NATURAL RESOURCE MANAGEMENT PLAN MODELING SUPPORT PROJECT

CUMULATIVE HYDRAULIC IMPACT ASSESSMENT

Prepared for
Sacramento Area Flood Control Agency
Sacramento County Department of Regional Parks

Prepared by
cbec, inc.

October 29, 2021

cbec Project #: 21-1023

This report is intended solely for the use and benefit of the Sacramento Area Flood Control Agency and the Sacramento County Department of Regional Parks. No other person or entity shall be entitled to rely on the details contained herein without the express written consent of cbec, inc., eco engineering, 2544 Industrial Boulevard, West Sacramento, CA 95691.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY OF ACRONYMS

Acronym	Meaning
2D	two-dimensional
AFO	American River Fair Oaks USGS gage (#)
ARCF	American River Common Features
cbec	cbec, inc. eco engineering
cfs	cubic feet per second
CVHS	Central Valley Hydrology Study
CVPIA	Central Valley Project Improvement Act
DEM	digital elevation model
EG	existing ground
FG	future grade
ft	feet
HEC-RAS	Hydraulic Engineering Center River Analysis System
HWM	highwater mark
kcfs	thousand cubic feet per second
LAR	lower American River
LiDAR	Light Detection and Ranging
NAVD 88	North American Vertical Datum of 1988
NRMP	Natural Resources Management Plan
Parkway	American River Parkway
RM	river mile
RTK-GPS	Real-Time Kinematic Global Positioning System
s	second
SAFCA	Sacramento Area Flood Control Agency
SCDRP	Sacramento County Department of Regional Parks
SHIP	spawning habitat improvement project
SREL	Sacramento River East Levee
SWW	Sacramento Weir Widening
USACE	United States Army Corps of Engineers
USGS	United States Geological Society
Water Forum	the Sacramento Water Forum
WSE	water surface elevation

1 INTRODUCTION

The Sacramento County Department of Regional Parks (SCDRP), in collaboration with the Sacramento Flood Control Agency (SAFCA) and local experts and stakeholders, have developed a Natural Resource Management Plan (NRMP) for the American River Parkway (SCDRP 2021). cbec, inc. eco engineering (cbec) has been tasked with assessing the hydraulic impacts of the proposed NRMP management actions within the lower American River (LAR). Section 2.1 provides details related to the NRMP sites.

In addition to the NRMP sites, this hydraulic impact assessment will incorporate the cumulative effects of other LAR projects that are in various stages of development. These other projects include:

- **ARCF projects** - the United States Army Corps of Engineers' (USACE) American River Common Features (ARCF) projects
- **CVPIA SHIP sites** - the United States Bureau of Reclamation, the United States Fish and Wildlife Service, and the Sacramento Water Forum's (Water Forum) Central Valley Project Improvement Act (CVPIA) Spawning Habitat Improvement Projects (SHIP)
- **Water Forum rearing projects** - The Sacramento Water Forum's (Water Forum) salmonid rearing habitat projects

For the ARCF projects, USACE, SAFCA, the California Department of Water Resources, and local experts and stake holders have been tasked with comprehensively assessing bank and levee protection for the lower 14 miles of LAR and 15 miles along the Sacramento River East Levee (SREL). Within LAR, this process has identified high priority sites that are currently under contract for new bank protection and habitat mitigation site designs (i.e., American River Contracts 1, 2, 3, and 4). This cumulative hydraulic assessment includes the latest ARCF project designs, as described in Section 2.2.

For CVPIA SHIP sites, Section 3406 (b)(13) of CVPIA directs the Department of Interior to develop and implement a program to restore and replenish, as needed, salmonid spawning gravel lost due to the construction and operation of Central Valley Project dams, bank protection projects, and other actions that have reduced the availability of spawning gravel and rearing habitat. The LAR CVPIA SHIP sites seek to add spawning gravels to LAR by constructing spawning riffles and side channels. This cumulative hydraulic assessment includes 10 CVPIA SHIP site designs, as described in Section 2.3.

For the Water Forum rearing projects, cbec (2020a) identified and prioritized 53 potential salmonid rearing habitat projects within LAR. This cumulative hydraulic assessment includes 8 of the sites that are most likely to be developed, as described in Section 2.4.

The cumulative hydraulic analysis was based on the 2017 topo-bathymetric digital elevation model (DEM) (Quantum Spatial, 2018 and cbec, 2018) and two-dimensional (2D) hydraulic models (cbec 2019 and cbec 2021a) developed for the LAR Current Condition DEM and 2D Model Development Project (a joint venture with the Water Forum and SAFCA) and USACE's ARCF project. cbec (2020b) documented the effects of ten 10 % concept designs for CVPIA SHIP sites, cbec (2021b) documented the hydraulic impacts of the latest ARCF project designs, and no prior reports have assessed hydraulic impacts for the Water Forum rearing sites, NRMP actions, or the cumulative effect of all these projects. This report focuses on the hydraulic

impacts of NRMP sites and the cumulative hydraulic effects of NRMP actions, ARCF projects, CVPIA sites, and Water Forum rearing projects.

1.1 COORDINATE SYSTEM AND UNITS

The model and data are in U.S. customary units. The horizontal projection is NAD83 NSRS 2007 State Plane CA Zone II (US feet) and the vertical datum is the North American Vertical Datum of 1988 (NAVD 88), feet.

1.2 ASSUMPTIONS AND LIMITATIONS

- The modeling assessment was guided by the significance criteria identified in the Environmental Impact Report (EIR). For water surface elevation (WSE) impacts, WSE increases are considered significant if WSEs are increased (i.e., greater than 0.0 ft relative to the existing condition) within the area of incipient levee overtopping (approximately river mile 7 to river mile 11.5) for the 160,000 and 192,000 cfs cumulative impact scenario. Outside of that area, an increase in WSE of greater than 0.1 ft is considered an impact if the wetted extent is in contact with or immediately adjacent to a federal or non-federal levee (i.e., river mile 18.5) for the 115,000 and 160,000 cfs cumulative impact scenario. For velocity impacts, model results are considered an impact (or further analysis is warranted) if increases in velocity occur under the 115,000 and/or 160,000 cfs cumulative scenario that could affect the structural stability of the levee system or otherwise damage Parkway infrastructure or protected habitat.
- The projects and management actions included in this hydraulic analysis range from conceptual polygons to 100% level of design; therefore, the results are subject to further analysis if a later stage of design differs from how a project was included in this hydraulic analysis.
- This analysis is intended to serve as a planning-level study to identify potentially problematic projects and the cumulative hydraulic impacts of the various ongoing efforts within LAR. If impacts are found, those will be highlighted for future project designers to address.
- The American River Contract 3 designs for ARCF are included at 35% level of design. These sites are currently being revised and the revised sites may have a high WSE impact. NRMP management actions may need to be revised in the vicinity of the American River Contract 3 sites if the WSE impacts of those ARCF projects yield a cumulative impact.

2 PROJECT SETTING

The American River Parkway (Parkway) encompasses about 5,000 acres at the foot of the American River watershed. Most of this landmass is confined by levees whose purpose is to safely contain watershed runoff released into the Parkway from Folsom Dam. During periods of intense rainfall in the watershed, the dam's water control manual prescribes the volume of these releases. The downstream levee system, which is part of a much larger flood management system known as the Sacramento River Flood Control Project, is designed based on engineering criteria tied to the water surface elevations (WSEs) generated by these prescribed releases. These WSEs are affected by the topography and land cover of the Parkway. Accordingly, proposed changes in topography and/or land cover that have the potential to raise WSEs must be reviewed and approved by the federal, state, and local agencies responsible for managing the

levee system in the Parkway. This process creates considerable uncertainty for agencies managing the Parkway, who are mandated under the American River Parkway Plan "to protect, enhance, and expand the Parkway's native willow, cottonwood, and valley oak-dominated riparian and upland woodlands that provide important shaded riverine aquatic habitat, seasonal floodplain, and riparian habitats; and the native live oak and blue oak woodlands and grasslands that provide important terrestrial and upland habitats." (Policy 3.2). To reduce this uncertainty and avoid landscape and flood risk management conflicts in the Parkway, local interests have worked with USACE and the California Central Valley Flood Protection Board to create a model – LAR2D - that is intended to serve as a planning and regulatory tool for managing proposed changes to the topography and land cover of the Parkway in a manner that preserves the design capacity and structural integrity of the flood control system.

Several coincident developments have created the need for this tool and the opportunity to develop it. First, is the implementation of the Congressionally authorized ARCF project which in its current phase is focused on ensuring that the levee system downstream of Folsom Dam can safely convey releases up to 160,000 cfs from Folsom Dam, recently made possible via the Folsom Dam Modification Project/Joint Federal Project. Under this authority, USACE is directed to install bank protection along lengthy reaches of the levee system in the Parkway to accommodate the increased velocities that this release will generate and avoid erosion that could destabilize the levee system, particularly in the narrowest reach of the system between Watt Avenue and H Street bridges. USACE is also directed to widen the Sacramento Weir and Bypass near the mouth of the American River to route more flow into the Yolo Bypass to avoid increasing the flow and WSEs downstream of the Sacramento River and American River confluence. The bank protection improvements, including off site mitigation for unavoidable impacts to Parkway fish and wildlife habitat, involve substantial changes to the topography and land cover of the Parkway. The Sacramento Weir Widening (SWW) project increases the conveyance capacity of the levee system downstream of the American River and lowers water surface elevations in the lower reaches of the Parkway.

In addition to these changes, SCDRP has drafted the NRMP (SCDRP 2021) for the Parkway, which serves as a roadmap for implementing Parkway Plan Policy 3.2 and other Parkway Plan policies that have the potential to alter the land cover of the Parkway. Finally, the Sacramento Water Forum has partnered with the U. S. Bureau of Reclamation under the authority of the Central Valley Project Improvement Act to develop a series of landscape alterations in the Parkway that are intended to provide improved spawning and rearing habitat for American River salmon and steelhead to ameliorate the impacts on these fish species of being cut off from their historic habitat in the watershed above Folsom Dam. Some of these improvements have been incorporated in the NRMP, some have not.

LAR2D has been created to guide the planning and management of these landscape and flood system modifications to ensure that the cumulative effect of these modifications does not compromise the design capacity or structural integrity of the flood control system in the Parkway. Toward this end, the model establishes an existing condition baseline for assessing cumulative impacts that represents the state of the flood control system and Parkway landscape prior to implementation of the current phase of the ARCF project (Sacramento Weir and Bypass widening and Parkway bank protection including off-site mitigation); the NRMP; and the Water Forum fish habitat improvement projects not currently

incorporated in the NRMP. The model is thus able to reflect the cumulative effects of these changes on the operation of the flood system by comparison to the existing condition. These effects are measured first and foremost by comparing the WSEs produced under the existing and cumulative condition by three recognized Folsom Dam release volumes: 115,000 cfs – the historic design release of the flood system adopted at the time Folsom Dam was constructed; 160,000 cfs – the design release identified by Congress as part of its 1999 ARCF authorization for managing the most extreme flood events in the watershed; and 192,000 cfs – the release which causes levee overtopping at the lowest points in the levee system. These effects are also measured by comparing the flow velocities produced by these releases throughout the Parkway.

The existing condition assumes the 2018 revision to the Water Control Manual for Folsom Dam signed by USACE and the Bureau of Reclamation is in place. This manual allows for greater flood storage in the reservoir beyond what the preceding operations manual (1986) designated, specifically a variable space allocation with an operating range of 400,000 – 600,000 acre-feet. These existing physical and operational conditions constitute the hydrologic existing condition and are carried forward in the analysis described below.

2.1 NRMP SITES

The NRMP report (SCRP 2021) divides LAR into 19 sections and describes potential management actions. These actions range from rehabilitating homeless encampments and areas impacted from gravel mining, managing invasive species, revegetating social trails, restoring native habitats, and adding/managing Parkway facilities (e.g., bathrooms and boat ramps). Site polygons were developed based on the management actions identified in the NRMP report (SCDRP 2021). See Figures 1 and 2 for an overview of the NRMP management action locations.

2.2 ARCF PROJECTS

ARCF projects are in various stages of development. cbec (2021b) documented the hydraulic effects of the ARCF projects, as shown in Table 1. See Figures 3 and 4 for an overview of the ARCF project site locations.

Table 1. List of ARCF projects included in the analysis*

Site Name	American R. Contract #	Bank Protection	Mitigation	Design Level	Designer
2-1	1	X		100 %	NHC
Glenn Hall	1		X	85%	USACE-SPK
Rio Americano	1		X	85%	USACE-SPK
2-2	2	X		65%	NHC
2-3	2	X		90%	NHC
Arden Pond	2		X	90%	HDR
Rossmoor	2		X	85%	USACE-SPK
1-1	3	X		35%	USACE-MVP

Site Name	American R. Contract #	Bank Protection	Mitigation	Design Level	Designer
3-1	3	X		35%	USACE-MVP
4-1	3	X		35%	USACE-MVP
Urrutia	4		X	10%	cbec

*Same list of sites and level of design as cbec (2021b)

2.3 CVPIA SHIP SITES

cbec (2020b) documented the effects of ten 10 % concept designs for CVPIA SHIP sites. Since that report, three of the sites have advanced to higher levels of design. Table 2 provides an overview of the CVPIA SHIP sites included in this analysis and their level of design. See Figure 5 and 6 for the locations of the CVPIA SHIP sites.

Table 2. List of CVPIA SHIP sites included in the analysis

Site Name	Design Level	Designer
Nimbus Basin	10%	cbec
Sailor Bar	100%	cbec
Lower Sailor Bar	60%	cbec
Sunrise	10%	cbec
Lower Sunrise	10%	cbec
Sacramento Bar	10%	cbec
El Manto	10%	cbec
Ancil Hoffman	100%	cbec
Upper Riverbend	10%	cbec
Riverbend	10%	cbec

*Site name from cbec (2020b)

2.4 WATER FORUM REARING SITES

cbec (2020a) identified and prioritized 53 potential salmonid rearing habitat projects within LAR for the Water Forum. Table 3 provides a list of the 8 sites included in this analysis. These sites are a subset of the higher priority and more likely projects that may be constructed. See Figures 5 and 6 for an overview of the Water Forum rearing site locations.

Table 3. List of Water Forum rearing sites included in the analysis

Site Number*	Design Level	Designer
03	concept	cbec
06	concept	cbec
09	concept	cbec
14	concept	cbec
19	concept	cbec

Site Number*	Design Level	Designer
21	concept	cbec
24	concept	cbec
25	concept	cbec

*Site number from cbec (2020a)

3 MODEL DEVELOPMENT

The Hydraulic Engineering Center River Analysis System (HEC-RAS) 2D hydrodynamic modeling software was used for the analysis. The models were developed and calibrated for the lower American River Current Condition DEM and 2D Model Development Project (a joint venture with the Water Forum and SAFCA) and USACE's ARCF Project.

3.1 MODEL DOMAIN

Two flood model domains were used for this analysis. For the upper portion of LAR (i.e., From Nimbus Dam to Watt Avenue), a 20-ft gridded mesh model was developed and reported in cbec (2019). Watt Avenue was a suitable place to end the upper model domain because high water marks (HWMs), a cbec stage gage, and the lack of tidal influences allowed a rating curve to be developed at that location. For the lower portion of LAR (i.e., the full federal leveed reach from RM 15.5 to the confluence with the Sacramento River), a 20-ft curvilinear mesh model was developed and reported in cbec (2021a). See Figures 7 and 8 for the model extents for the upper and lower domains, respectively.

3.2 BATHYMETRY AND TOPOGRAPHY

The existing ground (EG) topography and bathymetry was derived from a 2017 DEM. The 2017 EG DEM uses 2017 topo-bathymetric LiDAR (often called "Green LiDAR" that can penetrate water to varying depths) collected by Quantum Spatial (Quantum Spatial, 2018), and 2017 single-beam sonar and RTK-GPS survey points collected by cbec (cbec, 2018). All topographic surfaces and model results use the North American Vertical Datum of 1988 (NAVD 88). Finally, all surfaces incorporated the approximate bridge pier footprints into a 2-ft raster cell resolution DEM for hydraulic modeling purposes.

3.3 CALIBRATION AND VALIDATION

The model calibration and validation runs were based off HWMs acquired for the 1986 and 1997 high flow events and RTK-GPS WSE observations that cbec collected during the 2017 water year. The models were calibrated to the 1997 HWMs and then validated by applying the same roughness parameters to the 1986 HWMs and the observed WSEs for the 2017 water year. The mean and median calibration and validation results were generally within 0.1-0.15 ft of the WSE and HWM data with root-mean-square-errors between 0.2-0.4 ft (cbec, 2019 and cbec, 2021a). Table 4 provides an overview of the calibration and validation events. The LAR discharge data was obtained from the American River at Fair Oaks United States Geological Survey (USGS) gage (AFO, #11446500).

Table 4. Flow events for calibration and validation

Purpose	LAR Discharge (cfs)	Comments
Calibration	117,000	1/2/1997 observed HWMs
Validation	134,000	2/19/1986 observed HWMs
Validation	20,500	12/20/2016 observed WSE
Validation	60,300	1/11/2017 observed WSE
Validation	82,200	2/10/2017 observed WSE

3.4 MODELING PARAMETERS AND ASSUMPTIONS

The HEC-RAS 2D model meshes used for this project consist of mostly 20-ft gridded elements for the upper domain mesh and 20-ft curvilinear elements for the lower domain mesh. During the model development process, a grid size sensitivity test was conducted to achieve the best balance of accuracy and computational run times (cbec, 2019 and cbec, 2021a). The meshes were further refined with break lines along the levee crests and toes, channel banks, steep slope breaks, topographic high and low points, and bridge piers. The break lines ensure that the model mesh is enforced along topographic features that direct or prevent flow paths (e.g., a levee crest or bridge pier). In addition, the cell spacing along the bridge piers and levee toes were reduced to ~8-12 ft (i.e., smaller sizes to increase resolution of velocity calculations). Table 5 provides an overview of the model parameters.

Table 5. HEC-RAS 2D flood model parameters

Parameter	Value	Notes
HEC-RAS	Version 6.1.0	-
flow module	2D unsteady	-
equation set	SWE-ELM	-
theta (0.6 – 1.0)	0.9	-
initial condition	dry bed with warmup period	-
inflows	constant, sub-critical	EG slope = 0.001 (same as bed slope)
outflows	constant elevation	observed condition or rating curve
time step	2 seconds	-
eddy viscosity	0.0 for gridded mesh; 0.4 for curvilinear mesh*	-

*The curvilinear mesh has less numerical diffusion and requires eddy viscosity to provide accurate and stable results (cbec 2021a)

4 SCENARIOS ANALYZED

To assess hydraulic impacts, HEC-RAS scenarios were developed to represent different configurations of baseline (i.e., existing ground or "EG" conditions) and future grade (FG) conditions. Table 6 shows the 5 scenarios that were created for this analysis. Scenario 1 (S1) represents EG without the Sacramento Weir Widening (w/o SWW) project, and Scenario 2 represents EG with SWW (w/ SWW). The SWW project is part of the ARCF project, but its footprint is outside of the American River and the hydraulic model

domains. The SWW project increases the amount of water diverted from the Sacramento River to the Yolo Bypass, which lowers the WSEs within the Sacramento and American River confluence. Therefore, a separate scenario was created to show the effects of SWW on LAR hydraulics. The S1 and S2 scenarios were documented in cbec (2021a) and cbec (2021b), and the differences are included here for background information. Scenario 12 (S12) represents the latest ARCF project condition and was documented in cbec (2021b). NRMP1 represents the addition of the NRMP sites to EG w/o SWW (i.e., S1 + NRMP sites). This scenario provides a comparison to isolate the hydraulic impacts of only the NRMP actions. Lastly, NRMP2 represents the cumulative effect of NRMP, ARCF, CVPIA SHIP, and Water Forum rearing projects. Compared to S1, the NRMP2 scenario provides the full cumulative hydraulic impact.

Table 6. Design and roughness scenarios modeled

Scenarios	Project Sites	Sacramento Weir Widening (SWW)
S1*	None – EG	w/o SWW
S2*	None – EG	w/ SWW
S12*	All ARCF projects	w/ SWW
NRMP1	EG + NRMP sites	w/o SWW
NRMP2	EG + NRMP + ARCF + CVPIA SHIP + Water Forum rearing sites	w/ SWW

*S1 and S2 were documented in cbec (2021a) as part of cbec Project #20-1013 and S1, S2, and S12 were documented in cbec (2021b) as part of cbec Project #20-1041.

4.1 ROUGHNESS MODIFICATIONS

All sites represented in the model contain roughness override polygons that correspond to future landcover conditions (e.g., channel modification, herbaceous vegetation, angular riprap, shrubs/willows, and mature trees). For ARCF and CVPIA SHIP sites, the model incorporates DEM modifications according to the grading plans for the project sites. For NRMP and Water Forum rearing sites, the concepts are largely modeled with only the roughness overrides for landcover changes. Some small exceptions where DEM modifications were made for the NRMP sites include bathroom structures (at Riverbend and El Manto), a shade structure (at Harrington), a cartop boat launch (at Woodlake), and a culvert/bridge (at Woodlake). These structures were included in the model by applying approximate DEM modifications to block an appropriate amount of flow around the structures. Table 7 provides an overview of the roughness values used for the different landcover modifications made within the models. Note that the channel roughness values are different between the calibrated curvilinear mesh (i.e., lower domain) versus the calibrated gridded mesh (i.e., upper domain).

Table 7. Roughness modifications by landcover type

Landcover	Lower Domain	Upper Domain
Channel*	0.03	0.0275
Herbaceous Vegetation	0.03	0.03
Angular Riprap	0.04	0.04

Landcover	Lower Domain	Upper Domain
Riparian Vegetation (e.g., alders/willows)	0.05	0.05
Trees (e.g., cottonwoods/oaks)	0.07	0.07

*The curvilinear mesh for the lower domain model has less numerical diffusion and requires higher roughness values for the channel (cbec 2021a)

4.2 BOUNDARY CONDITIONS

Boundary conditions were developed for hydraulic impact assessments in cbec (2021a) and cbec (2021b). These boundary conditions include 3 LAR inflow values of 115,000 cfs, 160,000 cfs, and 192,000 cfs. Based on the Central Valley Hydrology Study (CVHS), 115,000 cfs represents an annual exceedance probability (AEP) of 1/50 to 1/200, 160,000 cfs represents the peak design discharge with an AEP of 1/325, and 192,000 cfs represents the approximate top-of-federal-levee discharge with an AEP of approximately 1/350 (USACE-SPK 2019b and USACE-SPK 2020). Table 8 shows the flow conditions used to model the 5 scenarios. All boundary conditions presented in Table 8 were extracted from the peak stage and flow condition at I-Street Bridge from the equivalent AEP event in USACE's ARCF-PED v6.1 model run (for without SWW, USACE-SPK 2018) and USACE's ARCF-PED v6.2 model run (for with SWW, USACE-SPK 2019). The boundary conditions show how the inclusion of the 65% design for SWW increases the amount of flow that is diverted from the Sacramento River by approximately 15,000 cfs and reduces overall WSEs within the Sacramento and American River confluence by approximately 1.5 ft.

Table 8. Boundary conditions for baseline scenarios with and without Sacramento Weir Widening

Scenarios	SWW	AEP Event	LAR Inflow (cfs)	Sac R. US Inflow near RM 61.1 (cfs)	Sac R. US Stage near RM 61.1 (ft)	NEMDC Inflow (cfs)	Sac R. DS Stage near RM 59.4 (ft, NAVD88)
S1, NRMP1	w/o SWW	1/200	115,000	6,500	35.77	5,700	34.98
S1, NRMP1	w/o SWW	1/325	160,000	-30,200	36.66	4,200	36.00
S1, NRMP1	w/o SWW	1/350	192,000	-58,100	36.91	3,700	36.48
S2, S12, NRMP2	w/ SWW	1/200	115,000	-9,100	34.29	5,700	33.69
S2, S12, NRMP2	w/ SWW	1/325	160,000	-47,400	34.85	4,200	34.52
S2, S12, NRMP2	w/ SWW	1/350	192,000	-73,700	35.46	3,700	35.28

[1]115,000 cfs represents the 1/200-yr AEP event for LAR according to the Central Valley Hydrology Study (USACE-SPK 2019b)

[2]160,000 cfs represents the 1/325-yr AEP event for LAR according to the Central Valley Hydrology Study (USACE-SPK 2019b)

[3]192,000 cfs represents the 1/350-yr AEP event for LAR according to the Central Valley Hydrology Study (USACE-SPK 2020)

For the scenarios, only the 1/200 AEP event w/o SWW has a positive inflow boundary condition for Sacramento River near RM 61.1. For stability and mass conservation reasons, the boundary condition at Sacramento River RM 61.1 was converted to a stage boundary condition for the scenarios with negative flow. Stage elevations were determined iteratively to achieve the intended flow split at the confluence (i.e., the correct total combined flow at I-Street and the correct reverse flow towards the Sacramento Weir). Table 8 provides both the stage and target flow at Sacramento River near RM 61.1.

5 HEC-RAS 2D MODEL RESULTS

The hydraulic analysis focuses on comparing results between the following scenarios:

- S2 minus S1 – to show the effects of SWW
- S12 minus S1 – to show the effects of ARCF projects
- NRMP1 minus S1 – to determine the individual effects of NRMP sites
- NRMP2 minus S12 – to show the additional effect of NRMP, CVPIA SHIP, and Water forum rearing sites
- NRMP2 minus S1 – to show the cumulative effect of ARCF, NRMP, CVPIA SHIP, and Water forum rearing sites compared to existing conditions

5.1 WSE DIFFERENCES

5.1.1 S2 MINUS S1

To document the WSE effects of SWW, outputs from S2 were compared to outputs from S1. Figures 9 and 10 show the spatial patterns of WSE change for the 160k cfs event, and Figures 11 and 12 show the spatial patterns for the 192 kcfs event. Table 9 summarizes the WSE reductions at select bridge crossings in the lower model domain where levee freeboard is a concern. This comparison shows that the implementation of the SWW project reduces peak WSEs by approximately 1.2-1.8 ft within the Sacramento and American River confluence. This effect diminishes to approximately 0.2-0.3 ft at H-St Bridge and approximately 0.1 ft near Watt Avenue. Outside of the federal leveed reach, the WSE differences due to SWW are negligible.

Table 9. WSE differences due to SWW (i.e., EG with SWW minus EG without SWW)

Figure #'s	Comparison	LAR Inflow (cfs)	H-St Bridge	Guy West Bridge	Howe Ave Bridge	Watt Ave Bridge
9 & 10	S2 minus S1	160,000	-0.33	-0.27	-0.19	-0.15
11 & 12	S2 minus S1	192,000	-0.22	-0.17	-0.12	-0.09

5.1.2 S12 MINUS S1

Figures 13-16 show the combined effects of ARCF projects (American River Contracts 1 through 4, including the mitigation projects and SWW) relative to EG without SWW. The ARCF project produces a large reduction in WSEs through most of the lower model domain. Table 10 summarizes the WSE reductions at a select number of LAR bridges where levee freeboard is a concern. WSEs are reduced by nearly 1 ft by Howe Ave Bridge and 0.75 ft near Watt Ave Bridge. These results show that the ARCF project

does not increase WSEs along federal or non-federal levees. Outside of the federal leveed reach, the WSE differences due to ARCF are minimal and localized.

Table 10. WSE differences due to ARCF projects and SWW (i.e., ARCF with SWW minus EG without SWW)

Figure #'s	Comparison	LAR Inflow (cfs)	H-St Bridge	Guy West Bridge	Howe Ave Bridge	Watt Ave Bridge
13 & 14	S12 minus S1	160,000	-0.36	-0.61	-0.94	-0.73
15 & 16	S12 minus S1	192,000	-0.23	-0.57	-0.92	-0.71

5.1.3 NRMP1 MINUS S1

Figures 17-22 show the how the addition of NRMP sites effect WSEs without including the mixed effects of other projects (i.e., ARCF, CVPIA SHIP, and water forum rearing sites are not included). These results show that the NRMP sites begin to increase WSEs above 0.1 ft relative to existing conditions near RM 3.5 and above. Table 11 summarizes the WSE increases at a select number of LAR bridges. Outside of the federal leveed reach, the WSE differences due to NRMP are negligible.

Table 11. WSE differences isolated to NRMP projects (i.e., EG and NRMP without SWW minus EG without SWW)

Figure #'s	Comparison	LAR Inflow (cfs)	H-St Bridge	Guy West Bridge	Howe Ave Bridge	Watt Ave Bridge
17 & 18	NRMP1 minus S2	115,000	0.16	0.14	0.13	0.21
19 & 20	NRMP1 minus S2	160,000	0.24	0.18	0.17	0.27
21 & 22	NRMP1 minus S2	192,000	0.22	0.13	0.14	0.22

5.1.4 NRMP2 MINUS S12

Figures 23-28 show the WSE differences of the cumulative model (i.e., ARCF, NRMP, CVPIA SHIP, and Water Forum rearing sites) relative to the ARCF project condition. These results show the effect of adding the NRMP, CVPIA, and Water Forum rearing sites. The differences within the federal leveed reach are similar to the NRMP1 minus S2 results since there are few Water Forum rearing sites within this stretch and no CVPIA SHIP sites. Table 12 summarizes the WSE differences at a select number of LAR bridges. Outside of the federal leveed reach, the WSE differences are largely driven by the effects of CVPIA SHIP and Water Forum rearing sites.

Table 12. WSE differences of cumulative results relative to ARCF projects (i.e., Cumulative results with SWW minus ARCF with SWW)

Figure #'s	Comparison	LAR Inflow (cfs)	H-St Bridge	Guy West Bridge	Howe Ave Bridge	Watt Ave Bridge
23 & 24	NRMP2 minus S12	115,000	0.18	0.16	0.15	0.23
25 & 26	NRMP2 minus S12	160,000	0.26	0.21	0.20	0.29
27 & 28	NRMP2 minus S12	192,000	0.25	0.16	0.17	0.25

5.1.5 NRMP2 MINUS S1

Figures 29-34 show the WSE differences of the cumulative model (i.e., ARCF, NRMP, CVPIA SHIP, and Water Forum rearing sites) relative to the existing condition (i.e., EG w/o SWW). These results show the total cumulative impact of ARCF, NRMP, CVPIA, and Water Forum rearing sites on WSEs. The differences within the federal leveed reach show a net reduction in WSE for 115,000 cfs and 160,000 cfs. At 192,000 cfs, there is a net reduction in WSE nearly everywhere within the federal leveed reach except for a short stretch near RM 6 where WSE increases are approximately 0.05 to 0.15 ft. This is not a location of incipient levee overtopping. Table 13 summarizes the WSE differences at a select number of LAR bridges.

Table 13. WSE differences of cumulative results relative to existing conditions (i.e., Cumulative results with SWW minus EG without SWW)

Figure #'s	Comparison	LAR Inflow (cfs)	H-St Bridge	Guy West Bridge	Howe Ave Bridge	Watt Ave Bridge
29 & 30	NRMP2 minus S1	115,000	-0.24	-0.40	-0.70	-0.45
31 & 32	NRMP2 minus S1	160,000	-0.08	-0.41	-0.74	-0.44
33 & 34	NRMP2 minus S1	192,000	0.05	-0.42	-0.74	-0.45

Outside of the federal leveed reach, there are no increases in WSE above 0.1 ft adjacent to a non-federal levee for 160,000 cfs and 192,000 cfs. At a flow of 115,000 cfs, there is an increase in WSE of 0.1-0.15 ft at RM 18.5 near a non-federal levee, but the wetted extent is over 50 ft from the toe of the levee, and there is over 10 ft of freeboard. All other WSE increases outside of the federal leveed reach do not impact non-federal levees and occur in areas with sufficient freeboard (i.e., greater than 3-ft of freeboard at the peak design discharge of 160,000 cfs). See Section 5.2 for more detail on freeboard calculations and results.

5.2 VELOCITY DIFFERENCES

5.2.1 S2 MINUS S1

To assess the velocity effects of SWW, outputs from S2 were compared to outputs from S1. Figures 35 and 36 show the spatial patterns of velocity change for the 160,000 event. With SWW, velocity increases within the channel by approximately 0.6 ft/s near Jibboom St and I-5 bridges, and the velocity differences diminish to less than 0.1 ft/s near Guy West Bridge and the Fairbairn Water Treatment Plant.

5.2.2 S12 MINUS S1

Figures 37-38 show the effects of ARCF with SWW. In general, the velocity differences show an increase in velocity of 0.3-0.6 ft/s within the channel downstream of Paradise Bend due to SWW, a significant decrease in velocity of up to 2 ft/s on the left bank and within the thalweg from RM 6 to RM 7 (due to Site 2-3), an increase of 0.2-0.3 ft/s within the channel upstream of Howe Ave Bridge (due to lower tailwater conditions from SWW and Site 2-3), and an increase in velocity of 0.4 ft/s on the outside bend adjacent to Arden Pond (RM 12).

5.2.3 NRMP1 MINUS S2

Figures 39-40 show the effects of the NRMP sites. In general, the velocity differences tend to be small and localized except for a few areas. From RM 2.5 to RM 5.5, the channel velocities are increased by 0.5 to 1 ft/s due to the restoration sites at Woodlake and Bushy Lake. In addition to the channel velocity increases, the increased roughness on the floodplain causes an increase in velocity along the North Levee adjacent to those sites (at RM 3 to 3.5, at RM 4, and at RM 5).

5.2.4 NRMP2 MINUS S12

Figures 41-42 show the effects of the NRMP, CVPIA SHIP, and Water Forum rearing sites. Within the lower domain (Figure 41), velocity differences are similar to NRMP1 minus S2 conditions, with the highest velocity differences near the Woodlake and Bushy Lake restoration sites (RM 2.5 to 5.5, see Figure 41). From RM 2.5 to RM 5.5, the channel velocities are increased by 0.5 to 1 ft/s due to the restoration sites at Woodlake and Bushy Lake. In addition to the channel velocity increases, the increased roughness on the floodplain also causes an increase in velocity along the North Levee adjacent to those sites (RM 3 to 3.5 and at RM 4 and at RM 5). Within the upper domain (Figure 42), the largest velocity increases occur adjacent to the CVPIA SHIP and Water Forum rearing sites.

5.2.5 NRMP2 MINUS S1

Figures 43-44 show the cumulative effects of ARCF, NRMP, CVPIA SHIP, and Water Forum rearing sites. Figures 43 shows significant channel velocity increases from RM 0 to 5 of approximately 1 ft/s due to SWW and the Woodlake and Bushy Lake restoration sites. Localized increases of velocity along the levee occur on both banks from RM 3 to 3.5 and RM 4 to 5. Velocity differences upstream from RM 6 to RM 12.5 are largely driven by ARCF projects. A significant decrease in velocity of up to 2 ft/s occurs on the left bank and within the thalweg from RM 6 to RM 7 (due to Site 2-3), an increase of 0.5-1.0 ft/s within the channel upstream of Howe Ave Bridge (due to lower tailwater conditions from SWW and Site 2-3), and an increase in velocity of 0.4 ft/s on the outside bend adjacent to Arden Pond (RM 12). Outside of the federal leveed reach, the velocity differences are mainly driven by CVPIA SHIP sites and Water Forum rearing sites.

5.3 LONGITUDINAL WSE AND FREEBOARD COMPARISONS

Figures 45 and 46 show how WSEs and levee / high ground elevations were extracted from the 2D model and DEM to create longitudinal profiles and calculate freeboard [1] values. Levee and high ground centerlines (i.e., ground adjacent to structures) were delineated (shown as orange points in Figures 45 and 46) and WSEs from the HEC-RAS outputs were extracted (shown as blue points in Figures 45 and 46) to plot the longitudinal profiles (See Figures 47 and 48) and calculate WSE differences and freeboard values (see Figures 49 through 52).

Figures 47 shows the longitudinal profile of 160,000 cfs results for NRMP2 and S1 within the lower domain model. This figure shows a clear separation in WSE between NRMP2 and S1 from RM 0 to RM 10 due to

[1] Freeboard is defined as the vertical distance between the WSE and the levee crest, or adjacent high ground elevation.

SWW and ARCF (i.e., Site 2-3). The spikes in the levee / high ground elevations occur at bridge crossings within the lower domain model.

Figure 48 shows the longitudinal profile of 160,000 cfs results for NRMP2 and S1 within the upper domain model. WSE differences in this figure are not discernable. Elevations along the north bank of the river vary widely with many areas having over 20 ft of freeboard relative to the 160,000 cfs WSE. The WSE profile shows some areas with stair-step like features. Since WSE results are extracted at the edge of the wetted extent and nearest to the adjacent levee / high ground, these stair-step like features are due to drops in WSE that occur due to flow obstructions like bridge abutments and mining tailings.

Figures 49 and 50 show the WSE differences between NRMP2 and S1 and freeboard values along the north bank of the river. Figure 49 shows the results within the lower model domain and Figure 50 shows the results within the upper model domain. The cumulative model results (i.e., NRMP2) show that WSEs have been reduced throughout the federal leveed reach except for the 192,000 cfs event at a valley distance upstream of 5-6 miles. Outside of the federal leveed reach, WSE increases do occur, but freeboard is generally much greater than 20 ft and never lower than 3-ft for the 160,000 cfs event where WSE increases occur.

Figures 51 and 52 show the WSE differences between NRMP2 and S1 and freeboard values along the south bank of the river. Figure 51 shows the results within the lower model domain and Figure 52 shows the results within the upper model domain. The cumulative model results (i.e., NRMP2) show that WSEs have been reduced throughout the federal leveed reach except for the 192,000 cfs event at a valley distance upstream of 5-6 miles. Outside of the federal leveed reach, WSE increases do occur, but freeboard is never lower than 3-ft for the 160,000 cfs event and WSEs increases are less than 0.1 ft adjacent to non-federal levees.

6 SUMMARY OF CONCLUSIONS

This hydraulic analysis found that the NRMP sites, when analyzed alone, increased WSEs by 0.15-0.25 ft within the federal leveed reach upstream of RM 3.5 (See Figures 17-22 and Table 11). The NRMP sites had negligible impact on WSEs upstream of the federal levees. When combined with the ARCF, CVPIA-SHIP, and Water Forum rearing sites, the cumulative result was a net reduction in WSEs for all three flows (115 kcfs, 160 kfcs, and 192 kcfs) throughout most of the federal leveed reach. A small exception occurred from RM 5.5 to 6.5 for the 192 kcfs event, where WSEs increased by 0.5-1.5 ft in the cumulative model. This is not a location of incipient levee overtopping, and the areas with lowest freeboard (approximately RM 7 to 11.5) still show a net reduction in WSE at all flows for the cumulative model. Upstream of the federal levees, the cumulative model shows that no WSE increases greater than 0.1 ft occur adjacent to non-federal levees and surrounding areas have greater than 3 ft of freeboard for the 160,000 cfs peak design discharge.

Several locations with potential velocity impacts were noted. The restoration sites at Woodlake and Bushy Lake increased velocities in the channel and along the levees from RM 3 to 5.5. Further analysis will be needed to determine if the velocity differences cause an impact to the channel bank and levees. If an

impact is found, the conceptual designs will need to be modified to reduce those velocity impacts. Lastly, 4 NRMP sites were removed from the analysis due to velocity and WSE impacts. Figure 53 shows the locations of those sites and the 160,000 cfs velocity differences. For projects to occur at these 4 sites, further analysis is required to reduce their impacts through some combination of modifying the project footprint, reducing the amount of mature tree plantings, and developing a grading plan to reduce velocity and WSE impacts.

7 REFERENCES

cbec, inc., 2018. LAR Current Condition DEM and 2D Model Development Project – Current Conditions DEM Report. Prepared for The Water Forum and The Sacramento Area Flood Control Agency.

cbec, inc., 2019. LAR Current Condition DEM and 2D Model Development Project – Flood Flow Hydrodynamic Modeling Report. Prepared for The Water Forum and The Sacramento Area Flood Control Agency. cbec Project #17-1005.

cbec, inc., 2020a. Lower American River Salmonid Habitat Improvement Project. Future Sites Flood Modeling - Phase 2 – Effects of Woody Material and Riparian Plantings. Prepared for the Sacramento Water Forum and the Sacramento Area Flood Control Agency. cbec Project #18-1025-2. April 28, 2020.

cbec, inc., 2020b. Lower American River Salmonid Rearing Habitat Enhancement Project Identification and Prioritization Report. Prepared for the Sacramento Water Forum and the U.S. Fish and Wildlife Service. cbec Project #18-1027. July 21, 2020.

cbec, inc., 2021a. Lower American River Hydrodynamic Model Development Report - SAFCA Lower American River 2D Cumulative Impacts Model Project. Prepared for the Sacramento Area Flood Control Agency and the U.S. Army Corps of Engineers. cbec Project #20-1013. September 17, 2021.

cbec, inc., 2021b. Lower American River ARCF Hydraulic Impact Scenario Results – Round 2. SAFCA Lower American River Hydraulic Impact Scenario Testing Project. Prepared for the Sacramento Area Flood Control Agency and the U.S. Army Corps of Engineers. cbec Project #20-1041. August 06, 2021.

Quantum Spatial, 2018. American River, California Topobathymetric LiDAR & Digital Imagery Technical Data Report. Prepared for cbec inc. eco engineering.

SCDRP, 2021. American River Parkway – Natural Resources Management Plan. Public Review Draft. Prepared for Sacramento County and Sacramento County Regional Parks. March 2021.

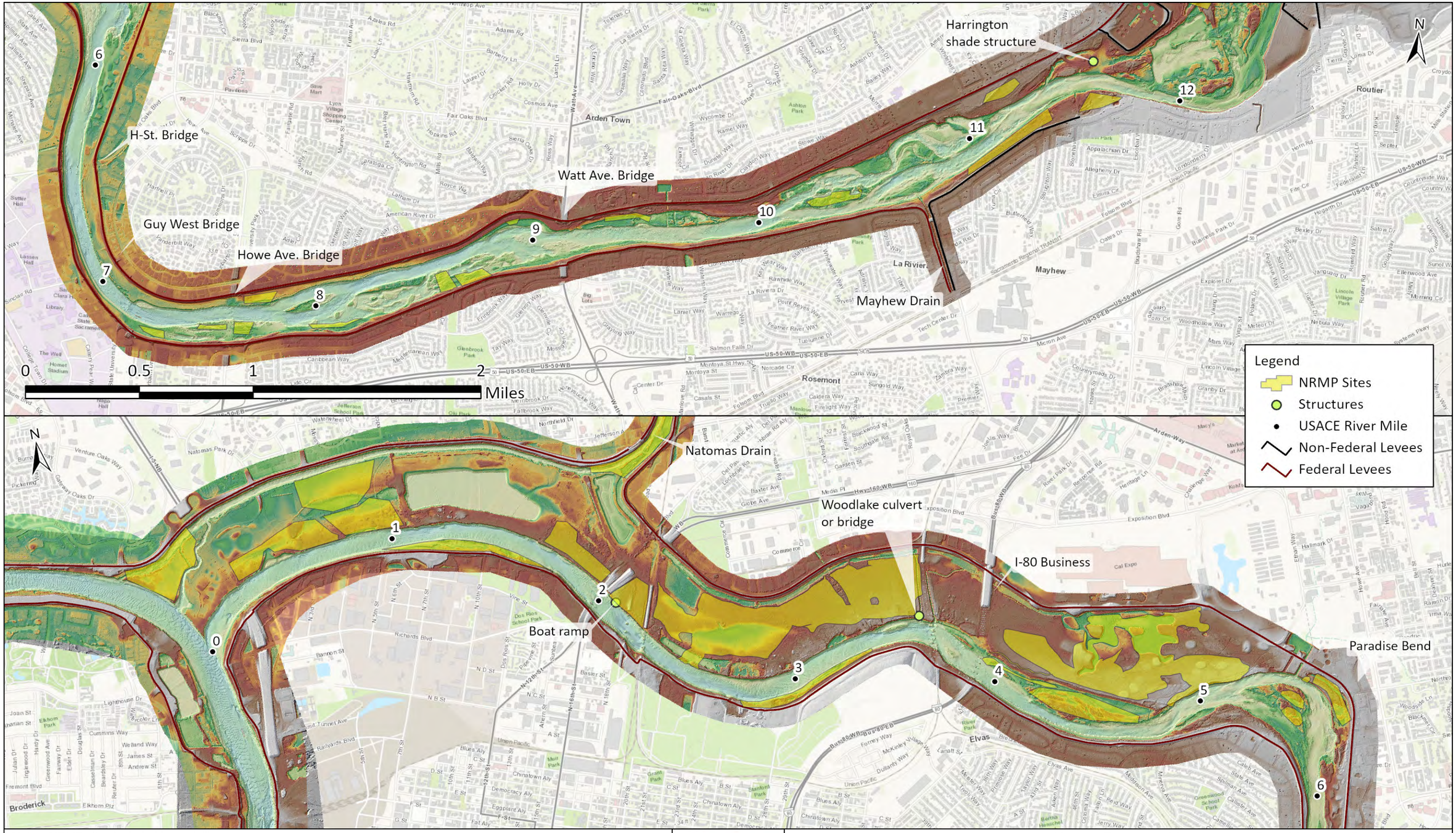
USACE-SPK, 2018. Memorandum for File: “HEC-RAS Release #6.1”. Hydraulic Technical Memo No. 03a. Prepared by CESPK-ED-HA. 03-Sep-2018

USACE-SPK, 2019a. Memorandum for File: “HEC-RAS Release #6.2 Model Updates”. Hydraulic Technical Memo No. 06. Prepared by CESPK-ED-HA. 05-Jul-2019

USACE-SPK, 2019b. Memorandum for Record: “CVHS Hydrograph Package for HEC-RAS Model Inputs”. Prepared by CESPK-ED-HH. 20-Feb-2019

USACE-SPK, 2020. Hydrology Technical Memorandum: For Developing WRDA 2016 Water Surface Profiles. 10-Apr-2020

FIGURES

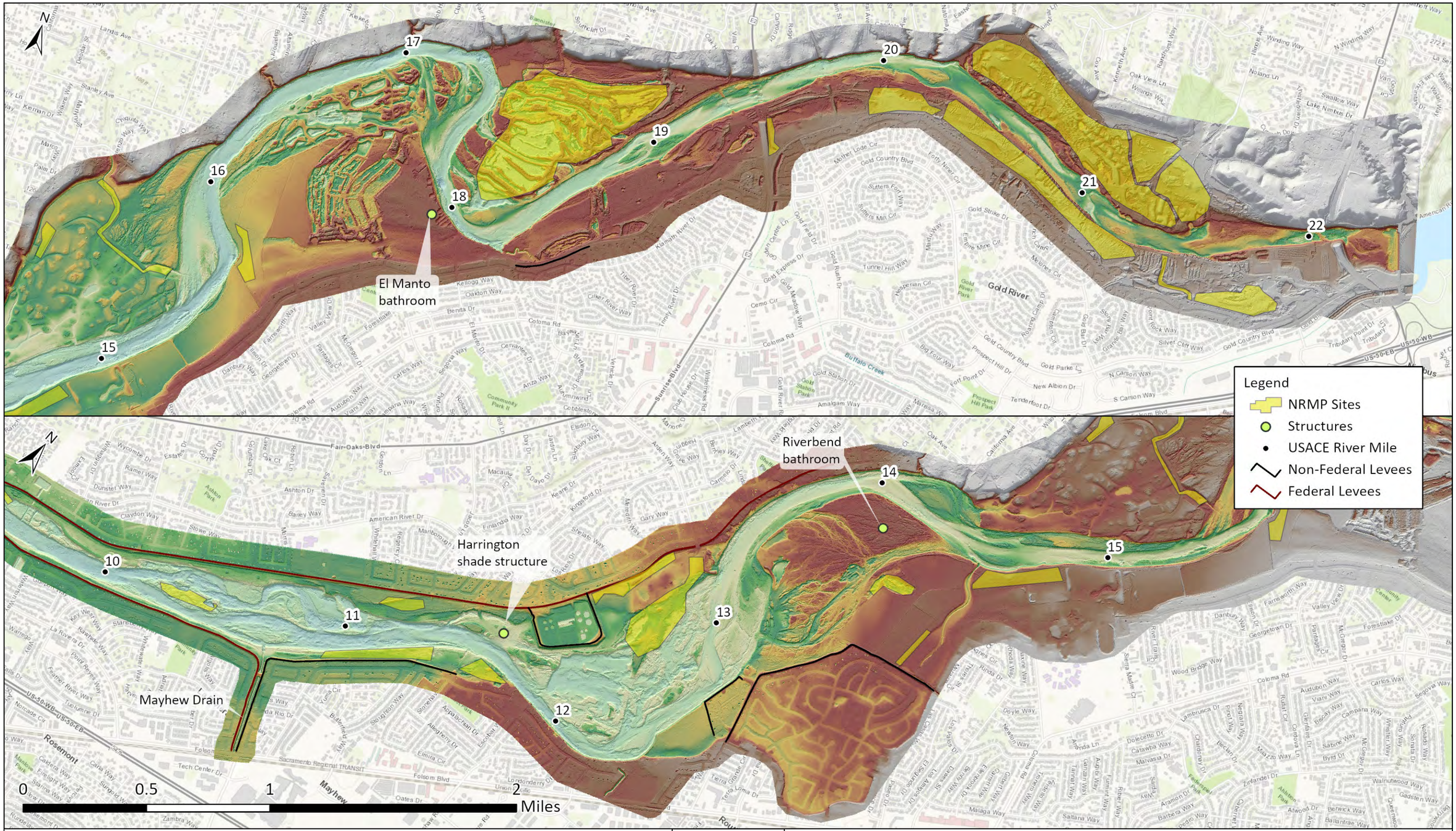


Notes: NRMP sites included in modelling

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
NRMP Sites – Lower Domain

Project No. 21−1023	Created By: MNC	**Figure 1**

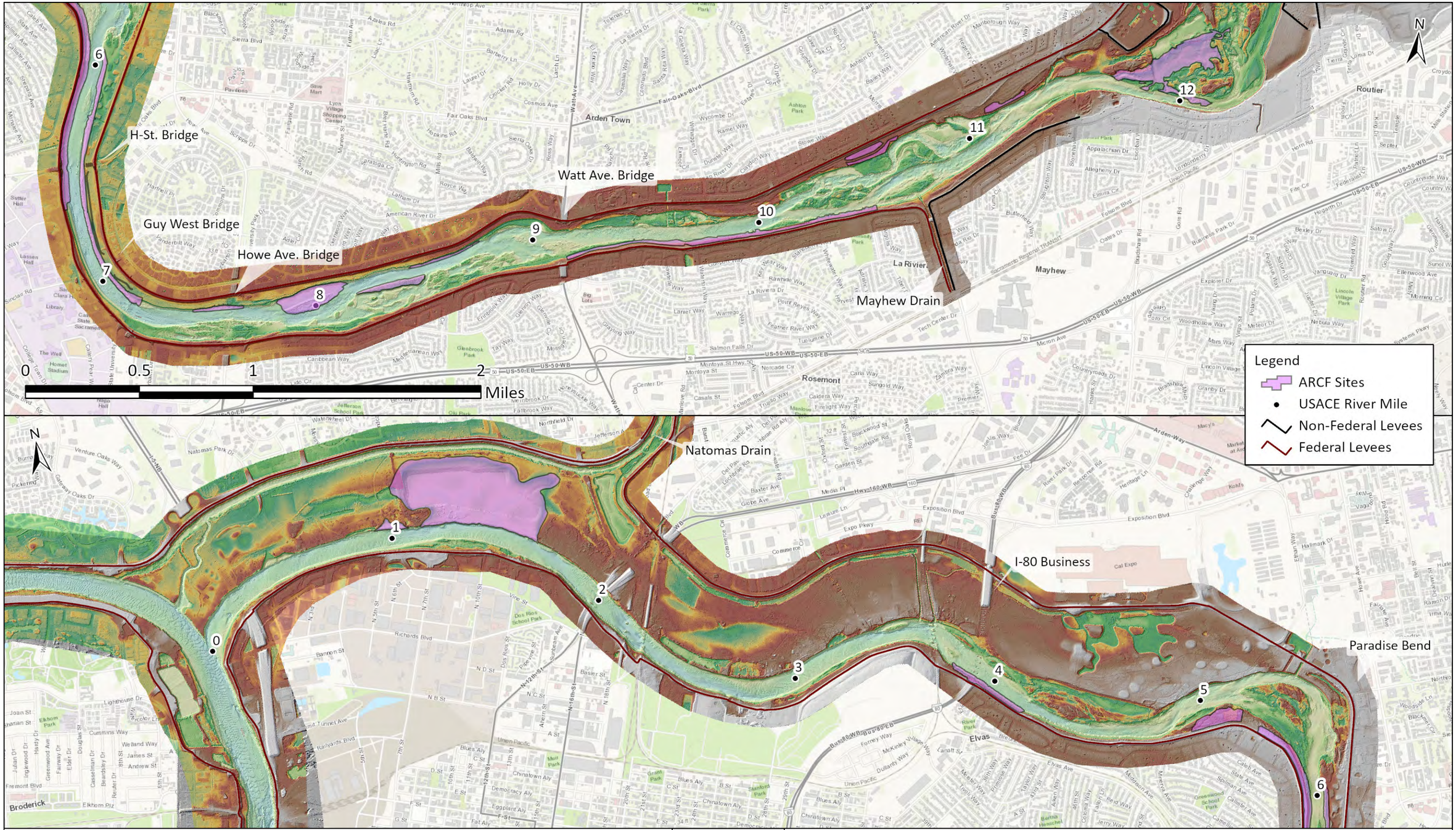


Notes: NRMP sites included in modelling

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
NRMP Sites – Upper Domain

Project No. 21−1023	Created By: MNC	**Figure 2**

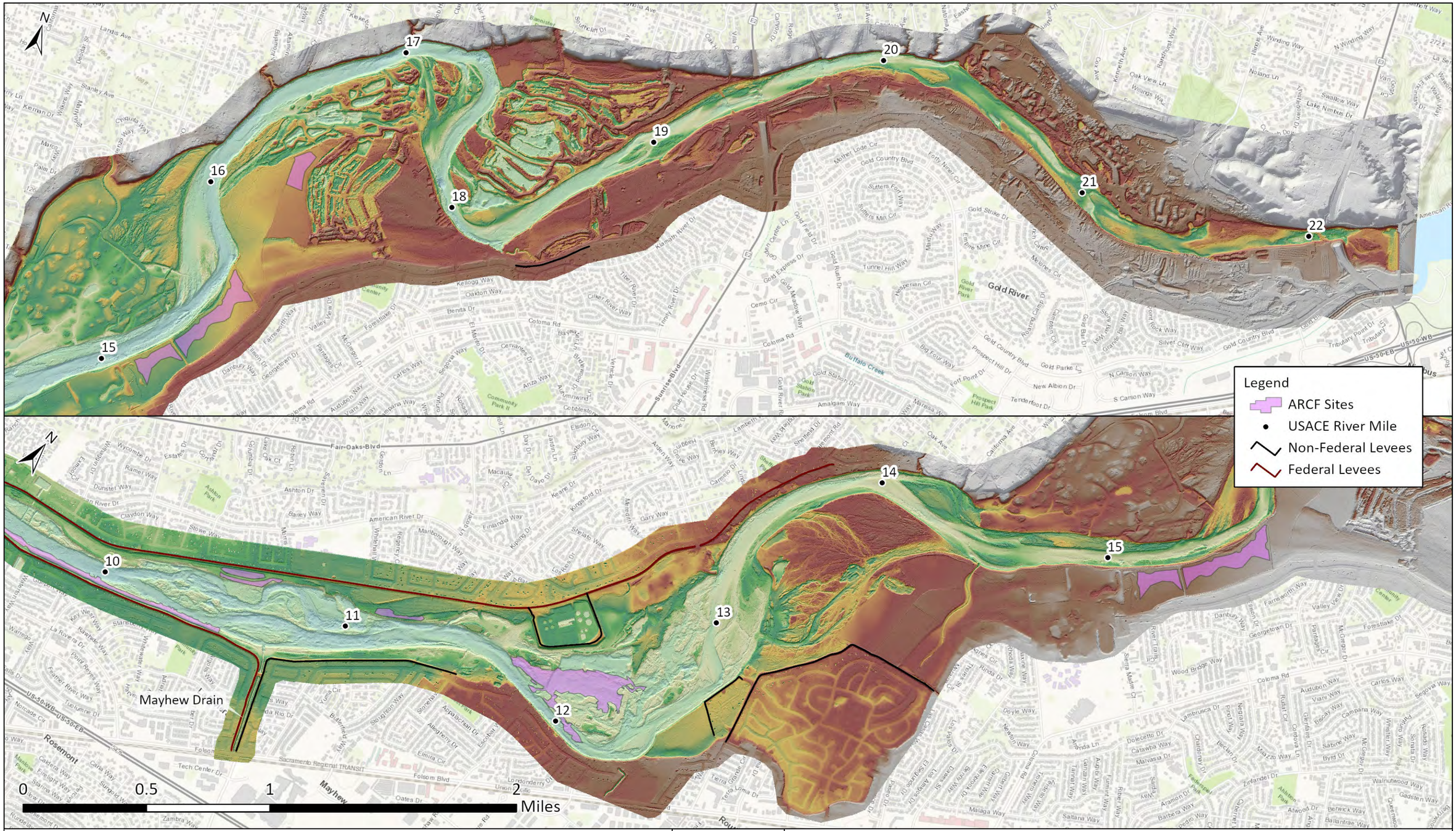


Notes: ARCF sites included in modelling

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
ARCF Sites – Lower Domain

Project No. 21−1023	Created By: MNC	**Figure 3**



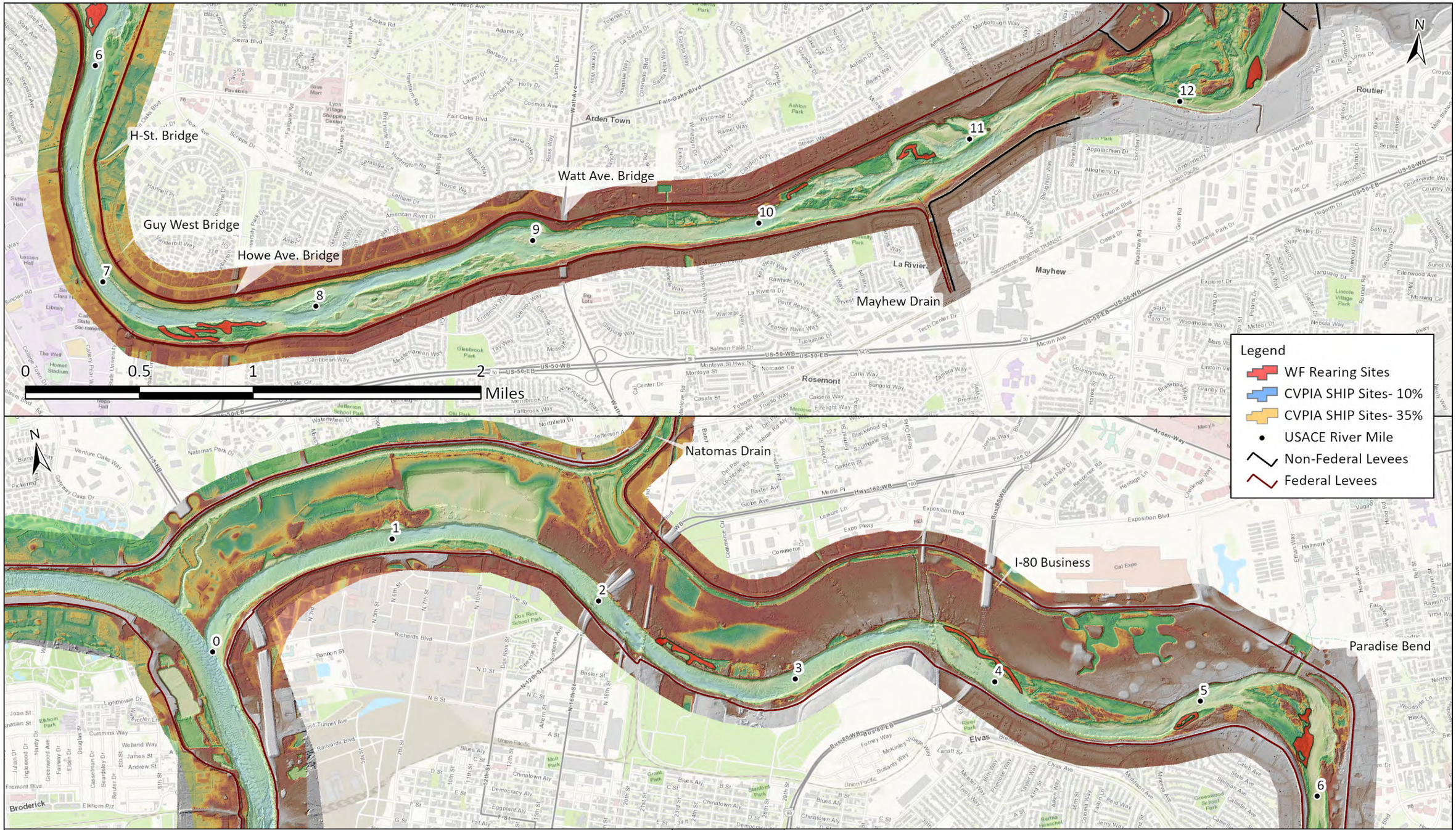
Notes: ARCF sites included in modelling

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

ARCF Sites – Upper Domain

Project No. 21−1023	Created By: MNC	**Figure 4**

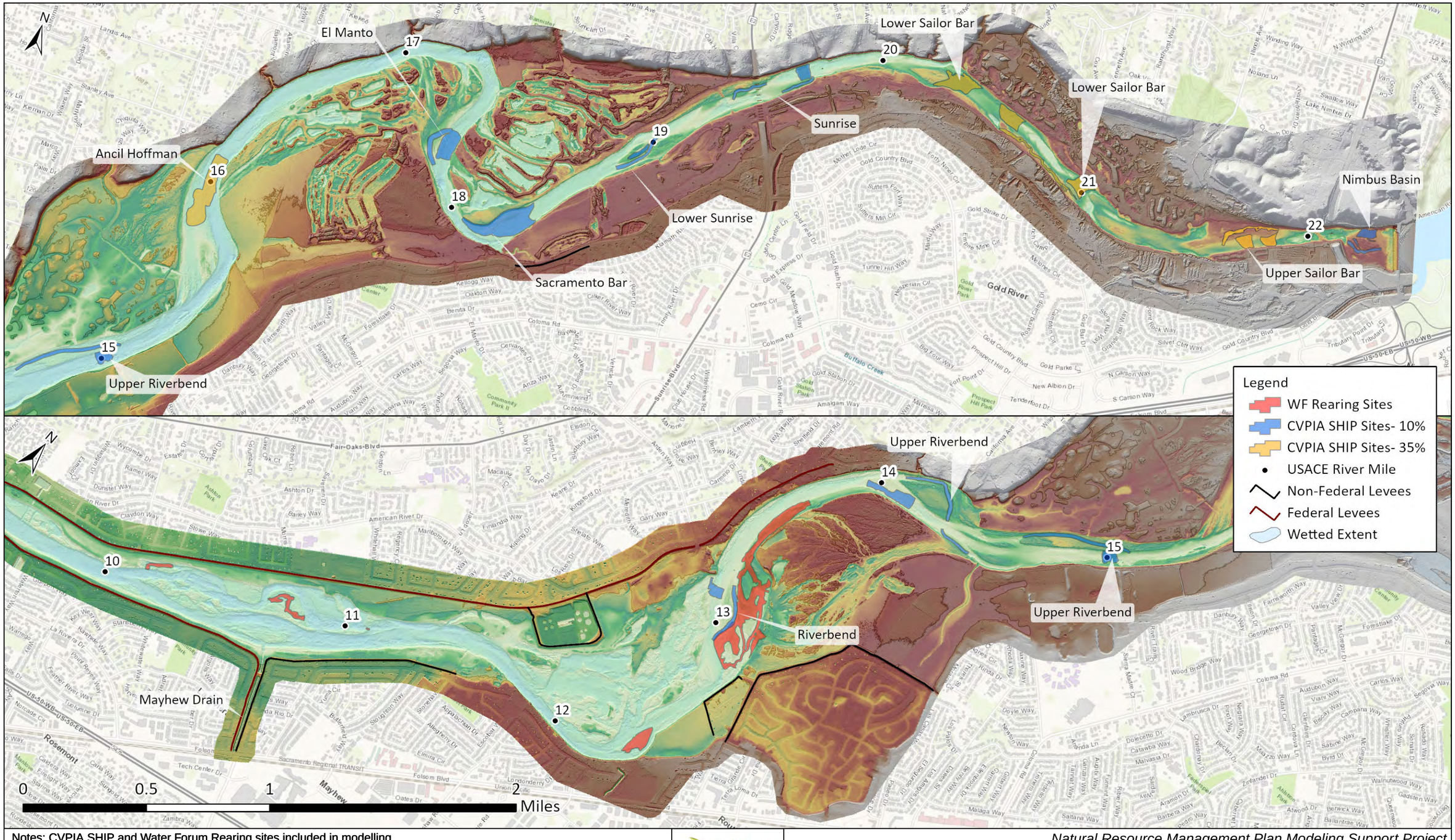


Notes: CVPIA SHIP and Water Forum Rearing sites included in modelling

Natural Resource Management Plan Modeling Support Project

CVPIA SHIP and Water Forum Rearing Sites – Lower Domain

Project No. 21−1023	Created By: MNC	**Figure 5**

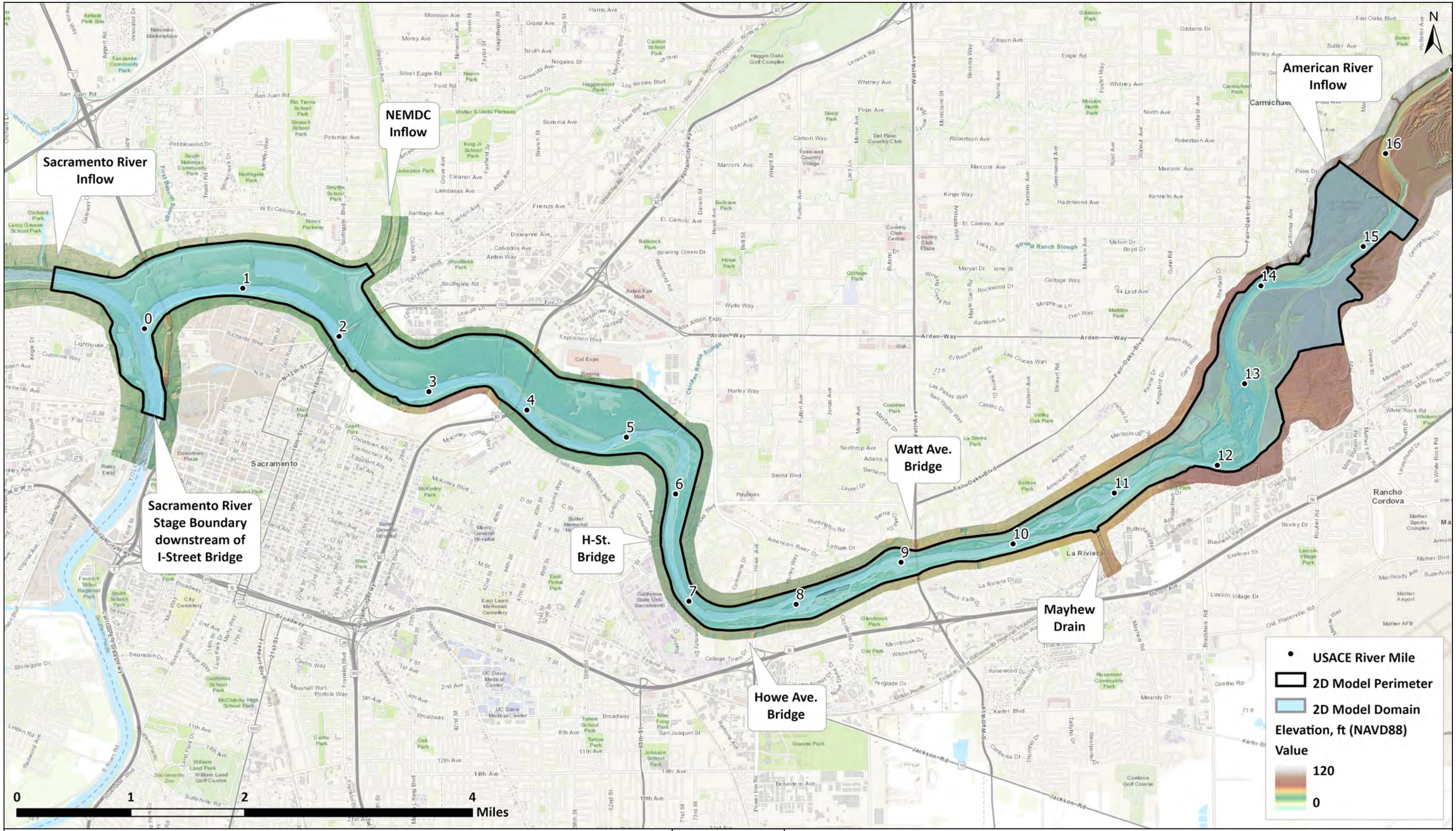


Notes: CVPIA SHIP and Water Forum Rearing sites included in modelling

Natural Resource Management Plan Modeling Support Project

CVPIA SHIP and Water Forum Rearing Sites – Upper Domain

Project No. 21−1023	Created By: MNC	**Figure 6**



Notes: Lower domain − curvilinear mesh HEC−RAS model (cbec 2021a)

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
Lower Model Domain

Project No. 21−1023	Created By: MDW	**Figure 7**

RM 0
RM 1
RM 2
RM 3
RM 4
RM 5
RM 6
RM 7
RM 8
RM 9
RM 10
RM 11
RM 12
RM 13
RM 14
RM 15
RM 16
RM 17
RM 18
RM 19
RM 20
RM 21
RM 22
RM 23

Legend
Non-Federal levees
Federal levees
River Mile (RM)
Model boundary
Elevation
(ft, NAVD88)
High : 120
Low : 0

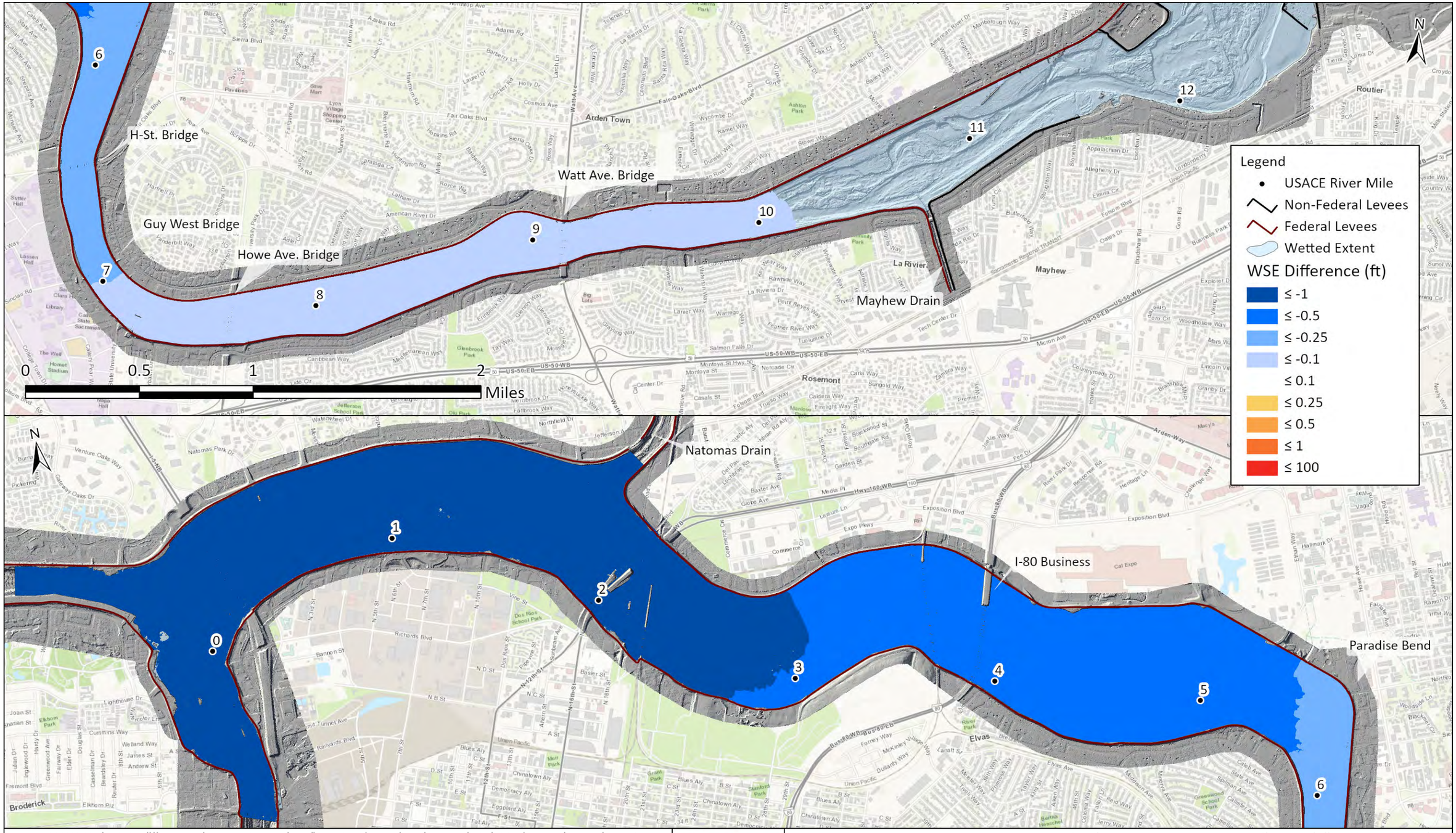
0 2 4 6 8 Miles

Notes: Upper domain – gridded mesh HEC–RAS model (cbec 2019a)

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
Upper Model Domain

Project No. 21–1023 | Created By: MDW | **Figure 8**



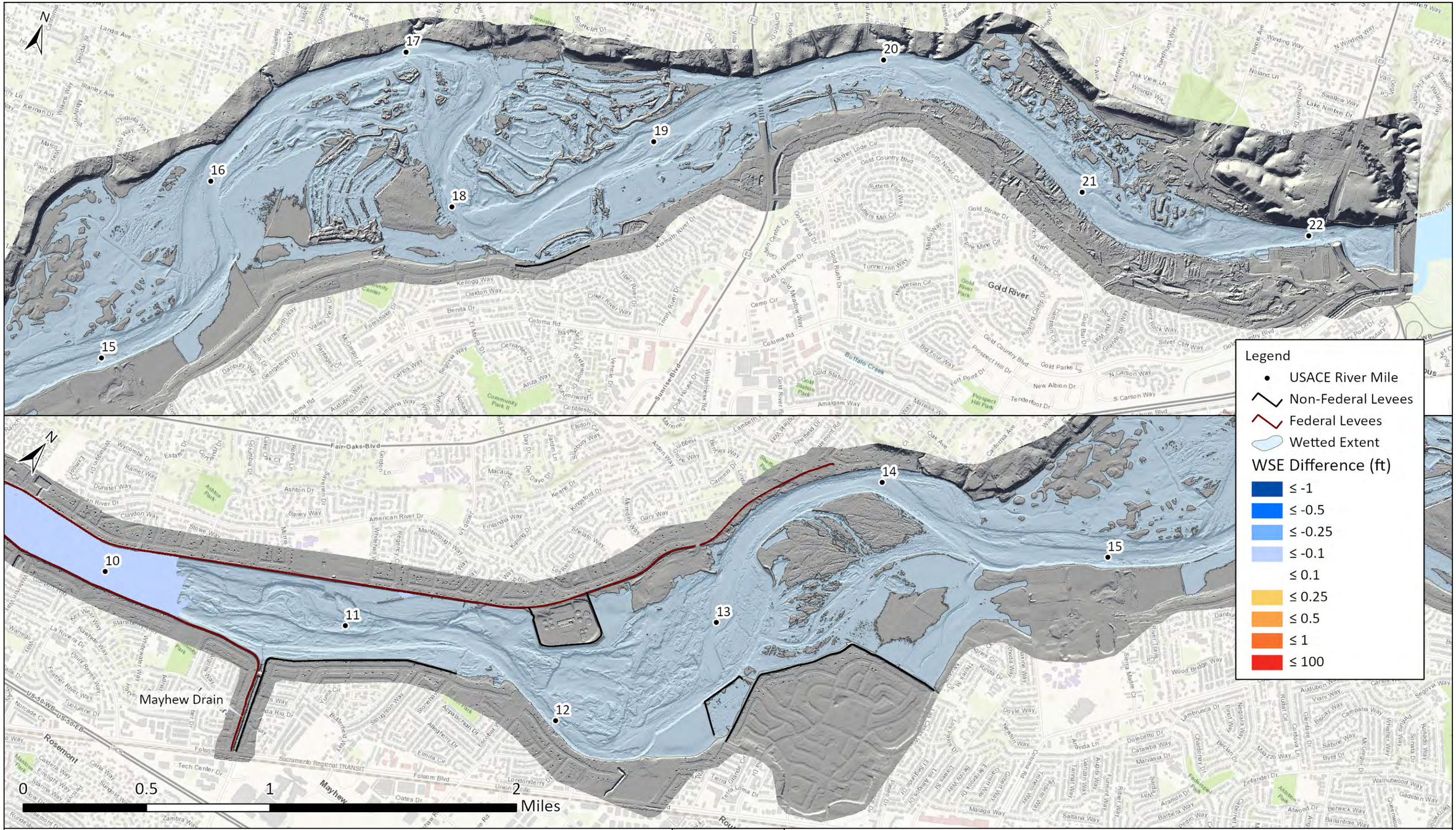
Notes: 160,000 cfs WSE differences between Scenario 2 (i.e., EG w/ SWW) and Scenario 1 (EG w/o SWW): S2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Scenario 2 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 9**



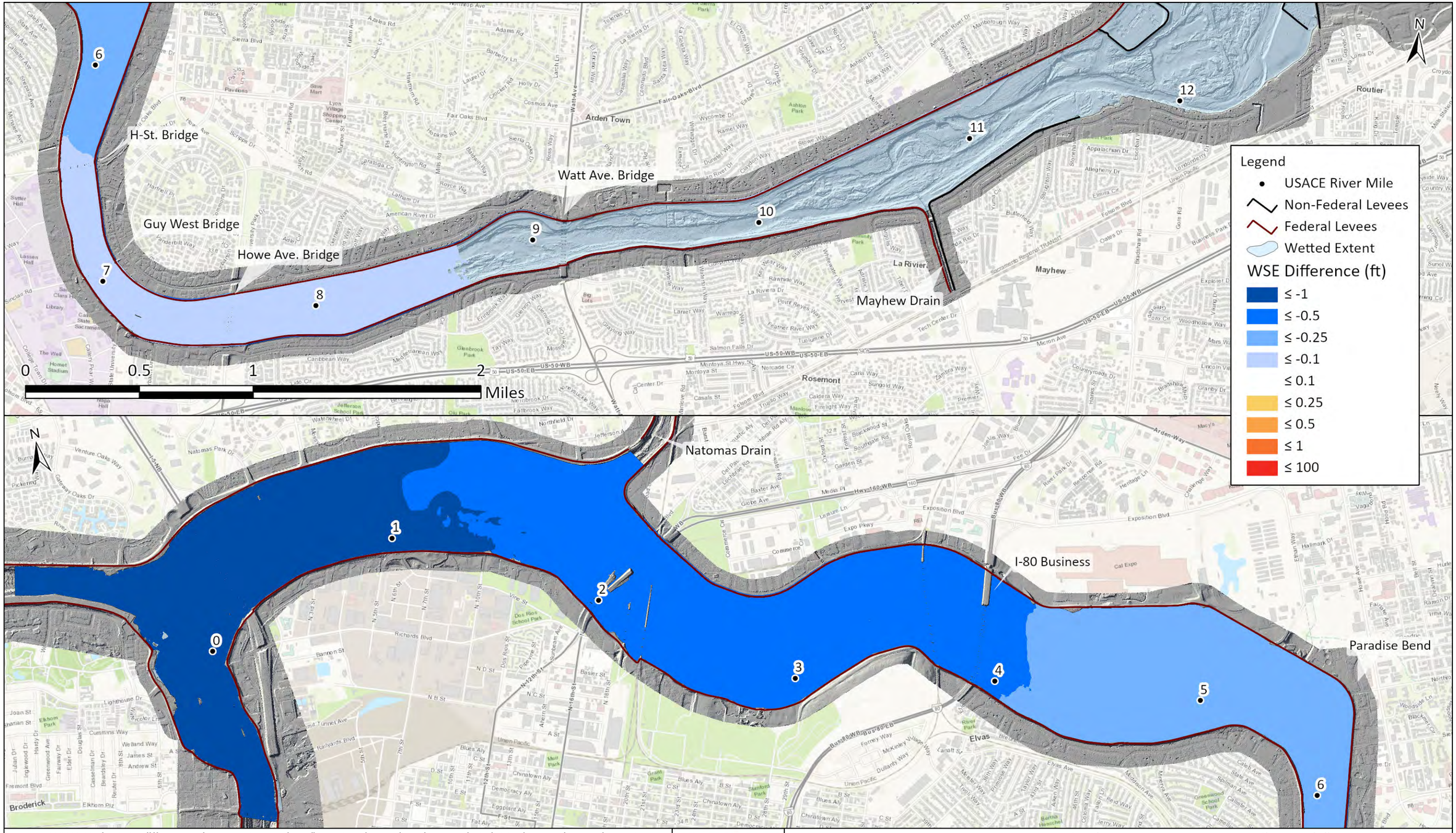
Notes: 160,000 cfs WSE differences between Scenario 2 (i.e., EG w/ SWW) and Scenario 1 (EG w/o SWW): S2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain Scenario 2 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 10**



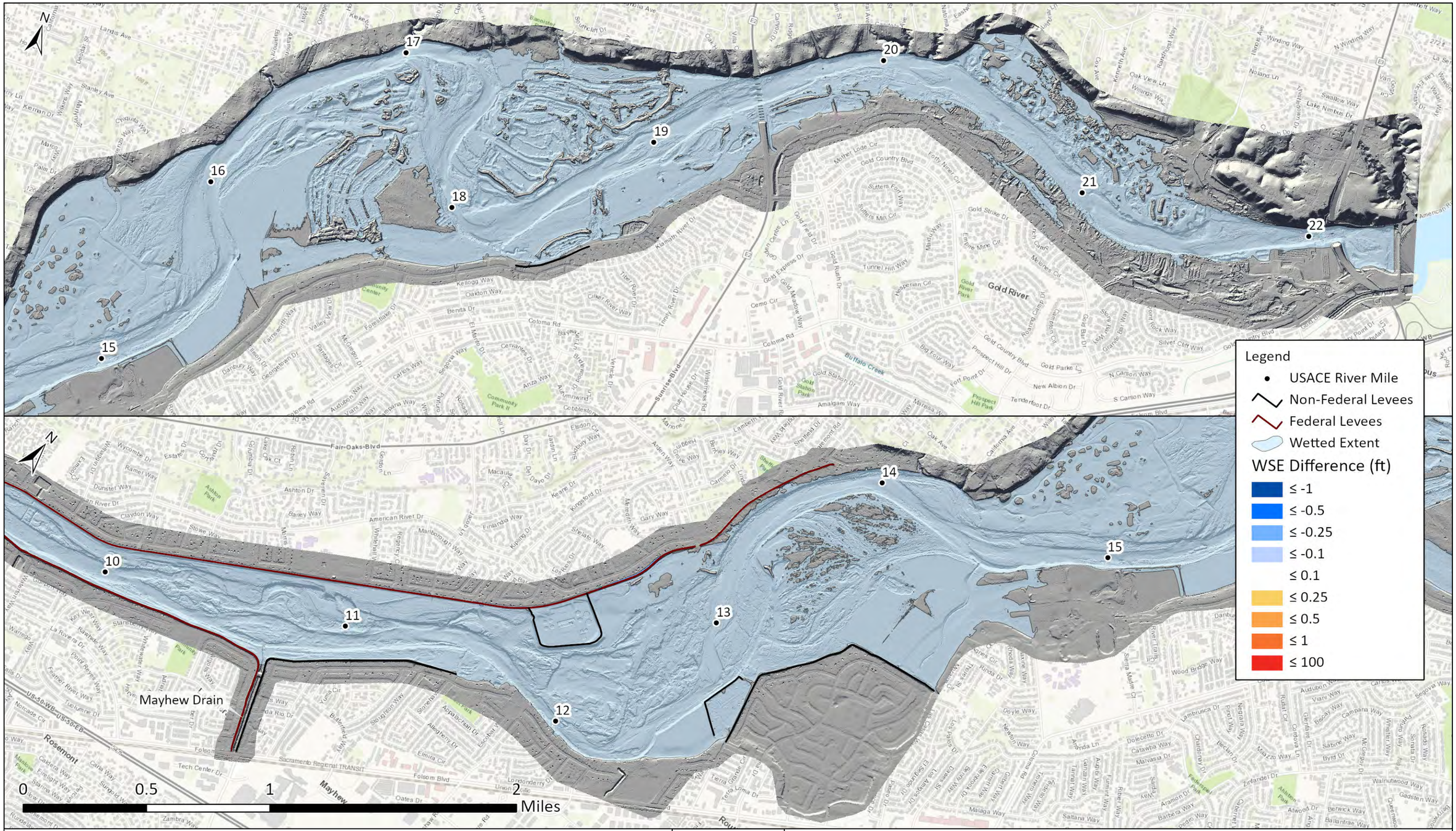
Notes: 192,000 cfs WSE differences between Scenario 2 (i.e., EG w/ SWW) and Scenario 1 (EG w/o SWW): S2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Scenario 2 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 11**



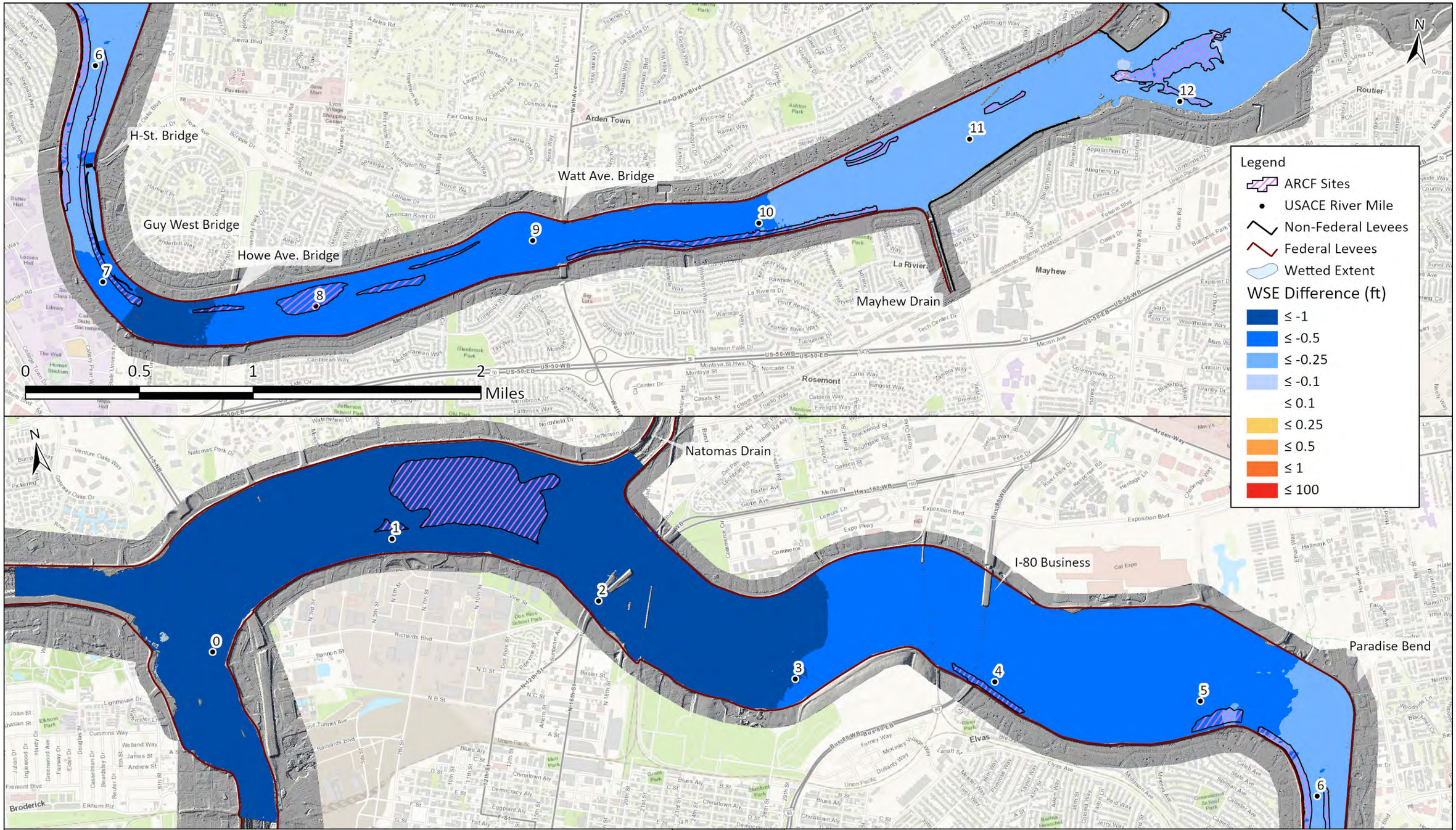
Notes: 192,000 cfs WSE differences between Scenario 2 (i.e., EG w/ SWW) and Scenario 1 (EG w/o SWW): S2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain Scenario 2 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 12**



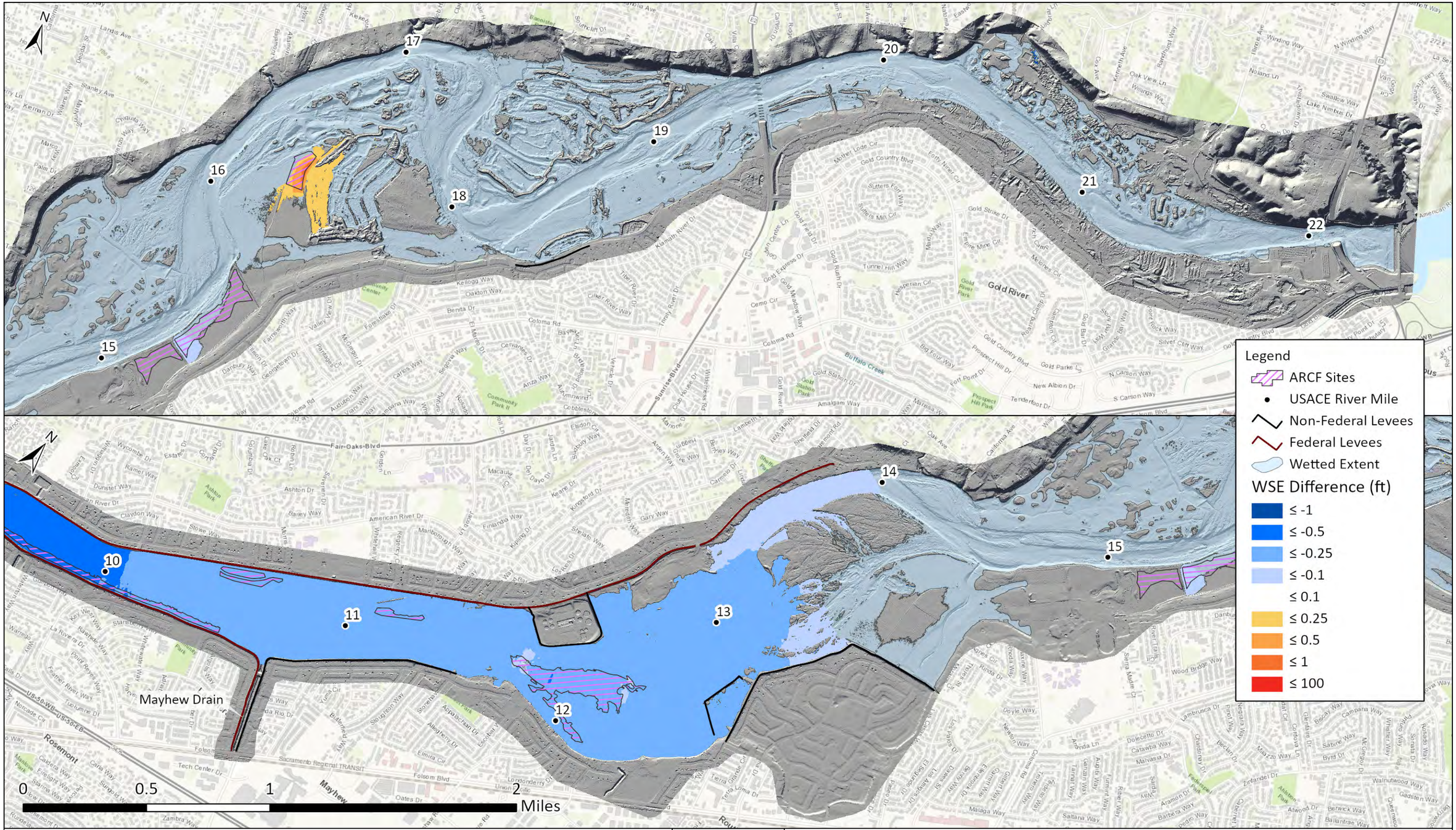
Notes: 160,000 cfs WSE differences between Scenario 12 (i.e., ARCF w/ SWW) and Scenario 1 (EG w/o SWW): S12 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Scenario 12 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 13**



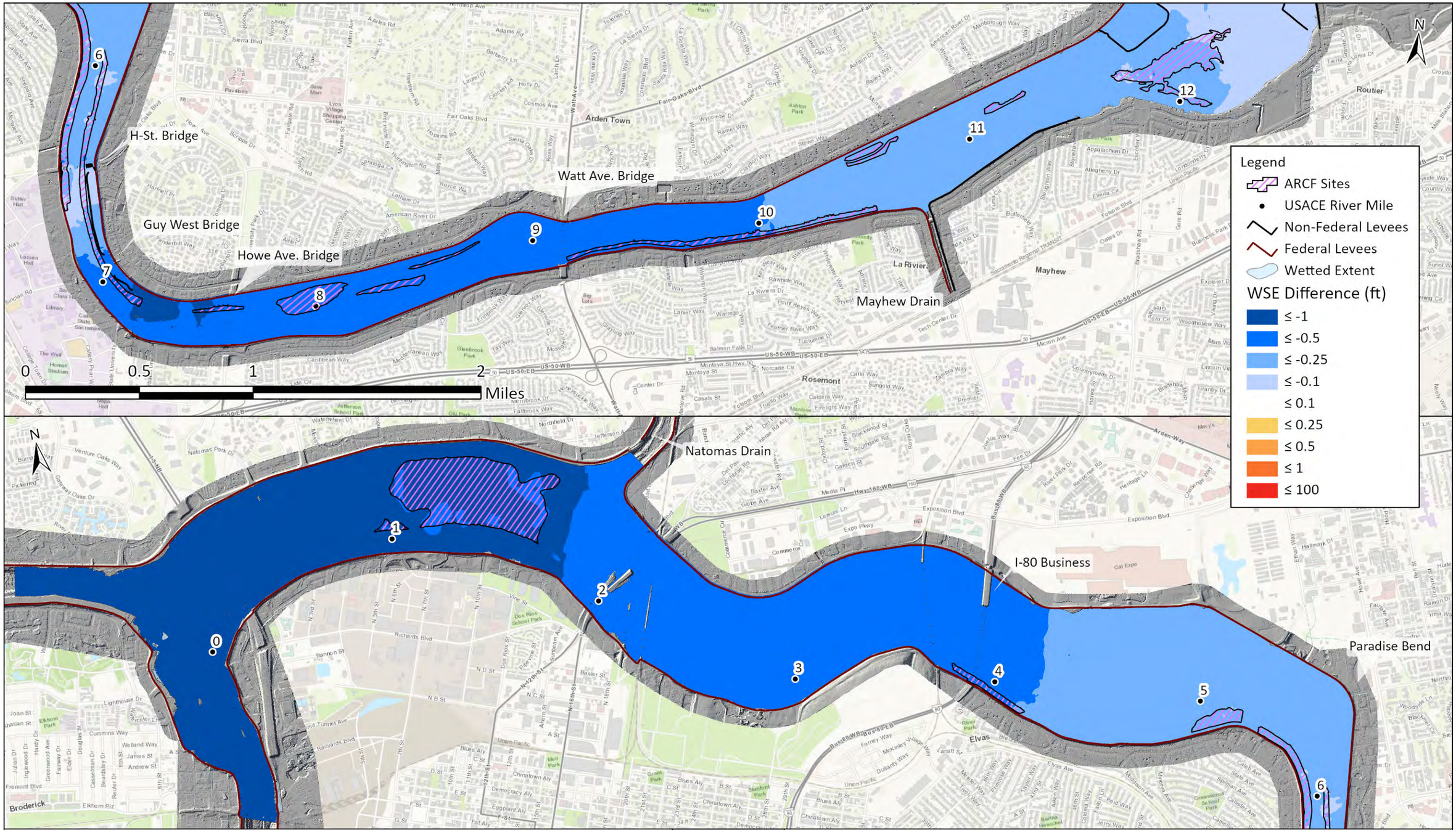
Notes: 160,000 cfs WSE differences between Scenario 12 (i.e., ARCF w/ SWW) and Scenario 1 (EG w/o SWW): S12 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain Scenario 12 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 14**



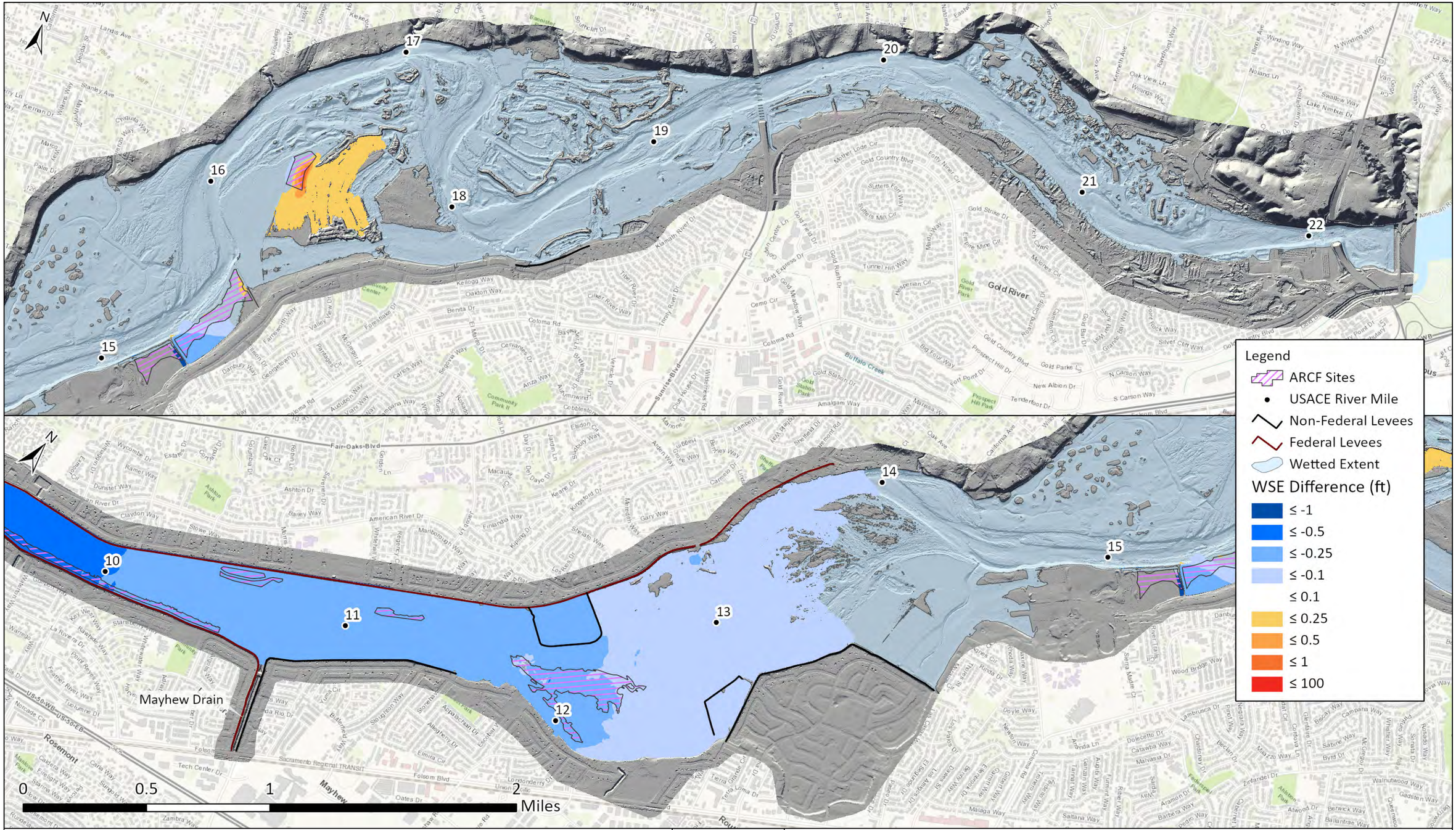
Notes: 192,000 cfs WSE differences between Scenario 12 (i.e., ARCF w/ SWW) and Scenario 1 (EG w/o SWW): S12 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Scenario 12 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 15**



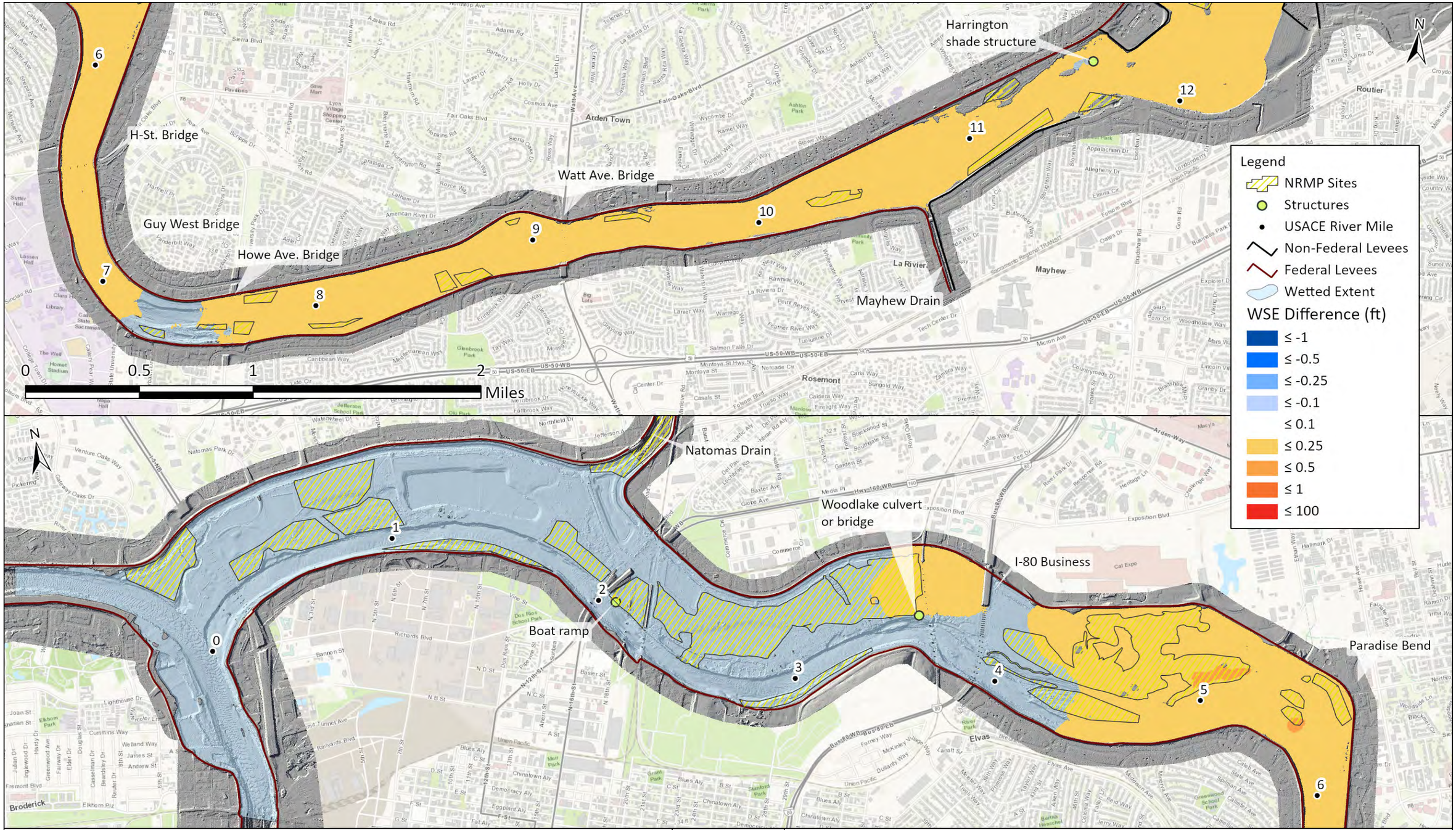
Notes: 192,000 cfs WSE differences between Scenario 12 (i.e., ARCF w/ SWW) and Scenario 1 (EG w/o SWW): S12 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain Scenario 12 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 16**

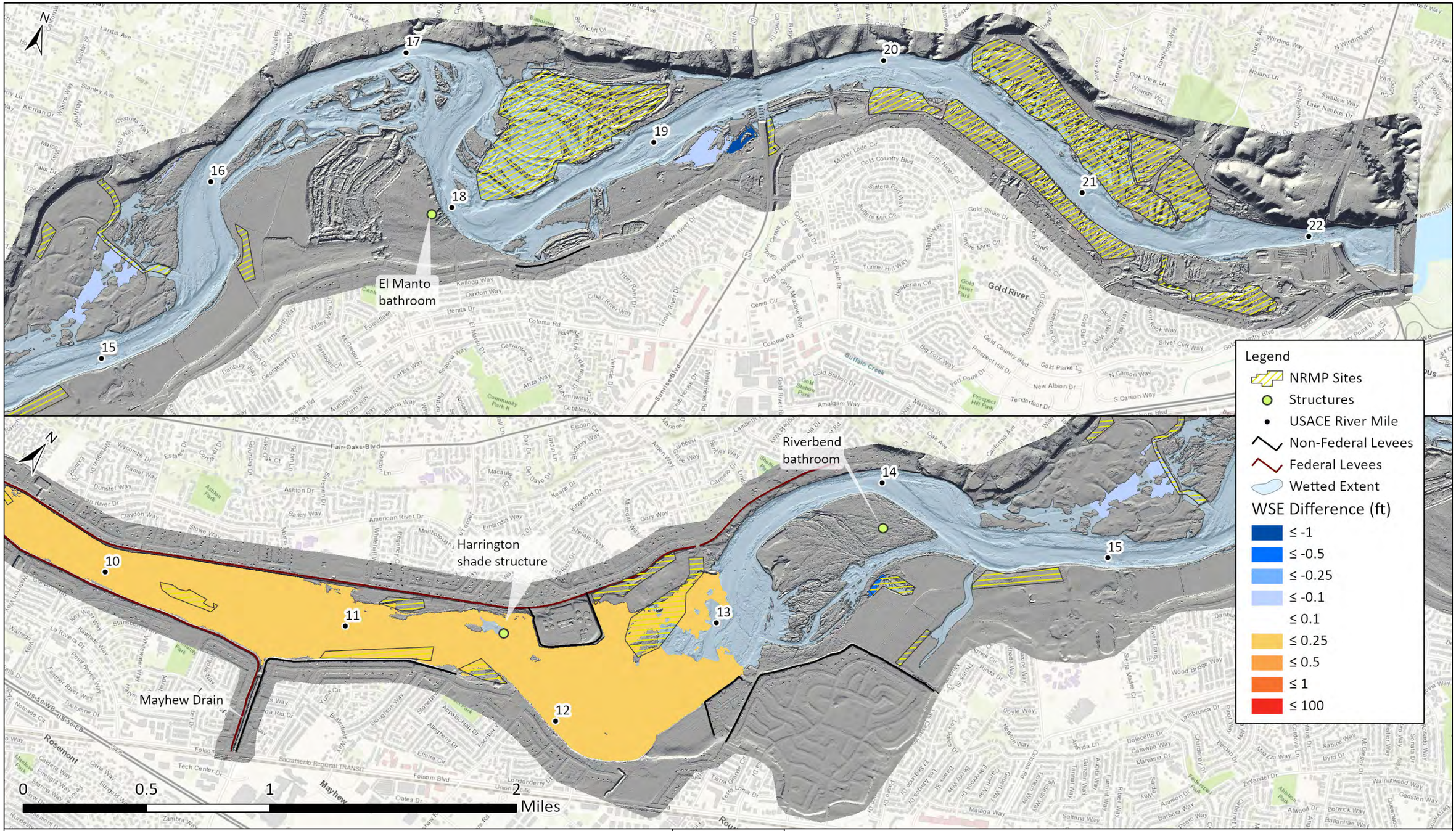


Notes: 115,000 cfs WSE differences between NRMP1 (i.e., EG + NRMP w/o SWW) and Scenario 1 (EG w/o SWW): NRMP1 minus S1

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP1 minus Scenario 1 – WSE (115 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 17**



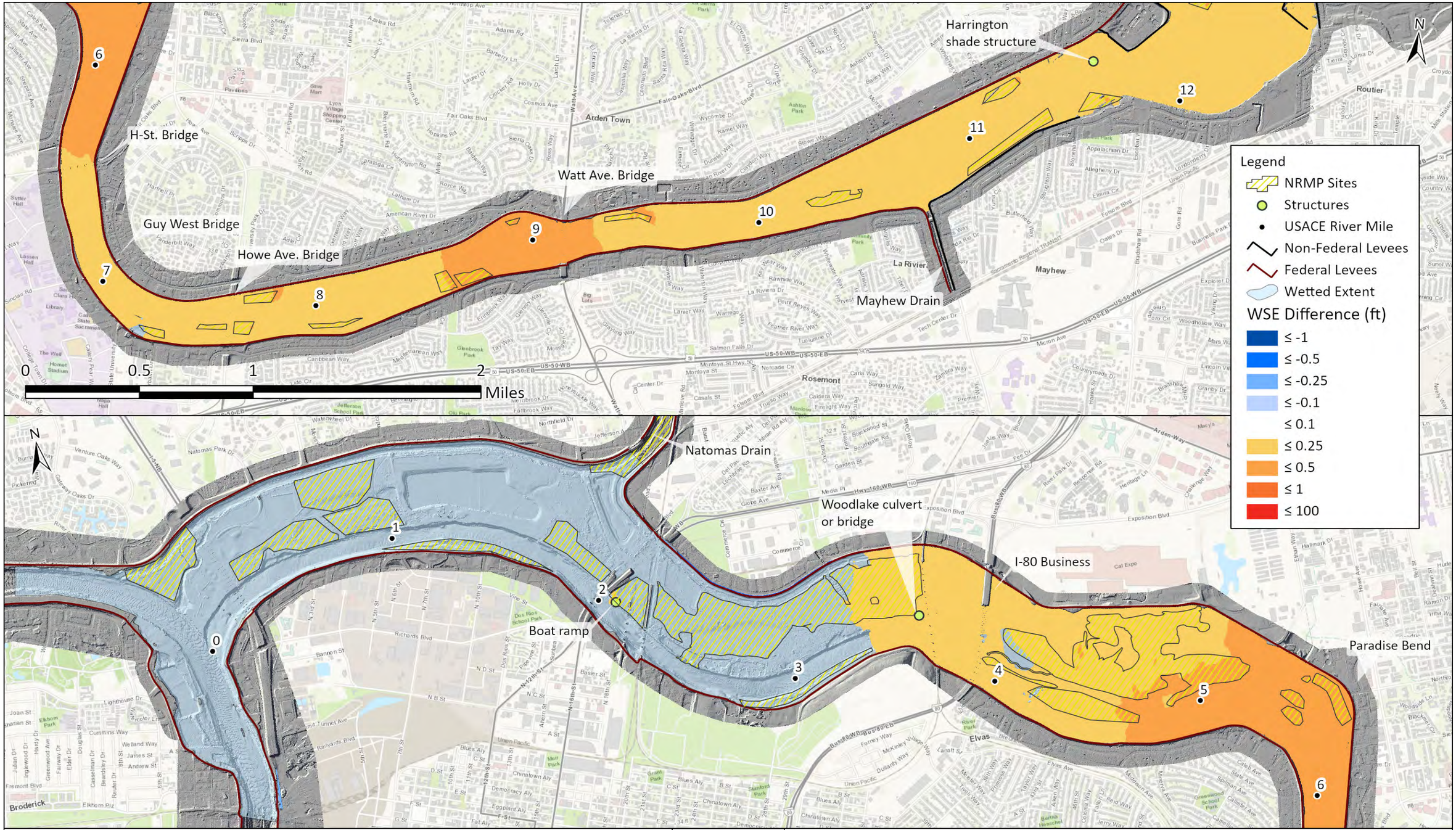
Notes: 115,000 cfs WSE differences between NRMP1 (i.e., EG + NRMP w/o SWW) and Scenario 1 (EG w/o SWW): NRMP1 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP1 minus Scenario 1 – WSE (115 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 18**



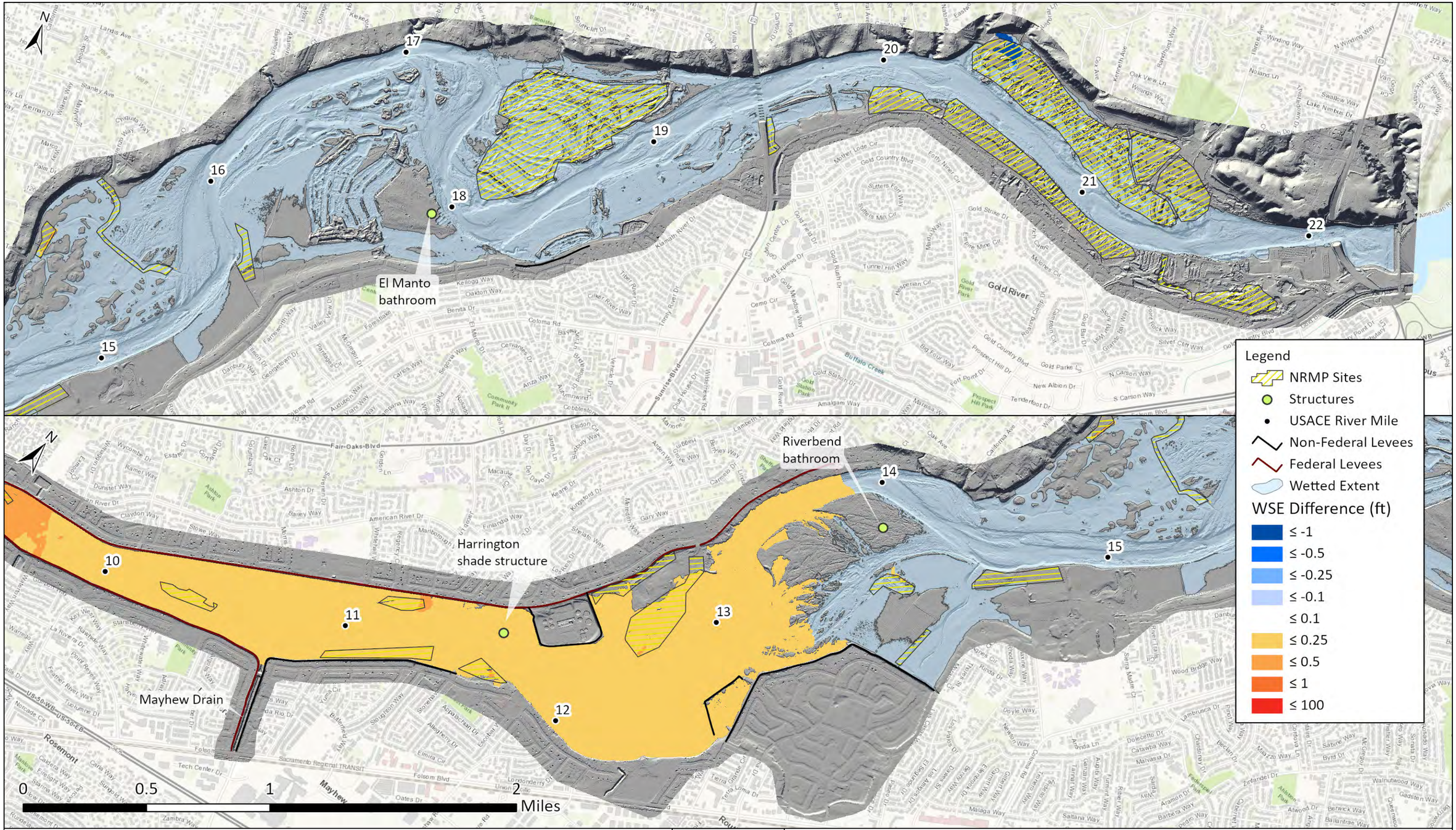
Notes: 160,000 cfs WSE differences between NRMP1 (i.e., EG + NRMP w/o SWW) and Scenario 1 (EG w/o SWW): NRMP1 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP1 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 19**



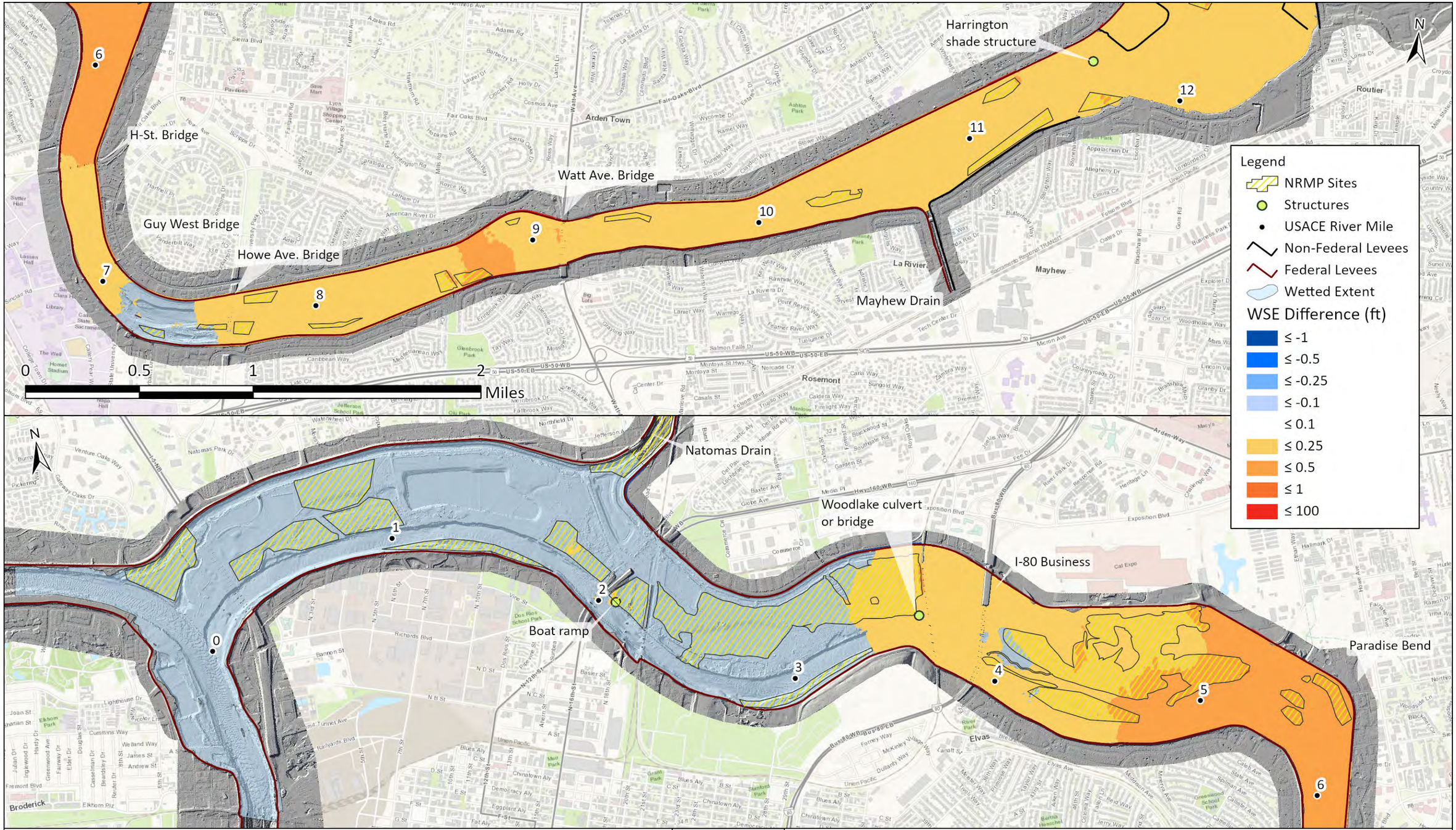
Notes: 160,000 cfs WSE differences between NRMP1 (i.e., EG + NRMP w/o SWW) and Scenario 1 (EG w/o SWW): NRMP1 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP1 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 20**



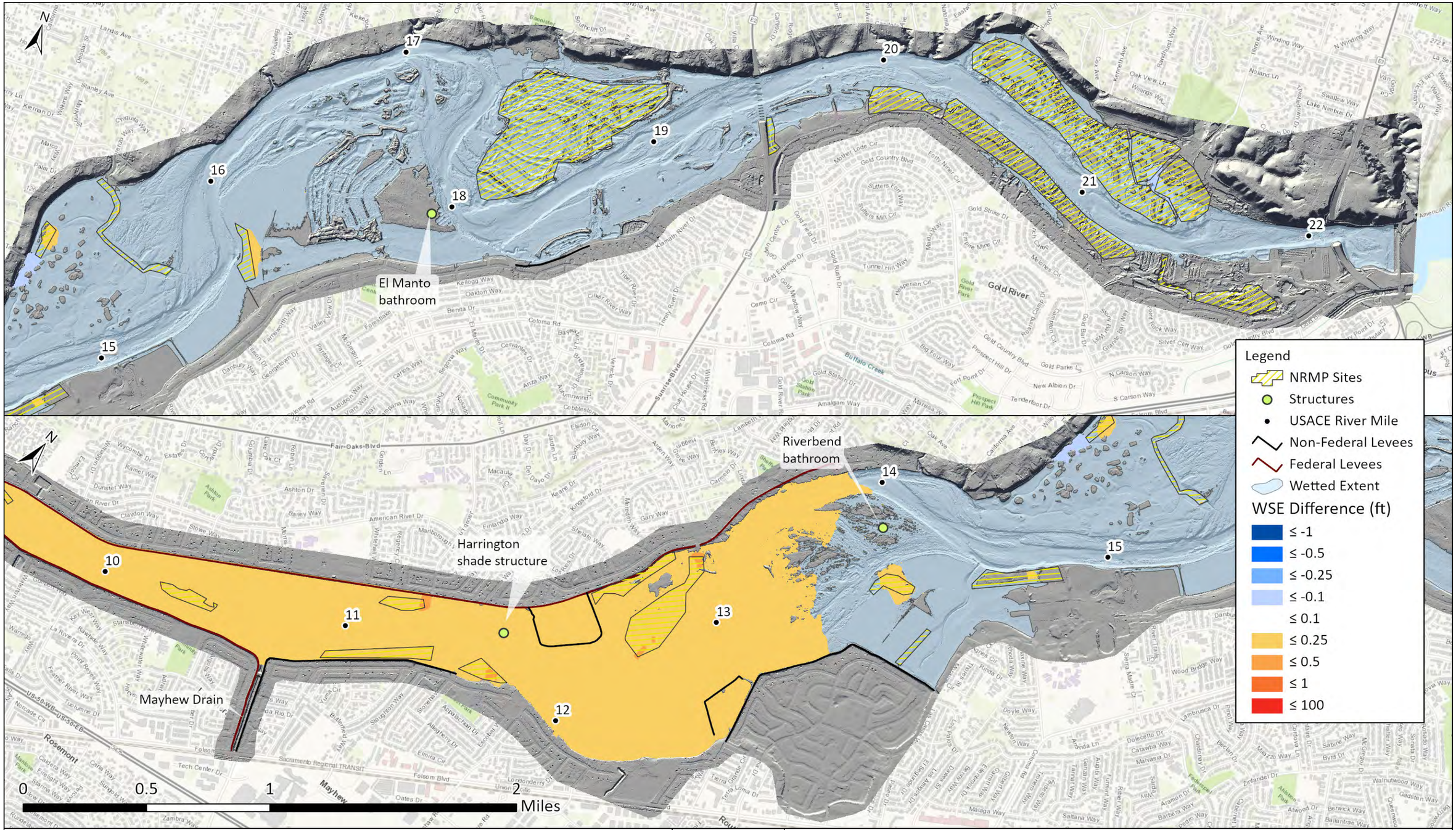
Notes: 192,000 cfs WSE differences between NRMP1 (i.e., EG + NRMP w/o SWW) and Scenario 1 (EG w/o SWW): NRMP1 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP1 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 21**



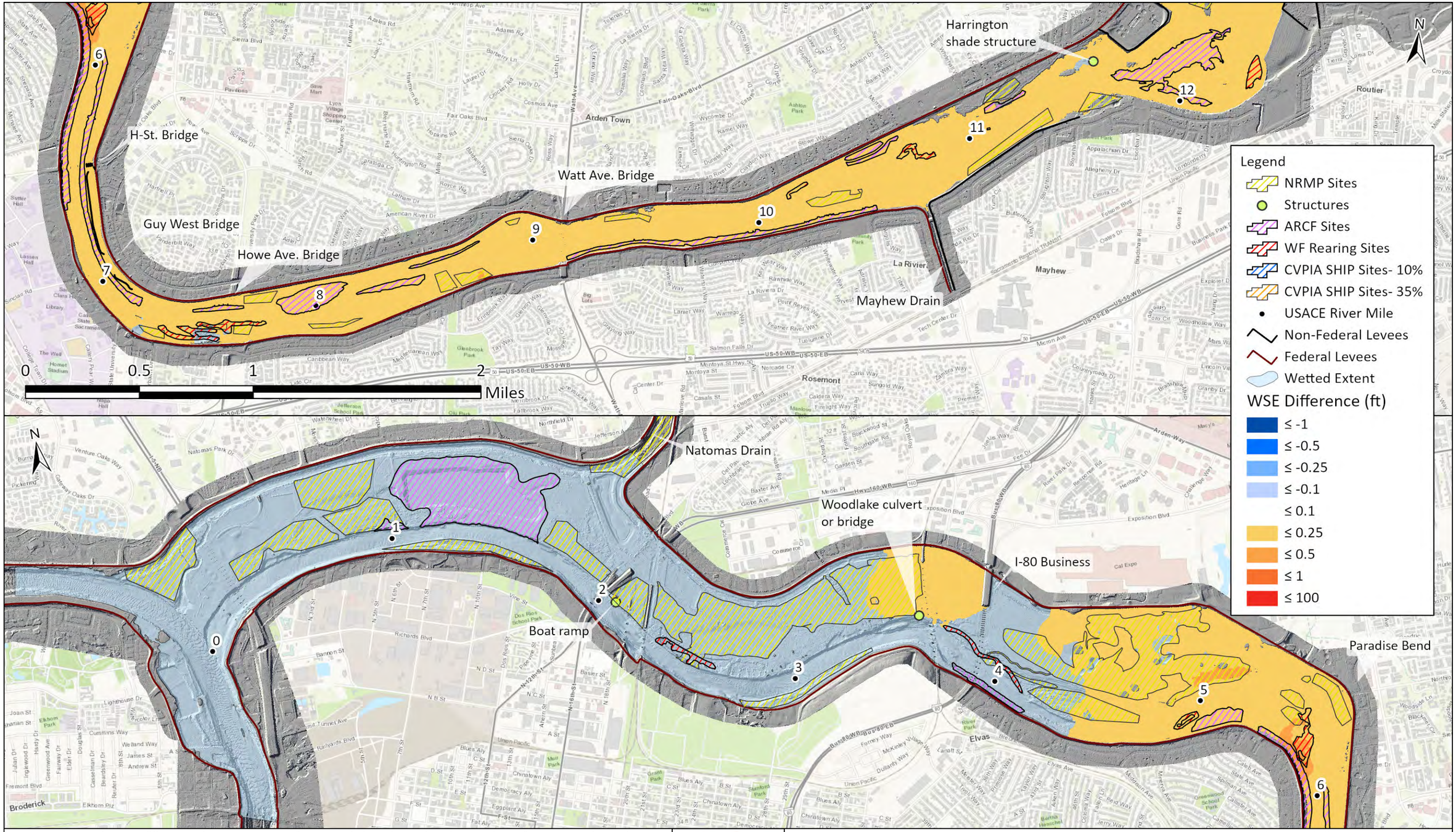
Notes: 192,000 cfs WSE differences between NRMP1 (i.e., EG + NRMP w/o SWW) and Scenario 1 (EG w/o SWW): NRMP1 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP1 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 22**



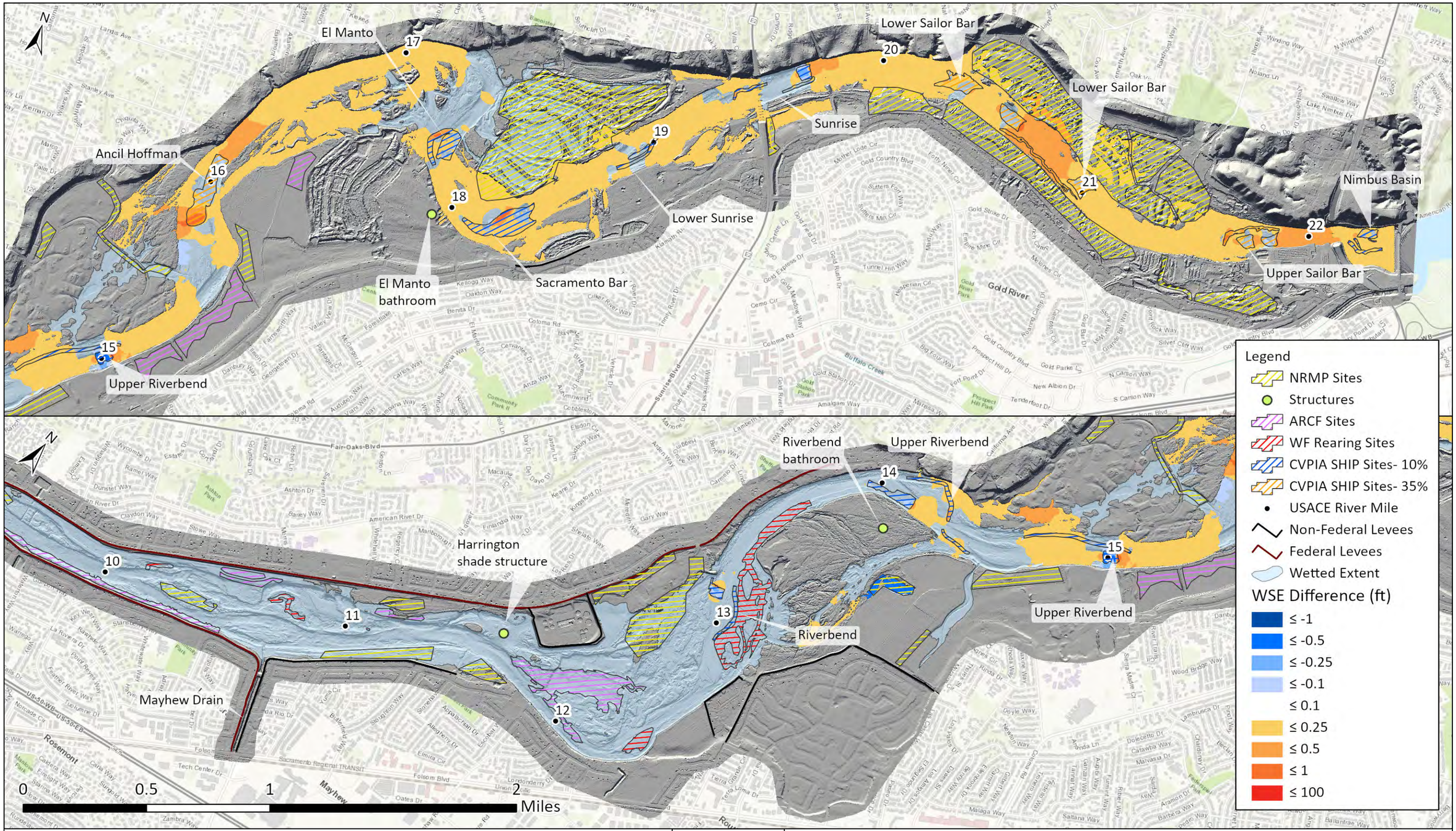
Notes: 115,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 12 (i.e., ARCF w/ SWW): NRMP2 minus S12

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP2 minus Scenario 12 – WSE (115 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 23**



Notes: 115,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 12 (i.e., ARCF w/ SWW): NRMP2 minus S12

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP2 minus Scenario 12 – WSE (115 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 24**

Harrington shade structure

H-St. Bridge

Watt Ave. Bridge

Guy West Bridge

Howe Ave. Bridge

Mayhew Drain

Natomas Drain

Woodlake culvert or bridge

I-80 Business

Boat ramp

Paradise Bend

0 0.5 1 2 Miles

N

Legend

- NRMP Sites
- Structures
- ARCF Sites
- WF Rearing Sites
- CVPIA SHIP Sites- 10%
- CVPIA SHIP Sites- 35%
- USACE River Mile
- Non-Federal Levees
- Federal Levees
- Wetted Extent

WSE Difference (ft)

- ≤ -1
- ≤ -0.5
- ≤ -0.25
- ≤ -0.1
- ≤ 0.1
- ≤ 0.25
- ≤ 0.5
- ≤ 1
- ≤ 100

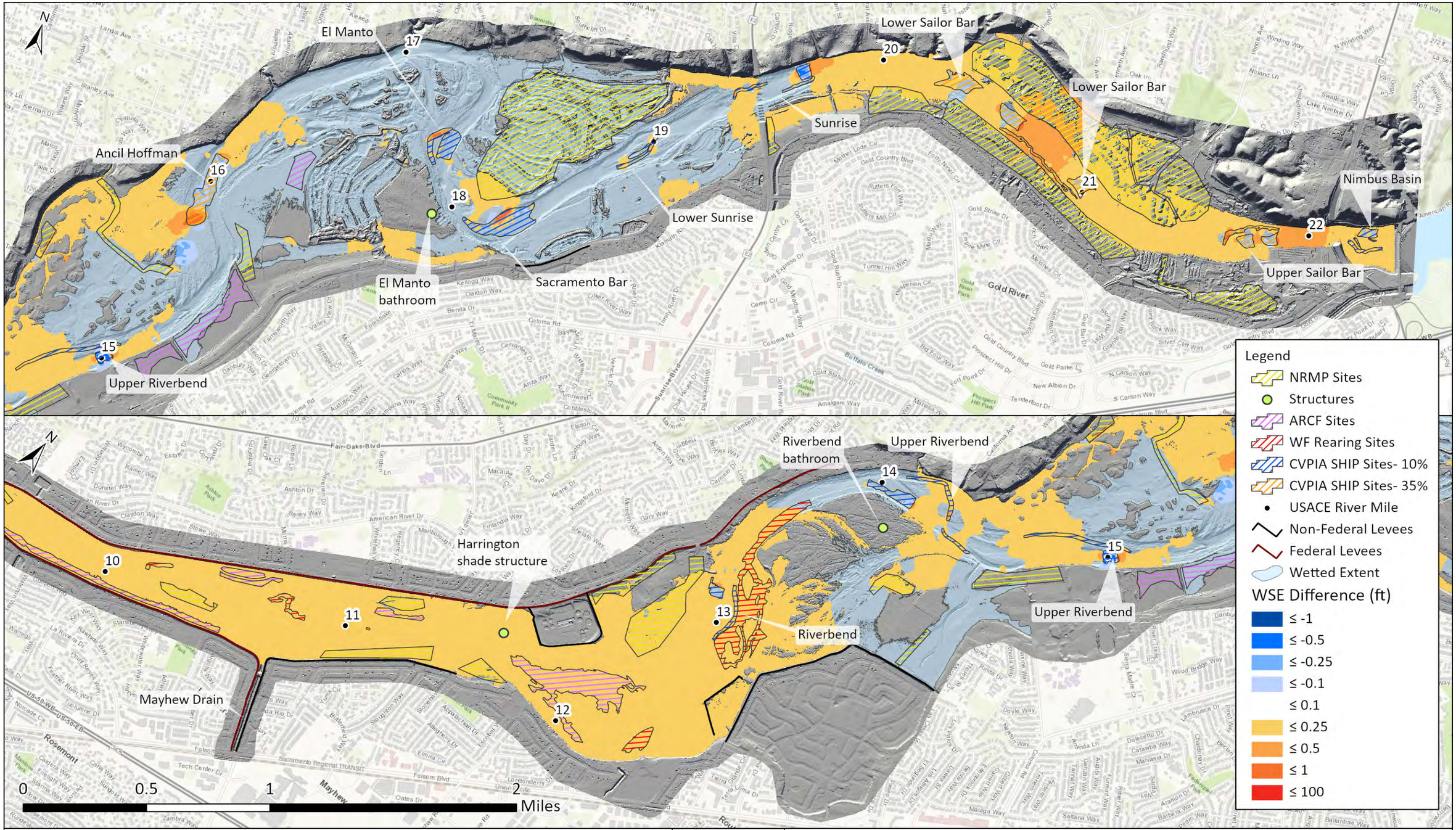
Notes: 160,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 12 (i.e., ARCF w/ SWW): NRMP2 minus S12

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP2 minus Scenario 12 – WSE (160 kcfs)

Project No. 21−1023 | Created By: MNC | **Figure 25**



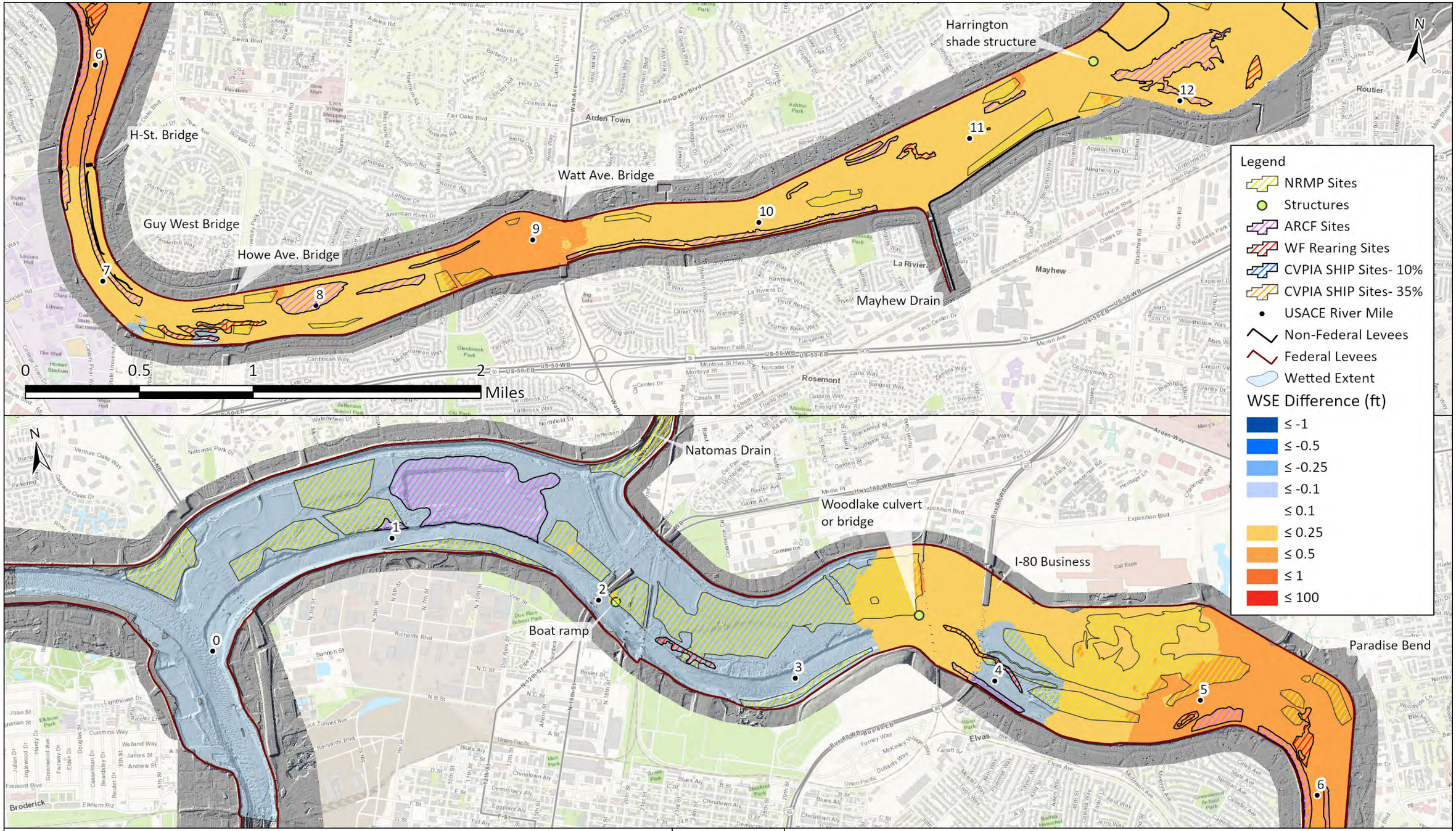
Notes: 160,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 12 (i.e., ARCF w/ SWW): NRMP2 minus S12

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP2 minus Scenario 12 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 26**



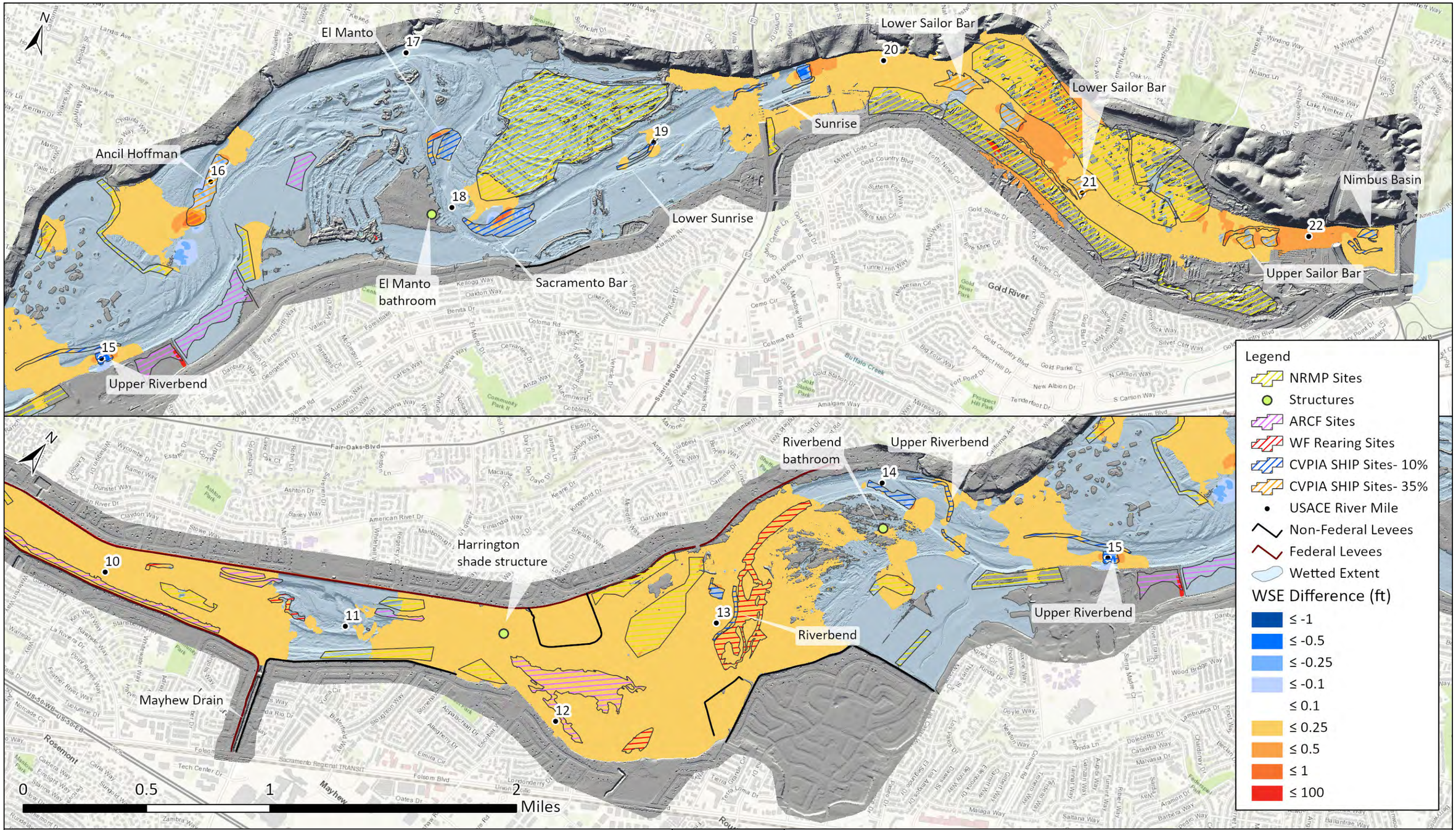
Notes: 192,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 12 (i.e., ARCF w/ SWW): NRMP2 minus S12

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP2 minus Scenario 12 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 27**



Notes: 192,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 12 (i.e., ARCF w/ SWW): NRMP2 minus S12

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP2 minus Scenario 12 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 28**

H-St. Bridge
Guy West Bridge
Howe Ave. Bridge
Watt Ave. Bridge
Harrington shade structure
Mayhew Drain
Natomas Drain
Woodlake culvert or bridge
Boat ramp
I-80 Business
Paradise Bend
Arden Town
Rosemont
Mayhew
Elvas
Routier
La Riviera
0 0.5 1 2 Miles
N

Legend
- NRMP Sites
- Structures
- ARCF Sites
- WF Rearing Sites
- CVPIA SHIP Sites- 10%
- CVPIA SHIP Sites- 35%
- USACE River Mile
- Non-Federal Levees
- Federal Levees
- Wetted Extent

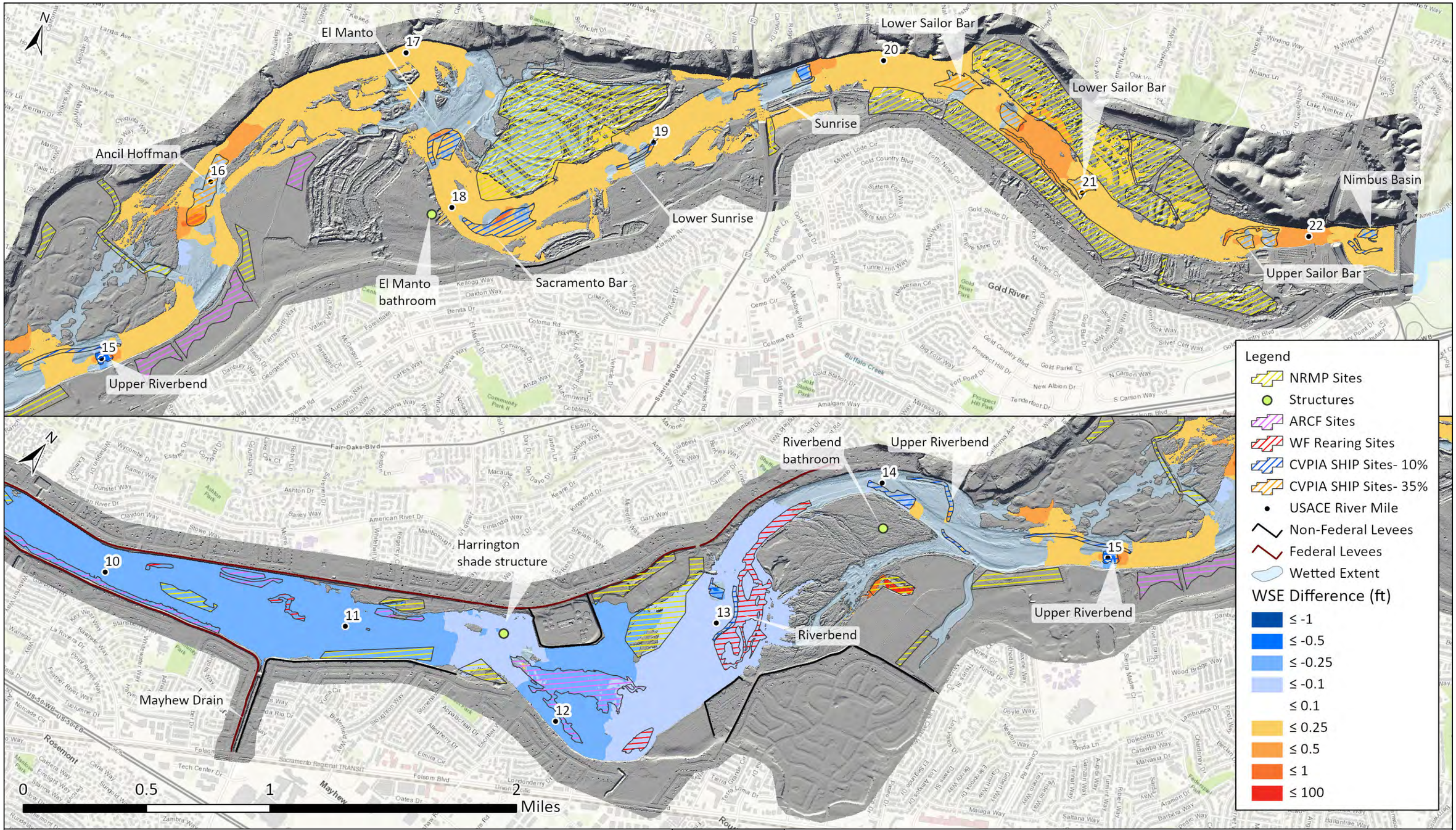
WSE Difference (ft)
- ≤ -1
- ≤ -0.5
- ≤ -0.25
- ≤ -0.1
- ≤ 0.1
- ≤ 0.25
- ≤ 0.5
- ≤ 1
- ≤ 100

Notes: 115,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 1 (i.e., EG w/o SWW): NRMP2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
Lower Domain NRMP2 minus Scenario 1 – WSE (115 kcfs)

Project No. 21−1023 | Created By: MNC | **Figure 29**



Notes: 115,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 1 (i.e., EG w/o SWW): NRMP2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

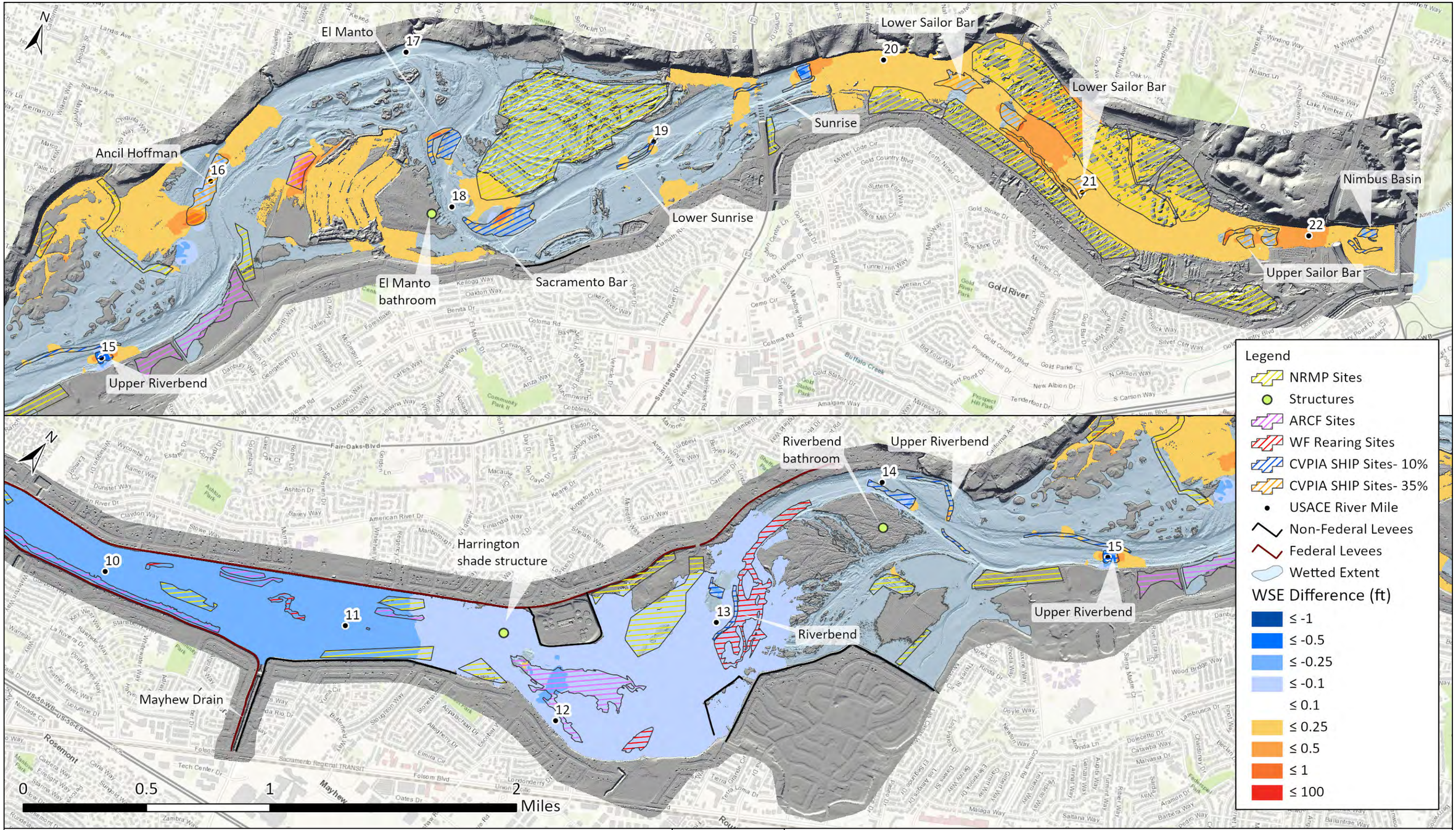
Upper Domain NRMP2 minus Scenario 1 – WSE (115 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 30**

Notes: 160,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 1 (i.e., EG w/o SWW): NRMP2 minus S1

Natural Resource Management Plan Modeling Support Project
Lower Domain NRMP2 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 31**



Notes: 160,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 1 (i.e., EG w/o SWW): NRMP2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP2 minus Scenario 1 – WSE (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 32**

Harrington shade structure

H-St. Bridge

Watt Ave. Bridge

Guy West Bridge

Howe Ave. Bridge

Mayhew Drain

Natomas Drain

Woodlake culvert or bridge

I-80 Business

Boat ramp

Paradise Bend

0 0.5 1 2 Miles

Legend

- NRMP Sites
- Structures
- ARCF Sites
- WF Rearing Sites
- CVPIA SHIP Sites- 10%
- CVPIA SHIP Sites- 35%
- USACE River Mile
- Non-Federal Levees
- Federal Levees
- Wetted Extent

WSE Difference (ft)

- ≤ -1
- ≤ -0.5
- ≤ -0.25
- ≤ -0.1
- ≤ 0.1
- ≤ 0.25
- ≤ 0.5
- ≤ 1
- ≤ 100

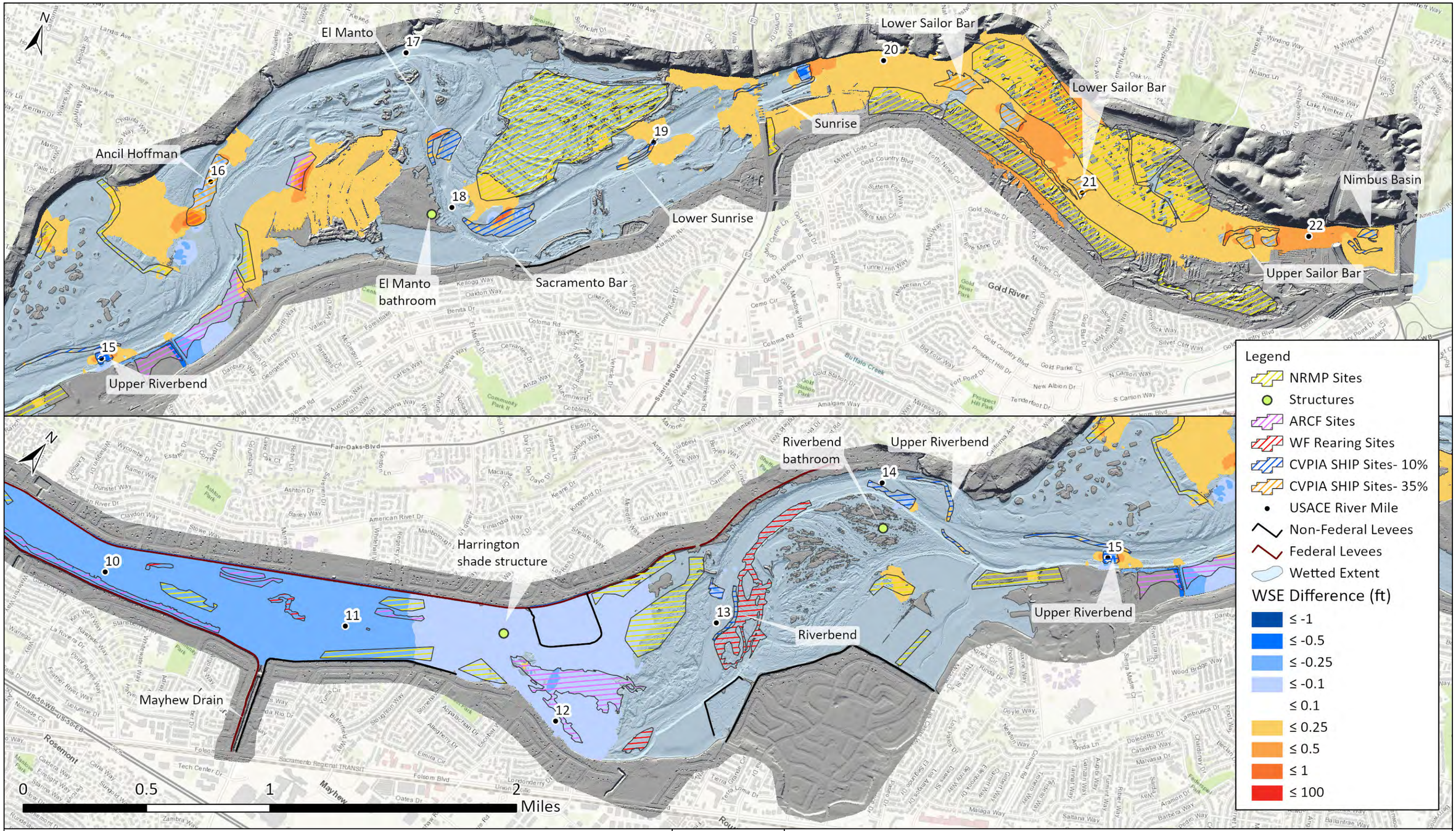
Notes: 192,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 1 (i.e., EG w/o SWW): NRMP2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP2 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023 | Created By: MNC | **Figure 33**



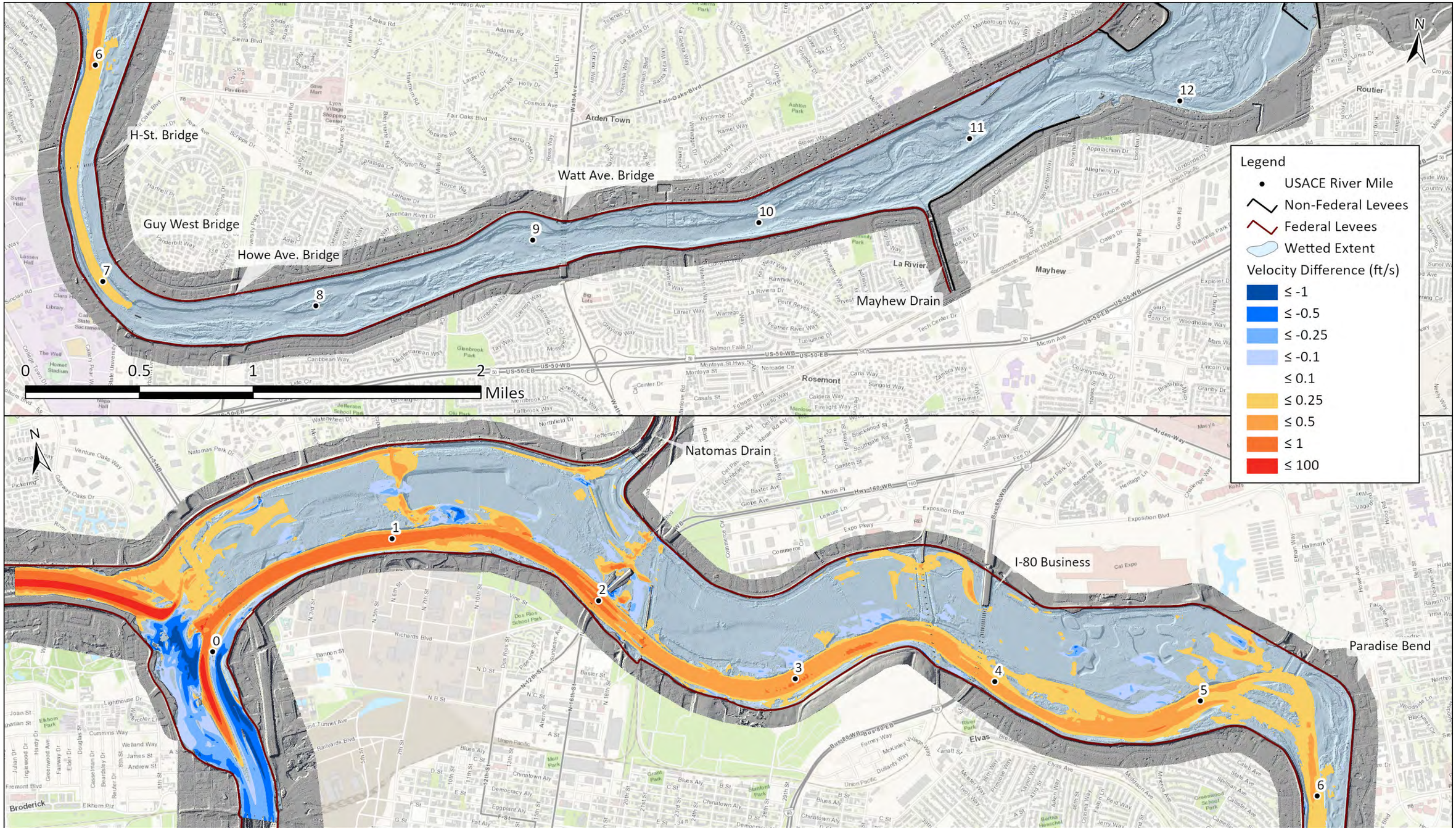
Notes: 192,000 cfs WSE differences between NRMP2 (i.e., Cumulative w/ SWW) and Scenario 1 (i.e., EG w/o SWW): NRMP2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP2 minus Scenario 1 – WSE (192 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 34**



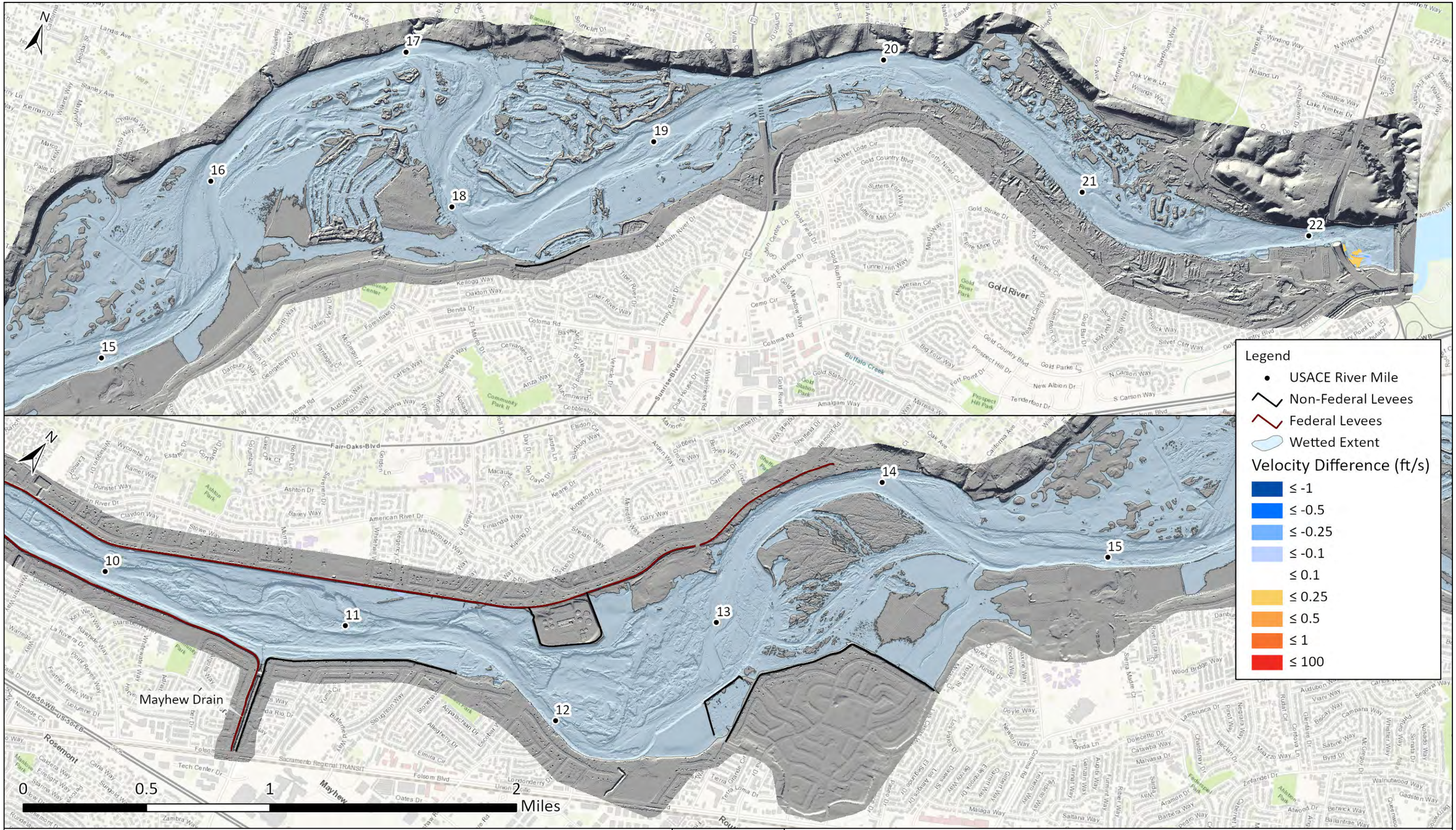
Notes: 160,000 cfs Velocity differences between Scenario 2 and Scenario 1: S2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Scenario 2 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 35**



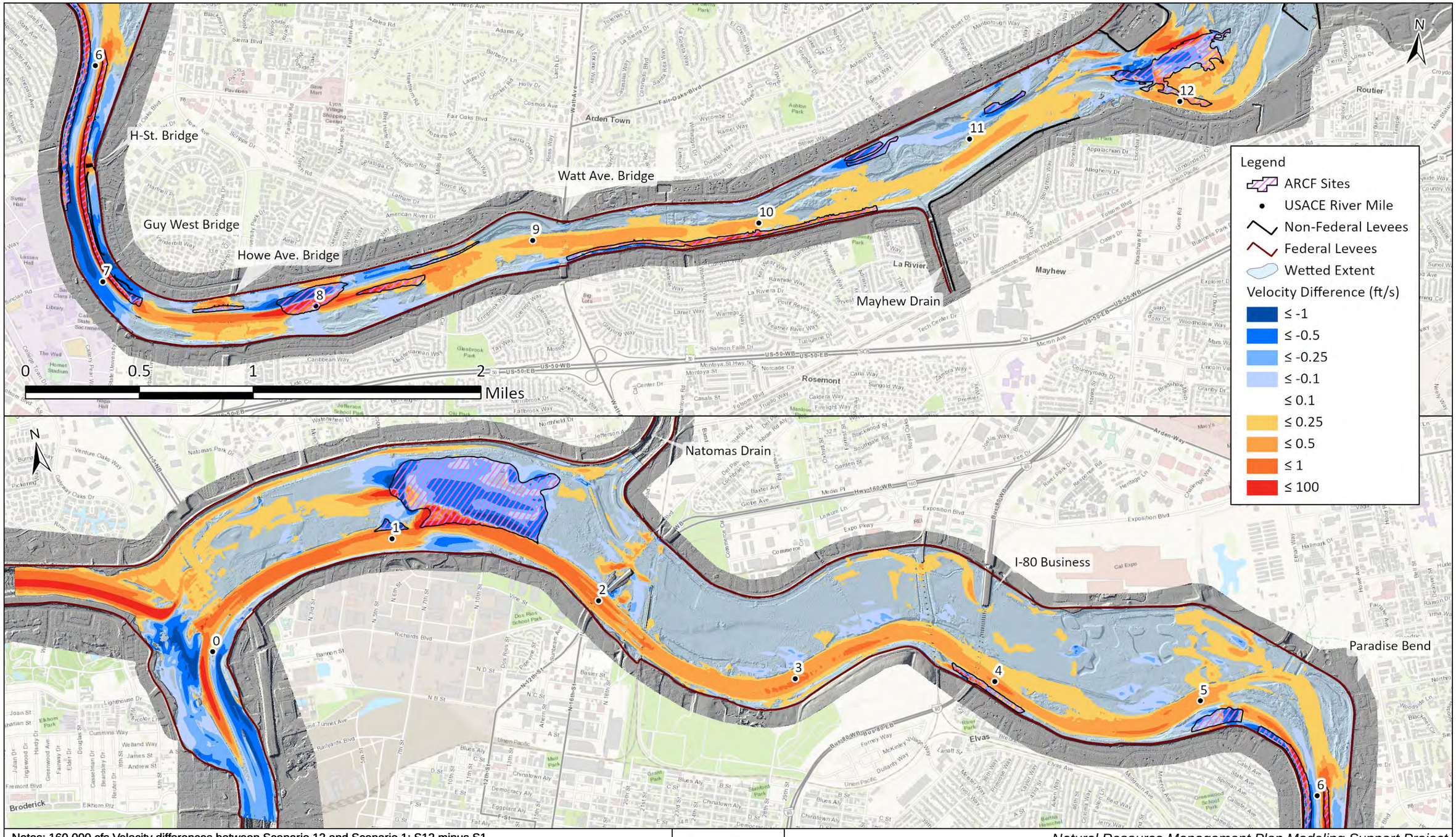
Notes: 160,000 cfs Velocity differences between Scenario 2 and Scenario 1: S2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain Scenario 2 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 36**



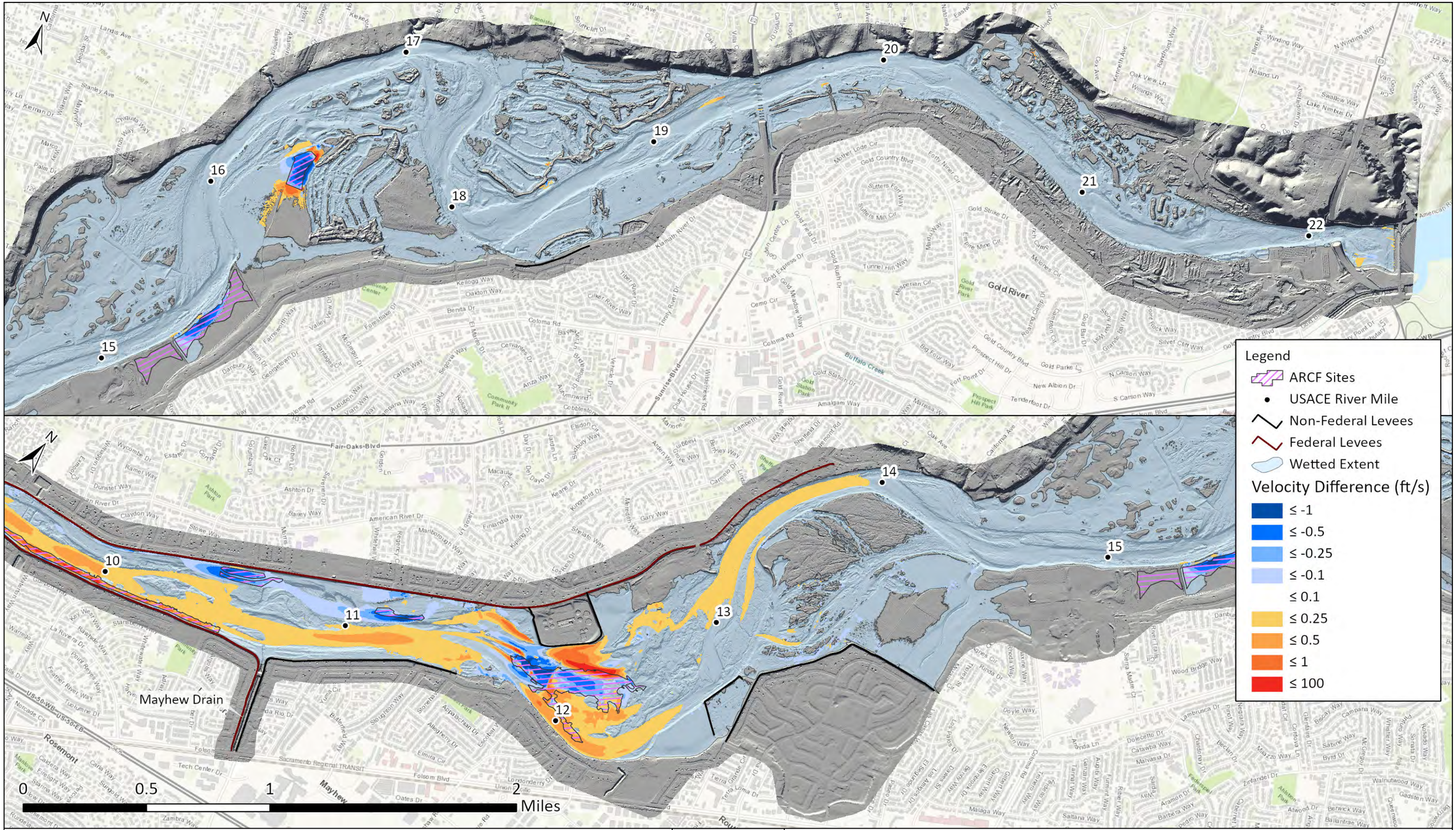
Notes: 160,000 cfs Velocity differences between Scenario 12 and Scenario 1: S12 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Scenario 12 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 37**



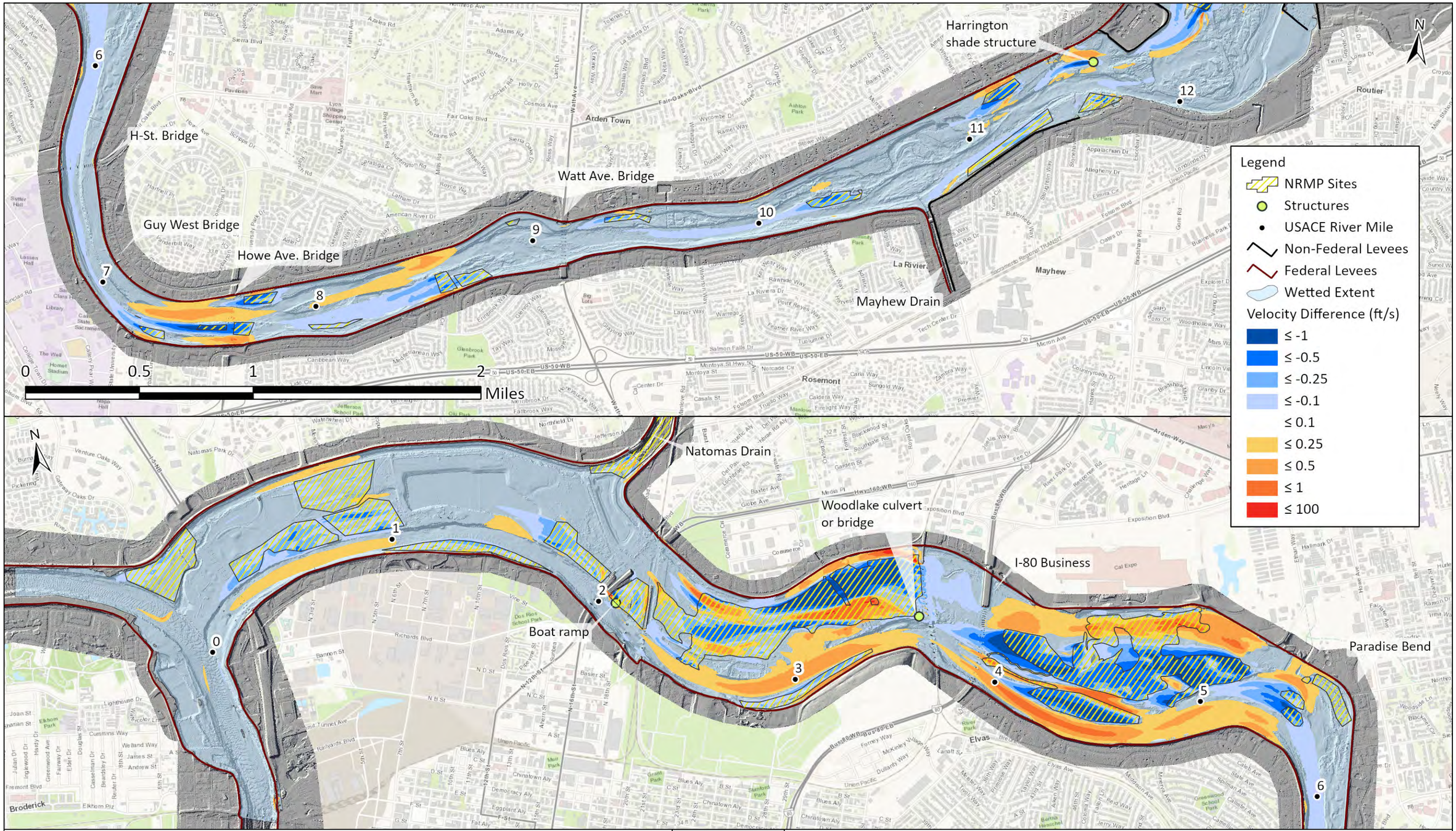
Notes: 160,000 cfs Velocity differences between Scenario 12 and Scenario 1: S12 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain Scenario 12 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 38**



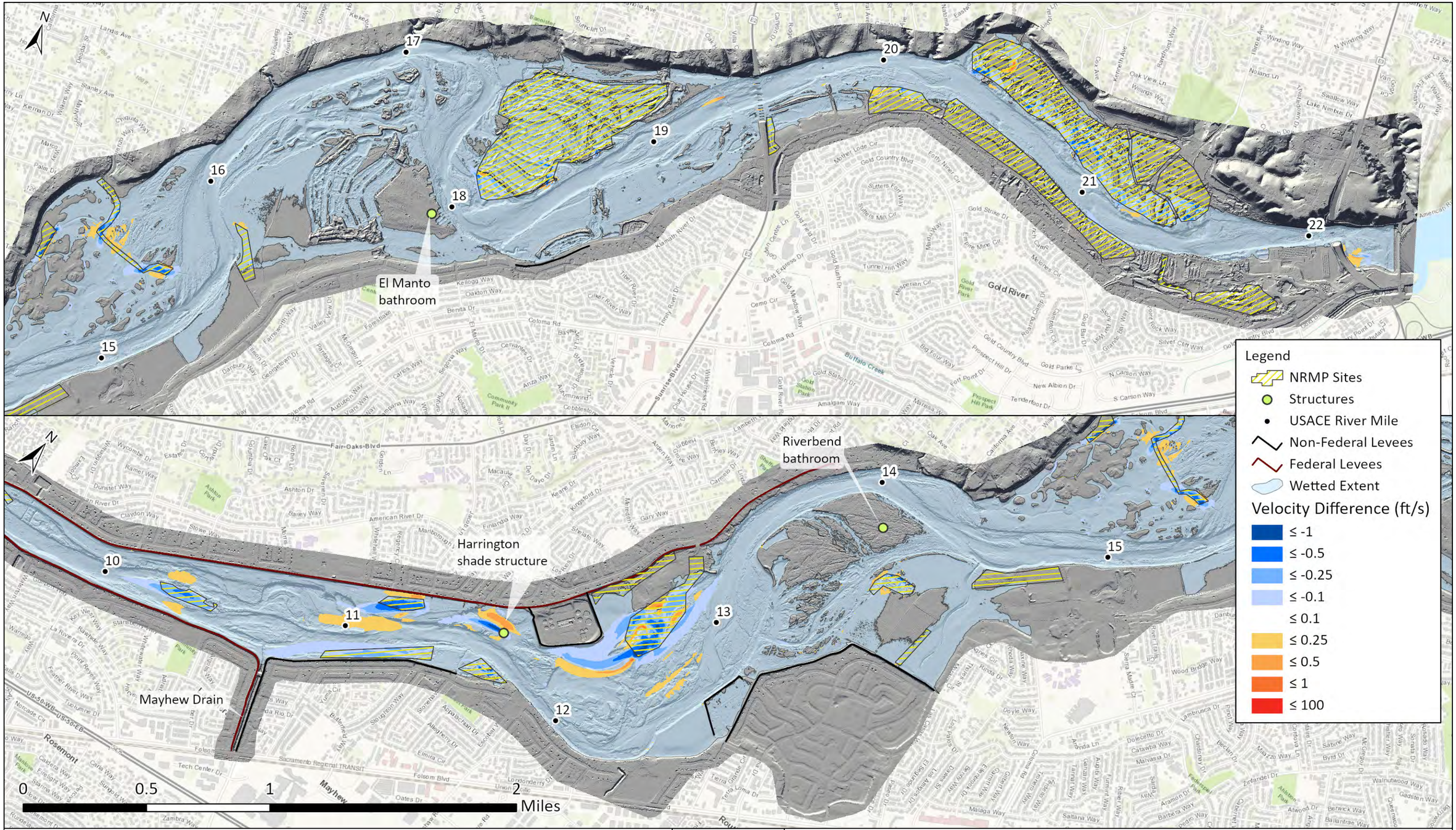
Notes: 160,000 cfs Velocity differences between NRMP1 and Scenario 1: NRMP1 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP1 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 39**



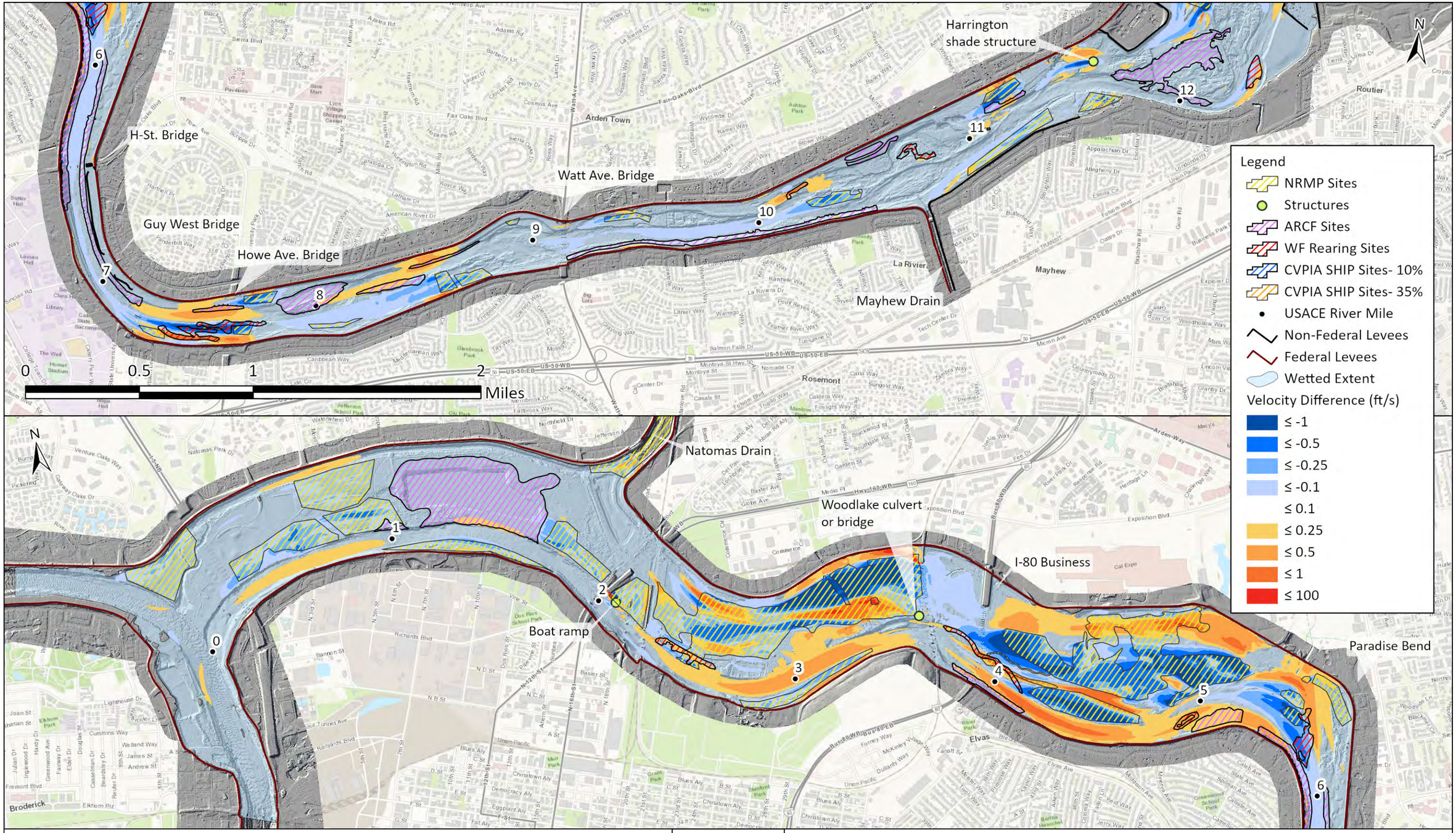
Notes: 160,000 cfs Velocity differences between NRMP1 and Scenario 1: NRMP1 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP1 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 40**

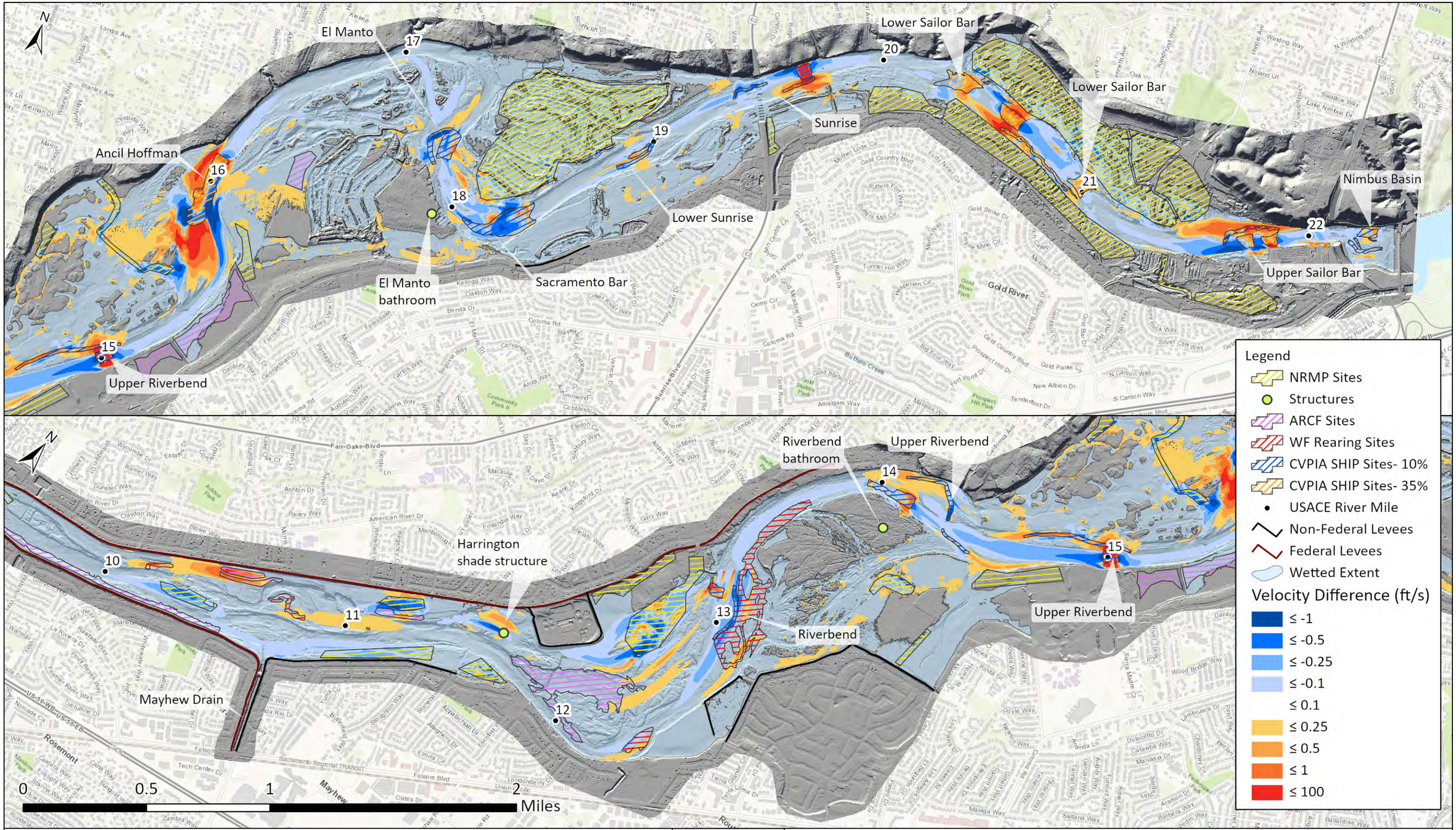


Notes: 160,000 cfs Velocity differences between NRMP2 and Scenario 12: NRMP2 minus S12

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP2 minus Scenario 12 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 41**

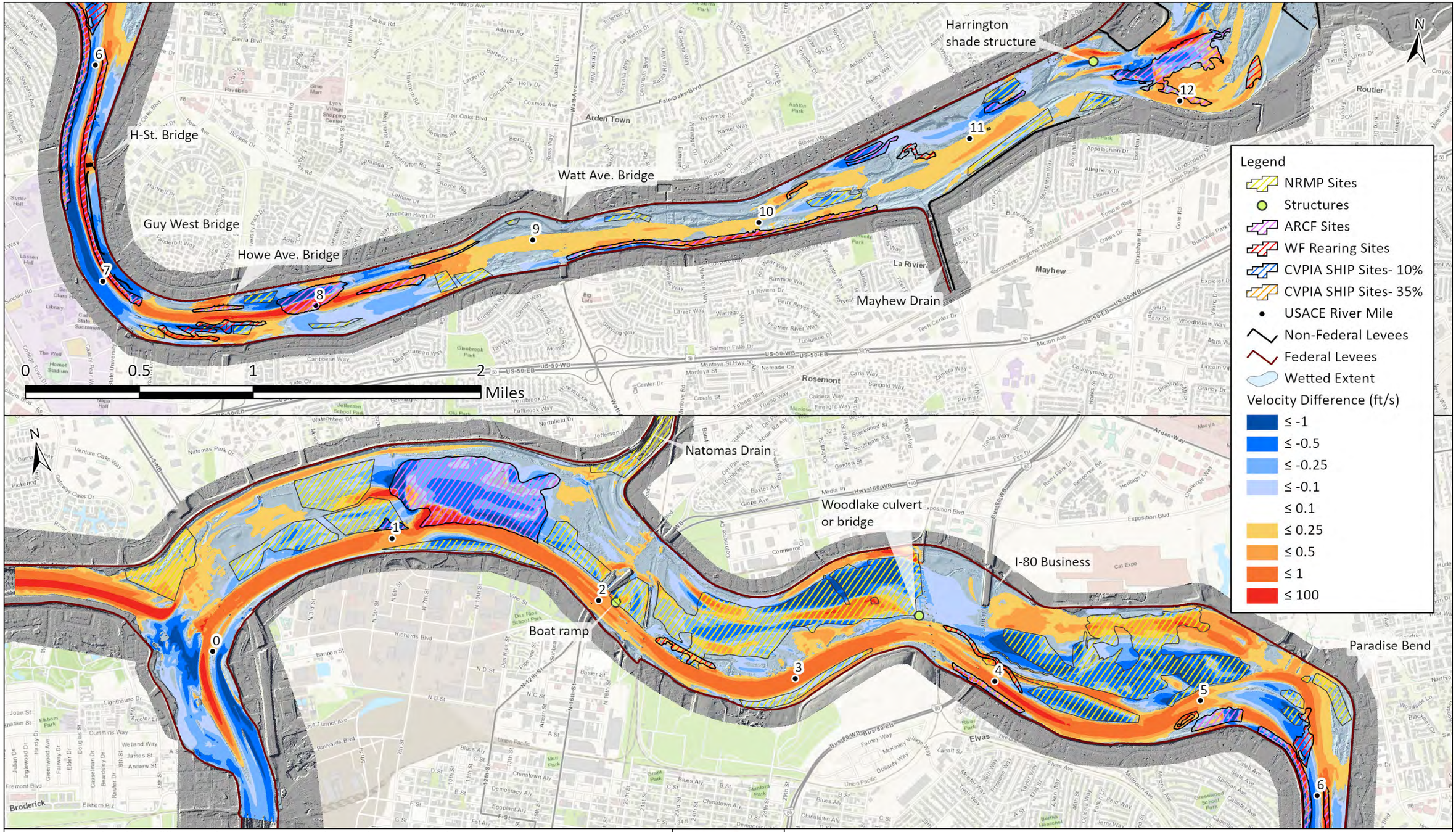


Notes: 160,000 cfs Velocity differences between NRMP2 and Scenario 12: NRMP2 minus S12

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP2 minus Scenario 12 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 42**

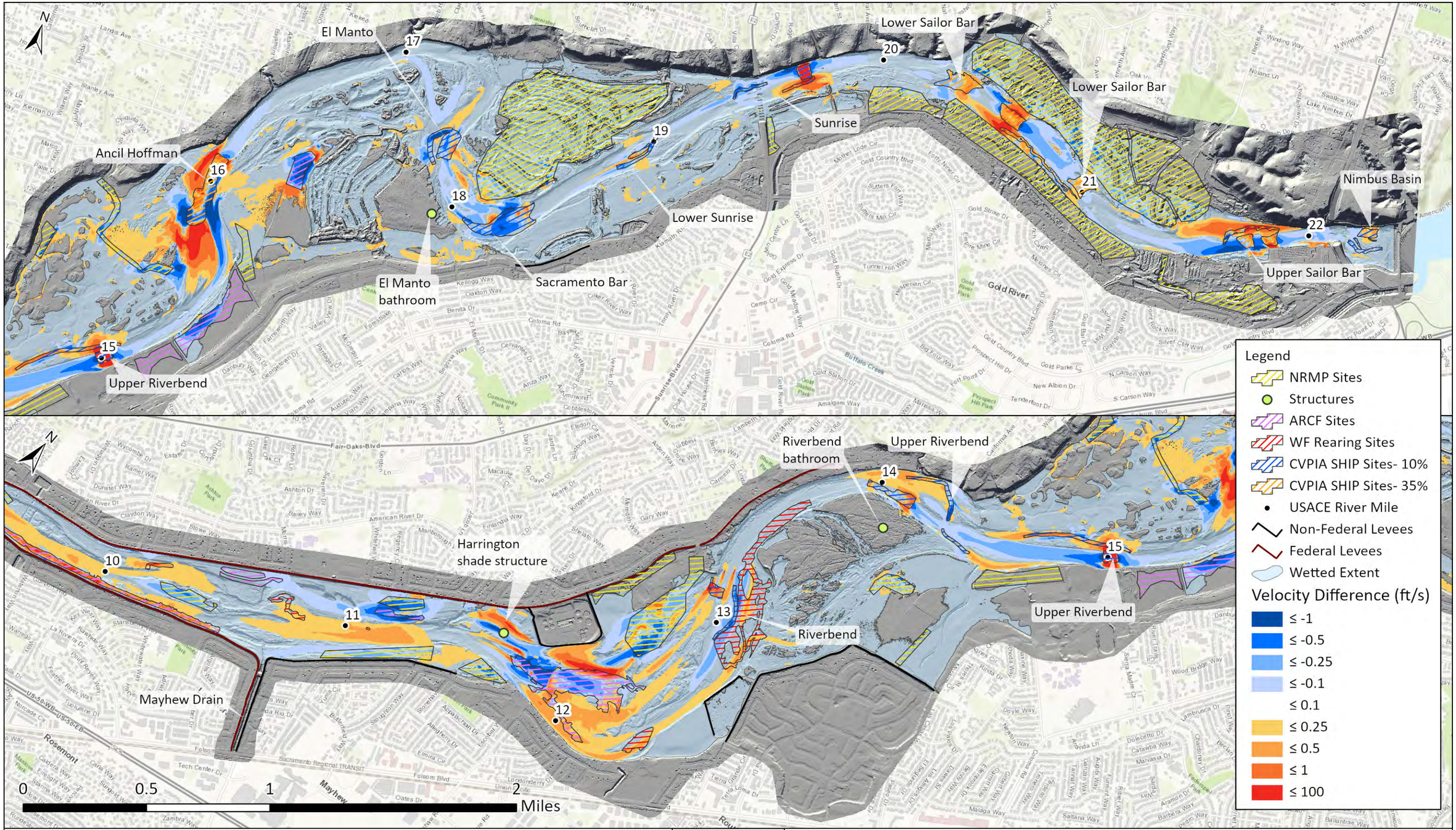


Notes: 160,000 cfs Velocity differences between NRMP2 and Scenario 1: NRMP2 minus S1

Natural Resource Management Plan Modeling Support Project

Lower Domain NRMP2 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 43**



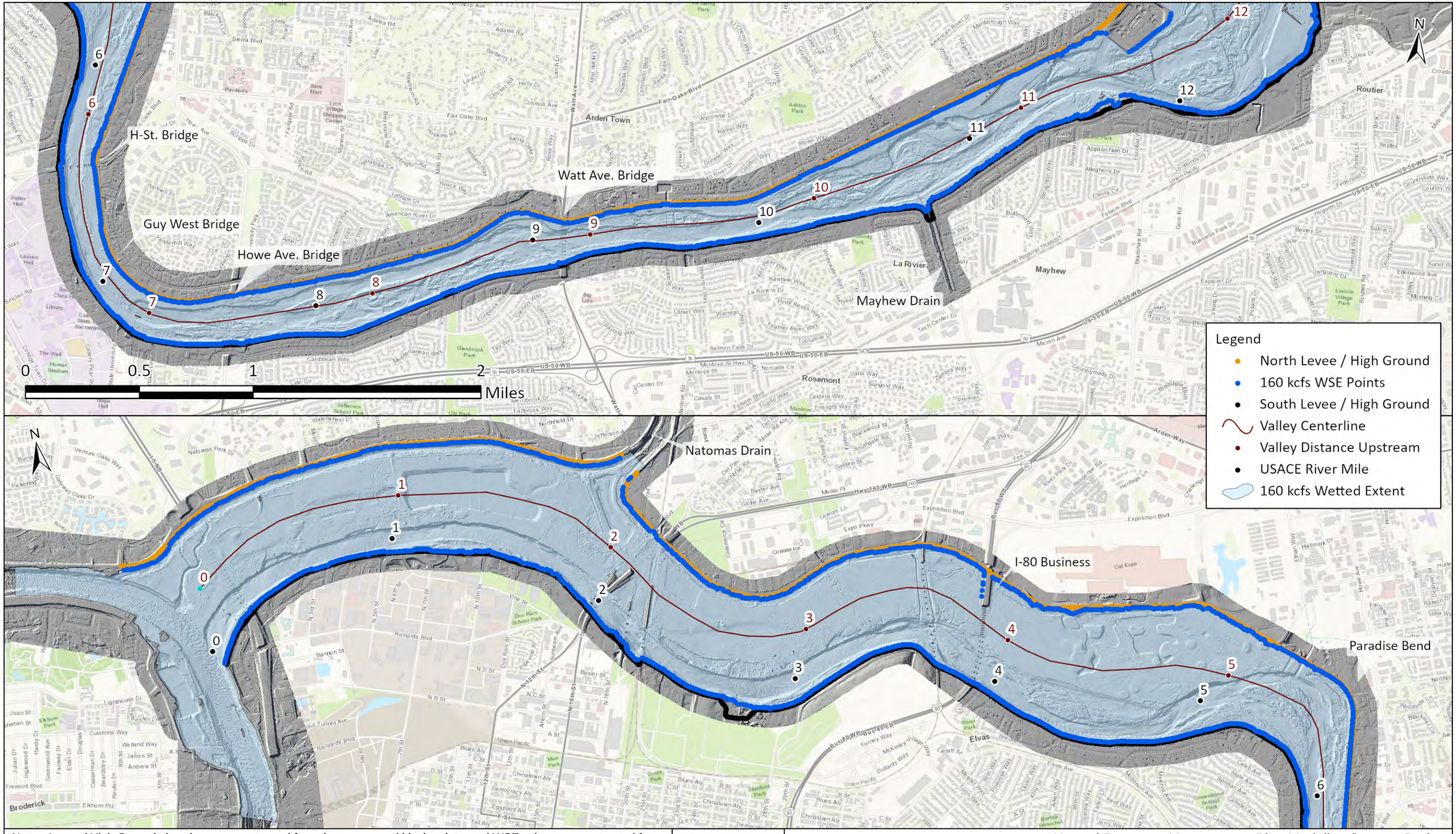
Notes: 160,000 cfs Velocity differences between NRMP2 and Scenario 1: NRMP2 minus S1

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain NRMP2 minus Scenario 1 – Velocity (160 kcfs)

Project No. 21−1023	Created By: MNC	**Figure 44**



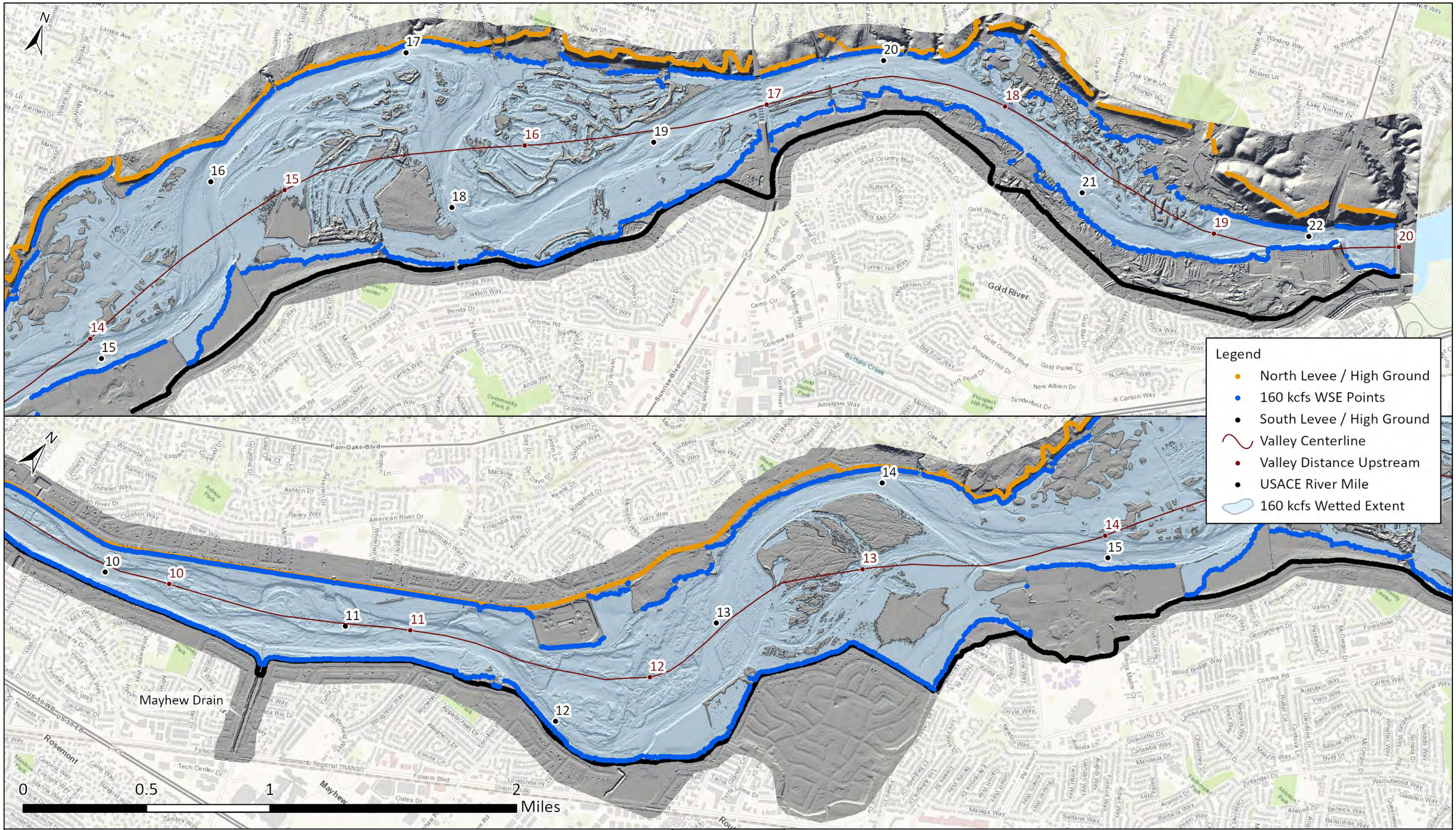
Notes: Levee / High Ground elevations were extracted from the orange and black points, and WSE values were extracted from the blue points. A search function was used to determine the WSE most closely associated with each levee point and calculate freeboard.

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Levee / High Ground and WSE Points

Project No. 21−1023	Created By: MNC	**Figure 45**



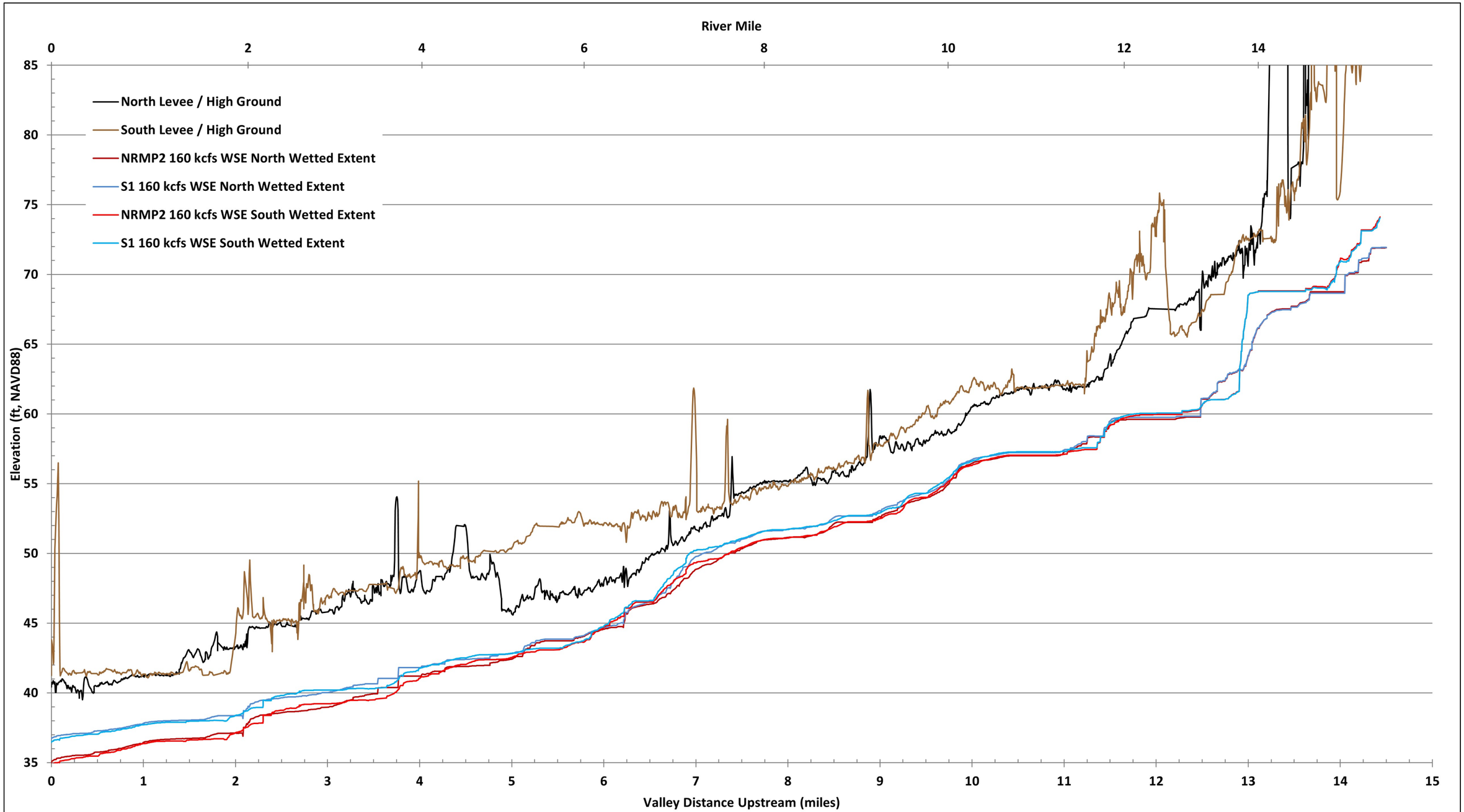
Notes: Levee / High Ground elevations were extracted from the orange and black points, and WSE values were extracted from the blue points. A search function was used to determine the WSE most closely associated with each levee point and calculate freeboard.

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain Levee / High Ground and WSE Points

Project No. 21−1023	Created By: MNC	**Figure 46**



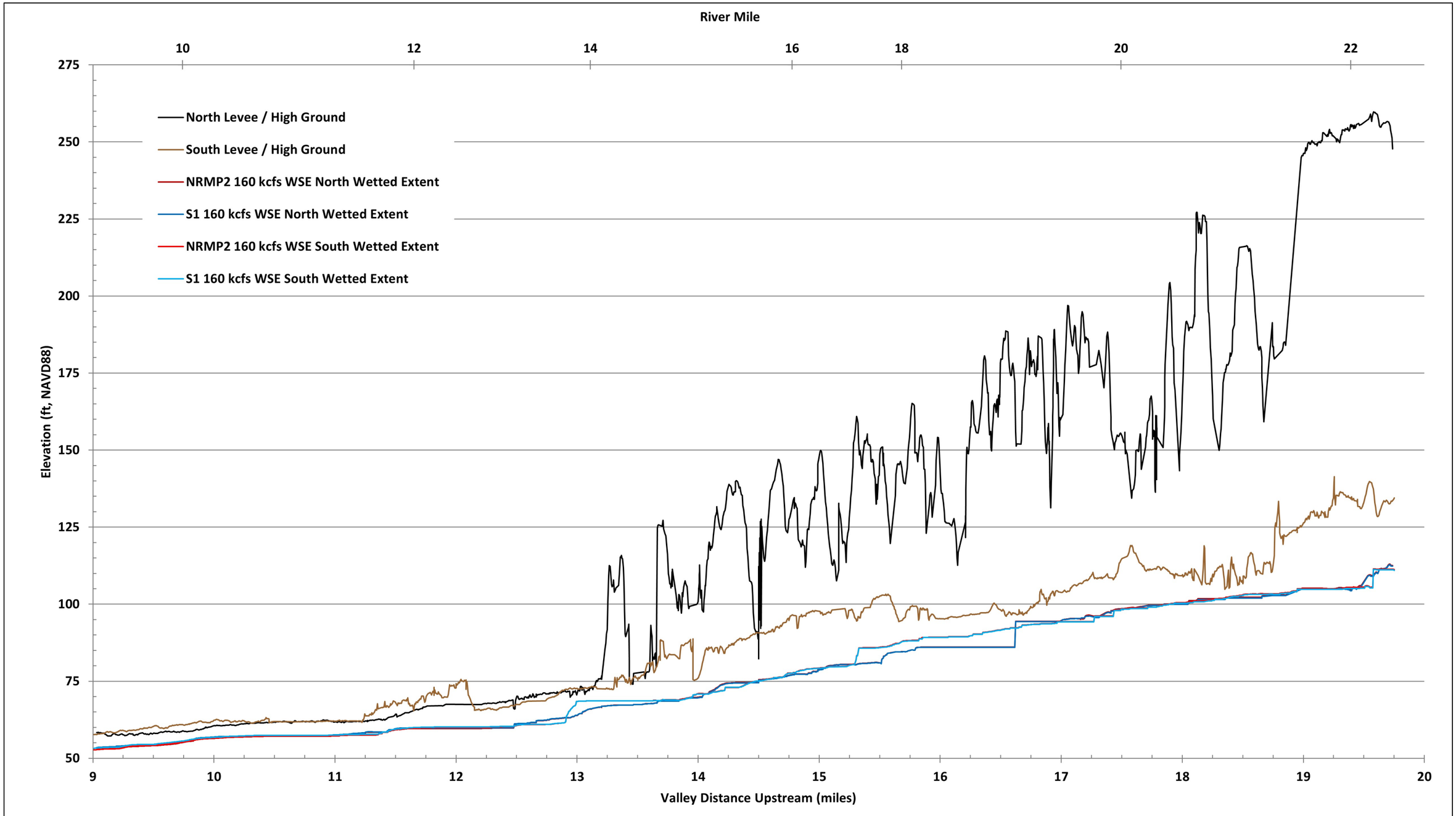
Notes: Longitudinal profile of levee / high ground elevations and 160,000 cfs WSEs

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain Longitudinal Profile

Project No. 21−1023	Created By: MDW	**Figure 47**

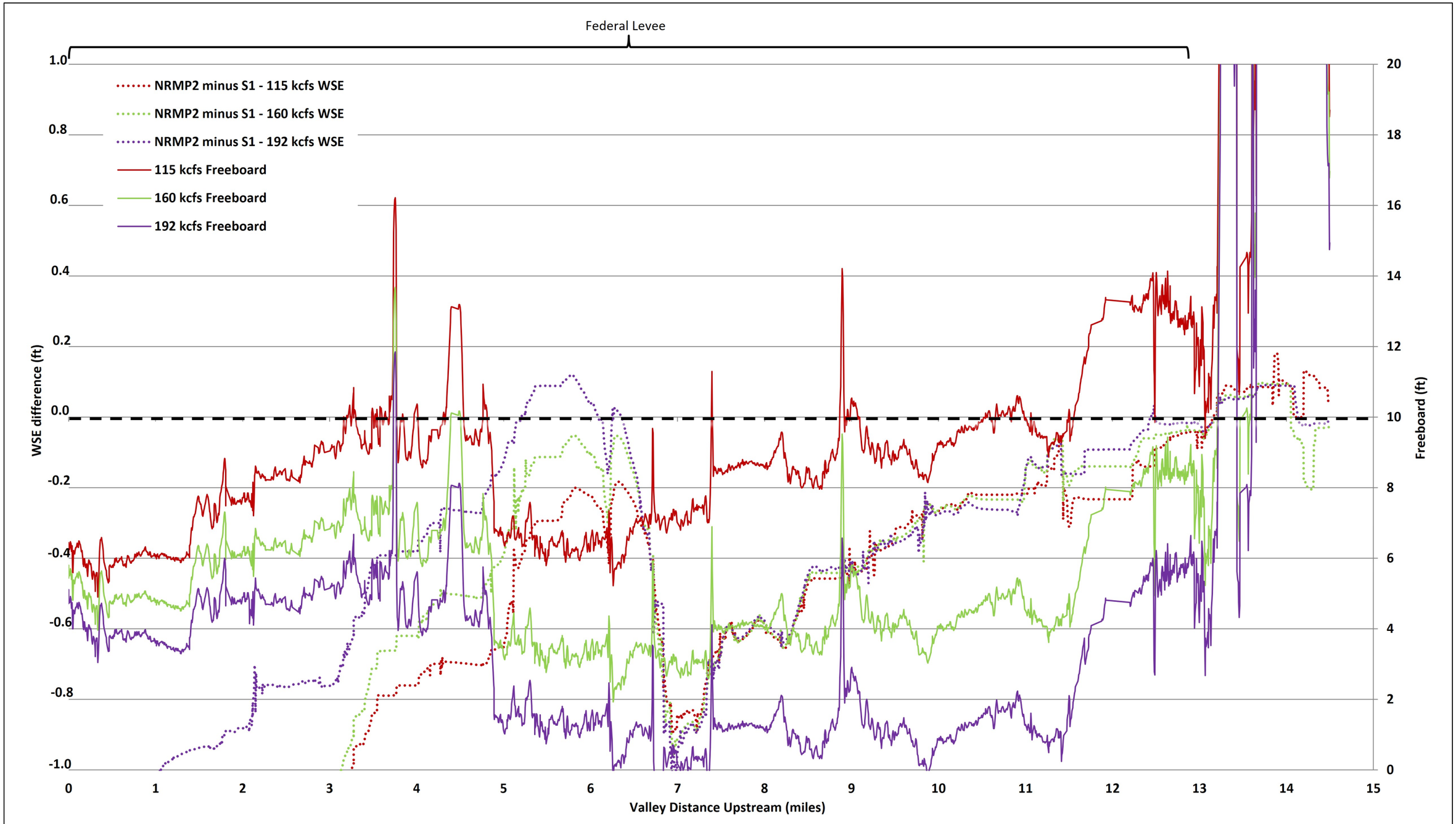


Notes: Longitudinal profile of levee / high ground elevations and 160,000 cfs WSEs

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
Upper Domain Longitudinal Profile

Project No. 21−1023 | Created By: MDW | **Figure 48**



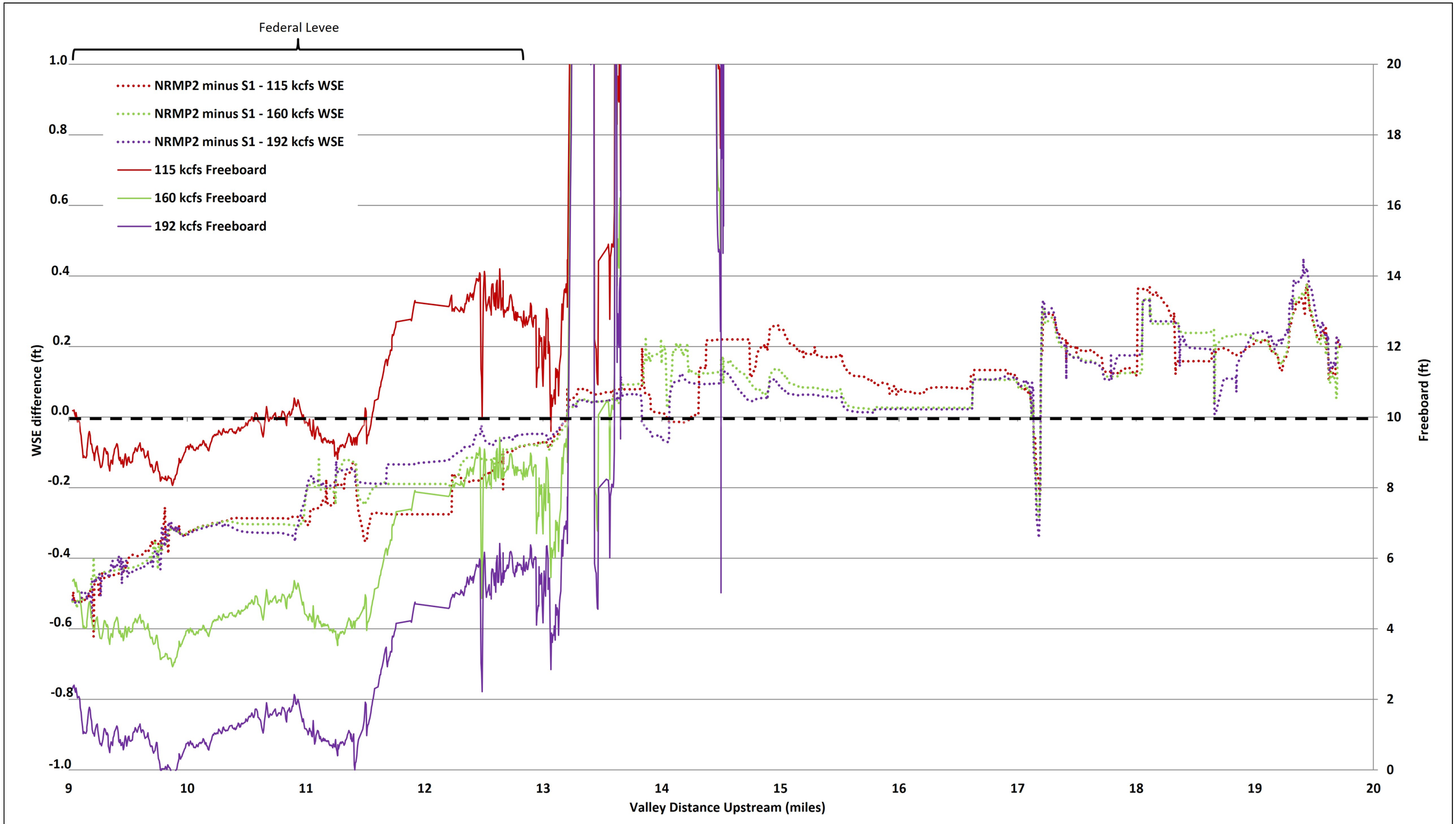
Notes: WSE differences and levee / high ground freeboard values along the north bank (i.e., right bank)

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain North Bank Longitudinal Profile

Project No. 21−1023	Created By: MDW	**Figure 49**



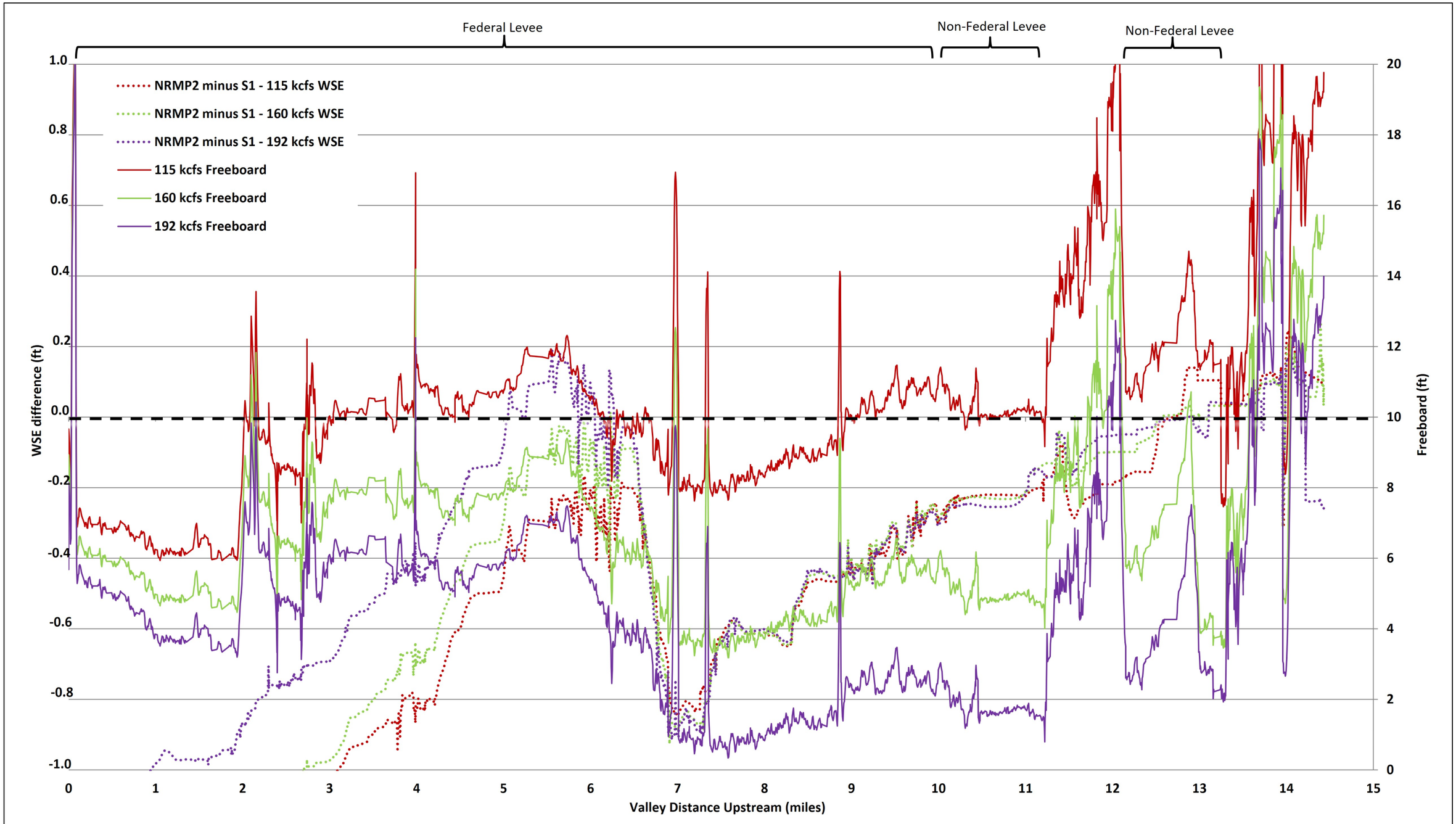
Notes: WSE differences and levee / high ground freeboard values along the north bank (i.e., right bank)

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Upper Domain North Bank Longitudinal Profile

Project No. 21−1023	Created By: MDW	**Figure 50**



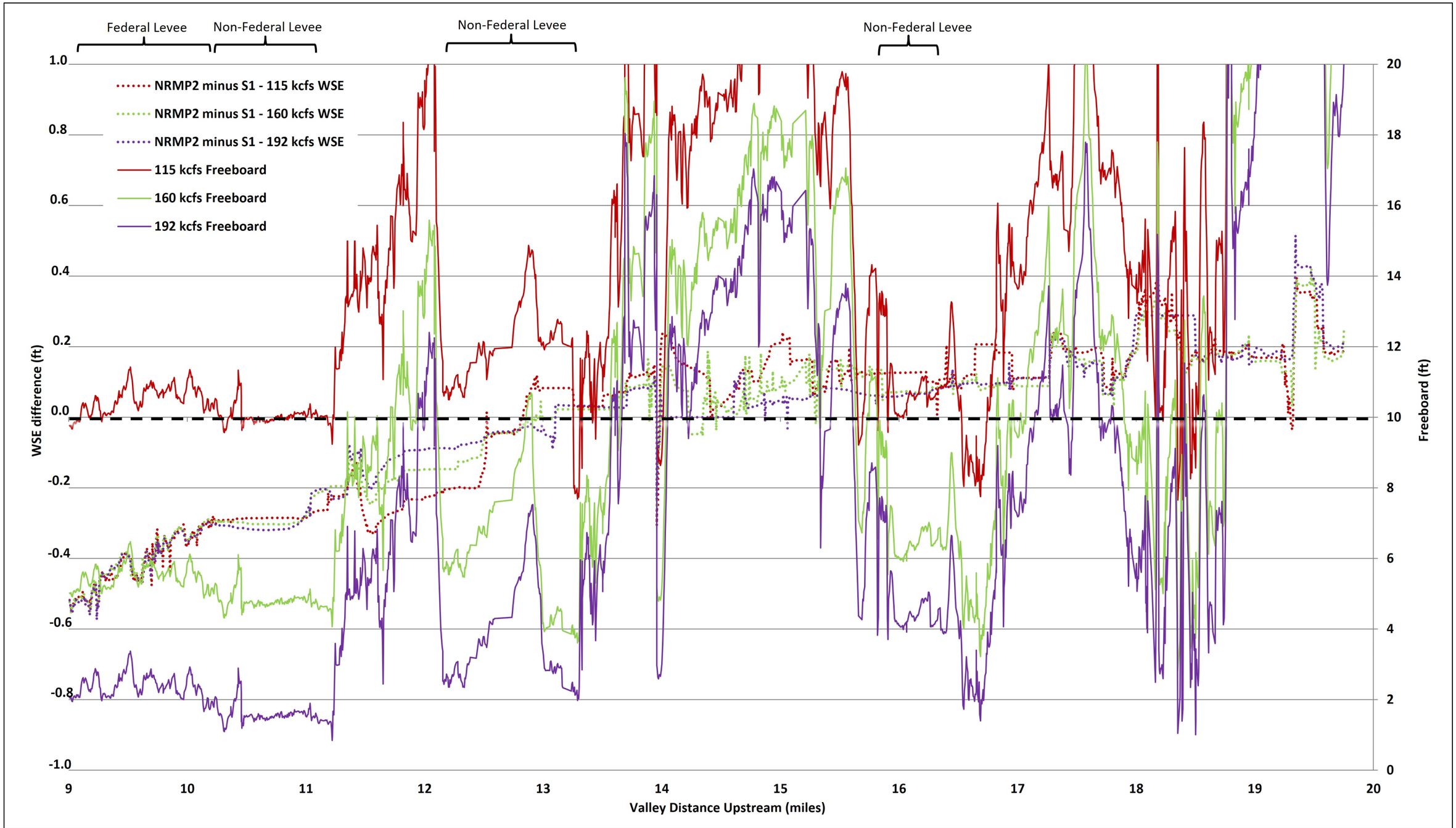
Notes: WSE differences and levee / high ground freeboard values along the south bank (i.e., left bank)

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

Lower Domain South Bank Longitudinal Profile

Project No. 21−1023 | Created By: MDW | **Figure 51**

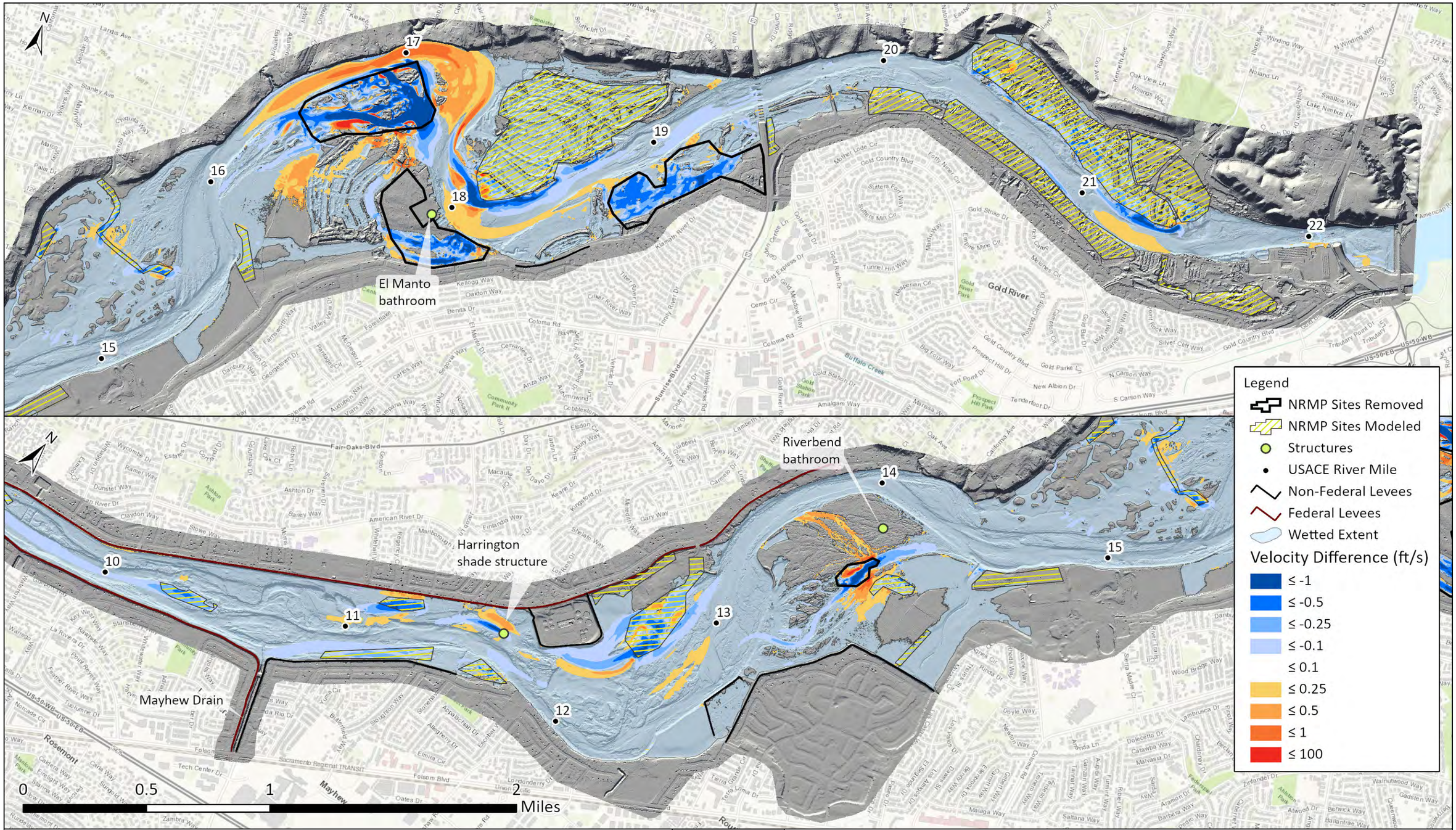


Notes: WSE differences and levee / high ground freeboard values along the south bank (i.e., left bank)

cbec eco engineering

Natural Resource Management Plan Modeling Support Project
Upper Domain South Bank Longitudinal Profile

Project No. 21−1023 | Created By: MDW | **Figure 52**



Notes: 160,000 cfs Velocity differences − showing 4 NRMP sites that were removed (shown with bold black outlines) due to impacts

cbec eco engineering

Natural Resource Management Plan Modeling Support Project

NRMP sites removed − 160 kcfs Velocity Differences

Project No. 21−1023	Created By: MNC	**Figure 53**