
2250
2200
0
200
400
600
800
1000
1200
1400
1600
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta


Baseline 5/28/2020
RS = 5170.287
.02
.03
.04
.05
Elevation (ft)
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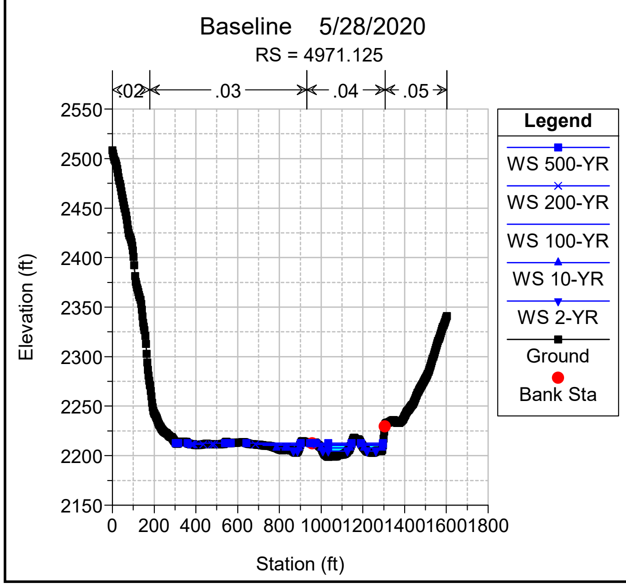
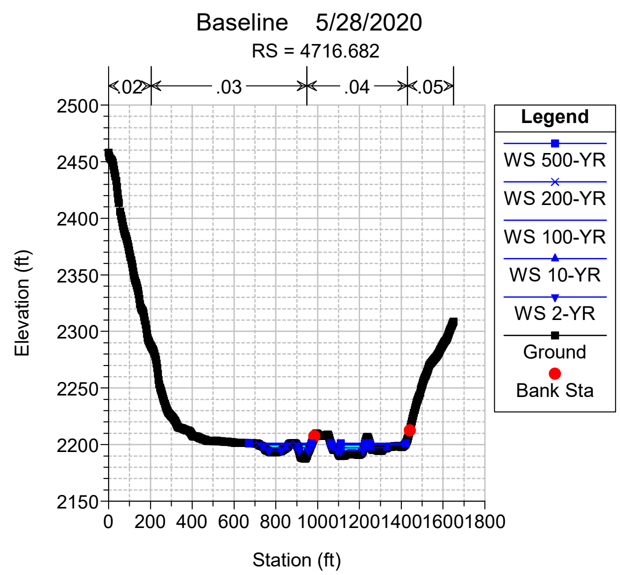
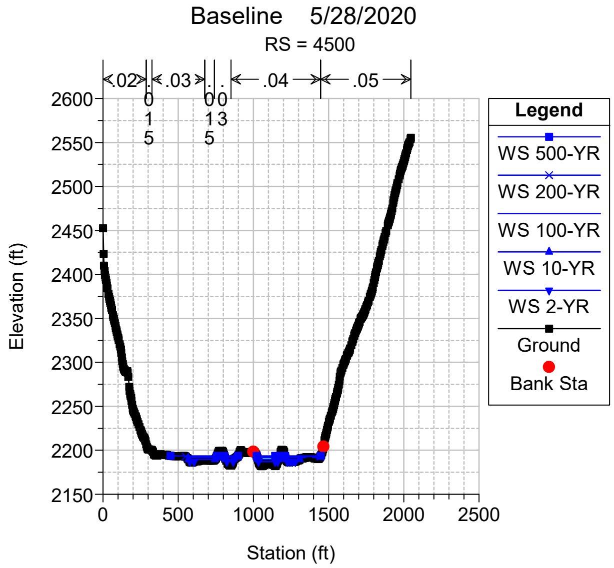
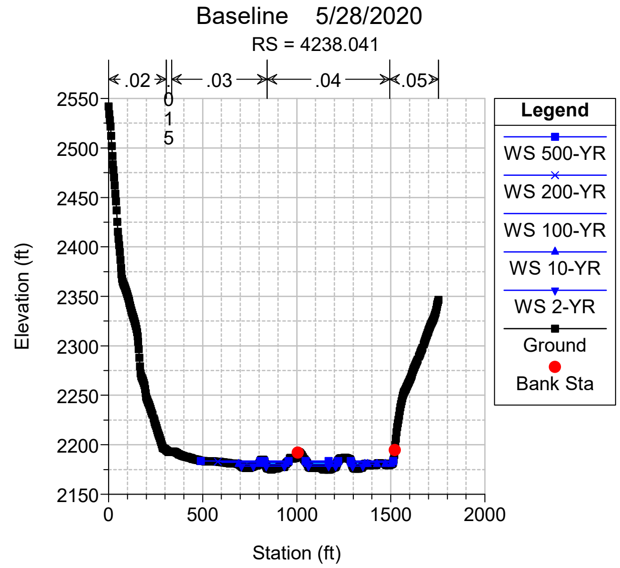
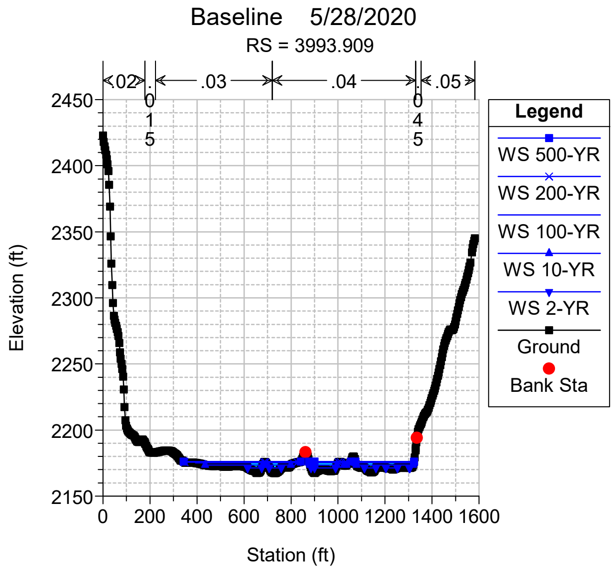
2400
2350
2300
2250
2200
0
200
400
600
800
1000
1200
1400
1600
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta

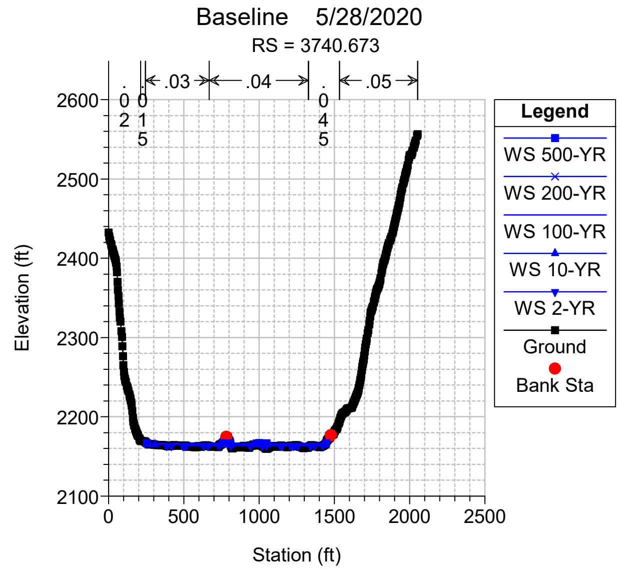

Baseline 5/28/2020
RS = 4971.125
.02
.03
.04
.05
Elevation (ft)
2550
2500
2450
2400
2350
2300
2250
2200
2150
0
200
400
600
800
1000
1200
1400
1600
1800
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta

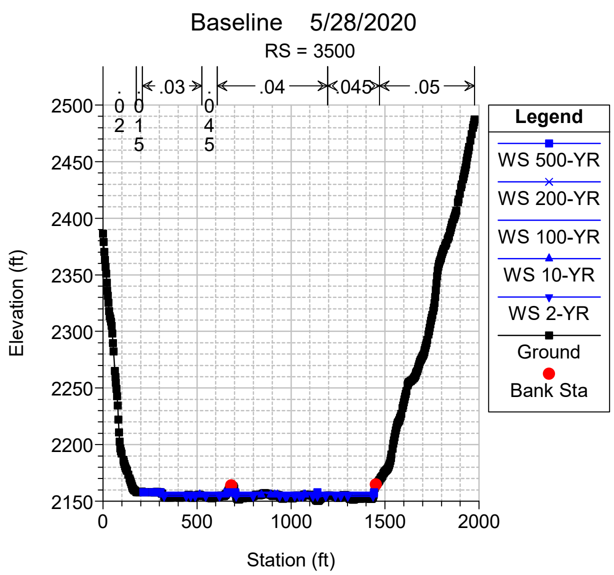

Baseline 5/28/2020
RS = 4716.682
.02
.03
.04
.05
Elevation (ft)
2500
2450
2400
2350
2300
2250
2200
2150
0
200
400
600
800
1000
1200
1400
1600
1800
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta

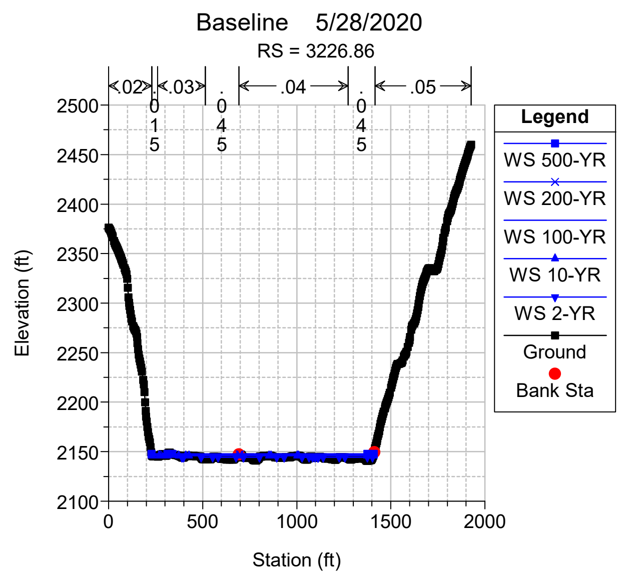

Baseline 5/28/2020
RS = 4500
.02
.03
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

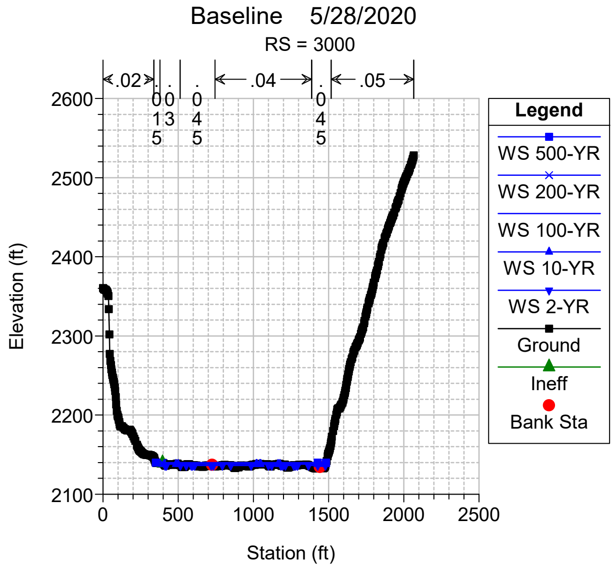

Baseline 5/28/2020
RS = 4238.041
.02
.03
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

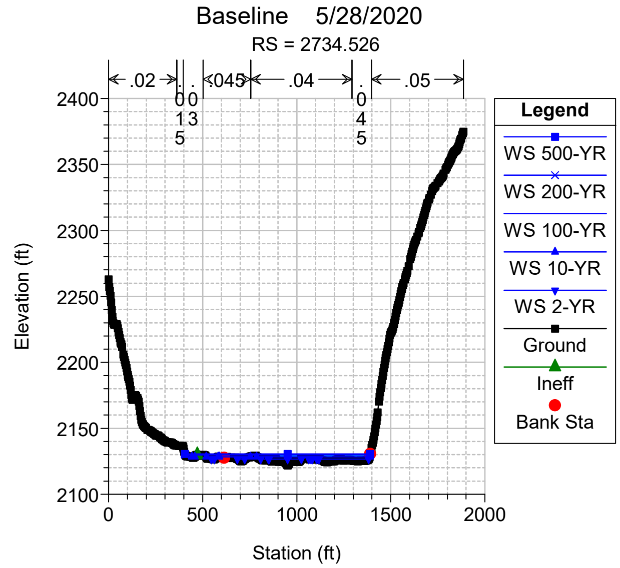

Baseline 5/28/2020
RS = 3993.909
.02
.03
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

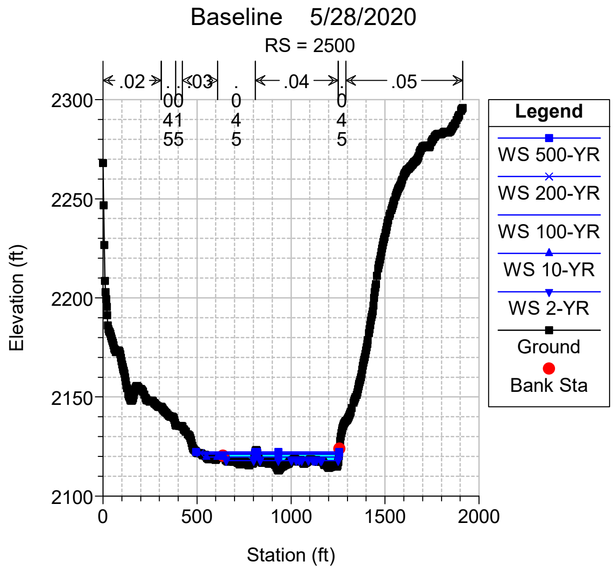

Baseline 5/28/2020
RS = 3740.673
.03
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

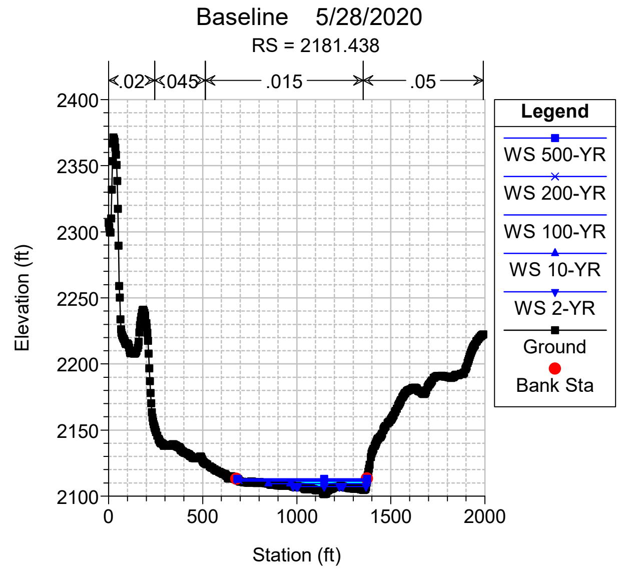

Baseline 5/28/2020
RS = 3500
.03
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

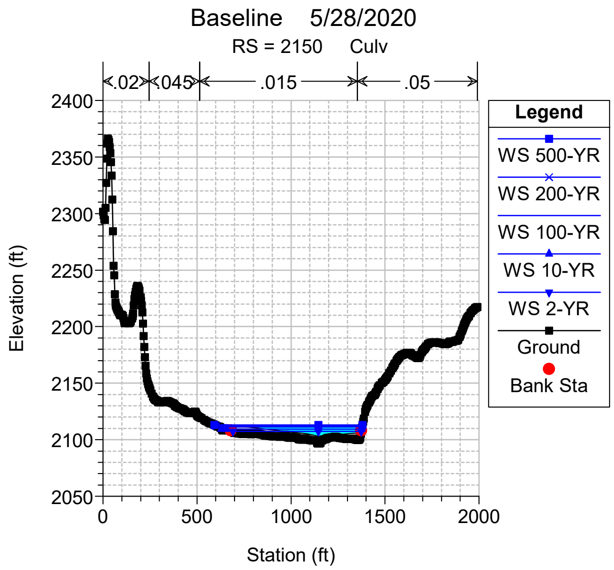

Baseline 5/28/2020
RS = 3226.86
.02
.03
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

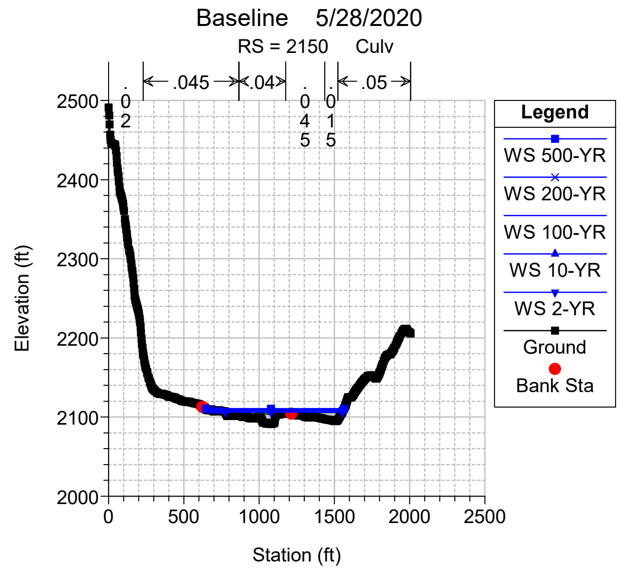

Baseline 5/28/2020
RS = 3000
.02
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

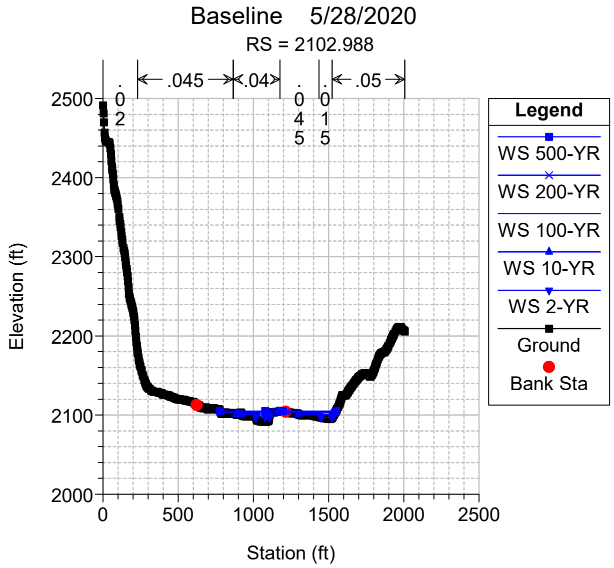

Baseline 5/28/2020
RS = 2734.526
.02
.045
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

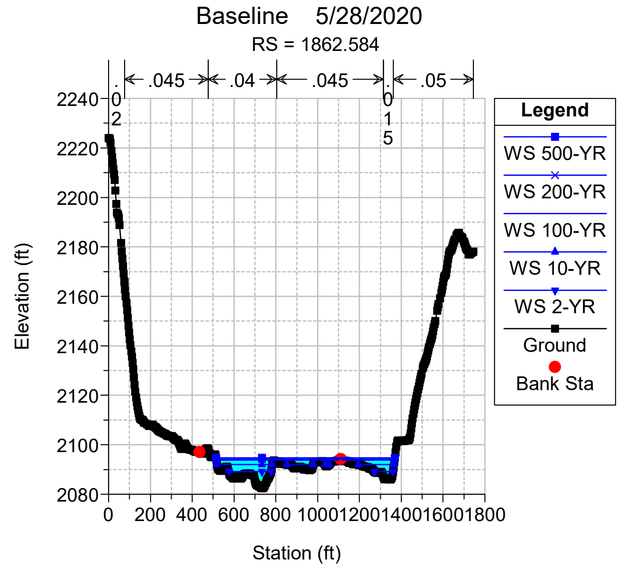

Baseline 5/28/2020
RS = 2500
.02
.03
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

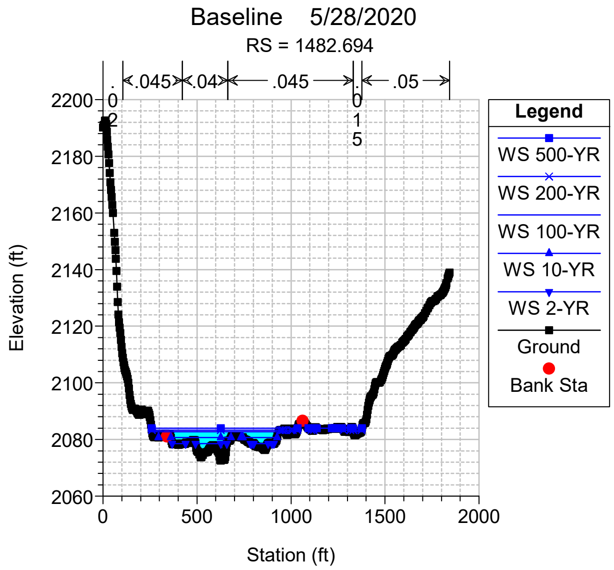

Baseline 5/28/2020
RS = 2181.438
.02
.045
.015
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

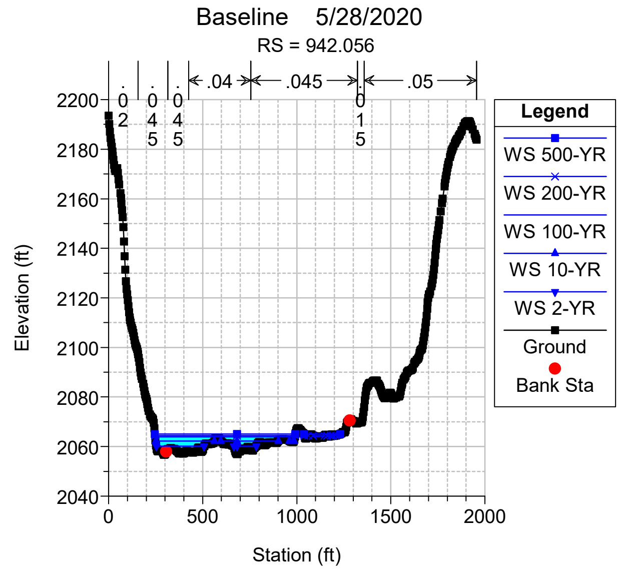

Baseline 5/28/2020
RS = 2150 Culv
.02
.045
.015
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

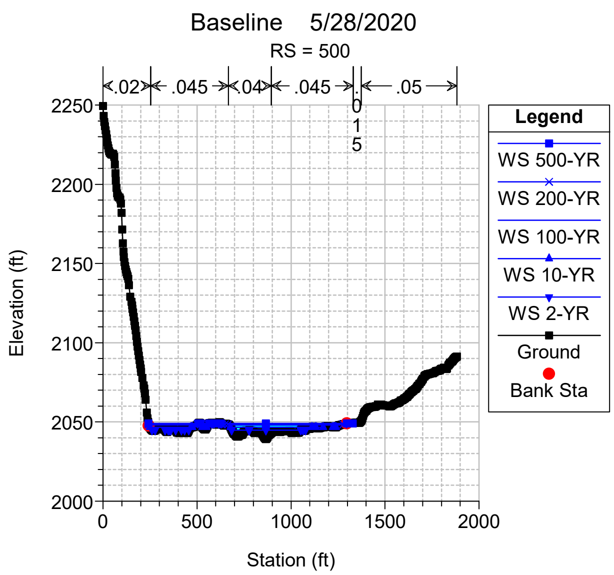

Baseline 5/28/2020
RS = 2150 Culv
.045
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
RS = 2102.988
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
RS = 1862.584
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
RS = 1482.694
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
RS = 942.056
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Baseline 5/28/2020
RS = 500
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

A.2 – Project Condition

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HEC-RAS Plan: ProposedAlt4Revised River: Whitewater Reach: Whitewater

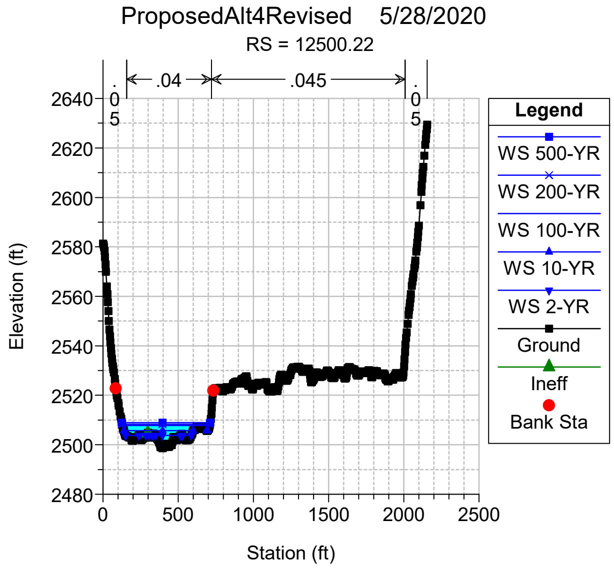
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Max Chl Dpth	Vel Chnl	Flow Area	Top Width	Froude # Chl	Top W Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)
Whitewater	12500.22	100-YR	31400.00	2498.57	2507.77	2507.77	2509.99	0.014381	9.20	11.96	2625.10	581.70	0.99	581.70
Whitewater	12500.22	10-YR	15900.00	2498.57	2505.74	2505.74	2507.38	0.015844	7.17	10.26	1549.15	466.16	0.99	466.16
Whitewater	12500.22	2-YR	4900.00	2498.57	2503.82	2503.82	2504.97	0.017775	5.25	8.60	569.91	381.00	1.00	381.00
Whitewater	12500.22	200-YR	37000.00	2498.57	2508.27	2508.27	2510.77	0.014166	9.70	12.68	2917.00	584.63	1.00	584.63
Whitewater	12500.22	500-YR	45000.00	2498.57	2508.99	2508.99	2511.81	0.013475	10.42	13.47	3341.06	588.58	1.00	588.58
Whitewater	12000.26	100-YR	31400.00	2477.64	2488.61	2488.61	2490.54	0.015617	10.97	11.15	2816.75	718.66	0.99	718.66
Whitewater	12000.26	10-YR	15900.00	2477.64	2487.10	2487.10	2488.55	0.016945	9.46	9.67	1643.54	651.30	1.00	651.30
Whitewater	12000.26	2-YR	4900.00	2477.64	2486.21	2486.21	2487.07	0.019298	8.56	7.47	655.85	583.15	0.99	583.15
Whitewater	12000.26	200-YR	37000.00	2477.64	2489.08	2489.08	2491.21	0.015209	11.44	11.72	3156.81	730.39	0.99	730.39
Whitewater	12000.26	500-YR	45000.00	2477.64	2489.61	2489.61	2492.11	0.015339	11.97	12.68	3548.88	733.53	1.02	733.53
Whitewater	11499.11	100-YR	31400.00	2461.11	2470.54	2470.54	2473.21	0.014128	9.43	13.10	2397.80	454.65	1.01	454.65
Whitewater	11499.11	10-YR	15900.00	2461.11	2468.59	2468.59	2470.30	0.016401	7.48	10.51	1513.49	448.99	1.01	448.99
Whitewater	11499.11	2-YR	4900.00	2461.11	2466.54	2466.54	2467.46	0.019857	5.42	7.72	634.85	344.83	1.00	344.83
Whitewater	11499.11	200-YR	37000.00	2461.11	2471.16	2471.16	2474.12	0.013652	10.05	13.81	2678.98	456.13	1.00	456.13
Whitewater	11499.11	500-YR	45000.00	2461.11	2471.99	2471.99	2475.35	0.013122	10.88	14.72	3056.50	457.74	1.00	457.74
Whitewater	10999.43	100-YR	31400.00	2440.40	2449.46	2449.46	2451.75	0.015900	9.06	12.14	2585.62	575.16	1.01	575.16
Whitewater	10999.43	10-YR	15900.00	2440.40	2447.64	2447.64	2449.21	0.018205	7.24	10.06	1580.77	521.68	1.02	521.68
Whitewater	10999.43	2-YR	4900.00	2440.40	2445.71	2445.71	2446.57	0.021006	5.31	7.44	659.03	385.27	1.00	385.27
Whitewater	10999.43	200-YR	37000.00	2440.40	2449.99	2449.99	2452.53	0.015294	9.59	12.80	2891.44	577.04	1.01	577.04
Whitewater	10999.43	500-YR	45000.00	2440.40	2450.70	2450.70	2453.58	0.014582	10.30	13.62	3304.96	580.50	1.00	579.08
Whitewater	10484.94	100-YR	31400.00	2421.97	2429.15	2429.15	2430.70	0.016719	7.18	10.62	3209.57	1027.91	1.01	615.73
Whitewater	10484.94	10-YR	15900.00	2421.97	2427.74	2427.74	2428.91	0.018670	5.77	9.25	1885.40	838.69	1.02	517.12
Whitewater	10484.94	2-YR	4900.00	2421.97	2425.82	2425.82	2426.63	0.019683	3.85	7.49	691.08	438.10	0.99	309.64
Whitewater	10484.94	200-YR	37000.00	2421.97	2429.55	2429.55	2431.22	0.016534	7.58	11.02	3634.83	1092.19	1.01	641.99
Whitewater	10484.94	500-YR	45000.00	2421.97	2430.17	2430.17	2431.87	0.016105	8.20	11.12	4375.82	1285.75	0.99	721.17
Whitewater	9960.646	100-YR	31400.00	2401.07	2407.15	2407.15	2408.45	0.020305	6.31	9.32	3439.89	1343.01	1.05	623.77
Whitewater	9960.646	10-YR	15900.00	2401.07	2405.94	2405.94	2406.94	0.020723	5.10	8.30	1995.32	1021.64	1.04	442.91
Whitewater	9960.646	2-YR	4900.00	2401.07	2404.50	2404.50	2405.10	0.021624	3.66	6.81	801.22	640.01	1.01	267.28
Whitewater	9960.646	200-YR	37000.00	2401.07	2407.46	2407.46	2408.89	0.019837	6.62	9.80	3860.73	1375.64	1.05	638.55
Whitewater	9960.646	500-YR	45000.00	2401.07	2407.89	2407.89	2409.47	0.018831	7.05	10.31	4459.07	1412.25	1.04	658.79
Whitewater	9500	100-YR	31400.00	2380.44	2387.34	2387.34	2388.97	0.013000	9.57	8.51	3255.33	1106.47	0.88	301.20
Whitewater	9500	10-YR	15900.00	2380.44	2385.32	2385.32	2386.78	0.016336	7.55	7.92	1669.98	568.56	0.95	175.26
Whitewater	9500	2-YR	4900.00	2380.44	2383.02	2383.02	2384.05	0.021335	5.25	4.81	615.48	324.64	0.92	75.73
Whitewater	9500	200-YR	37000.00	2380.44	2387.93	2387.93	2389.50	0.012074	10.16	8.26	3978.65	1329.08	0.85	367.51
Whitewater	9500	500-YR	45000.00	2380.44	2388.53	2388.53	2390.14	0.011714	10.76	8.47	4841.37	1547.99	0.86	435.26
Whitewater	8945.336	100-YR	31400.00	2359.64	2364.44	2364.44	2366.17	0.013476	8.99	6.45	3113.52	931.35	0.86	335.95
Whitewater	8945.336	10-YR	15900.00	2359.64	2362.55	2362.55	2363.99	0.012805	7.10	4.94	1702.57	585.51	0.77	129.08
Whitewater	8945.336	2-YR	4900.00	2359.64	2359.59	2359.59	2360.73	0.022013	4.14		572.30	252.20	0.00	
Whitewater	8945.336	200-YR	37000.00	2359.64	2364.97	2364.97	2366.67	0.016141	9.52	7.44	3646.24	1092.75	0.93	393.49
Whitewater	8945.336	500-YR	45000.00	2359.64	2365.63	2365.63	2367.36	0.014290	10.18	7.62	4421.67	1253.93	0.88	464.23
Whitewater	8319.714	100-YR	31400.00	2334.96	2338.54	2338.54	2340.05	0.015422	13.32	5.36	3295.35	1102.77	0.85	338.05
Whitewater	8319.714	10-YR	15900.00	2334.96	2336.48	2336.48	2338.04	0.017049	11.25	3.37	1602.42	538.19	0.78	55.48
Whitewater	8319.714	2-YR	4900.00	2334.96	2333.59	2333.59	2334.72	0.016195	8.37		576.08	258.55	0.00	
Whitewater	8319.714	200-YR	37000.00	2334.96	2338.94	2338.94	2340.57	0.014896	13.72	5.93	3754.48	1163.03	0.86	386.71
Whitewater	8319.714	500-YR	45000.00	2334.96	2339.38	2339.38	2341.21	0.016998	14.16	7.00	4277.67	1256.49	0.94	435.43
Whitewater	7500.067	100-YR	31400.00	2298.88	2305.20	2305.20	2306.66	0.013065	10.39	8.15	3320.27	1075.72	0.87	505.38
Whitewater	7500.067	10-YR	15900.00	2298.88	2303.63	2303.63	2304.86	0.013110	8.82	6.30	1884.11	764.52	0.82	366.49
Whitewater	7500.067	2-YR	4900.00	2298.88	2300.41	2300.41	2301.88	0.016204	5.60	3.92	523.18	188.66	0.79	60.18
Whitewater	7500.067	200-YR	37000.00	2298.88	2305.58	2305.58	2307.14	0.013675	10.76	9.02	3740.99	1132.99	0.91	513.25
Whitewater	7500.067	500-YR	45000.00	2298.88	2305.95	2305.95	2307.77	0.017116	11.14	10.85	4180.75	1191.24	1.04	516.92
Whitewater	6956.87	100-YR	31400.00	2274.97	2281.68	2281.68	2283.28	0.017129	9.10	9.83	3102.76	961.03	0.98	614.93
Whitewater	6956.87	10-YR	15900.00	2274.97	2280.40	2280.40	2281.51	0.013621	7.81	6.80	1978.66	794.61	0.82	549.49
Whitewater	6956.87	2-YR	4900.00	2274.97	2278.03	2278.03	2279.36	0.018295	5.45	5.63	573.10	298.88	0.96	179.20
Whitewater	6956.87	200-YR	37000.00	2274.97	2282.04	2282.04	2283.83	0.017717	9.46	10.63	3451.16	997.64	1.01	625.19
Whitewater	6956.87	500-YR	45000.00	2274.97	2282.58	2282.58	2284.54	0.017557	10.00	11.50	4021.73	1094.48	1.03	641.37
Whitewater	6560.167	100-YR	31400.00	2256.73	2265.03	2265.03	2266.68	0.014400	8.63	10.84	3109.83	949.06	0.97	579.34
Whitewater	6560.167	10-YR	15900.00	2256.73	2263.27	2263.27	2264.60	0.017027	6.87	9.27	1720.07	663.13	1.01	495.43
Whitewater	6560.167	2-YR	4900.00	2256.73	2261.20	2261.20	2262.08	0.018077	4.80	7.07	657.39	359.18	0.95	277.92
Whitewater	6560.167	200-YR	37000.00	2256.73	2265.42	2265.42	2267.24	0.015211	9.02	11.44	3489.45	1027.51	1.01	616.24
Whitewater	6560.167	500-YR	45000.00	2256.73	2265.95	2265.95	2268.01	0.015344	9.54	12.33	4049.71	1081.73	1.03	622.91
Whitewater	5917.389	100-YR	31400.00	2231.27	2241.09	2241.09	2243.35	0.012459	9.82	12.36	2713.08	632.11	0.95	447.32
Whitewater	5917.389	10-YR	15900.00	2231.27	2238.83	2238.83	2240.67	0.015400	7.56	10.93	1483.64	420.79	0.99	378.70
Whitewater	5917.389	2-YR	4900.00	2231.27	2236.33	2236.33	2237.42	0.018866	5.06	8.38	584.47	269.70	1.00	269.70
Whitewater	5917.389	200-YR	37000.00	2231.27	2241.58	2241.58	2244.12	0.012707	10.31	13.17	3025.66	654.55	0.97	449.86
Whitewater	5917.389	500-YR	45000.00	2231.27	2242.46	2242.46	2245.12	0.011369	11.19	13.58	3617.42	684.86	0.93	454.62
Whitewater	5651.635	100-YR	31400.00	2221.63	2230.22	2230.22	2232.62	0.015116	8.59	12.62	2555.27	541.57	1.00	474.47
Whitewater	5651.635	10-YR	15900.00	2221.63	2228.38	2228.38	2229.97	0.017226	6.75	10.22	1590.41	511.02	1.00	460.16
Whitewater	5651.635	2-YR	4900.00	2221.63	2226.51	2226.51	2227.32	0.020621	4.88	7.25	685.13	426.94	0.99	397.53
Whitewater	5651.635	200-YR	37000.00	2221.63	2230.81	2230.81	2233.44	0.014448	9.18	13.22	2880.11	551.01	0.99	478.60
Whitewater	5651.635	500-YR	45000.00	2221.63	2231.55	2231.55	2234.53	0.014045	9.92	14.08	3292.99	560.32	1.00	482.96
Whitewater	5381.783	100-YR	31400.00	2213.45	2224.59	2224.59	2228.17	0.011561	11.14	15.78	2143.42	293.27	0.95	205.41
Whitewater	5381.783	10-YR	15900.00	2213.45	2221.34	2221.34	2223.96	0.013569	7.89	13.33	1250.77	237.46	0.98	190.26
Whitewater	5381.783	2-YR	4900.00	2213.45	2218.15	2218.15	2219.48	0.017002	4.70	9.35	539.79	207.18	0.98	180.32
Whitewater	5381.783	200-YR	37000.00	2213.45	2225.29	2225.29	2229.43	0.012346	11.84	17.04	2349.98	303.23	1.00	207.50
Whitewater	5381.783	500-YR	45000.00	2213.45	2226.81	2226.81	2231.05	0.010764	13.36	17.33	2834.15	324.55	0.95	211.71
Whitewater	5170.287	100-YR	31400.00	2206.29	2216.70	2216.70	2220.24	0.012618	10.41	15.11	2078.42	290.73	1.00	290.73
Whitewater	5170.287	10-YR	15900.00	2206.29	2213.94	2213.94	2216.28	0.014199	7.65	12.27	1296.17	273.55	0.99	273.55

HEC-RAS Plan: ProposedAlt4Revised River: Whitewater Reach: Whitewater (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Max Chl Dpth	Vel Chnl	Flow Area	Top Width	Froude # Chl	Top W Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)
Whitewater	5170.287	2-YR	4900.00	2206.29	2211.21	2211.21	2212.33	0.017854	4.92	8.50	576.77	253.38	0.99	253.38
Whitewater	5170.287	200-YR	37000.00	2206.29	2217.56	2217.56	2221.48	0.012233	11.27	15.86	2332.34	295.33	1.00	295.33
Whitewater	5170.287	500-YR	45000.00	2206.29	2218.71	2218.71	2223.11	0.011850	12.42	16.82	2675.85	301.95	1.00	301.95
Whitewater	4971.125	100-YR	31400.00	2198.89	2211.21	2211.21	2215.00	0.012371	12.32	15.63	2009.54	265.11	1.00	265.11
Whitewater	4971.125	10-YR	15900.00	2198.89	2207.98	2207.98	2210.64	0.013593	9.08	13.08	1215.20	226.83	1.00	226.83
Whitewater	4971.125	2-YR	4900.00	2198.89	2204.45	2204.45	2205.98	0.016000	5.56	9.92	493.82	159.50	0.99	159.50
Whitewater	4971.125	200-YR	37000.00	2198.89	2212.16	2212.16	2216.31	0.011930	13.27	16.34	2263.84	270.43	1.00	270.43
Whitewater	4971.125	500-YR	45000.00	2198.89	2213.39	2213.39	2218.04	0.011567	14.50	17.31	2600.39	276.98	1.00	276.98
Whitewater	4716.682	100-YR	31400.00	2189.95	2201.51	2201.51	2204.71	0.012719	13.95	14.35	2188.51	337.76	0.99	337.76
Whitewater	4716.682	10-YR	15900.00	2189.95	2198.98	2198.98	2201.11	0.014532	11.42	11.72	1357.12	315.67	1.00	315.67
Whitewater	4716.682	2-YR	4900.00	2189.95	2195.18	2195.18	2196.73	0.015971	7.62	10.00	489.86	155.63	0.99	155.63
Whitewater	4716.682	200-YR	37000.00	2189.95	2202.29	2202.29	2205.83	0.012378	14.73	15.09	2452.56	343.29	1.00	343.29
Whitewater	4716.682	500-YR	45000.00	2189.95	2203.33	2203.33	2207.31	0.011945	15.77	15.99	2815.01	350.80	0.99	350.80
Whitewater	4500	100-YR	31400.00	2181.93	2193.84	2193.84	2196.74	0.013144	11.91	13.65	2300.63	392.24	0.99	392.24
Whitewater	4500	10-YR	15900.00	2181.93	2191.22	2191.22	2193.41	0.014426	9.29	11.89	1337.14	301.53	1.00	301.53
Whitewater	4500	2-YR	4900.00	2181.93	2187.66	2187.66	2189.07	0.016863	5.73	9.52	514.52	182.79	1.00	182.79
Whitewater	4500	200-YR	37000.00	2181.93	2194.54	2194.54	2197.75	0.012814	12.61	14.37	2575.50	397.64	1.00	397.64
Whitewater	4500	500-YR	45000.00	2181.93	2195.48	2195.48	2199.09	0.012380	13.55	15.24	2953.23	405.09	0.99	405.09
Whitewater	4238.041	100-YR	31400.00	2174.70	2184.18	2184.18	2187.02	0.013600	9.48	13.52	2322.68	406.13	1.00	406.13
Whitewater	4238.041	10-YR	15900.00	2174.70	2181.95	2181.95	2183.83	0.015611	7.25	11.02	1442.65	382.46	1.00	382.46
Whitewater	4238.041	2-YR	4900.00	2174.70	2179.01	2179.01	2180.30	0.016922	4.31	9.12	537.45	205.70	0.99	205.70
Whitewater	4238.041	200-YR	37000.00	2174.70	2184.84	2184.84	2188.01	0.013397	10.14	14.26	2594.24	413.25	1.00	413.25
Whitewater	4238.041	500-YR	45000.00	2174.70	2185.85	2185.85	2189.31	0.012692	11.15	14.92	3016.23	430.63	0.99	430.63
Whitewater	3993.909	100-YR	31400.00	2167.49	2176.81	2176.81	2179.53	0.013385	9.32	13.21	2376.09	433.06	0.99	433.06
Whitewater	3993.909	10-YR	15900.00	2167.49	2174.61	2174.61	2176.46	0.015335	7.12	10.92	1455.89	393.01	1.00	393.01
Whitewater	3993.909	2-YR	4900.00	2167.49	2172.37	2172.37	2173.29	0.018718	4.88	7.67	638.96	342.00	0.99	342.00
Whitewater	3993.909	200-YR	37000.00	2167.49	2177.47	2177.47	2180.47	0.012942	9.97	13.91	2660.15	437.08	0.99	437.08
Whitewater	3993.909	500-YR	45000.00	2167.49	2178.32	2178.32	2181.73	0.012534	10.83	14.82	3036.76	441.92	1.00	441.92
Whitewater	3740.673	100-YR	31400.00	2159.79	2167.02	2167.02	2169.11	0.014824	7.23	11.61	2704.03	1143.52	0.99	637.41
Whitewater	3740.673	10-YR	15900.00	2159.79	2165.41	2165.41	2166.77	0.016774	5.62	9.36	1698.61	1092.43	0.99	612.16
Whitewater	3740.673	2-YR	4900.00	2159.79	2163.73	2163.73	2164.44	0.020006	3.94	6.73	728.43	794.78	0.99	505.87
Whitewater	3740.673	200-YR	37000.00	2159.79	2167.50	2167.50	2169.85	0.014454	7.71	12.29	3011.37	1151.29	1.00	639.28
Whitewater	3740.673	500-YR	45000.00	2159.79	2168.17	2168.17	2170.83	0.013852	8.38	13.09	3437.51	1161.46	1.00	641.89
Whitewater	3500	100-YR	31400.00	2150.27	2157.72	2157.72	2159.63	0.016326	7.45	11.09	2831.62	1096.53	1.00	738.11
Whitewater	3500	10-YR	15900.00	2150.27	2156.26	2156.26	2157.50	0.018432	5.99	8.95	1777.30	1038.83	0.99	699.34
Whitewater	3500	2-YR	4900.00	2150.27	2154.43	2154.43	2155.22	0.022237	4.16	7.12	688.26	670.85	1.00	435.94
Whitewater	3500	200-YR	37000.00	2150.27	2158.18	2158.18	2160.29	0.015540	7.91	11.66	3173.91	1215.89	0.99	739.23
Whitewater	3500	500-YR	45000.00	2150.27	2158.78	2158.78	2161.19	0.014965	8.51	12.45	3613.60	1232.80	0.99	740.62
Whitewater	3226.86	100-YR	31400.00	2140.47	2146.93	2146.93	2148.43	0.015749	6.46	9.80	3200.76	1118.48	0.97	709.49
Whitewater	3226.86	10-YR	15900.00	2140.47	2145.73	2145.73	2146.75	0.018334	5.26	8.04	1968.29	1012.71	0.99	679.37
Whitewater	3226.86	2-YR	4900.00	2140.47	2144.20	2144.20	2144.86	0.021898	3.72	6.11	757.75	588.15	0.98	423.05
Whitewater	3226.86	200-YR	37000.00	2140.47	2147.29	2147.29	2148.95	0.015282	6.82	10.29	3582.04	1142.94	0.97	718.28
Whitewater	3226.86	500-YR	45000.00	2140.47	2147.76	2147.76	2149.65	0.014728	7.29	10.96	4084.84	1160.15	0.97	718.93
Whitewater	3000	100-YR	31400.00	2132.60	2139.17	2139.17	2140.63	0.015541	6.57	9.82	3251.00	1095.72	0.99	718.16
Whitewater	3000	10-YR	15900.00	2132.60	2138.05	2138.05	2139.01	0.016314	5.45	7.84	2060.45	1038.74	0.98	699.01
Whitewater	3000	2-YR	4900.00	2132.60	2136.50	2136.50	2137.16	0.017124	3.90	6.55	777.19	577.66	0.98	381.20
Whitewater	3000	200-YR	37000.00	2132.60	2139.57	2139.57	2141.14	0.014413	6.97	10.21	3703.66	1129.26	0.97	718.16
Whitewater	3000	500-YR	45000.00	2132.60	2139.99	2139.99	2141.81	0.014440	7.39	10.99	4179.31	1132.55	0.98	718.16
Whitewater	2734.526	100-YR	31400.00	2121.69	2129.80	2129.80	2131.29	0.012666	8.11	9.99	3275.58	982.32	0.90	775.20
Whitewater	2734.526	10-YR	15900.00	2121.69	2128.27	2128.27	2129.43	0.016598	6.58	8.70	1868.51	841.38	0.99	738.64
Whitewater	2734.526	2-YR	4900.00	2121.69	2126.66	2126.66	2127.33	0.021129	4.97	6.57	747.47	555.12	0.99	540.10
Whitewater	2734.526	200-YR	37000.00	2121.69	2130.09	2130.09	2131.83	0.013588	8.40	10.84	3557.88	984.06	0.95	775.63
Whitewater	2734.526	500-YR	45000.00	2121.69	2130.59	2130.59	2132.57	0.013284	8.90	11.54	4055.78	986.36	0.95	776.40
Whitewater	2500	100-YR	31400.00	2112.87	2121.19	2121.19	2123.15	0.014392	8.32	11.38	2817.47	716.80	0.96	602.68
Whitewater	2500	10-YR	15900.00	2112.87	2119.59	2119.59	2120.94	0.017073	6.72	9.38	1712.91	656.18	0.98	585.55
Whitewater	2500	2-YR	4900.00	2112.87	2117.87	2117.87	2118.61	0.022708	5.00	6.89	710.80	488.21	1.01	488.21
Whitewater	2500	200-YR	37000.00	2112.87	2121.56	2121.56	2123.83	0.014970	8.69	12.24	3087.37	722.96	0.99	604.69
Whitewater	2500	500-YR	45000.00	2112.87	2122.32	2122.32	2124.72	0.013230	9.45	12.64	3649.62	752.58	0.96	609.20
Whitewater	2181.438	100-YR	31400.00	2101.57	2111.21	2111.21	2113.26	0.002625	9.64	11.49	2731.64	680.21	1.01	680.21
Whitewater	2181.438	10-YR	15900.00	2101.57	2109.27	2109.27	2110.84	0.002961	7.70	10.07	1578.29	511.96	1.01	511.96
Whitewater	2181.438	2-YR	4900.00	2101.57	2107.19	2107.19	2108.07	0.003742	5.62	7.55	649.30	379.88	1.02	379.88
Whitewater	2181.438	200-YR	37000.00	2101.57	2111.67	2111.67	2113.96	0.002564	10.10	12.15	3044.59	682.71	1.01	682.71
Whitewater	2181.438	500-YR	45000.00	2101.57	2112.33	2112.33	2114.90	0.002401	10.76	12.86	3498.21	686.61	1.00	685.82
Whitewater	2150		Culvert											
Whitewater	2102.988	100-YR	31400.00	2091.39	2103.22	2103.22	2105.63	0.004779	11.83	7.81	2848.60	645.94	0.64	324.18
Whitewater	2102.988	10-YR	15900.00	2091.39	2101.07	2101.07	2102.87	0.004254	9.68	6.69	1694.59	442.37	0.54	199.83
Whitewater	2102.988	2-YR	4900.00	2091.39	2097.11	2097.11	2098.62	0.009121	5.72	9.56	499.12	172.42	0.79	86.98
Whitewater	2102.988	200-YR	37000.00	2091.39	2103.97	2103.97	2106.48	0.004665	12.58	7.51	3360.56	706.24	0.61	376.03
Whitewater	2102.988	500-YR	45000.00	2091.39	2104.89	2104.89	2107.45	0.004369	13.50	7.65	4044.82	754.26	0.60	415.47
Whitewater	1862.584	100-YR	31400.00	2082.49	2093.83	2093.83	2095.67	0.005787	11.34	7.97	3243.65	837.40	0.70	586.68
Whitewater	1862.584	10-YR	15900.00	2082.49	2092.20	2092.20	2093.47	0.004096	9.71	6.25	2045.51	623.01	0.59	426.86
Whitewater	1862.584	2-YR	4900.00	2082.49	2089.20	2089.20	2090.31	0.004776	6.71	5.18	742.45	293.68	0.54	203.76
Whitewater	1862.584	200-YR	37000.00	2082.49	2094.28	2094.28	2096.28	0.006088	11.79	8.49	3626.33	857.57	0.72	598.22
Whitewater	1862.584	500-YR	45000.00	2082.49	2094.85	2094.85	2097.10	0.006453	12.36	9.20	4111.75	859.43	0.73	599.13
Whitewater	1482.694	100-YR	31400.00	2072.50	2082.69	2082.69	2084.60	0.012615	10.19	11.17	2884.07	779.84	0.95	636.50
Whitewater	1482.694	10-YR	15900.00	2072.50	2080.69	2080.69	2082.29	0.016082	8.19	10.16	1565.04	508.69	1.02	506.00

HEC-RAS Plan: ProposedAlt4Revised River: Whitewater Reach: Whitewater (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Max Chl Dpth	Vel Chnl	Flow Area	Top Width	Froude # Chl	Top W Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)
Whitewater	1482.694	2-YR	4900.00	2072.50	2078.58	2078.58	2079.54	0.013847	6.08	7.86	623.03	330.48	1.01	330.48
Whitewater	1482.694	200-YR	37000.00	2072.50	2083.26	2083.26	2085.23	0.011849	10.76	11.42	3339.40	849.79	0.93	661.06
Whitewater	1482.694	500-YR	45000.00	2072.50	2083.95	2083.95	2086.01	0.011149	11.45	11.75	3979.29	1009.05	0.91	693.08
Whitewater	942.056	100-YR	31400.00	2056.91	2063.90	2063.90	2065.74	0.014815	7.32	10.60	2901.04	799.69	1.00	741.01
Whitewater	942.056	10-YR	15900.00	2056.91	2062.26	2062.26	2063.60	0.015938	5.68	8.98	1723.99	643.03	1.00	586.56
Whitewater	942.056	2-YR	4900.00	2056.91	2060.08	2060.08	2060.98	0.021933	3.50	7.38	648.78	372.23	1.01	319.21
Whitewater	942.056	200-YR	37000.00	2056.91	2064.41	2064.41	2066.35	0.014121	7.83	10.92	3324.98	861.43	1.00	802.07
Whitewater	942.056	500-YR	45000.00	2056.91	2065.07	2065.07	2067.13	0.013370	8.49	11.28	3920.50	942.48	1.00	882.27
Whitewater	500	100-YR	31400.00	2039.26	2048.07	2048.07	2049.79	0.016085	8.81	10.51	2987.75	892.93	1.01	889.86
Whitewater	500	10-YR	15900.00	2039.26	2046.64	2046.64	2047.86	0.016366	7.38	8.87	1791.66	737.28	1.00	737.28
Whitewater	500	2-YR	4900.00	2039.26	2044.80	2044.80	2045.57	0.018988	5.54	7.02	698.16	473.91	1.02	473.91
Whitewater	500	200-YR	37000.00	2039.26	2048.52	2048.52	2050.37	0.015696	9.26	10.90	3395.50	935.18	1.01	931.08
Whitewater	500	500-YR	45000.00	2039.26	2049.12	2049.12	2051.11	0.015082	9.86	11.32	3977.49	1007.75	1.00	998.37


ProposedAlt4Revised 5/28/2020
RS = 12500.22
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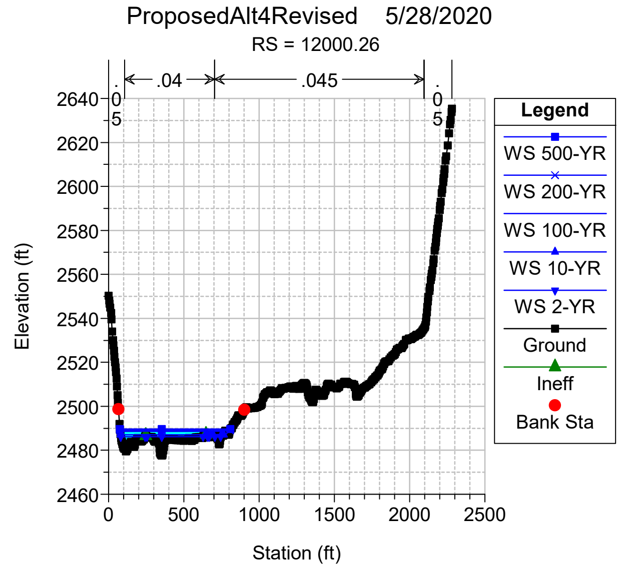
.045
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)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RS = 12000.26
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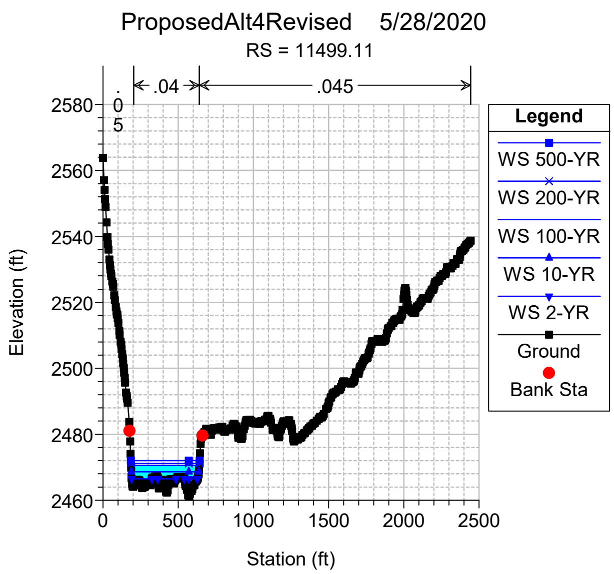
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)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RS = 11499.11
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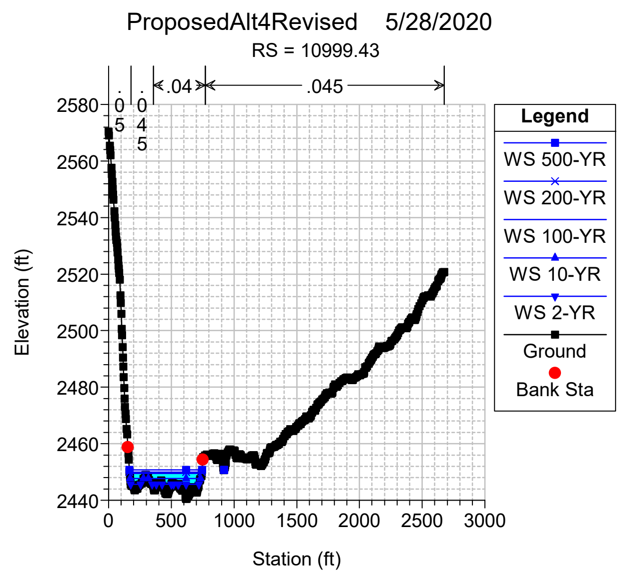
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)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RS = 10999.43
.04
.045
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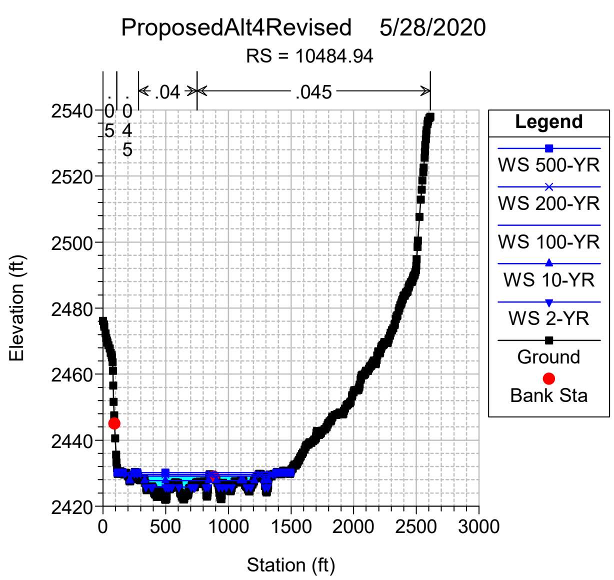
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)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RS = 10484.94
.04
.045
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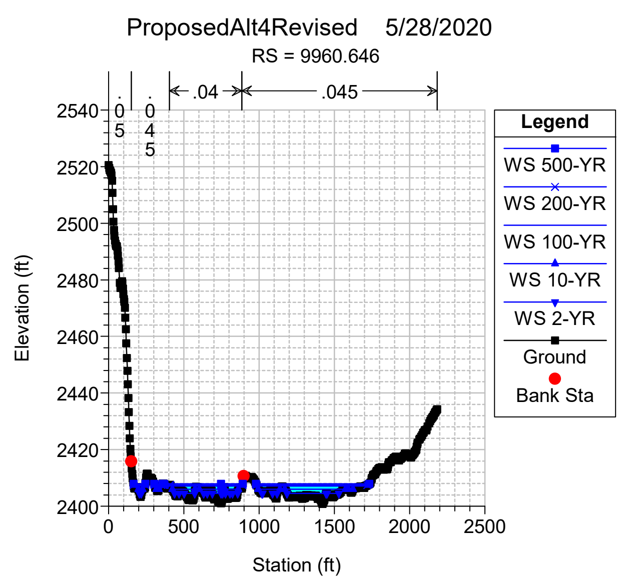
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


ProposedAlt4Revised 5/28/2020
RS = 9960.646
.04
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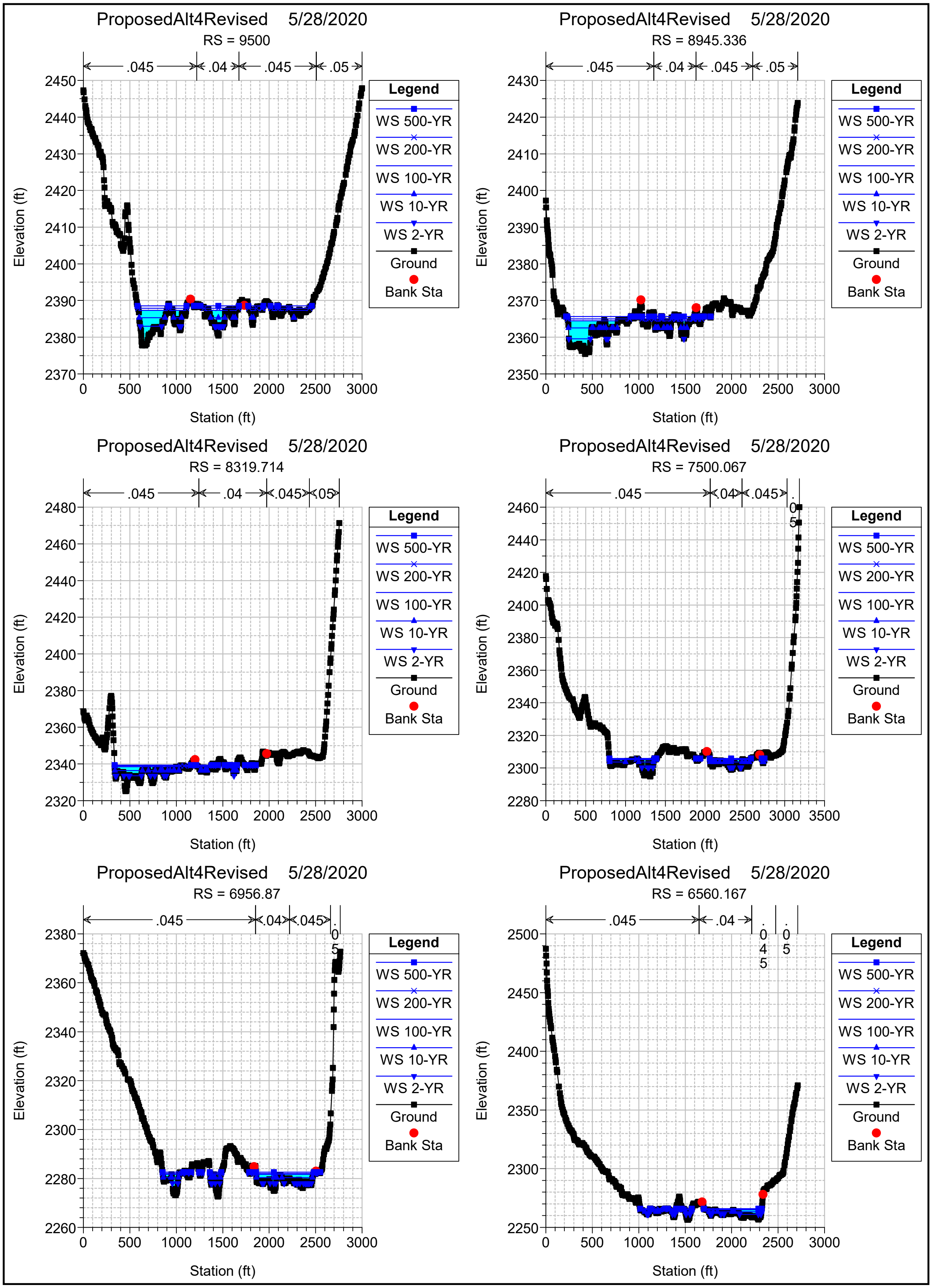
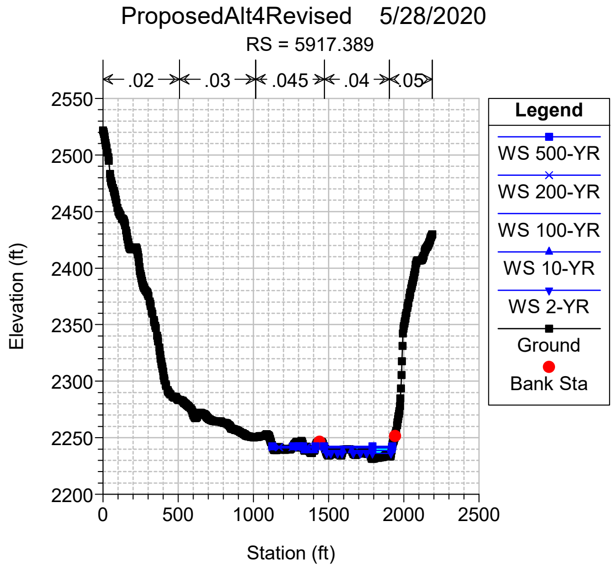
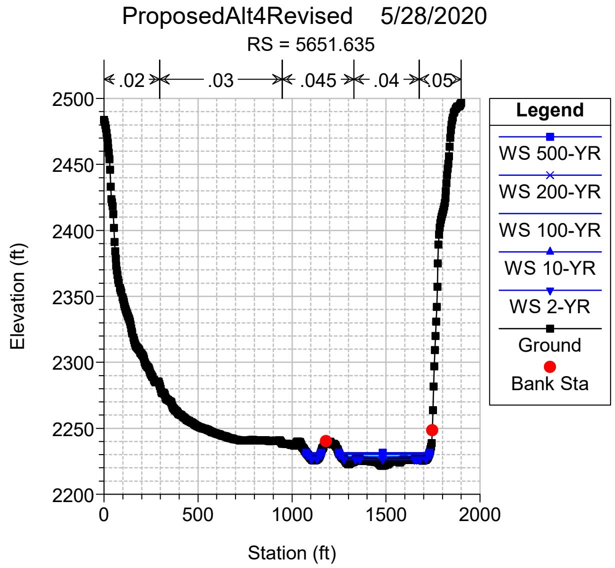
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)

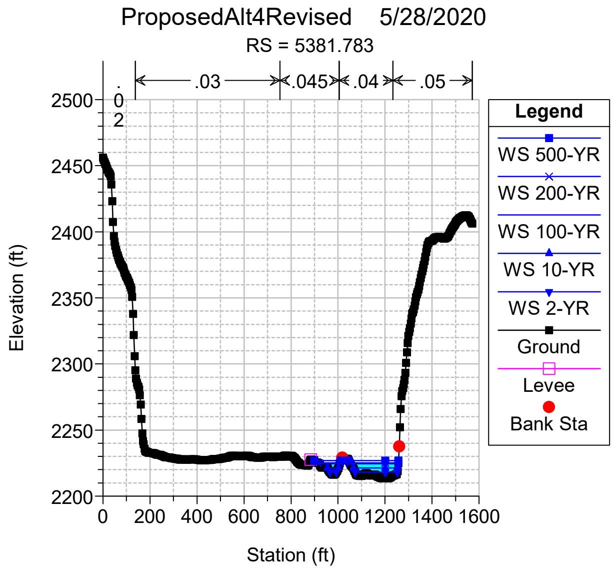

ProposedAlt4Revised 5/28/2020
RS = 9500
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
2450
2440
2430
2420
2410
2400
2390
2380
2370
0 500 1000 1500 2000 2500 3000
Station (ft)
ProposedAlt4Revised 5/28/2020
RS = 8945.336
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
2430
2420
2410
2400
2390
2380
2370
2360
2350
0 500 1000 1500 2000 2500 3000
Station (ft)
ProposedAlt4Revised 5/28/2020
RS = 8319.714
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
2480
2460
2440
2420
2400
2380
2360
2340
2320
0 500 1000 1500 2000 2500 3000
Station (ft)
ProposedAlt4Revised 5/28/2020
RS = 7500.067
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
2460
2440
2420
2400
2380
2360
2340
2320
2300
2280
0 500 1000 1500 2000 2500 3000 3500
Station (ft)
ProposedAlt4Revised 5/28/2020
RS = 6956.87
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
2380
2360
2340
2320
2300
2280
2260
0 500 1000 1500 2000 2500 3000
Station (ft)
ProposedAlt4Revised 5/28/2020
RS = 6560.167
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
2500
2450
2400
2350
2300
2250
0 500 1000 1500 2000 2500 3000
Station (ft)



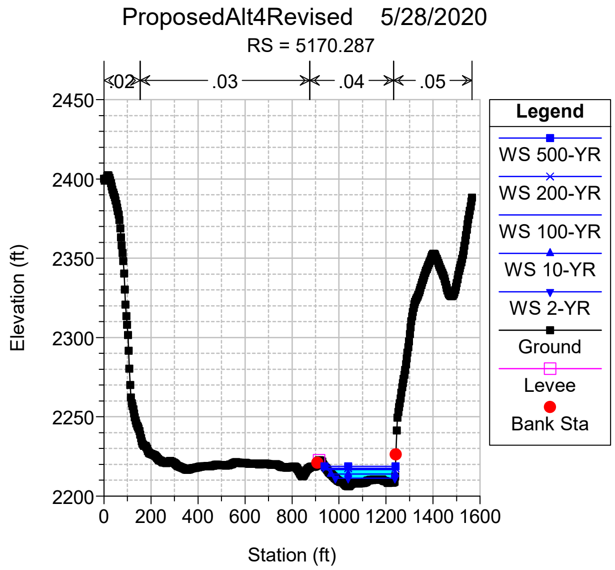
ProposedAlt4Revised 5/28/2020
RS = 5917.389
.02 .03 .045 .04 .05
Elevation (ft)
2550 2500 2450 2400 2350 2300 2250 2200
Station (ft)
0 500 1000 1500 2000 2500
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta



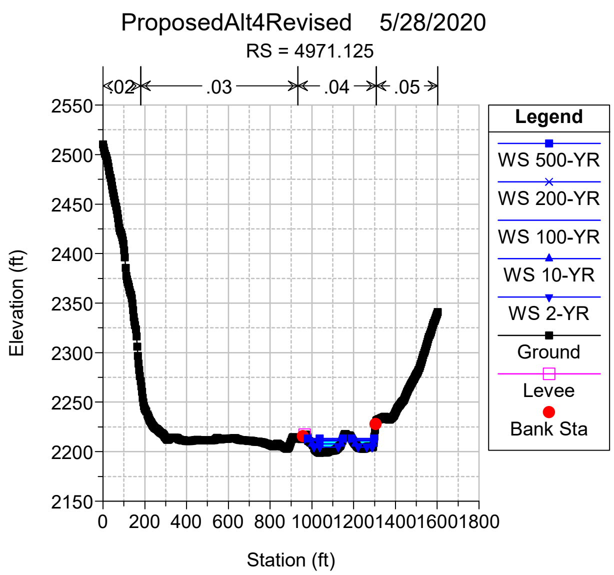
ProposedAlt4Revised 5/28/2020
RS = 5651.635
.02 .03 .045 .04 .05
Elevation (ft)
2500 2450 2400 2350 2300 2250 2200
Station (ft)
0 500 1000 1500 2000
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta



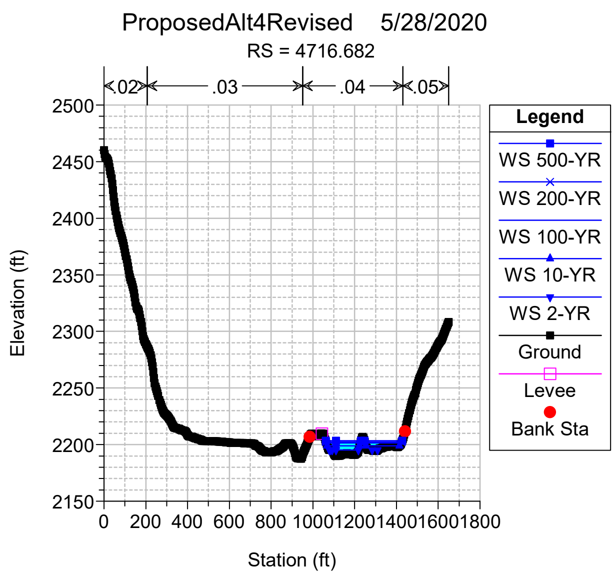
ProposedAlt4Revised 5/28/2020
RS = 5381.783
.02 .03 .045 .04 .05
Elevation (ft)
2500 2450 2400 2350 2300 2250 2200
Station (ft)
0 200 400 600 800 1000 1200 1400 1600
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Levee
Bank Sta



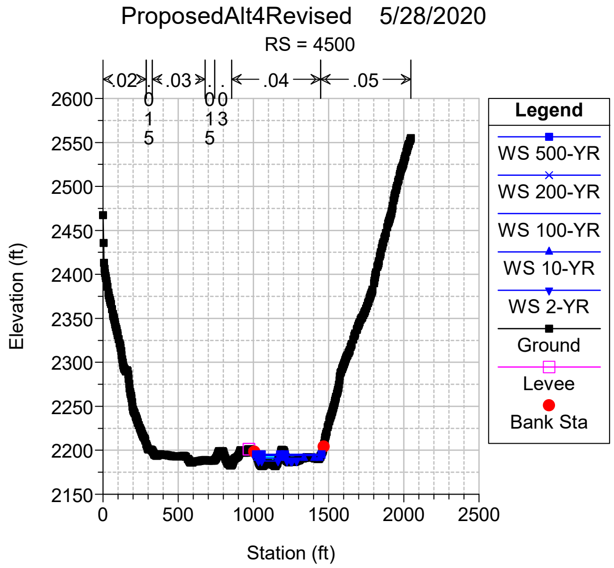
ProposedAlt4Revised 5/28/2020
RS = 5170.287
.02 .03 .04 .05
Elevation (ft)
2450 2400 2350 2300 2250 2200
Station (ft)
0 200 400 600 800 1000 1200 1400 1600
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Levee
Bank Sta

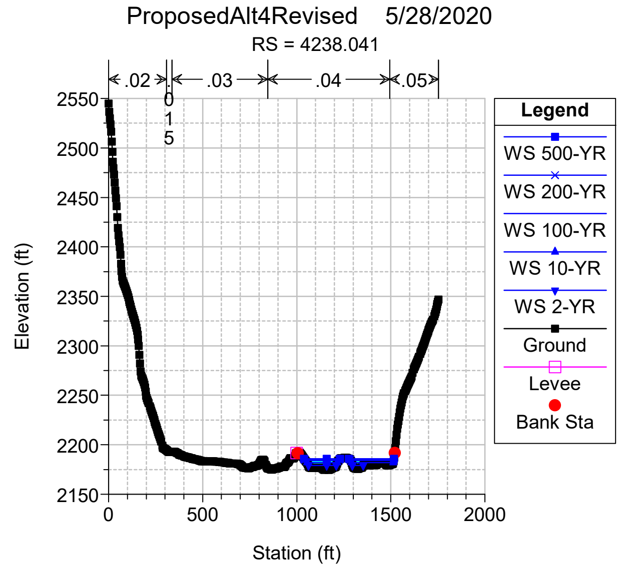


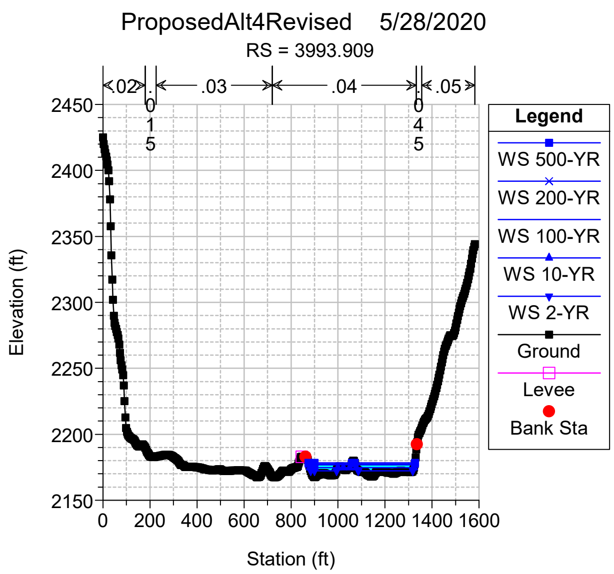
ProposedAlt4Revised 5/28/2020
RS = 4971.125
.02 .03 .04 .05
Elevation (ft)
2550 2500 2450 2400 2350 2300 2250 2200 2150
Station (ft)
0 200 400 600 800 1000 1200 1400 1600 1800
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Levee
Bank Sta

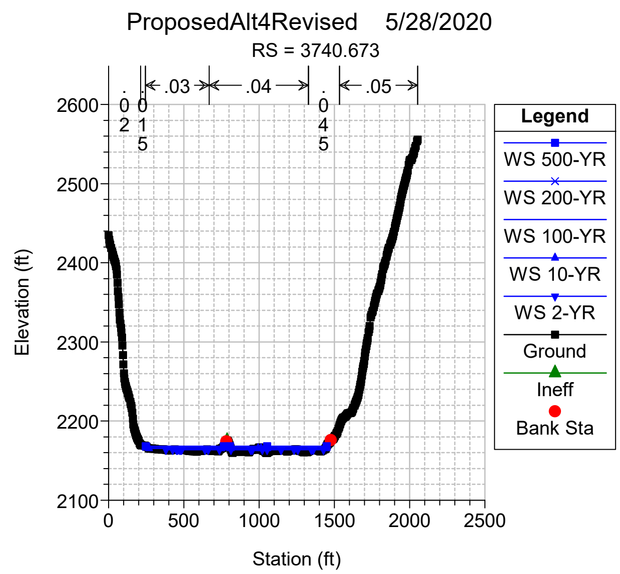


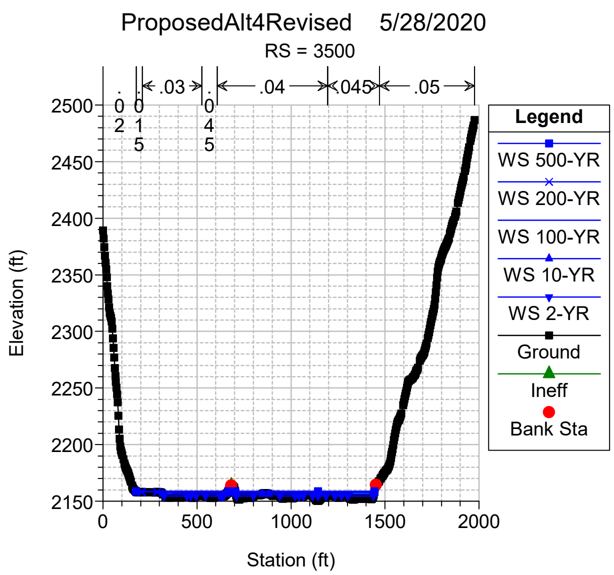
ProposedAlt4Revised 5/28/2020
RS = 4716.682
.02 .03 .04 .05
Elevation (ft)
2500 2450 2400 2350 2300 2250 2200 2150
Station (ft)
0 200 400 600 800 1000 1200 1400 1600 1800
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Levee
Bank Sta

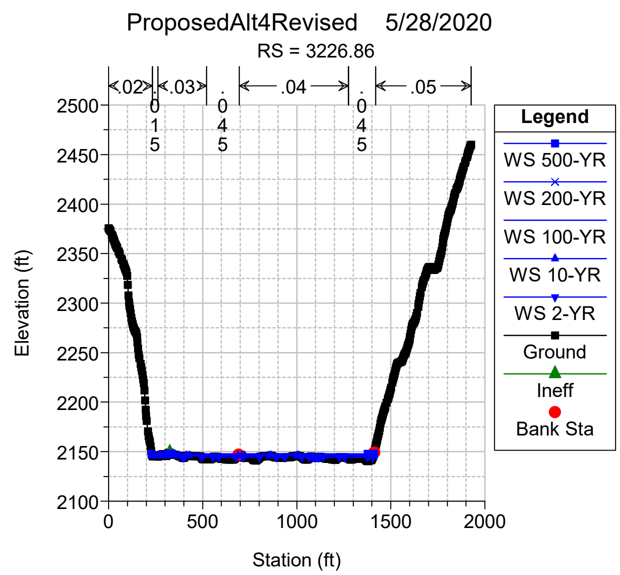

ProposedAlt4Revised 5/28/2020
RS = 4500
.02
.03
.04
.05
Elevation (ft)
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Levee
Bank Sta

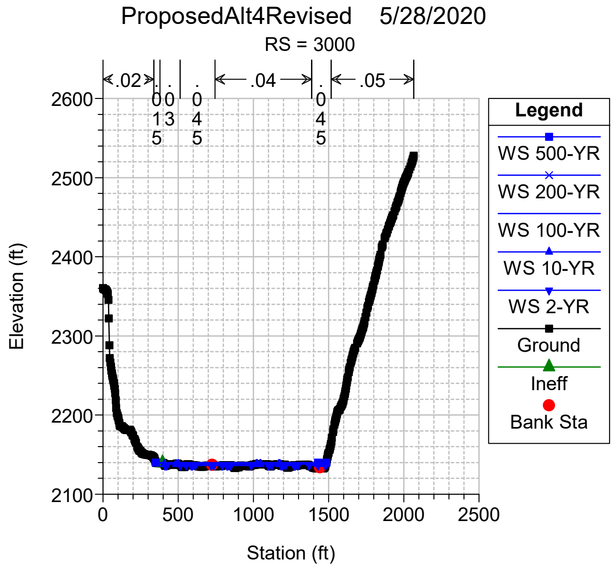

ProposedAlt4Revised 5/28/2020
RS = 4238.041
.02
.03
.04
.05
Elevation (ft)
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Levee
Bank Sta

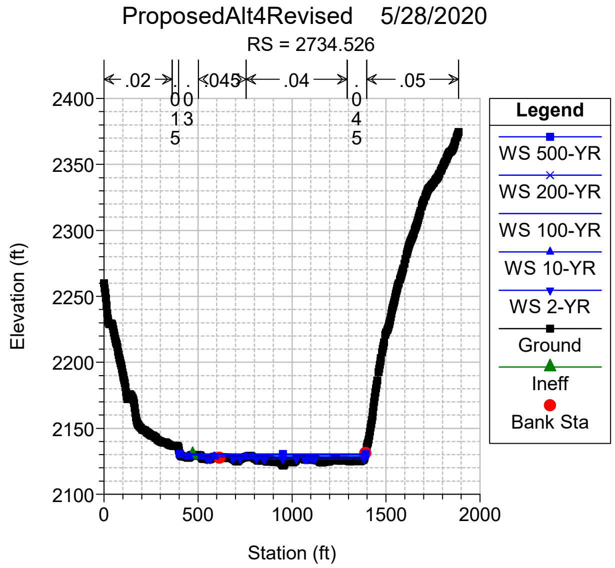

ProposedAlt4Revised 5/28/2020
RS = 3993.909
.02
.03
.04
.05
Elevation (ft)
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Levee
Bank Sta


ProposedAlt4Revised 5/28/2020
RS = 3740.673
.03
.04
.05
Elevation (ft)
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta


ProposedAlt4Revised 5/28/2020
RS = 3500
.03
.04
.045
.05
Elevation (ft)
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta


ProposedAlt4Revised 5/28/2020
RS = 3226.86
.02
.03
.04
.05
Elevation (ft)
Station (ft)
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta


ProposedAlt4Revised 5/28/2020
RS = 3000
.02
.045
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2100
2200
2300
2400
2500
2600
0
500
1000
1500
2000
2500


ProposedAlt4Revised 5/28/2020
RS = 2734.526
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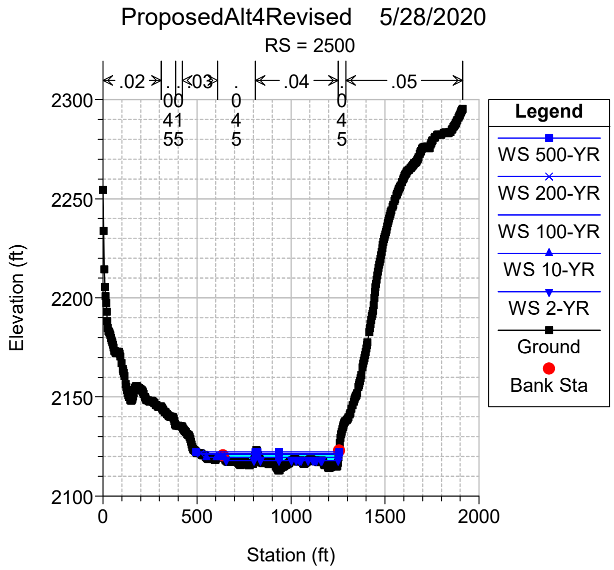
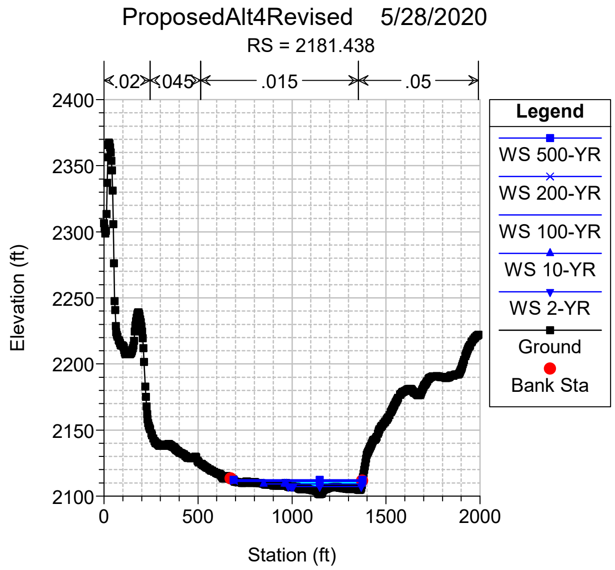
.045
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2100
2150
2200
2250
2300
2350
2400
0
500
1000
1500
2000


ProposedAlt4Revised 5/28/2020
RS = 2500
.02
.03
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2100
2150
2200
2250
2300
0
500
1000
1500
2000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RS = 2181.438
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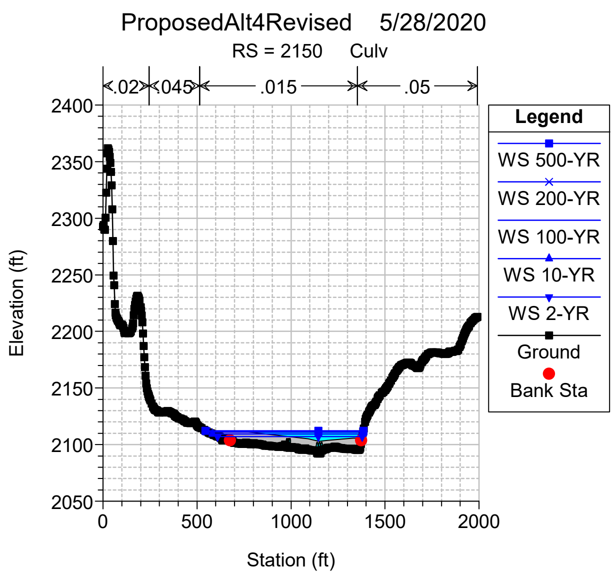
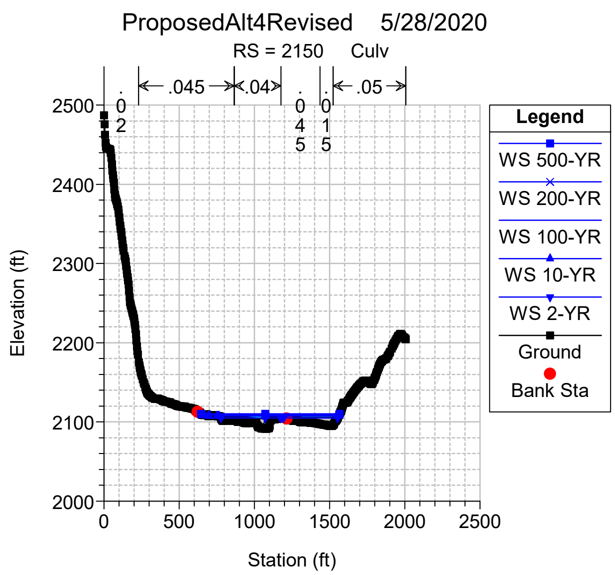
.045
.015
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2100
2150
2200
2250
2300
2350
2400
0
500
1000
1500
2000


ProposedAlt4Revised 5/28/2020
RS = 2150 Culv
.02
.045
.015
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2050
2100
2150
2200
2250
2300
2350
2400
0
500
1000
1500
2000


ProposedAlt4Revised 5/28/2020
RS = 2150 Culv
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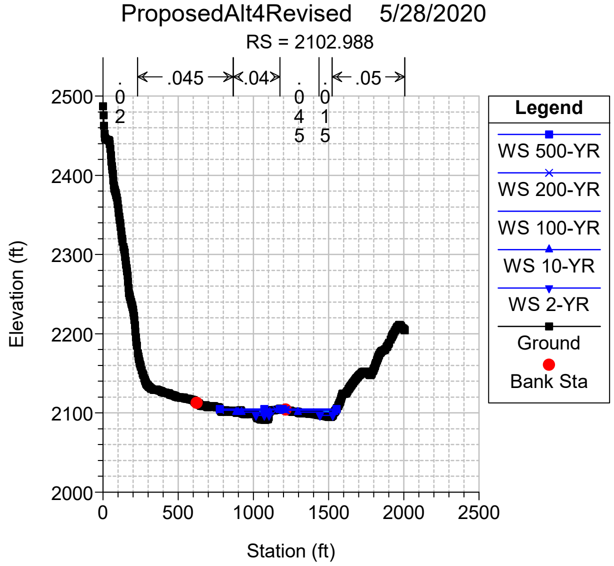
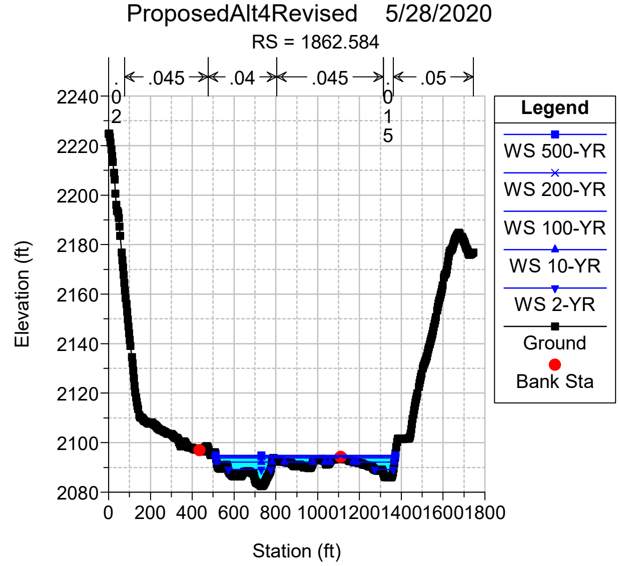
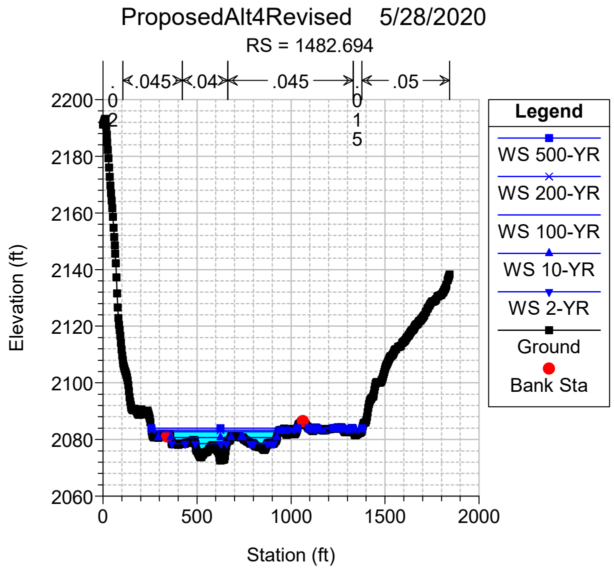
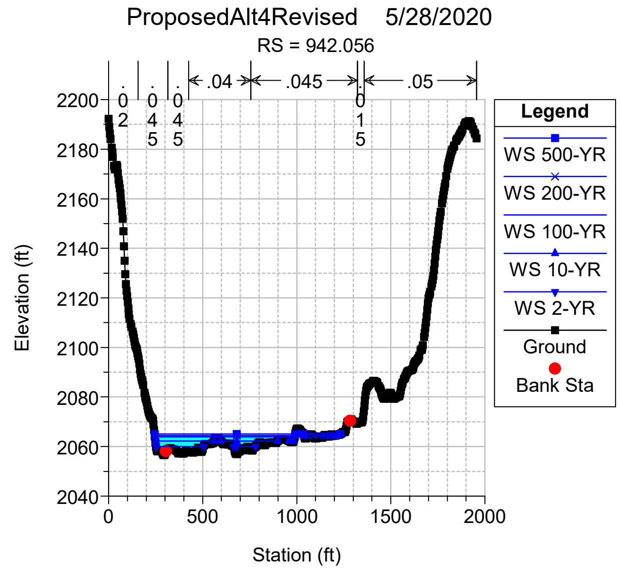
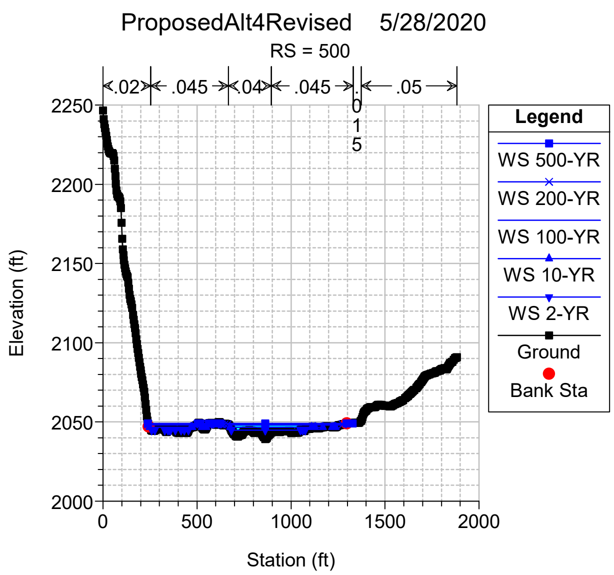
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)
2000
2100
2200
2300
2400
2500
0
500
1000
1500
2000
2500


ProposedAlt4Revised 5/28/2020
RS = 2102.988
.045
.04
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


ProposedAlt4Revised 5/28/2020
RS = 1862.584
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


ProposedAlt4Revised 5/28/2020
RS = 1482.694
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


ProposedAlt4Revised 5/28/2020
RS = 942.056
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)


ProposedAlt4Revised 5/28/2020
RS = 500
.02
.045
.04
.045
.05
Legend
WS 500-YR
WS 200-YR
WS 100-YR
WS 10-YR
WS 2-YR
Ground
Bank Sta
Elevation (ft)
Station (ft)