Appendix B-1

Hydraulic Analysis

ESA

Final

OWENS RIVER WATER TRAIL

Hydraulic Analysis

ESA

OWENS RIVER WATER TRAIL

Hydraulic Analysis

The Owens River Water Trail (ORWT or project) would require clearing of emergent vegetation (tules and cattail) and excavation of sediment along an approximately 6.3-mile section of the Lower Owens River to allow for recreational navigation. Maintenance of the project may also include periodic vegetation clearing beyond initial construction. The hydraulic model prepared by Northwest Hydraulic Consultants (NHC) for LADWP in 2012 was used for the baseline scenario. ESA adapted NHC hydraulic models of a portion of the project area to evaluate various vegetation clearing and excavation treatments to inform the environmental review.

Hydraulic Modeling

ESA adapted NHC hydraulic models to evaluate a baseline scenario and several design scenarios.

Baseline Scenario Models

In 2012, NHC was contracted by Los Angeles Department of Water and Power (LADWP) for hydraulic model development to study representative reaches within the Lower Owens River Project (LORP) and to support future studies on the effects of various management activities (NHC, 2012). NHC developed one-dimensional HEC-RAS models of five non-contiguous representative sites within the LORP. Each modeled area was approximately 2 miles in length, and model geometry was represented by approximately 60-80 cross sections per model. Cross sections were surveyed by Los Angeles Department of Water and Power (LADWP) between 2009 and 2010. The five LORP models were provided to ESA to facilitate evaluation of the ORWT project in support of the environmental review.

Of the 5 areas modeled by NHC, Plot 4 and Plot 5 are located within the ORWT project area (Figure 1). The Plot 4 model covers approximately 2.2 miles of river and extends from 0.2 miles downstream of the Lone Pine Narrow Gauge Road Bridge (RM 43.85) to RM 45.8. The Plot 5 model covers approximately 2.5 miles of river and extends from RM 46.6 to 0.1 miles upstream of the Keeler Railroad Bridge (RM 48.7). The methods used by NHC to develop the models are described in a report entitled “Lower Owens River Project Hydraulic Model” (NHC, 2012) and briefly summarized below.

While both the Plot 4 and Plot 5 models are within the project area, they are non-contiguous and do not cover the entire project area. It should be noted that the put-in and take-out areas, as well as approximately one mile of river between the downstream extent of Plot 4 and the upstream extent of Plot 5, were not included in the models. ESA utilized the existing models “as-is” to represent a baseline condition. ESA did not independently verify the modeling methods or results, or extend the model domain.

Throughout the project area, the channel is characterized by areas of open water bordered by tules separated by short sections of channel that are either bridged or entirely occluded by tules, and in places large wood (NHC, 2012). NHC noted a “marsh region” in Plot 4 where the single channel split into multiple flow paths with indistinct and discontinuous channels (Figure 1). Additionally, debris jams or beaver dams were observed in the open water areas within the marsh, further contributing to shallow inundation over the valley floor. The marsh region described by NHC was also noted in the field reconnaissance performed by ESA, where it was observed that there was not an obvious main channel (ESA, 2018a). NHC noted that this area is essentially acting as a large densely vegetated floodplain and extends across the entire valley floor. At the downstream end of this area, NHC observed that there was a large drop in the water surface elevation (WSE) where the shallow floodplain flows rejoin the channel.

Channel geometry and vegetation conditions are represented in the one-dimensional HEC-RAS models based on the surveyed channel cross sections (Figures 2 and 3). Survey points describe the coordinates and elevation used to construct the channel and floodplain model geometry and additional details such as the location of channel banks, thalweg, boundaries of tules and other vegetation, as well as other channel characteristics. The roughness parameter, Manning’s n, can be spatially varied across the model cross section to represent zones of differing hydraulic roughness. NHC used different Manning’s n values to represent roughness conditions associated with overbank vegetation, tules, and open water (Table 1) (NHC, 2012). In areas of particularly dense tules, ineffective flow areas were also specified. Ineffective flow areas were simulated as part of the wetted area of the channel, but not contributing to flow conveyance.

TABLE 1
ROUGHNESS VALUES FROM NHC BASELINE MODELS (NHC, 2012)

Roughness Type	Manning’s n Roughness Value
Overbank Vegetation	0.15
Tules	0.70
Open Water	0.065

NHC calibrated the Plot 4 and Plot 5 models using measured water surface taken along the length of both modeled areas. Water surface elevations were surveyed during a period of base flow with daily discharges measured at the Keeler Bridge of 49 cfs and 48 cfs for the Plot 4 and Plot 5 surveys, respectively. Roughness values were adjusted for the overbank vegetation, tules, and open water sections of channel to achieve best fit between the simulated and observed water levels. For the Plot 4 model, NHC found that adjusting the horizontally varied roughness parameter alone did not provide the increase in water surface levels needed to match observed water levels (NHC, 2012). In areas where tules spanned the channel, NHC applied the obstruction option in HEC-RAS to raise the bed level to 2 to 3 feet below the observed water surface to further increase water levels. For the Plot 5 model, the obstruction option was not used and calibration was performed by adjusting roughness values. The calibrated models were shown to generally reproduce observed water levels for the base flow condition to within 0.5 ft (NHC, 2012).

In both the Plot 4 and Plot 5 model areas there are a number of secondary channels that are active at base flow and/or higher discharges. Where possible, NHC modeled the flow into and returning from major secondary channels at various main channel discharges. Five secondary channels were modeled in Plot 4 and four secondary channels in Plot 5. NHC performed additional qualitative calibration using aerial imagery showing the extent of inundation at base flow and at higher flows to determine when secondary channels were connected to the main channel. NHC represented flow into secondary channels as split reaches, where secondary channel topography data were available, or as flow over a lateral weir where topography data were not available. In the models provided to ESA by NHC, secondary channels were not explicitly represented; however, flows in the main channel were varied longitudinally within the HEC-RAS models to represent flow losses and gains due to flow into and re-entry from secondary channels as calculated by NHC.

Design Scenario Models

ESA adapted the model geometry for the NHC Plot 4 and Plot 5 models to represent design scenarios for the ORWT (Table 2). Five scenarios were simulated to assess the potential effects of vegetation clearing and occlusion removal and project designs (Table 3). Scenario 1 represents excavation of the channel bed at mapped occlusions, including the marsh region, to 7 feet below the existing water level. Scenario 1 represents the project described in the ORWT Construction Plan develop by the County of Inyo (COI) in 2016. Scenario 2 represents the maximum impact, with excavation along the entire project area to establish continuous 4 ft water depth. Scenarios 3 and 4 restrict excavation only to the marsh region to create a continuous single channel of a specified width (Table 3). Lastly, Scenario 5 represents excavation to 1 ft below channel bed level at mapped occlusions to remove vegetation root mass and creation of a continuous single channel through the marsh area. All design scenarios also include clearing of vegetation to widths specified for each scenario (Table 3).

Field reconnaissance was performed by ESA in May 2018 to map the location and size of occlusions to inform hydraulic model design and support estimation of construction quantities and costs. NHC Plot 4 and Plot 5 models provided to ESA were adapted from the NGVD 29 vertical datum to NAVD 88 to correspond to elevations surveyed by ESA during field reconnaissance. All subsequent design scenario modeling was performed using the NAVD 88 vertical datum.

TABLE 2
NHC HEC-RAS MODELS ADAPTED FOR PROJECT DESIGN SIMULATIONS

Plot	HEC-RAS Profile
4	A4-P1
5	A5-P1

TABLE 3
SUMMARY OF DESIGN SCENARIOS

Scenario Conditions	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Clearing Vegetation	To minimum of 10 ft-wide along entire project length	To minimum of 10 ft-wide along entire project length	To minimum of 10 ft-wide along entire project length	To minimum of 6 ft-wide along entire project length	To minimum of 10 ft-wide along entire project length
Excavation Location	Excavation at mapped occlusions	Excavation along entire project length	Excavate only in marsh region to create continuous 10 ft-wide channel	Excavate only in marsh region to create continuous 6 ft-wide channel	Excavate in marsh region to create continuous 15 ft-wide channel and at remaining mapped occlusions
Excavation Dimensions	10 ft-wide section at 7 ft below *existing* WSE	10 ft-wide section at 4 ft below *design* WSE	10 ft-wide channel at uniform slope through marsh region	6 ft-wide channel at uniform slope through marsh region	15 ft-wide channel at uniform slope through marsh region 15 ft-wide excavation to 1 ft below existing ground surface at occlusions to remove tule roots

Channel improvement scenarios were represented in the model by adjusting the cross section geometry, roughness values for the main channel and their lateral extents within the cross section, and the locations of ineffective flow areas (Figures 2 and 3). Vegetation clearing was represented in the models by lowering the channel roughness along the “cleared” area and/or by decreasing the portion of the channel represented as ineffective flow area. Cross sections that required vegetation clearing were determined by comparing the width of the channel represented using the existing open water roughness value and the width between ineffective flow areas on the channel banks (if present) to the minimum cleared width of the design scenario (Table 3). If either the open water roughness width or the spacing between ineffective flow areas was less than the width specified for vegetation clearing for each scenario in Table 3, the open water roughness value extent was widened and the roughness value was lowered (Table 4), or the ineffective flow areas extents were decreased to achieve the target spacing.

Removal of occlusions was represented in the models by removing obstructions in Plot 4, lowering the cross section elevations of the streambed as described in Table 3, and by decreasing the channel roughness value and changing the lateral extent of the “excavated” roughness value in the cross section in accordance with the excavation width (Table 3, Figures 2 and 3). Cross sections altered to represent excavation of occlusions were the nearest cross sections bounding the occlusions mapped in the field by ESA.

For Scenarios 2, 3, 4, and 5, where a continuous excavated channel was modeled at a uniform slope, the HEC-RAS channel design/modification geometry tool was used. The channel design/modification tool allows the user to enter a design template to be applied to multiple cross sections in the model at fixed elevations or based on a slope from the upstream or downstream cross section. For Scenario 2, the excavated channel template was projected at a slope that matched the overall channel slope for the entire model length for Plot 4 and Plot 5 (Figures 4 and

5). For Scenarios 3, 4, and 5, where the uniform channel was only excavated through the marsh region, the design/modification tool was applied to create a uniform slope only through the section of the existing channel with higher thalweg elevations (marsh region) in Plot 4 (Figure 4). Vegetation clearing and excavation of the channel were modeled following the thalweg, and as such the “cleared” and/or “excavated” widths of channel are roughly centered on the deepest part of the adjusted cross section (Figures 2-5).

TABLE 4
ROUGHNESS PARAMETER VALUES FOR DESIGN SCENARIO MODELS

Roughness Type	Manning’s n roughness value
Open Water Channel	0.065*
Cleared/Mowed Channel	0.055**
Excavated Channel	0.045**
Tules	0.70*
Overbank Vegetation	0.15*

*Value unchanged from NHC baseline scenario model (NHC, 2012).
**Roughness values for the cleared/mowed and excavated conditions were estimated using the Cowan method with a base roughness value selected to represent the sediment grain sizing and adjusting for channel characteristics, including: degree of irregularity, variation in cross section, obstructions, vegetation, and degree of channel meandering

Boundary Conditions

Hydraulic model simulations were conducted assuming steady-state conditions (flow not varying over time). The data needed for steady-state modeling under the subcritical flow conditions, typical of natural channels, were flow for the upstream boundary condition and stage for the downstream boundary conditions. Baseline and design scenario modeling were performed for two simulated discharges (Table 5). Under the provisions of the LORP, LADWP is required to maintain a minimum discharge of 40 cfs at all times throughout the Lower Owens River. Due to evapotranspiration losses, base flow releases are frequently in excess of the 40 cfs minimum discharge to meet the legal requirement throughout the LORP. Flows measured by LADWP during a base flow condition in 2009 were 49 cfs and 48 cfs in Plot 4 and Plot 5, respectively. Daily discharge data for 2017 and 2018 support the observations noted by NHC. Daily flows can be as low as 40 cfs, but fluctuate near 50 cfs on average. As such, the observed flows of 49 cfs and 48 cfs for Plot 4 and Plot 5, respectively, were selected to simulate the base flow condition in the project area. In addition to a guaranteed base flow discharge, the LORP provides for seasonal habitat flows up to 200 cfs in proportion to snowmelt runoff. A seasonal habitat flow study was conducted by LADWP in June 2011. A maximum flow of 205 cfs was released to the Lower Owens River. Significant flood attenuation was observed during the habitat flow pulse with discharge measured at Keeler Bridge, the approximate downstream extent of the ORWT project area, at 75 cfs. Seasonal habitat flows in the model were therefore simulated using 75 cfs for both Plot 4 and Plot 5.

The downstream stage boundary was simulated as normal depth for Plot 4 and as a known water surface elevation for Plot 5. Under the normal water surface boundary condition, the river stage is calculated assuming uniform flow given a water surface slope. The slope specified for the normal stage boundary was 0.0006 ft/ft to match the slope of the channel bed near the downstream boundary of Plot 4. A known water surface stage boundary was specified for Plot 5 because the downstream extent of the model was just upstream from the older Keeler railroad bridge, which acts as a hydraulic control structure causing a backwater upstream of the structure. Known water surface values were derived from the stage-discharge relationship from the Keeler measuring station.

TABLE 5
FLOWS SIMULATED FOR BASELINE AND DESIGN SCENARIO MODELS

Plot	Base Flow (cfs)	Habitat Flow (cfs)
4	49	75
5	48	75

Results

Hydraulic simulations were run for baseline scenario and all design scenarios at base flow and habitat flow conditions. A comparison of simulations for the base flow condition is summarized in Table 6. The bed and water surface elevation profiles from the hydraulic model simulations for base flow can also be found in Figures 4 and 5. Model results for all design scenario simulations at base flow show a decrease in average water surface elevation relative to the baseline scenario model results. The decrease in water surface elevation was more pronounced in Plot 4 than Plot 5 due to the backwater associated with the marsh region in Plot 4 baseline scenario (Figure 4). The decrease in water surface elevation was more uniform in Plot 5 because there was not a large discontinuity in the water levels present in the baseline scenario (Figure 5). The same pattern can be observed for wetted width, where the decrease in wetted width for design scenarios was more pronounced in Plot 4 (Table 6). As described by NHC (2012), the marsh region in Plot 4 functions as a thickly vegetated floodplain with no continuous channel, with shallow inundation valley-wide. Removing occlusions or excavating a uniform channel through the marsh region results in a significant reduction in wetted width.

While all design scenarios involved some level of excavation of the channel bed, no design scenario results reflect an increase in the average water depth at base flow compared to baseline scenario. Design scenario simulation results suggest that channel clearing, widening, or excavation will increase conveyance and decrease the water depth over the project area. This is supported by an increase in average channel velocity across all modeled design scenarios relative to the baseline scenario model (Table 6). However, for some design scenarios the minimum channel depth would increase relative to baseline scenario or remain unchanged (Scenarios 2 and 4).

Hydraulic model results suggest that for all design scenarios recreational passage of paddle craft would be possible. While no minimum depth value was established for recreational passage, the minimum depth for all design scenarios predicted was 1.6 ft (Scenario 1 in Plot 5), while average depth values were in the range of 3.4 – 5.1 ft.

Model simulations of habitat flow conditions were performed to assess the potential for design scenarios to affect flooding and flow in secondary channels. NHC calculated that for the baseline scenario model during the base flow condition, two of five major secondary channels were activated in Plot 4 with a maximum flow into the secondary channels of 1.8% of the main channel discharge (NHC, 2012). In Plot 5, two of four major secondary channels were activated with a maximum flow into secondary channels of 3.5% of the main channel discharge. During the higher habitat flow condition, NHC predicted that all major secondary channels were activated with maximum discharge into secondary channels increasing to 9.9% and 24.3% for Plot 4 and Plot 5, respectively.

Table 6 Base flow simulation results for baseline and design scenarios for Plot 4 and Plot 5 HEC-RAS models

	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Plot 4						
Minimum Channel Depth (ft)	2.2	2.0	3.2	2.1	3.0	1.9
Average Channel Depth (ft)	5.9	4.1	3.4	4.0	5.1	4.0
Average Change WSE (ft)	--	-3.0	-5.6	-2.8	-1.8	-3.1
Maximum Change WSE (ft)	--	-4.9	-7.6	-4.7	-3.3	-5.2
Minimum Wetted Width (ft)	48.0	10.0	10.6	10.4	28.2	15.4
Average Wetted Width (ft)	182.9	56.7	23.3	58.5	75.9	55.6
Average Channel Velocity (ft/s)	0.3	0.6	1.4	0.6	0.6	0.8
Median Channel Shear Stress (lb/sq ft)	0.01	0.05	0.07	0.05	0.04	0.05
Plot 5						
Minimum Channel Depth (ft)	2.4	1.6	3.1	2.0	2.4	1.7
Average Channel Depth (ft)	5.0	4.3	4.3	4.1	4.3	4.1
Average Change WSE (ft)	--	-1.1	-3.6	-0.9	-0.7	-1.2
Maximum Change WSE (ft)	--	-2.7	-5.4	-1.8	-1.4	-2.5
Minimum Wetted Width (ft)	34.5	21.3	10.6	24.8	26.5	21.4
Average Wetted Width (ft)	59.2	47.7	21.1	50.5	52.8	47.0
Average Channel Velocity (ft/s)	0.4	0.7	1.3	0.7	0.8	0.8
Median Channel Shear Stress (lb/sq ft)	0.05	0.05	0.06	0.07	0.07	0.05

In Plot 4, simulations predict that all habitat flow water surface elevations would be lower than the water surface elevation predicted for the base flow condition under the baseline scenario. Figure 6 displays Scenario 5 base flow and habitat flow water surface elevations relative to the same parameters under the baseline scenario in Plot 4. Given the limited interaction between the main stem and the secondary channels predicted by NHC for baseline scenario at base flow, the design scenario simulation results suggest secondary channels would be hydraulically disconnected in Plot 4 for the base flow and habitat flow conditions. The decrease in water surface elevations for all scenarios also suggest that overbank inundation will be reduced in frequency and magnitude for all design scenarios. We believe this is largely due to the removal of obstructions in the channel and the reduced backwater effect as a result of channel excavation in Plot 4.

In Plot 5, the habitat flow water surface elevations simulated for the design scenarios were similar to the base flow water surface elevations under the baseline scenario. Figure 7 displays Scenario 5 base flow and habitat flow water surface elevations relative to water surface elevations for base flow under baseline scenario in Plot 5. These results suggest that at base flow, the design scenarios will most likely be hydraulically disconnected from secondary channels. During the habitat flow for design scenarios, the diversions to secondary channels in Plot 5 should be similar to the predicted discharges by NHC for baseline scenario base flow. As in Plot 4, the decrease in water surface elevations for design scenarios suggest that overbank inundation will be reduced in frequency and magnitude for all design scenarios.

Excavation Quantities

Excavation quantities were estimated at a conceptual level to inform the assessment of scenarios.

Methods

Excavation quantities were estimated based on model geometry and field observations (ESA, 2018a). For scenarios where excavation was modeled at mapped occlusions (Scenario 1 and Scenario 5), ESA measured water depth at the upstream and downstream faces of each occlusion, as well as the length of the occlusion where possible. Where access was not possible, depths and lengths were estimated from visual observations. Excavation volumes for each occlusion were estimated as the average depth of excavation estimated from the upstream and downstream faces of the occlusion multiplied by the length of the occlusion and the design width (Table 3). For Scenario 1, the excavation depths included the amount at the upstream and downstream faces required to reach 7 ft depth, assuming that the water surface at the time of observation would not change due to occlusion removal. For Scenario 5, excavation at occlusions was intended to remove the tule root mass only, which was estimated to extend to 1 ft below existing bed level. Excavation quantities for all mapped occlusions were summed to estimate a total excavation quantity.

For design scenarios with a uniform excavated channel (Scenarios 2, 3, 4, and 5), excavation quantities were estimated using the HEC-RAS design/modification tool, which provides a cross sectional area of the channel excavation template being applied to each cross section. Using the end area average method, the cut area at each cross section was multiplied by the length between cross sections to estimate volumes. Volumes between cross sections were summed to estimate a total excavation quantity. For Scenario 2, it was assumed that excavation would be continuous throughout the project area, including the channel upstream of Plot 4, between Plot 4 and Plot 5, and downstream of Plot 5. Excavation quantities were calculated by determining the average excavation volume per linear distance in Plot 4 and Plot 5 and then multiplying by the lengths of channel not covered by the Plot 4 or Plot 5 models. For Plot 4, an adjusted excavation volume per unit length did not include the marsh region excavation volume or length. This was done as the excavation associated with the marsh region was unrepresentative of areas upstream or downstream. The volume of excavation upstream of Plot 4 was calculated using the Plot 4 adjusted average excavation volume per length. The volume of excavation between Plot 4 and Plot 5 was calculated using the average excavation volume per unit length from Plot 5, as the channel slope between Plot 4 and Plot 5 is more similar to the channel slope in Plot 5. The volume of excavation downstream of Plot 5 was also calculated using the Plot 5 average excavated volume per unit length value.

For Scenarios 3 and 4, excavation quantities were calculated using the design/modification tool, and use of the end area average method was limited to the marsh region in Plot 4. Those scenarios did not require extrapolation to the areas of channel without model coverage. For Scenario 5, the total excavation quantity was calculated using both field survey data and the design/modification tool, as excavation was specified as occurring at mapped occlusions and a continuously excavated uniform channel through the marsh region.

Excavation quantities assume that the material excavated is sediment and not vegetation biomass. Vegetation volumes that will be removed were not estimated given the uncertainty in the density and height of vegetation, and other factors. Realistically, excavated bed material will be comprised of some mixture of mineral sediment, organic matter, and vegetation.

A key difference between scenarios is the method of initial channel excavation. For Scenarios 1 and 2 it was assumed that a barge-based excavator would be placed at either the upstream or downstream end of the project and would excavate throughout the length of the project area. For barge-based excavation, it was assumed that the barge would require a minimum depth of 3 ft across a 10 ft-wide section of channel, which could increase to 4 ft required depth, depending on the load carried by the barge. Scenario 1 did not meet the minimum depth requirement for either Plot 4 or Plot 5. Scenario 2 did meet the minimum 3 ft depth requirement for Plot 4 and Plot 5, but did not meet the more conservative 4 ft depth threshold desired for barge-based excavation. For Scenarios 3 through 5, it was assumed that the continuous depth requirement of a 3 to 4 ft draft needed for the barge would not be met and that excavation would be conducted via either amphibious vehicle (e.g., Truxor or Aquamog) or terrestrially. For Scenarios 3 and 4 it was assumed that no excavation would be performed at occlusions, just vegetation clearing.

Results

Excavation volume totals varied considerably between design scenarios with greater than a factor of 90 difference between the scenarios with the least and the greatest excavation (Table 7). Excavation quantities were the least for Scenarios 3 and 4, where excavation was limited to creating a uniform channel through the marsh region in Plot 4. Scenario 1 and Scenario 5 represented an intermediate level of excavation. The Scenario 5 excavation volume was less than Scenario 1, due to the channel deepening at occlusions required for Scenario 1 (excavation to 7 ft below existing water surface level). Scenario 2 represents the greatest level of excavation with 10 times the excavation of the next highest scenario. The estimated cost of excavation for the design scenarios ranged from under $20,000 to over $1,700,000 (Table 7). The values in Table 7 do not include all construction costs and therefore are only valid for relative comparisons among the scenarios.

TABLE 7
INITIAL CONSTRUCTION EXCAVATION QUANTITIES AND COSTS

Scenario	Excavation Volume (CY)	Cost ($40/CY)*
1	4,737	$189,500
2	42,729	$1,709,100
3	831	$33,200
4	465	$18,600
5	2,995	$119,800

*Initial channel excavation costs calculated using assumed cost of $40/CY (based on personal communication with Lance Dohman of Aquatic Environments, Inc.). The $40/CY cost represents only in-channel excavation work required to remove material. This value does not include site spreading, mobilization and demobilization, transport, or material disposal costs.

Vegetation Management

Vegetation management level of effort was estimated at a conceptual level to inform the assessment of scenarios.

Methods

As noted in the 2014 LORP Adaptive Management Plan, emergent vegetation encroachment in the form of tules (bulrush and cattails) has been an issue within the Lower Owens River (Ecosystem Sciences, 2014). Within the ORWT project area, current conditions of dense emergent vegetation growth do not permit for recreational passage. It is assumed that even after initial design construction some level of vegetation management will be required to maintain recreational passage within the project area. In order to calculate the level of effort to manage vegetation within the project area, the hydraulic model simulation results were assessed to determine whether the scenarios could mitigate tule growth. It was assumed that emergent vegetation could be characterized by cattail (*Typha latifolia*) and hardstem bulrush (*Shoenoplectus acutus*), which were observed to be the primary species present in the channel within the project area. According to USDA Fire Effects Information System (FEIS), cattails can tolerate up to 3 ft water depth, while hardstem bulrush can tolerate up to 5 ft of continuous submergence (Esser, 1995; Gucker, 2008).

Additionally, Groeneveld and French (1995) found that at a certain combination of water depth and flow velocity that the drag forces on tules would cause individual bulrush stems to permanently deform (lodging) and lose function. The study was intended to provide a tool to inform potential flow management standards to manage emergent vegetation for the LORP. The authors developed an index calculated as the flow velocity multiplied by the depth divided by the stem diameter. The study found that 95% of tule stems would lodge at an index value of 12.8. Using an assumed stem diameter of 2cm (suggested by the study), the drag force index value was calculated for each cross section from the hydraulic simulation results for all design scenarios.

The length of channel requiring ongoing vegetation removal was calculated from the simulated water depth and drag force index. Using the river stations of the modeled cross sections and the simulation results, the river stations where the simulated hydraulic conditions would drop below the 5 ft depth criteria or the 12.8 drag force index criteria were linearly interpolated. Using this information, the channel was assumed to require ongoing vegetation management in sections where neither the depth or drag force criteria were met. For each design scenario, the length of channel requiring vegetation management was calculated for Plot 4 and Plot 5.

As described in Section 2.3 above, estimating the vegetation maintenance lengths for the sections of channel within the project area that are not covered by the Plot 4 or Plot 5 models required extrapolation. For Plot 4, the percentage of the total length requiring ongoing vegetation management was calculated. For Plot 5, the percentage of channel length requiring management was adjusted to be the percentage of channel length not meeting the vegetation management criteria thresholds upstream of the backwatered area at the downstream extent of Plot 5. This was done as the backwater at the downstream end of Plot 5 caused by the Keeler railroad crossing structure does not represent typical conditions in Plot 5. The length of vegetation management upstream of Plot 4 was calculated using the percentage requiring maintenance from Plot 4. The length of vegetation management between Plot 4 and Plot 5 was calculated using the adjusted percent requiring management from Plot 5, as channel slope between Plot 4 and Plot 5 was more similar to channel slope through Plot 5. Downstream of Plot 5 it was assumed that no ongoing vegetation management was required. This is due to the backwater condition downstream of Plot 5. At the downstream boundary of Plot 5, all design scenarios exceeded 5 ft depth, so it was assumed that the channel downstream of Plot 5 also met or exceeded the 5 ft depth criteria to exclude vegetation. Extrapolated vegetation management lengths for the channel areas not covered by the Plot 4 and Plot 5 models were calculated for all design scenarios and added to calculated Plot 4 and Plot 5 management lengths to provide estimates of overall vegetation management required.

Results

Level of effort for ongoing vegetation management is similar for all design scenarios, except for Scenario 2 (Table 8). The hydraulic model results suggest that only Scenario 2 would be capable of passively managing emergent vegetation. Under Scenario 2, the effect of concentrating flow in a narrower channel would lead to a combination of depth and flow that would produce drag forces in excess of what was predicted to cause permanent deformation of tules (Groeneveld and French, 1995). Scenario 2 did not meet the 5 ft depth requirement to exclude vegetation except at the downstream end of Plot 5, where backwatering was caused by the Keeler railroad structure. Under all other design scenarios, the model results predict that there would be sections of channel within the project area that would meet the depth and/or drag force criteria needed to exclude vegetation, but that the design scenarios could not passively exclude vegetation, and would require ongoing maintenance over the project lifespan. There was little difference in the level of effort predicted to manage vegetation between design Scenarios 1, 3, 4, and 5, with work time ranging from 1.1-1.3 weeks annually (Table 8).

Level of effort estimates for design scenarios do not consider the effects of root removal on ongoing maintenance of emergent vegetation. Design scenarios 1, 2, and 5 assume that occlusions will be excavated to at least below emergent vegetation root level. In this way, vegetation maintenance estimations performed by assessing depth and drag force may not be accurate for scenarios 1, 2, and 5 in the period before vegetation re-establishes in the excavated areas. It is likely that vegetation management would not be required at the excavated sites until some time after initial construction at which point colonization from rhizomal reproduction or through seed dispersal would have re-established vegetation in the channel. For design Scenarios 3 and 4, where vegetation would be mowed or cleared, vegetation maintenance estimates based on depth or drag force should be more appropriate to describe ongoing vegetation maintenance work immediately following design construction.

TABLE 8
VEGETATION MAINTENANCE LENGTHS AND ESTIMATED WORK DURATION

Scenario	Vegetation Maintenance Length (ft)	Vegetation Maintenance Time (weeks)*
1	12,717	1.1
2	0	0
3	14,595	1.3
4	13,068	1.2
5	13,742	1.2

*Vegetation maintenance work duration was calculated assuming vegetation clearing would be done using a Truxor. The vegetation cutting rate was assumed to be 5 ft/min and the open water drive rate to be 100 ft/min, based on drive speed of 0-100m/min (Aquaclear Water Management). Work times assume 8 hours of operation per day excluding deployment time and equipment maintenance. Frequency of maintenance is not specified and would depend on tule growth rate.

Discussion

Model Limitations

Hydraulic model results are intended to be used for impact analysis to compare relative differences between scenarios. ESA has not independently assessed the quality of modeling methods and results received from NHC.

Channel Evolution

Hydraulic model simulation results predict increased flow velocities and shear stress for all design scenarios. As noted by ESA, increase in shear stress for the project area would slightly increase the capacity of the channel to transport sediment and would create a higher degree of sediment transport continuity. The increase in shear stress is, however, unlikely to shift the system from stable to unstable and result in channel incision or avulsion (ESA, 2018b). While the results suggest little overall change in sediment transport capacity, design scenarios show a more even distribution of shear stress throughout the project area due to the removal of occlusions.

Habitat Flow

As predicted by the design scenario hydraulic model simulation results, all scenarios would lead to a decrease in water surface elevation. This decrease in water surface elevation would result in less frequent activation and decreased magnitude of flows to secondary channels. Similarly, floodplain inundation frequency and magnitude would be decreased. Model simulation results predict that for Plot 4, higher flows achieved during seasonal habitat flow releases may not activate secondary channels and that flow may no longer spill onto the floodplain. For Plot 5, the model results suggested that habitat flows would result in similar activation and flow in secondary channels as current base flow conditions.

During the field survey in May 2018, ESA observed that at base flow, secondary channels contained water even though modeling by NHC predicted little or no secondary channel activity. It is hypothesized that the inundation in secondary channels is driven by the level of the groundwater table. No piezometer or well data were available for the project site to assess surface water-groundwater interactions.

References

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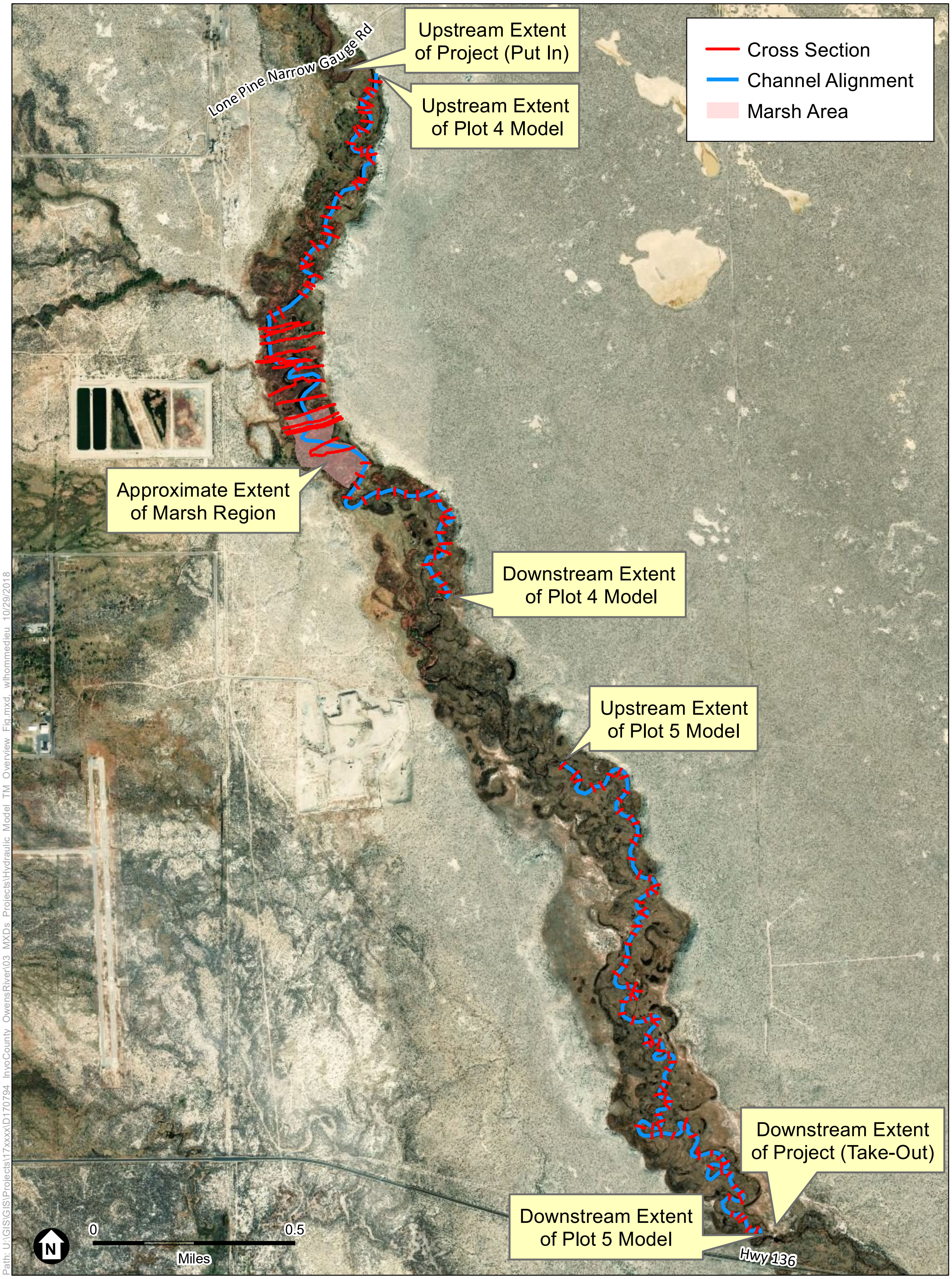
Figures



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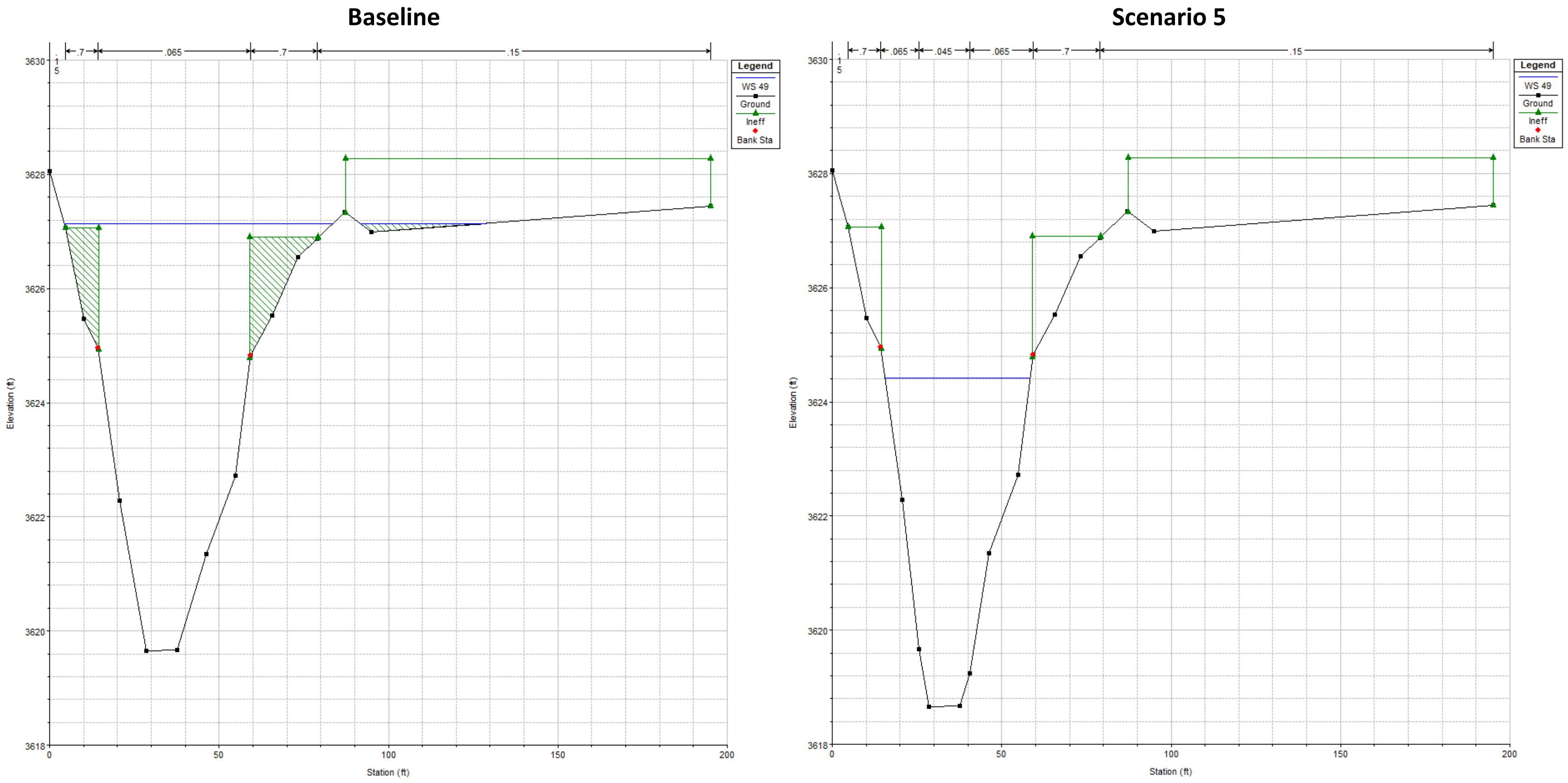
SOURCE: HEC-RAS model (ESA, 2018); Imagery (ESRI, 2018)

Owens River Water Trail EIR

Figure 1
Project Area
Hydraulic Model Extents

ESA



Baseline

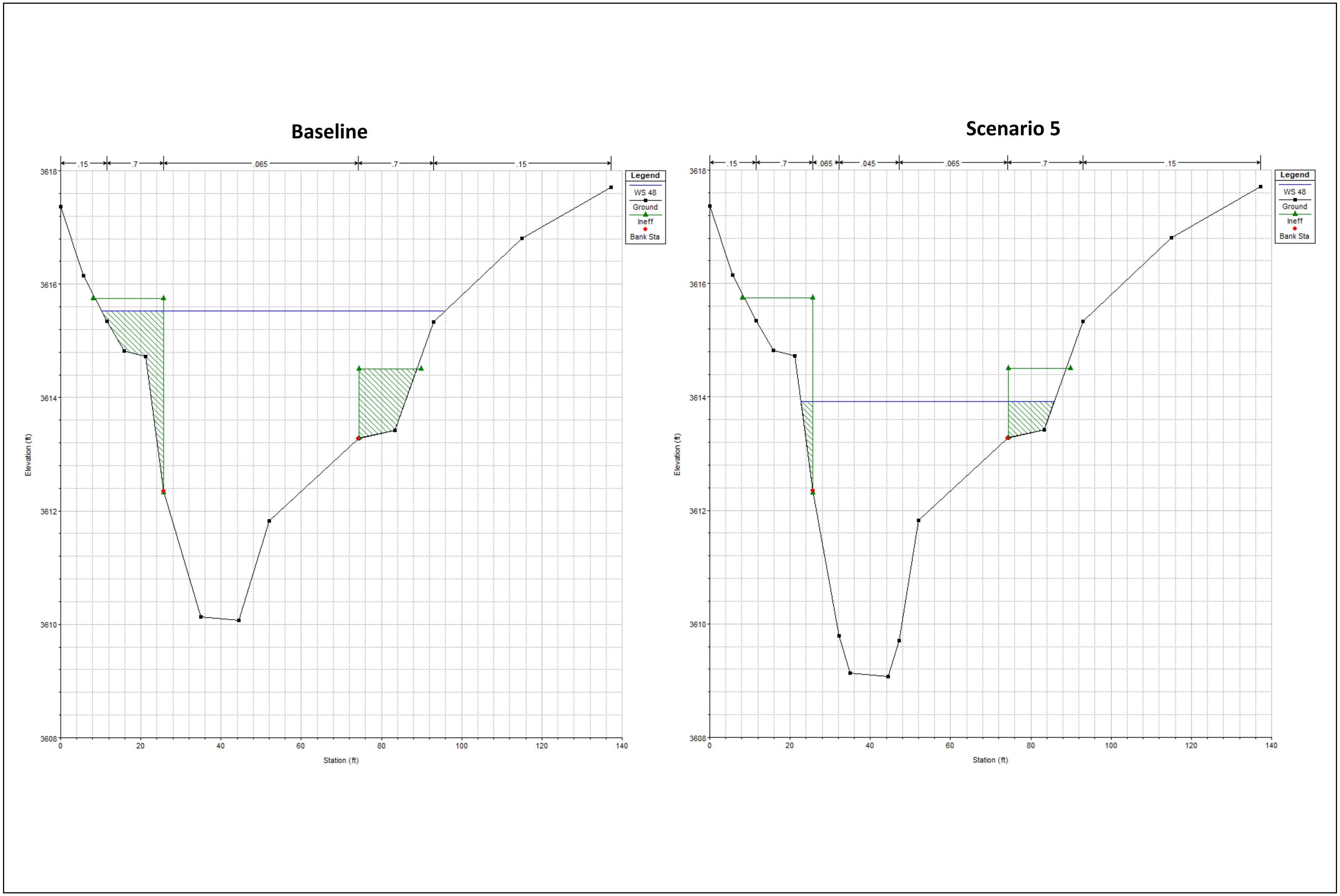
Scenario 5

SOURCE: ESA ORWT HEC-RAS model (Plot 4)
NOTES: Water surface elevation shown for base flow discharge. Ineffective flow areas depicted by hatched green regions. Roughness values and their extents shown above the cross section.

Owens River Water Trail EIR

Figure 2

Plot 4 - Model Typical Cross Section
Baseline Conditions versus Scenario 5

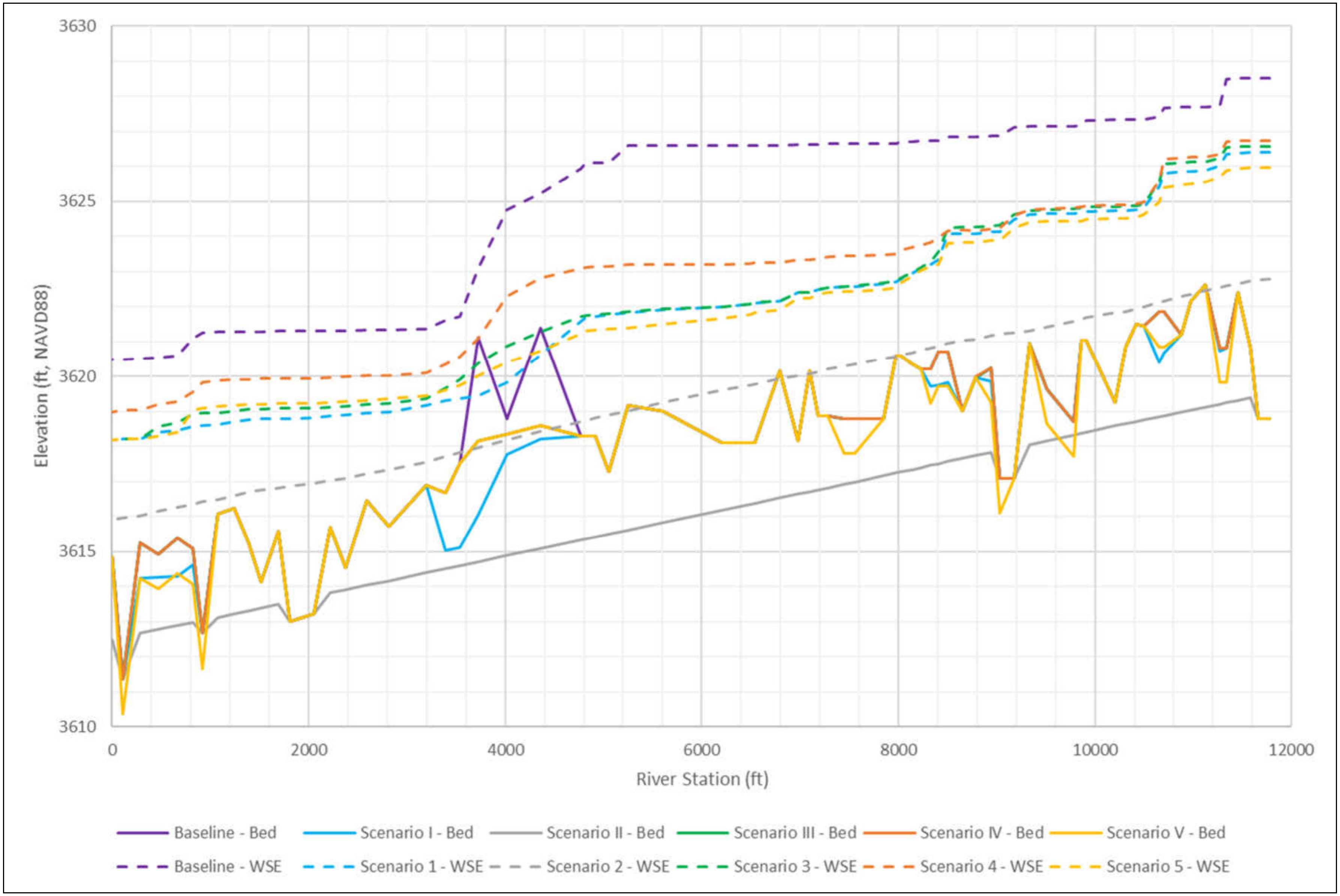


SOURCE: ESA ORWT HEC-RAS model (Plot 5)
NOTES: Water surface elevation shown for base flow discharge. Ineffective flow areas depicted by hatched green regions. Roughness values and their extents shown above the cross section.

Owens River Water Trail EIR

Figure 3

Plot 5 - Model Typical Cross Section
Baseline Conditions versus Scenario 5

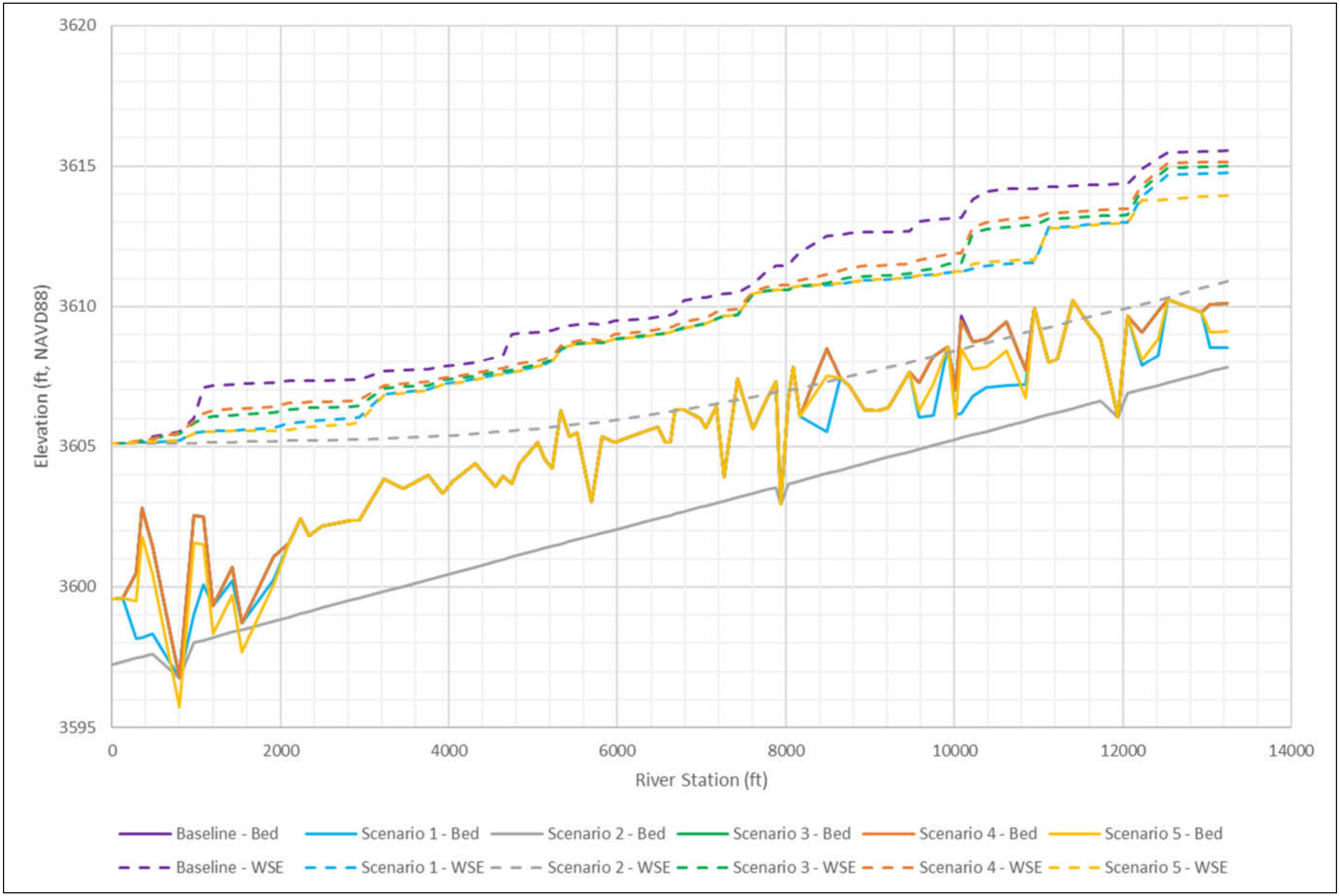


SOURCE: ESA ORWT HEC-RAS model (Plot 4)

Owens River Water Trail EIR

Figure 4

Plot 4 – Water Surface Profile (Base Flow)
Hydraulic Model Results

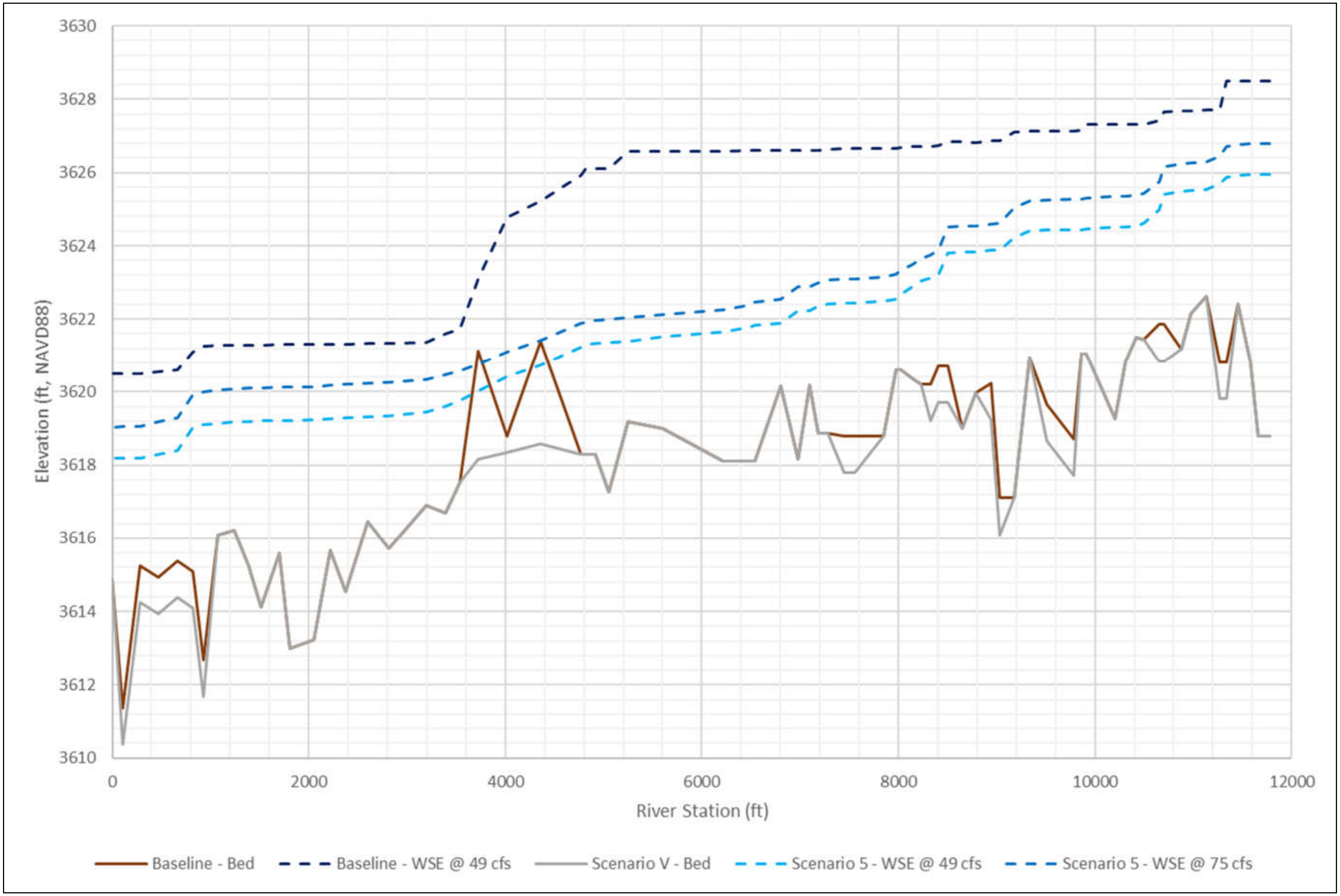


SOURCE: ESA ORWT HEC-RAS model (Plot 5)

Owens River Water Trail EIR

Figure 5

Plot 5 – Water Surface Profile (Base Flow)
Hydraulic Model Results

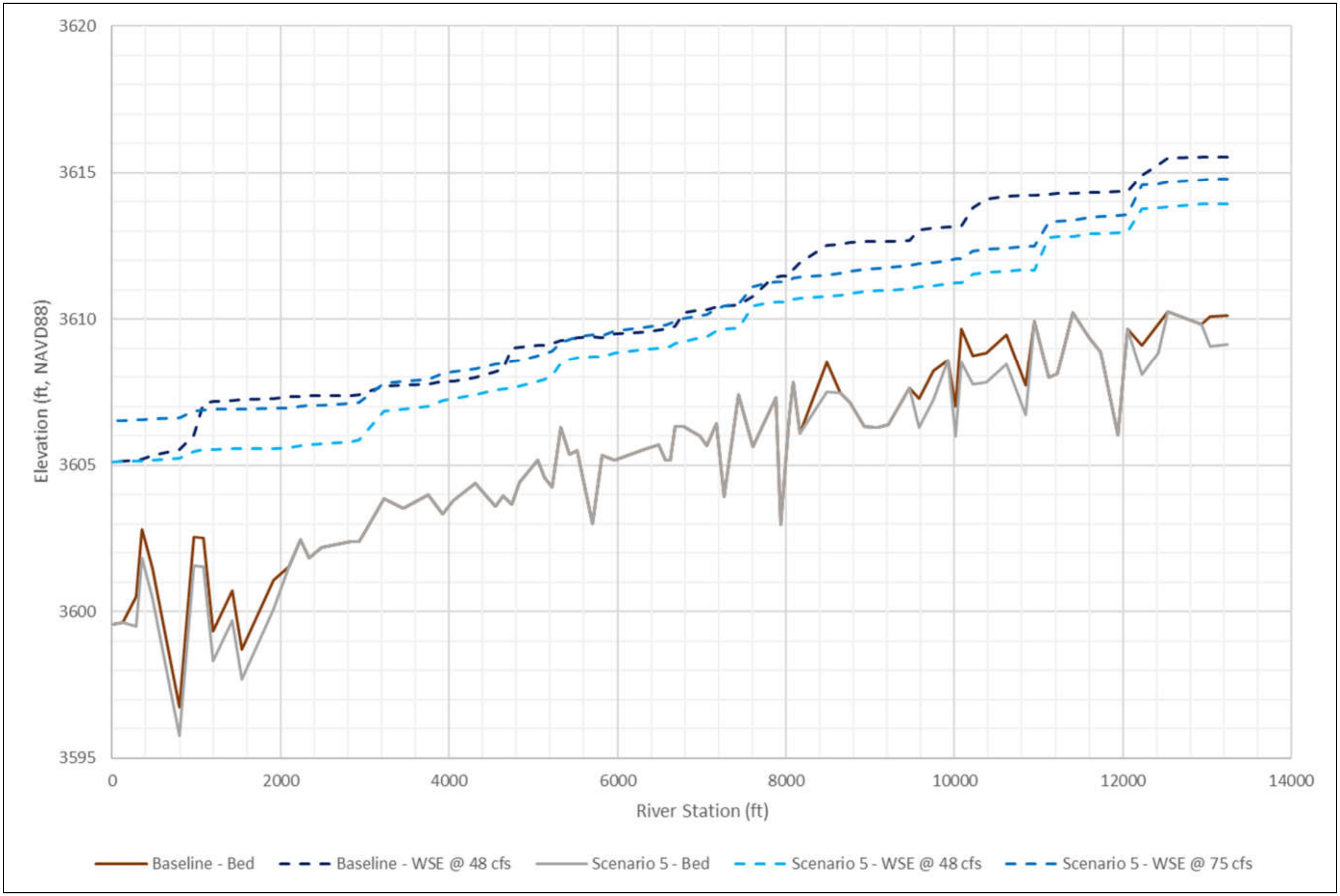


SOURCE: ESA ORWT HEC-RAS model (Plot 4)

Owens River Water Trail EIR

Figure 6

Plot 4 – Baseline versus Design Water Surface Elevation Hydraulic Model Results



SOURCE: ESA ORWT HEC-RAS model (Plot 5)

Owens River Water Trail EIR

Figure 7

Plot 5 – Baseline versus Design Water Surface Elevation
Hydraulic Model Results