Appendix E

Hydraulics

Shorty's Island / Meander Reach
Ecosystem Restoration

Kootenai River, Idaho

Draft Continuing Authorities Program Section 1135
Detailed Project Report and Integrated
Environmental Assessment

June 2012

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1 INTRODUCTION

Appendix E presents hydraulic analyses performed to support the development of the 35 percent design of the substrate placement and to assess the influence of the proposed substrate placement on hydraulic conditions in the Kootenai River. General information on existing hydraulic, hydrologic and geomorphic conditions was presented in Chapter 3 of the Main Report and is not repeated in this appendix.

The analysis in this Appendix came from two primary sources. Tetra Tech performed one-dimensional hydraulic analysis of the Kootenai River with and without substrate placement using a one-dimensional hydraulic model. The one-dimensional model used for hydraulic analyses in this appendix was the U.S. Army Corps of Engineers HEC-RAS. The USGS analyzed multibeam bathymetry they had collected to evaluate bed forms in the area of substrate placement and applied a two-dimensional hydraulic model to evaluate hydraulic conditions in the area of the proposed substrate placement and to identify potential influences of the substrate placement on local hydraulic conditions. The two-dimensional hydraulics analyses were performed using the USGS FaSTMECH model.

Specific topics presented in Appendix E:

- Evaluation of bedforms performed by the USGS
- Description of the one-dimensional hydraulic model
- Determination of water surface elevation to guide placement of substrate
- Determination of the influence of substrate placement on flooding conditions
- Analysis of incipient motion conditions for the placed substrate
- Description of the two-dimensional hydraulic model applied by the USGS
- Two-dimensional modeling of local hydraulic effects of the placed substrate performed by the USGS

2 EVALUATION OF BEDFORM HEIGHT BY THE USGS

One of the primary concerns for the substrate placement is the potential for burial by sand deposition. The USGS helped investigate this concern by reviewing the bathymetric data to identify bedform amplitudes and seasonal elevation changes (scour and fill) as a critical part of that risk assessment. To provide more information to evaluate and guide the design, the USGS looked at the detailed bathymetric measurements to map bedform heights and to obtain information about seasonal bed elevation adjustments in the vicinity of the proposed substrate placements.

2.1 METHODOLOGY

Multibeam hydroacoustic bathymetry data collected during several different time periods were used to analyze bedforms on the Kootenai River between ~235.5 RKM (146.3 RM) and ~229 RKM (142.3 RM). Bathymetry was measured in the vicinity of Shorty's Island in April of 2008 at a flow of approximately 6,120 cfs, at Myrtle Creek in April of 2010 at ~12,800 cfs, and throughout the study reach in June of 2010 at flows between 29,000 cfs and 40,600 cfs (Figure 2.1). Bedforms were measured along longitudinal transects oriented parallel to stream flow for all available bed surveys. The height of each bedform was recorded and the average height, maximum height, and wavelength for each transect were determined. Transect data and visual inspection of the bed topography were used to delineate polygons with average bedform height classified into 5 categories: 0-0.5 m, 0.5 to 1 m, 1.0 to 1.5 m, 1.5 to 2.0 m, and 2.0 to 2.5 m (0-1.6ft, 1.6 to 3.3 ft, 3.3 to 4.9 ft, 4.9 to 6.6 ft, 6.6 to 8.2 ft). Areas of the bed where lower amplitude bedforms (typically less than about 0.5 m (1.6 ft)) were possibly present, but difficult to distinguish from clay terraces, are shown in grey. Areas of the bed where it was not possible to assess the presences or absence of bedforms are shown as undetermined in white. Areas that are undetermined generally coincide with clay terraces identified by Gary Barton in the facies maps. Bathymetry and average bedform height maps for the entire study reach measured in June 2010 are shown in Figures 2.2 and 2.3. Detailed maps and discussion are provided below for areas near Myrtle Creek, Shorty South, and Shorty North.

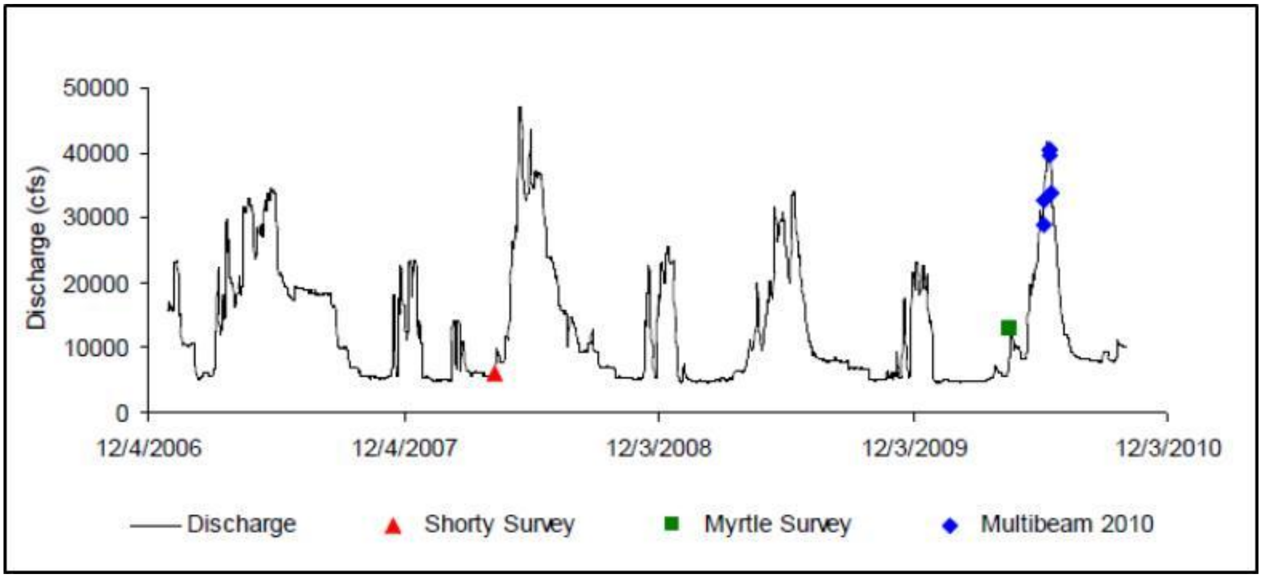

Figure E-1. Kootenai River Discharge and Bathymetric Survey Dates (USGS)

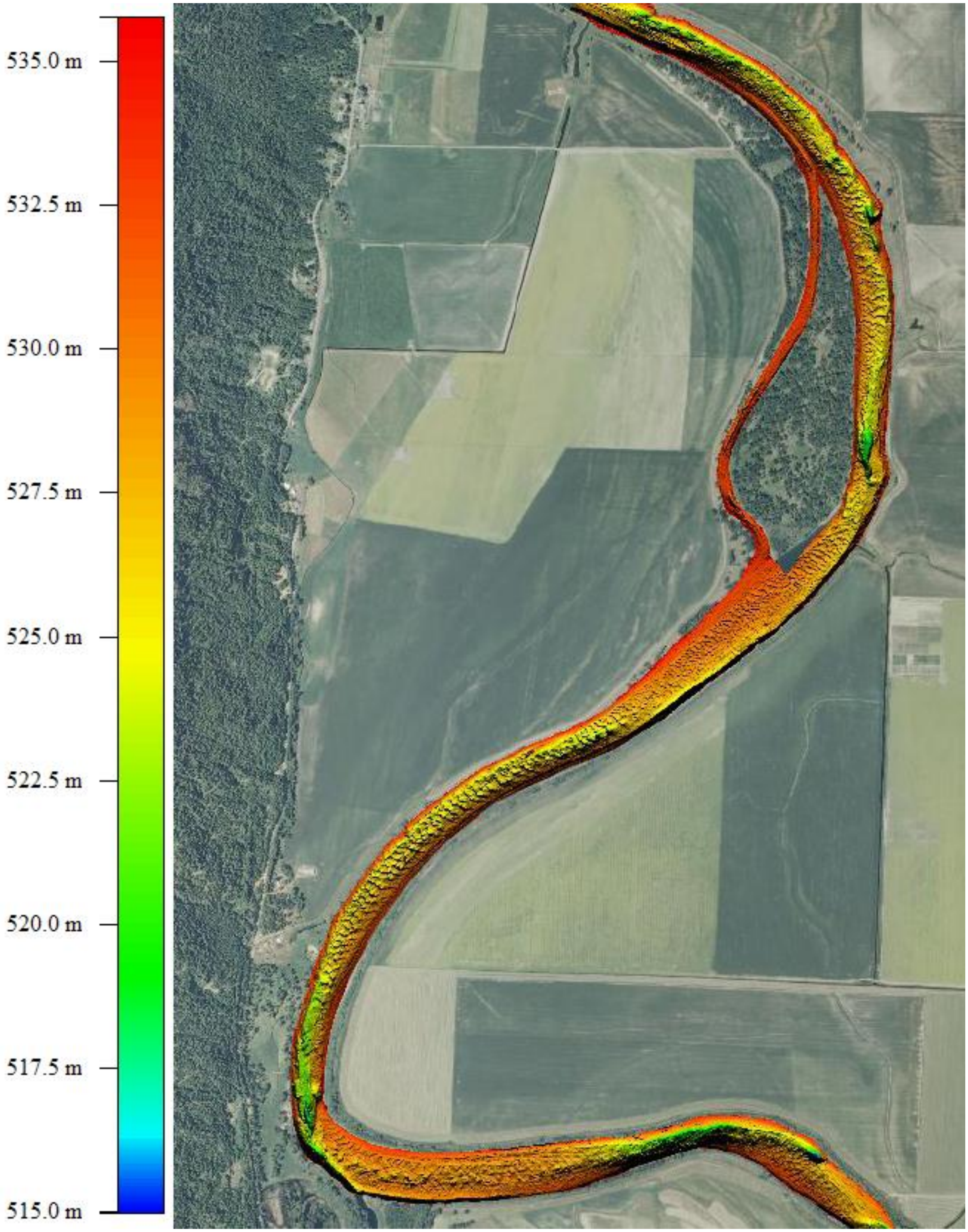

Figure 2-2. Bathymetry Collected in 2010 between Myrtle Creek and Shorty's North(USGS)

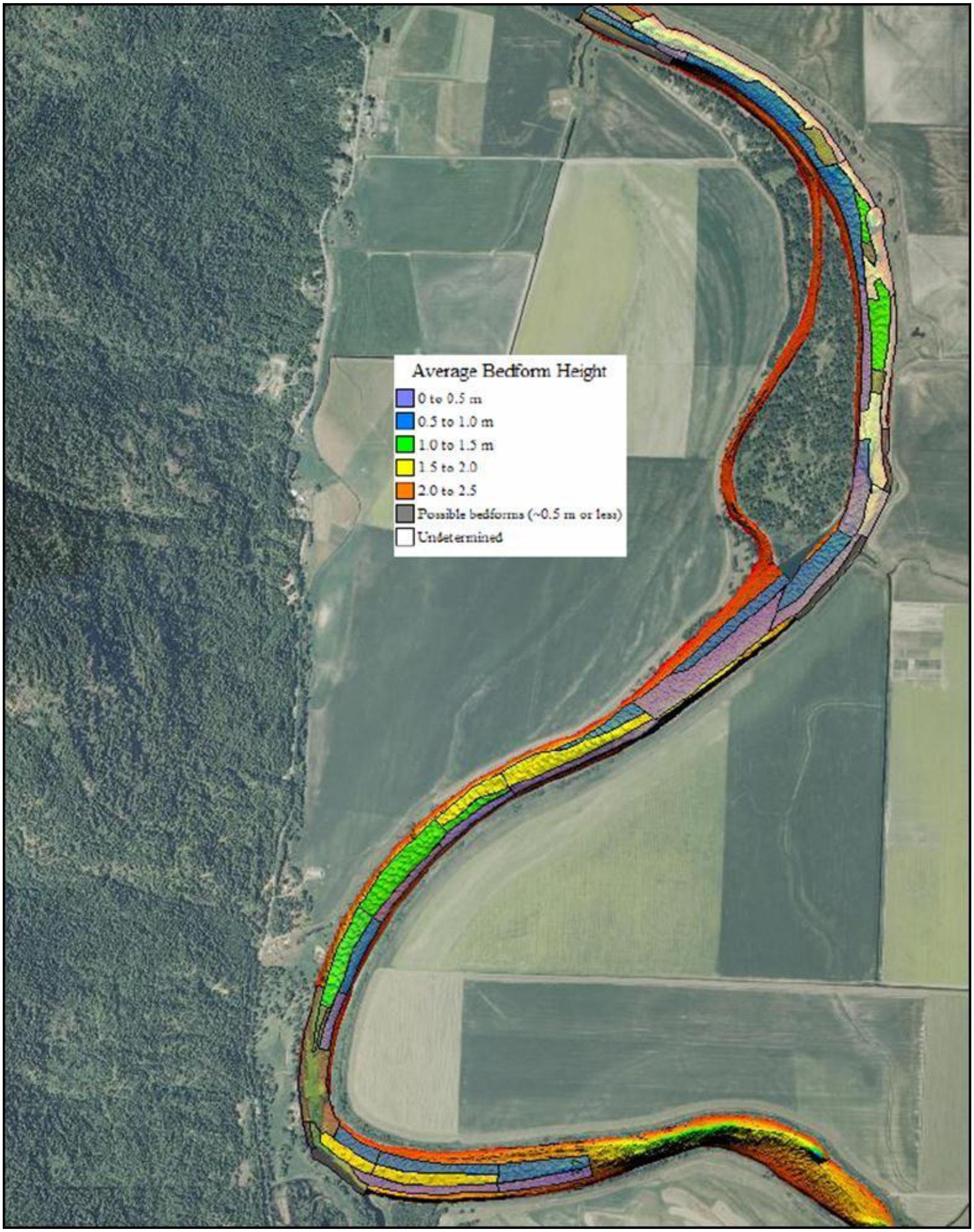

Figure 2-3. Average Bedform Height Determined from June 2010 Bathymetry (USGS)

2.2 SUMMARY OF BEDFORM MORPHOLOGY OBSERVATIONS

Results of the USGS bedform observations for each of the three substrate placement sites developed from the June 16, 2010 bathymetry are presented below.

2.2.1 MYRTLE CREEK

The June 16, 2010 Myrtle Creek bathometry collected at a discharge of 39,600 cfs was processed and the dune bed form heights interpreted from the variation in the bathymetry by the USGS. Figure 2.4 shows the shaded images of the bed forms (left hand side) and the estimation of the bed form height (right hand side). The proposed substrate placement on clay shelves are identified on each figure. From interpretation of the bathymetry, the USGS indicated the bedforms in the vicinity of proposed substrate placements on the clay shelves may be small dunes that are 5 to 30 cm (2.0 to 11.8 in) in height but these features are not very distinct and may be simply variability in the bed combined with measurement noise. Review of videography taken by Gary Barton of the USGS indicated that the area was clay without bedforms (July 20-22, 2010). Interpretation of the bathymetry by the USGS indicated that dunes up to 50cm high may be present along the outside of the bend in the vicinity of the upstream clay shelf, although interpretation of the bed in this region is also difficult. Transect 234.75A (represented by the dark vertical line crossing the substrate placements in Figure 2.4) is a good example of areas that were difficult to interpret, but that may contain both large and small in the bed irregularities, on the order of 20cm (7.9 in) or less, that could be interpreted as mobile bedforms (Figure 2.5).

On the sand areas identified in the facies map (Note: substrate placement is not proposed for any areas mapped as sand), the bedforms are dunes ranging about 0.5m to 2m (1.6 to 6.6 ft). Just of the Myrtle Creek site the dunes are between 0.5 and 2m (1.6 and 6.6 ft) high. On the inside of the bend through the Myrtle Creek site the sand area transitions to primarily small dunes that are 5 to 30cm (2.0 to 11.8 in) high near the deep pools. Proceeding downstream past the area of proposed substrate placement, the bedforms increase in size to 1 to 1.5m (3.3 to 4.9 ft) high.

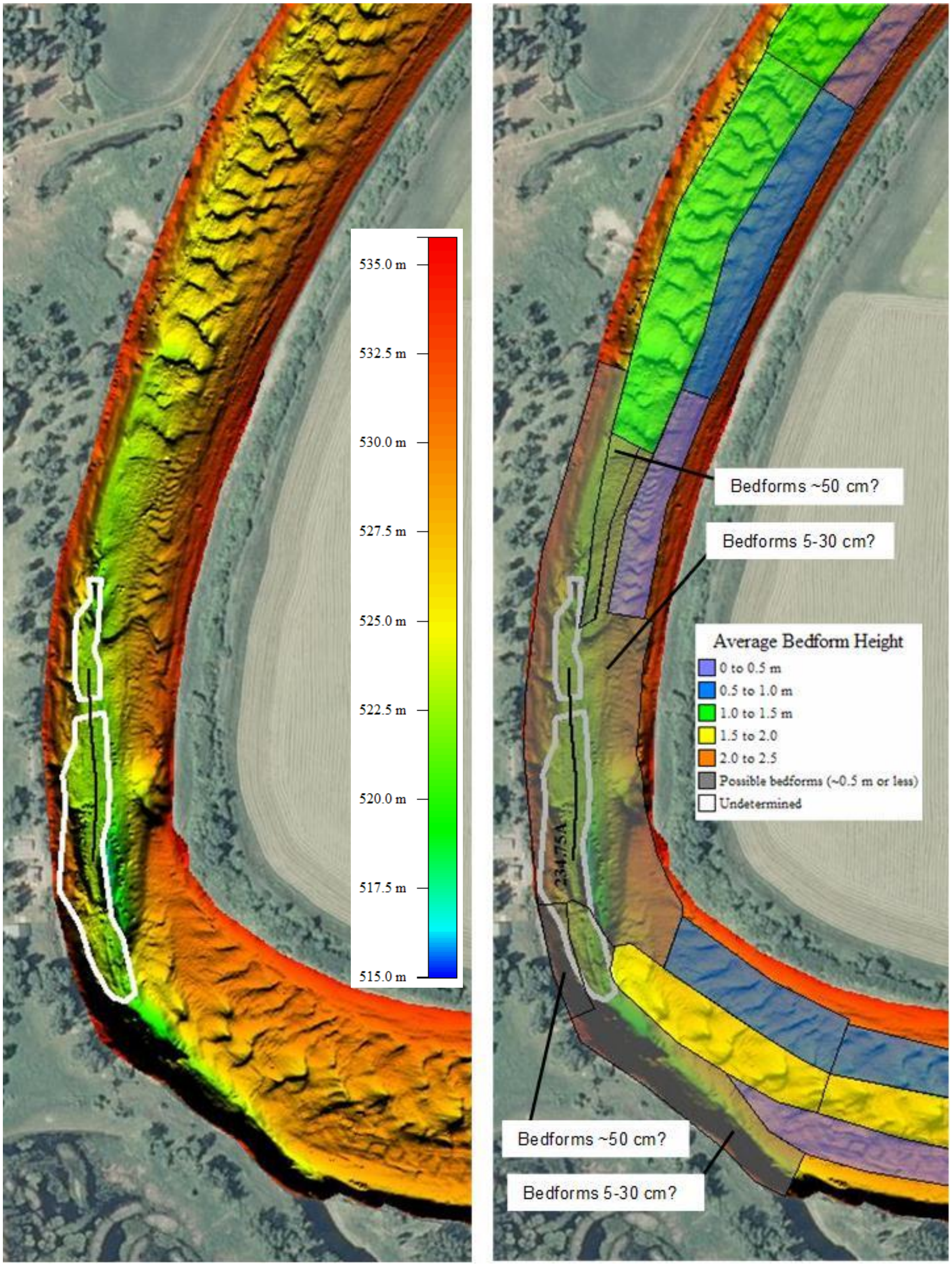

Figure 2-4. Bathymetry Collected near Myrtle Creek in June 2010 (left) and Associated Average Bedform Height (right) (USGS)

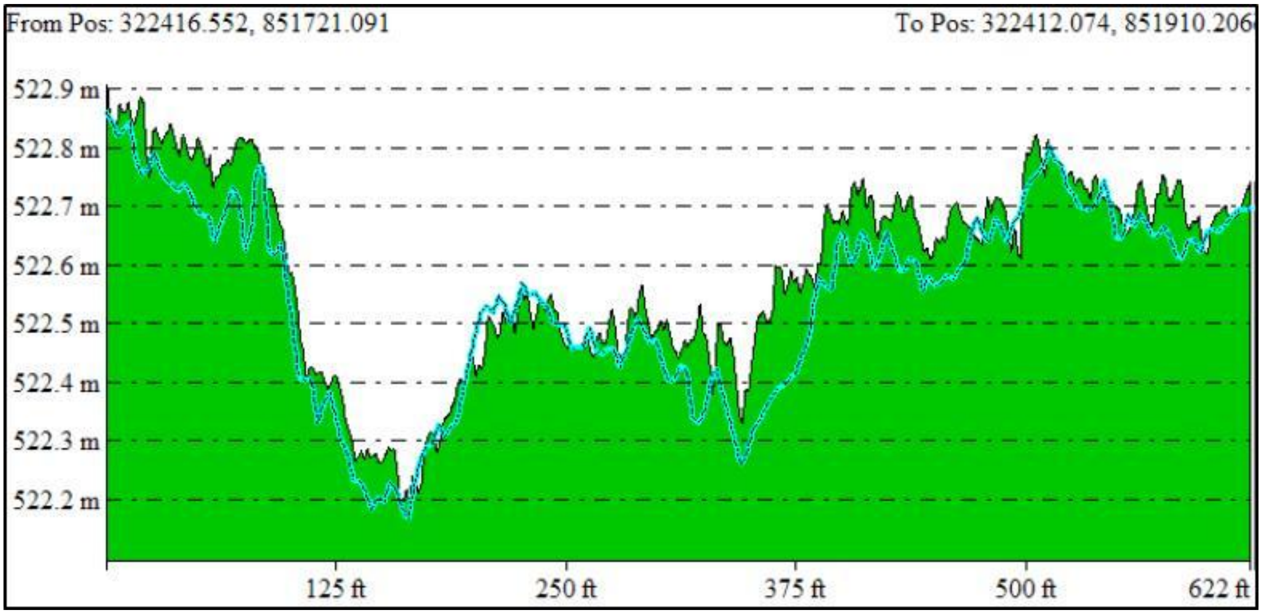

Figure 2-5. Transect 234.75A showing bathymetry collected at Myrtle Creek in June 2010 in light blue and bathymetry collected in April 2010 in green (USGS)

2.2.2 SHORTY'S SOUTH

The bathymetry for Shorty's South was collected at a flow of 33,800 cfs on June 19, 2010. The plans proposed for Shorty Island South are largely located on clay shelves with either low amplitude bedforms or areas where the presence or absence of bedforms could not easily be determined by the USGS (Figure 2.6). The far outside (river right) of the bend may have some dune features as high as ~50cm (20 in), but these are largely located in shallow terrain. The left side of the channel in regions identified as sand bed in the facies map contains dunes that are up to 1m (3.3 ft) high in the upstream portion of the Shorty's South site. Transect 231A shows an example of these dunes (Figure 2.7). Downstream of the proposed substrate placement, the center of the channel has dunes that are 1 to 1.5m (3.3 to 4.9 ft) high (see transect 230.25B on Figure 2.8), and up to 0.5 m (1.6 ft) high to the left of center. The far left side of the channel appears to be mantled by smaller bedforms.

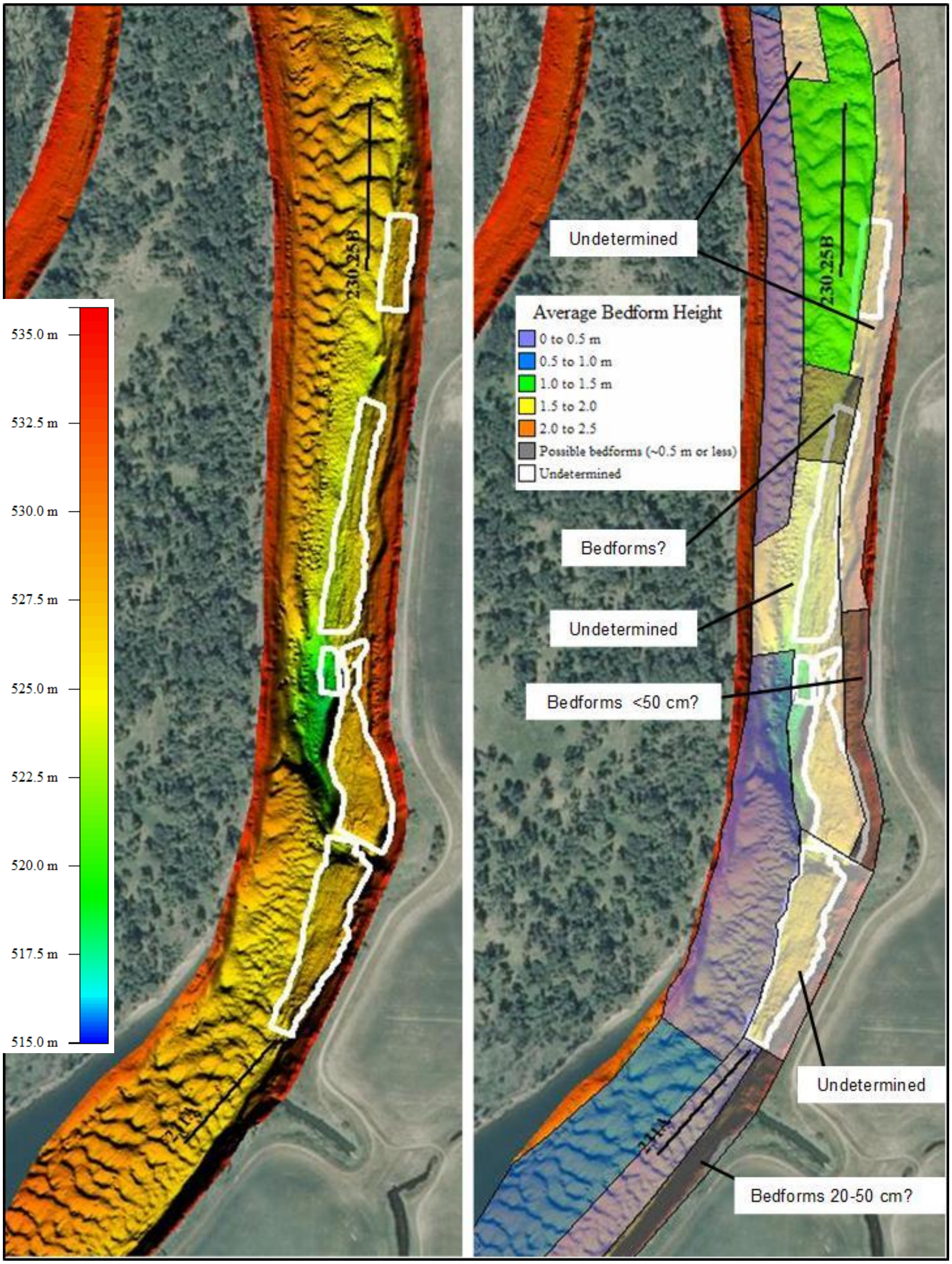

Figure 2-6. Bathymetry Collected near Shorty's South in June 2010 (left) and Associated Average Bedform Height (right) (USGS)

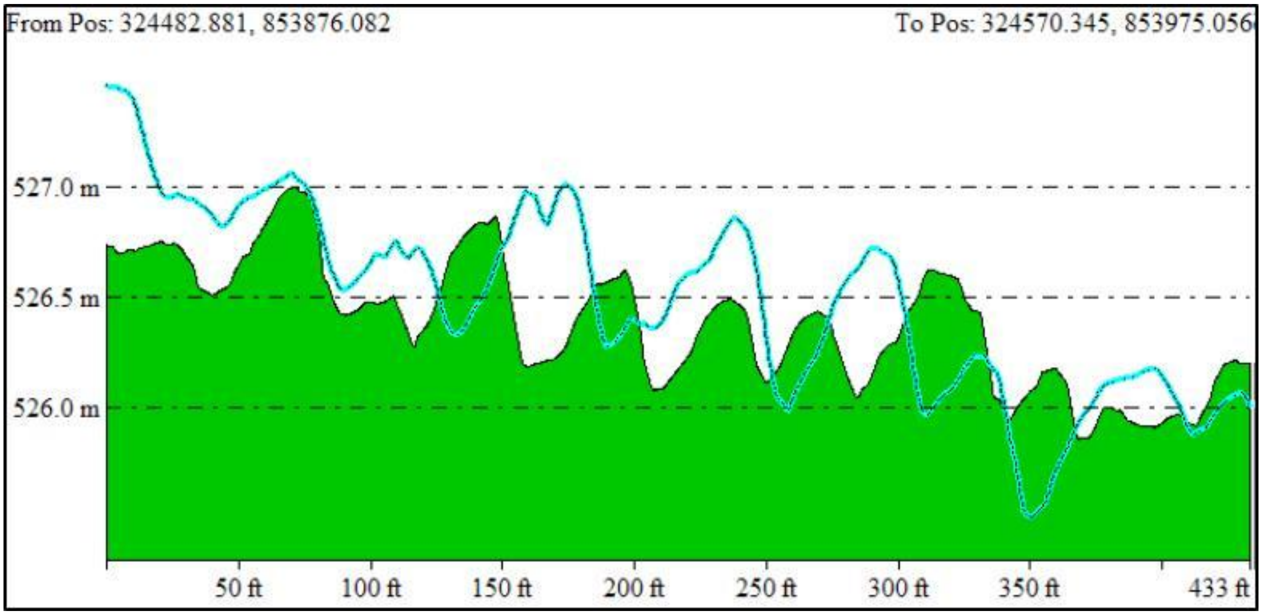

Figure 2-7. Transect 231A Showing Bathymetry Collected at Shorty's South in June 2010 in Light Blue and Bathymetry collected in April 2008 in green (USGS)

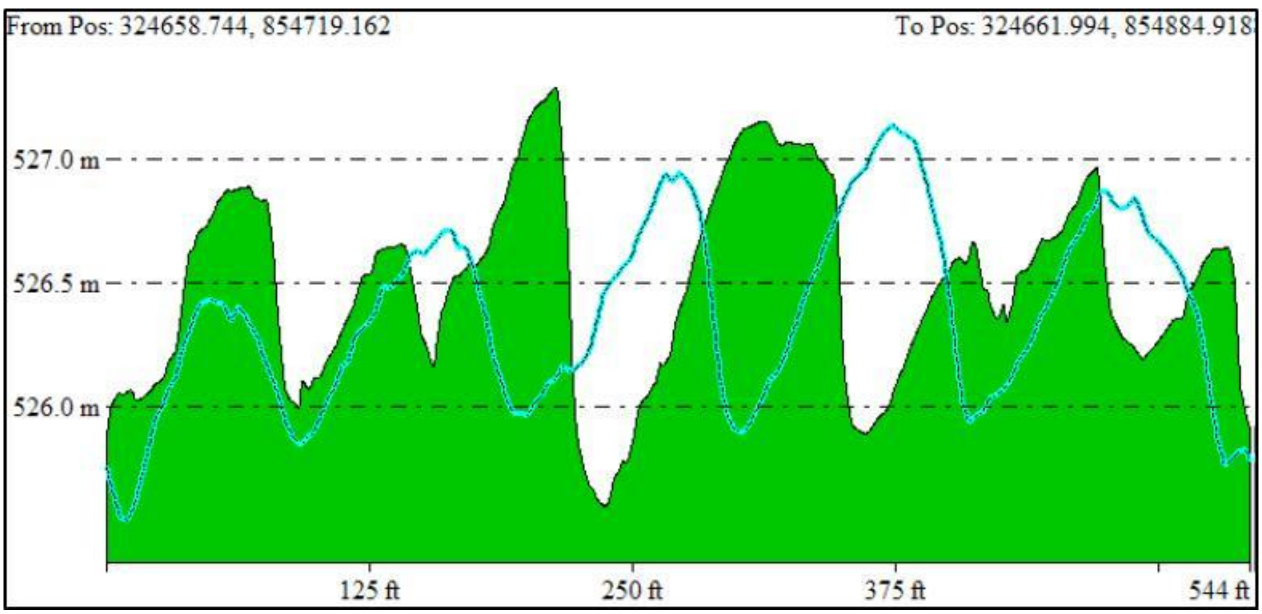

Figure 2-8. Transect 230.25B at Showing Bathymetry Collected at Shorty's South in June 2010 in Light Blue and Bathymetry Collected in April 2008 in Green (USGS)

2.2.3 SHORTY'S NORTH (NOTE: THIS SITE WAS DROPPED FROM THE RECOMMENDED PLAN IN JUNE 2012)

The majority of the area in this region not identified as sand bed does not have easily discernible bedforms and appears to be clay or clay overlain by small patches of sand or gravel (Figure 2.9). The bathymetry used to estimate the bedforms was collected at a flow of 39,500 cfs on June 16, 2010. The areas identified as sand in the facie map appear to have a small area of bedforms less than ~50 cm (20 in) in height near the upstream end of this reach. The rest of the sand areas have dunes with an average height of 0.5 to 1.0 m (1.6 to 3.3 ft). The left side of the channel appears to have smaller scale bedforms. Transect 229.75B shows small bedforms that are typically less than 20 cm (7.9 in) at low flow and as much as 50 cm (20 in) at the higher discharge (Figure 2.10). The total elevation difference between the high and low flow survey at this transect is less than 50 cm (20 in).

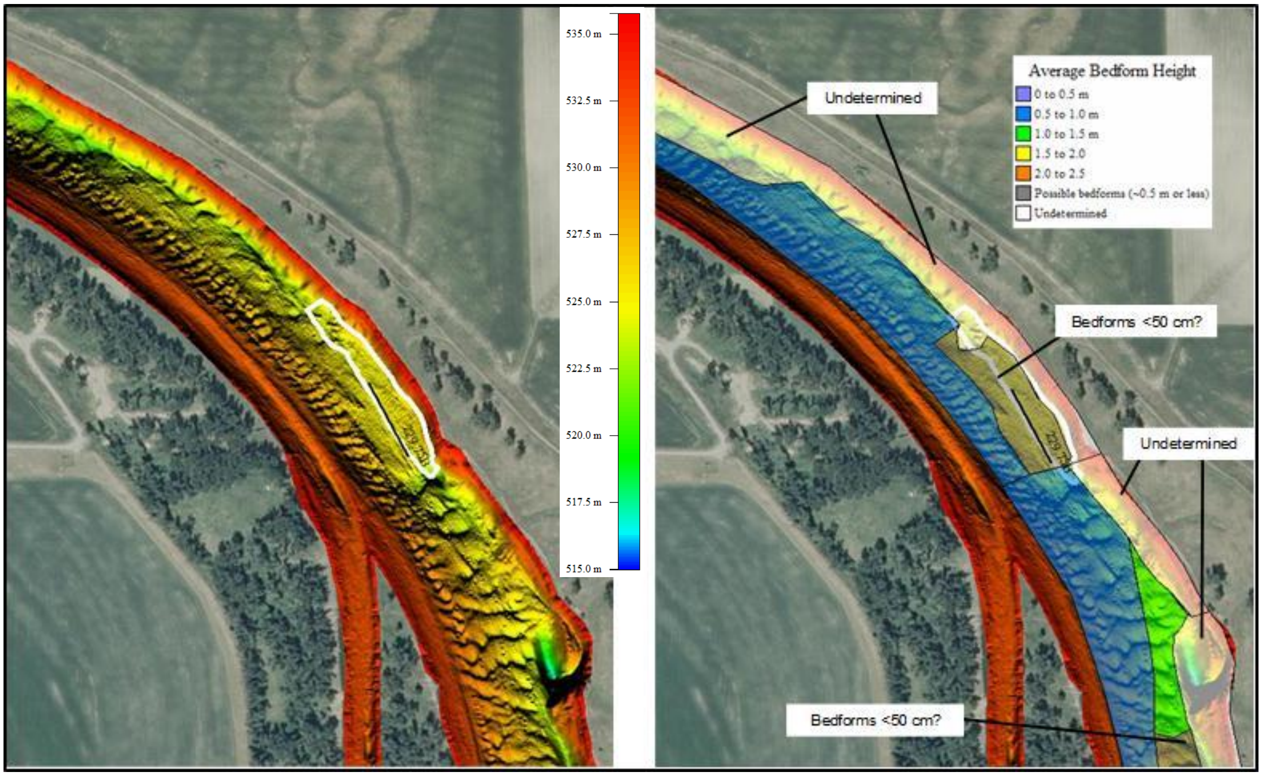

Figure 2-9. Bathymetry Collected near Shorty's North in April 2008 (left) and Associated Average Bedform Height (right) (USGS)

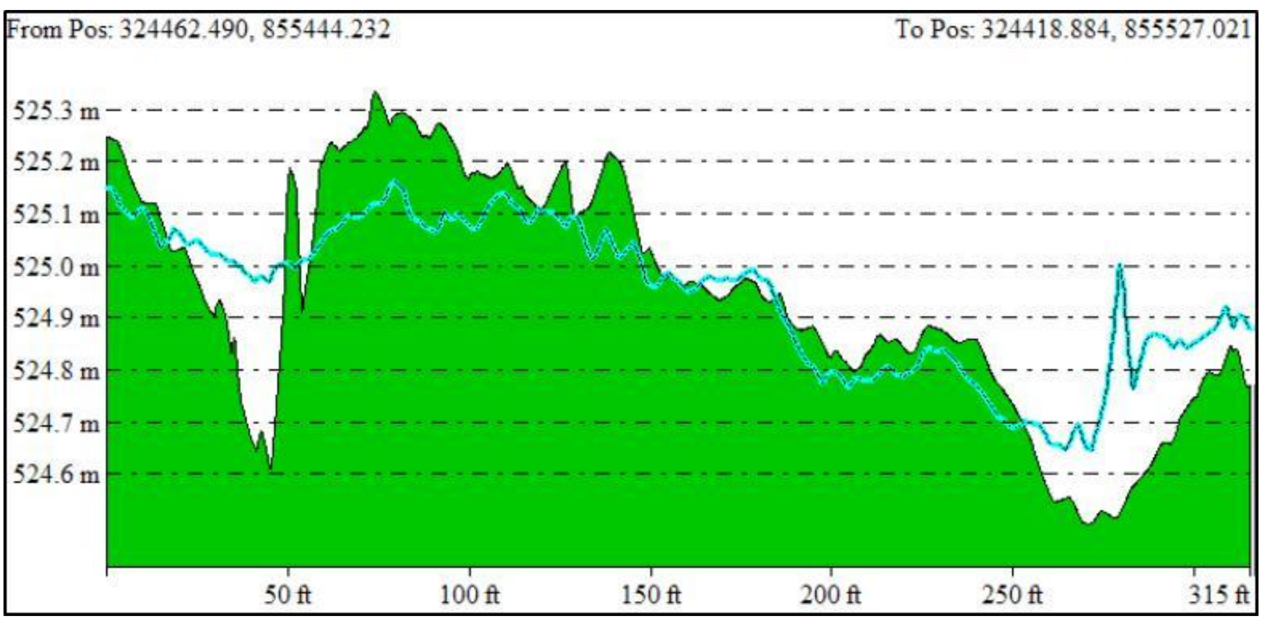

Figure 2-10. Transect 229.75B Showing Bathymetry Collected at Shorty's North in June 2010 in Light Blue and Bathymetry Collected in April 2010 in Green (USGS)

3 ONE-DIMENSIONAL HYDRAULIC MODELING (HEC-RAS)

Tetra Tech performed one-dimensional hydraulic analysis of the Kootenai River with and without substrate placement using a one-dimensional hydraulic model. The modeling was applied to:

- Determine water surface elevation to guide placement of substrate
- Determine the influence of substrate placement on flooding conditions
- Analyze incipient motion conditions for the placed substrate

3.1 MODEL DESCRIPTION AND DEVELOPMENT

The hydraulic analysis was performed using Version 4.1.0 of the U.S. Army Corps of Engineers HEC-RAS computer software (USACE 2010). HEC-RAS is a Windows-based computer modeling system for one-dimensional analysis of stream hydraulics, one component of which allows the user to compute steady-state water-surface profiles with algorithms similar to those used in the HEC-2 program (USACE 2010).

HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The steady flow routine of HEC-RAS is intended for calculating water surface profiles for steady gradually varied flow. The system can handle a single river reach, a dendritic system, or a full network of channels. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head) (USACE 2010).

The effects of various obstructions such as bridges, culverts, dams, weirs, and other structures in the floodplain may be considered in the computations. The steady flow system is designed for application in floodplain management and flood insurance studies to evaluate floodway encroachments. Also, capabilities are available for assessing the change in water surface profiles due to channel modifications and levees (USACE 2010).

3.1.1 GEOMETRY

The HEC-RAS model used to evaluate the hydraulic conditions at the site was obtained from the River Design Group (RDG) and includes the entire Kootenai River within the boundaries of the State of Idaho (RM 105.6 – RM 171.9 along the Kootenai). The model contains 695 cross-sections. The model is based on a previous USGS model (Berenbrock, 2005) which was updated in August 2010 for the current investigation (USGS 2010).

The project area discussed in this report comprises a 4-mile segment of the model, from below Shorty's Island (RM 142) to upstream of the confluence with Myrtle Creek (RM 146). Figure 3.1 shows the project area within the project area between RM 142 and RM 146. It is important to note that while the downstream reach lengths within the HEC-RAS model are all correct, the numerical names of the cross-sections themselves may not exactly match the longitudinal river distance and should not be used to judge exact river mile distance within the project site.

The proposed substrate placements are in the vicinity of Shorty's Island. Model analysis covered two scenarios:

A. *Existing Without Project*: The cross-sections are the original RAS sections from the Berenbrock model. This model assumes no natural geomorphic changes will occur in the near future.

B. *Existing With Project:* The cross-sections were modified to include the gravel placements in the river, based on cross-sectional analysis from project designs. This model also assumes no natural geomorphic changes will occur in the near future, and that the only changes to the channel geometry will be the proposed placements.

Figure 3.2 shows the locations of the three substrate placement sites under evaluation: Shorty's North, Shorty's South, and Myrtle Creek. Shorty's North placement site is on the right-hand side of the river and spans four cross-sections from HEC-RAS section 142.244 upstream to 142.345. Shorty's South project site runs along the right side of the river. This site covers eleven cross-sections, from HEC-RAS section 142.88 upstream to 143.211. Lastly, the Myrtle Creek project site covers seven cross-sections, from HEC-RAS section 145.243 upstream to 145.46. The proposed placement is on the left-side of the river.

The project as formulated in November 2011 when this analysis was conducted consisted of two types of substrate placements, based on their location within the cross-section: placement of suitable substrate on clay shelves and placement of suitable substrate on clay beds. The clay shelf placements are generally 2-feet in height while the bed placements are generally 8-feet in height. The placements are named with designations CB (substrate placement on clay bed) and CS (substrate placement on clay shelf) and are numbered from downstream to upstream. The location of the proposed substrate placement types are distinguished in Figure 3.2.

During the spring of 2012, the project was reformulated to address results of the substrate sustainability workshop held in February 2012 and to reduce the implementation costs. As a result of the sustainability workshop, as well as comments received on the November 2011 35 percent design, the 8-feet high beds were replaced with 2-feet thick substrate placements. Based on input at the workshop and review of the USGS facies mapping and videography, it was determined that the 8-feet thick beds were not required to avoid burial by migrating dunes. The hydraulic analysis presented in this section as well as the 2D modeling of the with-project condition were based on the assume 8-feet thick substrate placements. These analyses are conservative relative to the currently proposed 2-feet thick placements and were not redone with the revised placement thicknesses.

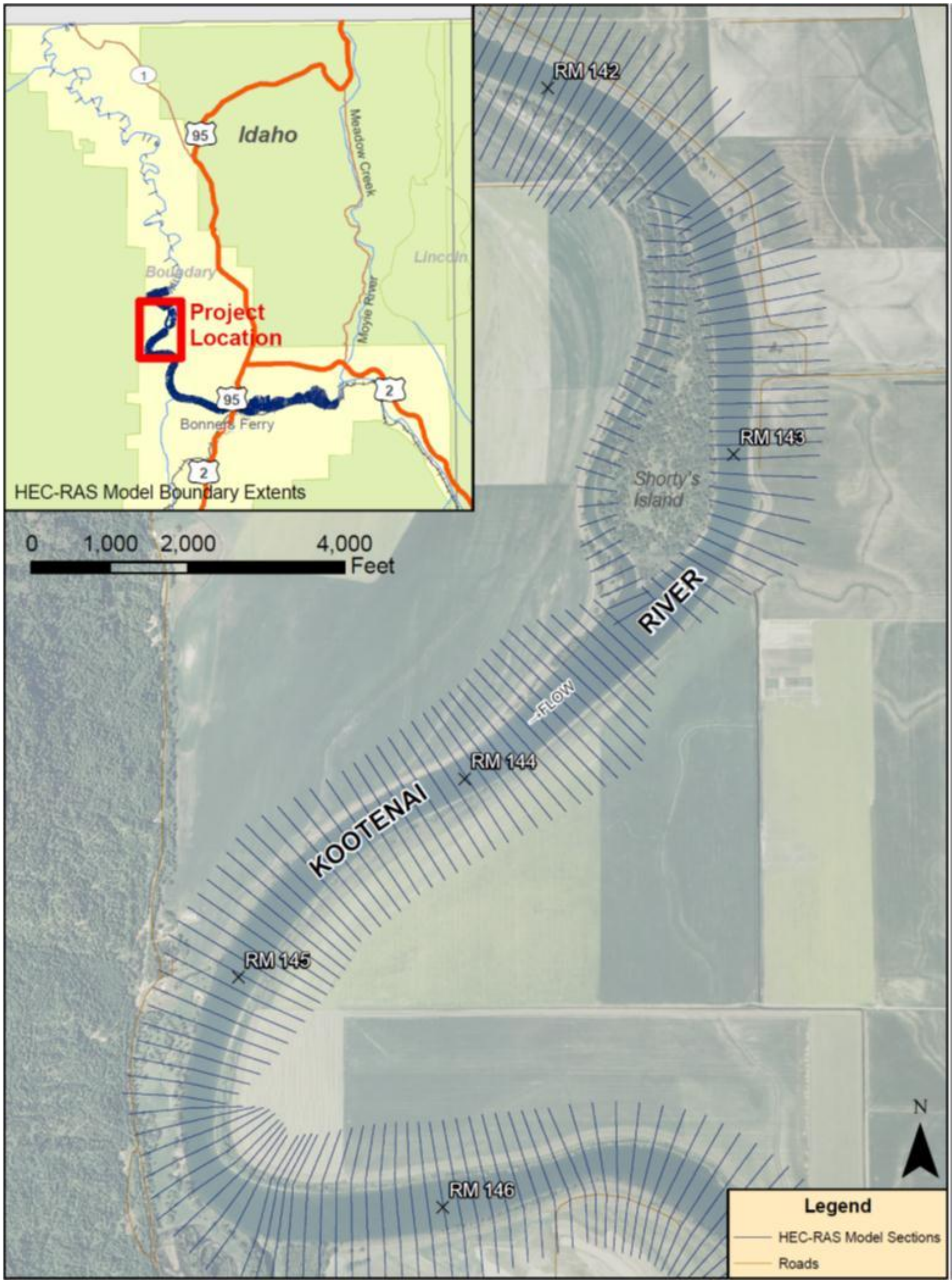

Figure 3-1. HEC-RAS Model Cross Sections within the Project Area, RM 142 to 146.

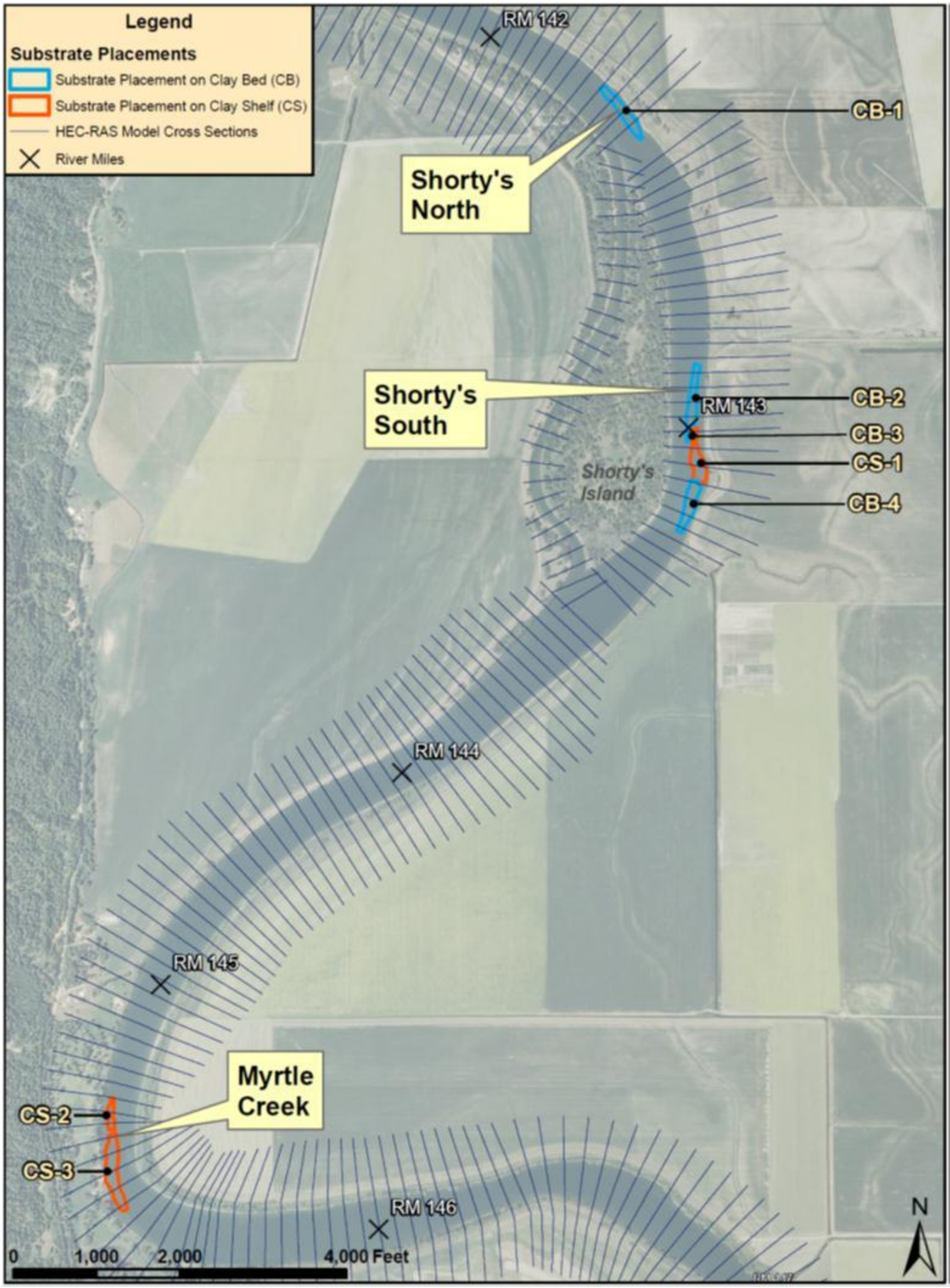

Figure 3-2. Proposed Substrate Placement Sites near Shorty's Island

The design plans (Appendix B) for each placement were used to pull locations and dimensions of each substrate placement at each HEC-RAS cross-section within the project site. To develop the existing with project model the existing without project model was modified by adjusting the cross-section itself to include the substrate placements. The Manning's n-values were increased from an average of about 0.026 in the area of the substrate placement to 0.035 to represent the material with a D_{90} of 8to 12 inches.

Figures 3.3 and 3.4 are examples of typical sections under existing without project conditions and existing with project conditions. Figure 3.3, XS 143.143, is a substrate placement on clay bed in Shorty's South. Figure 3.4, XS 143.073, shows a substrate placement on clay shelf in Shorty's South.

3.1.2 HYDROLOGY AND BOUNDARY CONDITIONS

The modeled flows for HEC-RAS hydraulic analyses ranged from 5,450 cfs to 70,119 cfs at Porthill, the downstream boundary of the model. The low flow is representative of the lowest flow recorded at the Porthill USGS gage. The high flow corresponds to the 100-year event as defined in the FEMA flood Insurance Study (FIS) for Bonners Ferry (FEMA 1985) of 65,000 cfs. Adjusting the flow for the factor of approximately 7 percent to account for inflow produces the 70,119 cfs at the Porthill USGS gage. Porthill, Idaho, the downstream extent of the hydraulic model, is approximately 20 miles upstream of the beginning of Kootenay Lake in British Columbia. The low flow of 5,045 cfs at Porthill was reduced by approximately 7 percent to determine the low flow at the project area of 5,052 cfs. .

Stage-discharge information at Porthill, Idaho is available at USGS Gage 12322000 on the Kootenai River. This is an international gaging station and the discharge recorded represents the total amount of flow passing over the border into Canada. The gage has a long data history, with continuous data from 1928 to present. Libby Dam was closed in 1972, limiting the flows in the Kootenai River. In 1992, the dam began implementing "Sturgeon Flows" for maximum sturgeon habitat benefit. This further limited and regulated the flows. Therefore only post-Sturgeon Flow data are used in this analysis.

The stage-discharge data from this time period shows a wide range of potential water surface elevations which could match a particular discharge in the Kootenai River at Porthill. For instance, at typical KRWS spawning season flow, the water surface elevations at Porthill have a range of 7 vertical feet. The range of stage measurements at Porthill for any flow may depend on time of year, Kootenai Lake operations, dam operations, or maintenance. Therefore, it is not a simple task to assign a water surface elevation at Porthill as a downstream boundary condition for a flow profile in the HEC-RAS model.

The downstream boundary conditions were therefore set for each individual event. They were not picked from a rating curve, but were judged as a function of flow and downstream lake level. The boundary condition for the lowest flow profile was coupled with the lowest downstream water surface elevation recorded at Porthill in post-sturgeon years. This ensured a conservatively low water surface elevation throughout the reach. For the typical KRWS spawning season flow (30,000 cfs at Porthill / 27, 810 cfs at the project site) and the 45,000 cfs moderate high flow, a median lake level was used as the downstream boundary condition. The 100-year flow boundary condition was calibrated based on a water surface elevation of 1764.1 ft, published in FEMA's FIS at Bonners Ferry (FEMA 1985). See Table 3.1 for the flows and boundary conditions set for each flow profile in the HEC-RAS model.

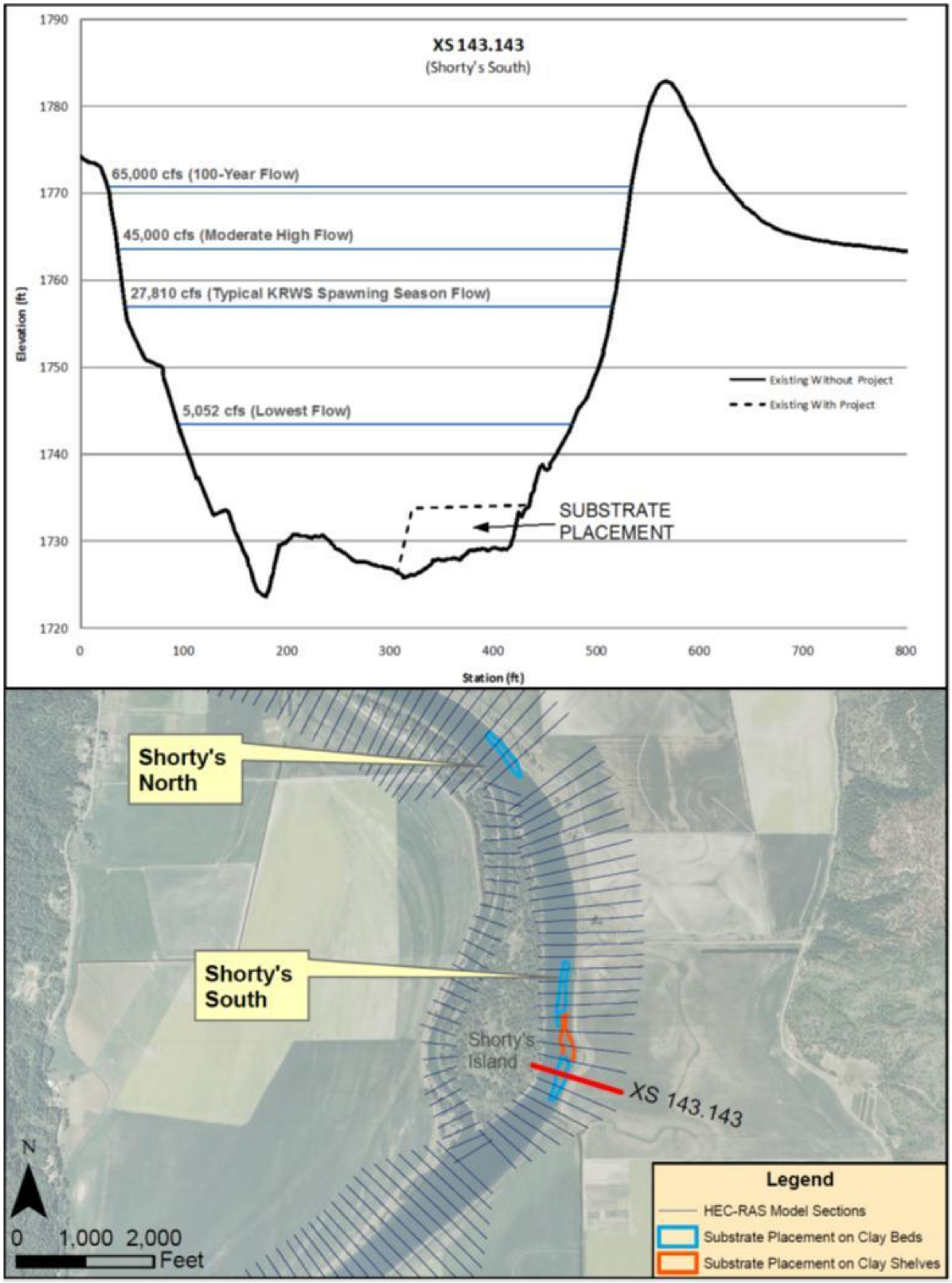

Figure 3-3. HEC-RAS Section XS 143.143 Showing Substrate Placement on Clay Bed and its Location in the Project Area

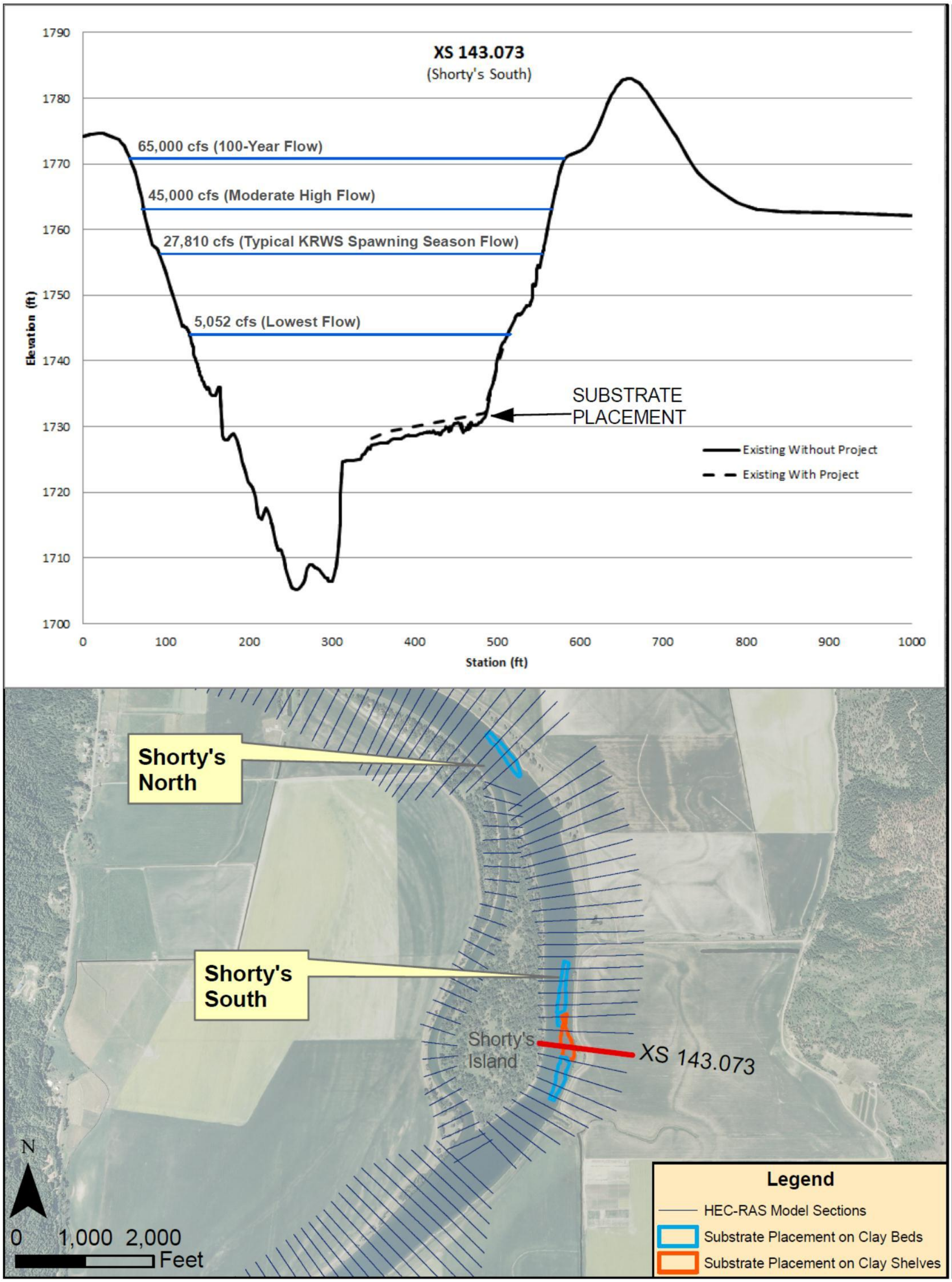

Figure 3-4. HEC-RAS Section XS 143.073 Modified to Show the Proposed Substrate Placement on Clay Shelf and its Location in the Project Area.

Table 3-1. Four Flow Profiles and Associated Boundary Conditions Analyzed in the HEC-RAS Model

Profile	Description	Q (cfs)[1]		Porthill Boundary Condition (ft)
		Bonners Ferry	Porthill	
5,052 cfs	*Lowest Flow*	5,052	5,450	1743.0
27,810 cfs	*Typical KRWS Spawning Season Flow*	27,810	30,000	1751.7
45,000 cfs	*Moderate High Flow*	45,000	48,544	1757.9
65,000 cfs	*100-YR at Bonners Ferry*	65,000	70,119	1764.1

[1] A 7% difference in flows between Bonners Ferry and Porthill generally makes up for incoming flows downstream of Shorty's Island.

3.1.3 CALIBRATION AND MANNING'S N-VALUES

The original USGS model was calibrated using stage or discharge from eleven stream-gaging stations located in the study reach, and six calibration points at these gages. In addition, the lowest calibrated flow event in the model was to a synoptic stage survey conducted on March 17, 2010 (USGS 2010).

Selection of streamflow conditions for model calibration was based on three criteria: (1) stage and discharge were limited to the post Libby Dam period, specifically during 2002-2009 when the bathymetry was mapped; (2) streamflow should be evenly distributed between low flow (less than 6,000 cfs) and the post Libby Dam period peak instantaneous flow (64,300 cfs, June 19, 2006 at the Tribal Hatchery gage, station 12310100) so that the model could be adequately calibrated over the range of likely streamflow; and, (3) because HEC-RAS was used as a steady-state model, calibration conditions were selected that represented periods of relatively constant water-surface elevation and discharge. In addition, the influence of backwater conditions in the study reach from Lake Kootenay levels varies over seasons and storm events. Efforts were made to choose calibration events that also represented "average" backwater conditions in the reach, such that for a given calibration event, the water-surface elevation at Porthill was approximately a median value for the range of historical conditions at that discharge (USGS, 2010).

The model was calibrated by comparing measured and simulated water surface elevations at eleven selected sites for seven events covering a range of flows (5,522 cfs through 63,049 cfs at Porthill). The channel roughness values were adjusted to minimize the difference between the measured and simulated water surface elevations, and model calibration was considered adequate for each site and calibration flow event with the difference was within ±0.15 ft. Calibration reaches were defined between each gage in the study reach, and adjustments to the channel roughness values were made equally to cross sections within each calibration reach (USGS 2010).

Final calibrated channel Manning's n values for the entire model ranged from 0.023 to 0.045 with 0.031 being typical. In the reach containing the Shorty's and Myrtle Creek sites (from Tribal Hatchery to Klockman Ranch) the n values range from 0.025 to 0.029 with 0.026 being an average value (USGS, 2010). Overbank Manning's n values were not adjusted from the value of 0.06 used in the previous Berenbrock model (Berenbrock, 2005).

Roughness values are generally highest in the Canyon Reach and lower in the Braided and Meandering Reaches. In general, the roughness values decrease as discharge increases. This trend, however, is complicated as side channels and bars are inundated under different flow conditions. The 1-D model may also be unable to fully represent the complex flow, especially in the Braided Reach and at large, likely unsteady flow events (USGS, 2010).

3.2 DETERMINATION WATER SURFACE ELEVATIONS TO GUIDE SUBSTRATE PLACEMENT

Water surface elevations to help guide the vertical extent of substrate placement were determined using HEC-RAS. Two flows conditions were utilized. To optimize the depth value associated with spawning conditions, the typical spawning season flow of 27,810 cfs in the project area (30,000 cfs at Porthill) was used to ensure the substrate placements are at optimum depths for KRWS spawning. The second flow was a low flow of 5,052 cfs at the project site and represents a low flow to ensure that the substrate is not placed so high in the water column that it will create a navigation hazard.

3.2.1 RESULTS FOR TYPICAL KRWS SPAWNING FLOW

A depth of 16-feet or greater over the substrate placement provides the optimal HSI depth value of 1. Therefore, the upper limit of substrate placement was set at 15-feet below the modeled 27,810 cfs water surface elevation at the project site. Placing the substrate in deeper areas of the channel also locates them in the higher velocity areas of the channel, which helps attract the KRWS for spawning. The resulting water surface elevations for the 4 mile project area from the downstream end of Shorty's North to the upstream end of Myrtle Creek range from 1756.61 to 1757.24 feet (Figure 3.5, Table 3.2).

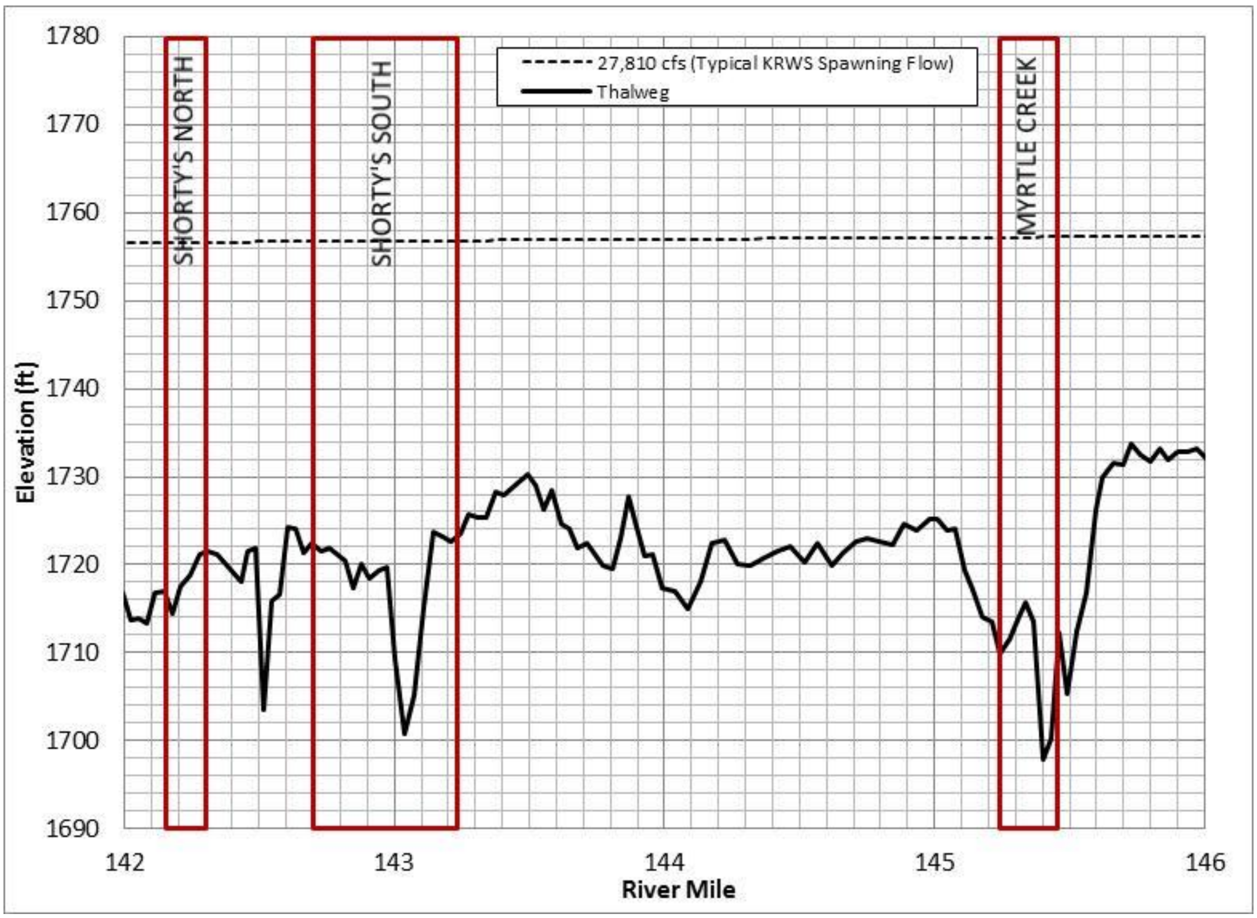

Figure 3-5. Typical KRWS Spawning Flow (27,810 cfs through the project site) Water Surface Elevations Under Existing Without Project Conditions.

Table 3-2. Typical KRWS Spawning Flow (27,810 cfs through the project site) Water Surface Elevations Under Existing Without Project Conditions.

XS	Location	Water Surface Elevation (ft)
142.21	Shorty's North	1756.61
142.311		1756.64
142.757		1756.73
142.972	Shorty's South	1756.76
143.073		1756.81
143.179		1756.81
143.276		1756.85
145.243	Myrtle Creek	1757.20
145.368		1757.22
145.46		1757.25

3.2.2 RESULTS FOR LOW FLOW CONDITION

The substrate placement should not be exposed during the low-flow condition or be so low as to hinder navigation through the channel. To address this concern, the water surface elevations for an extreme low flow condition, lowest flow and stage at the Porthill gage since 1990, was modeled. The flow associated with this condition was 5,052 cfs in the project area (5,450 cfs at Porthill). The results of the water surface elevation are plotted in Figure 3.6. To prevent the substrate placement from being a navigation hazard, the placements were designed with a minimum of 3 feet of depth above them at the low flow condition. The water surface elevations resulting through the project site ranged from 1743.86 feet at the downstream end of the placements in Shorty's North to 1744.13 feet at the upstream end of the Myrtle Creek placements (Table 3.3).

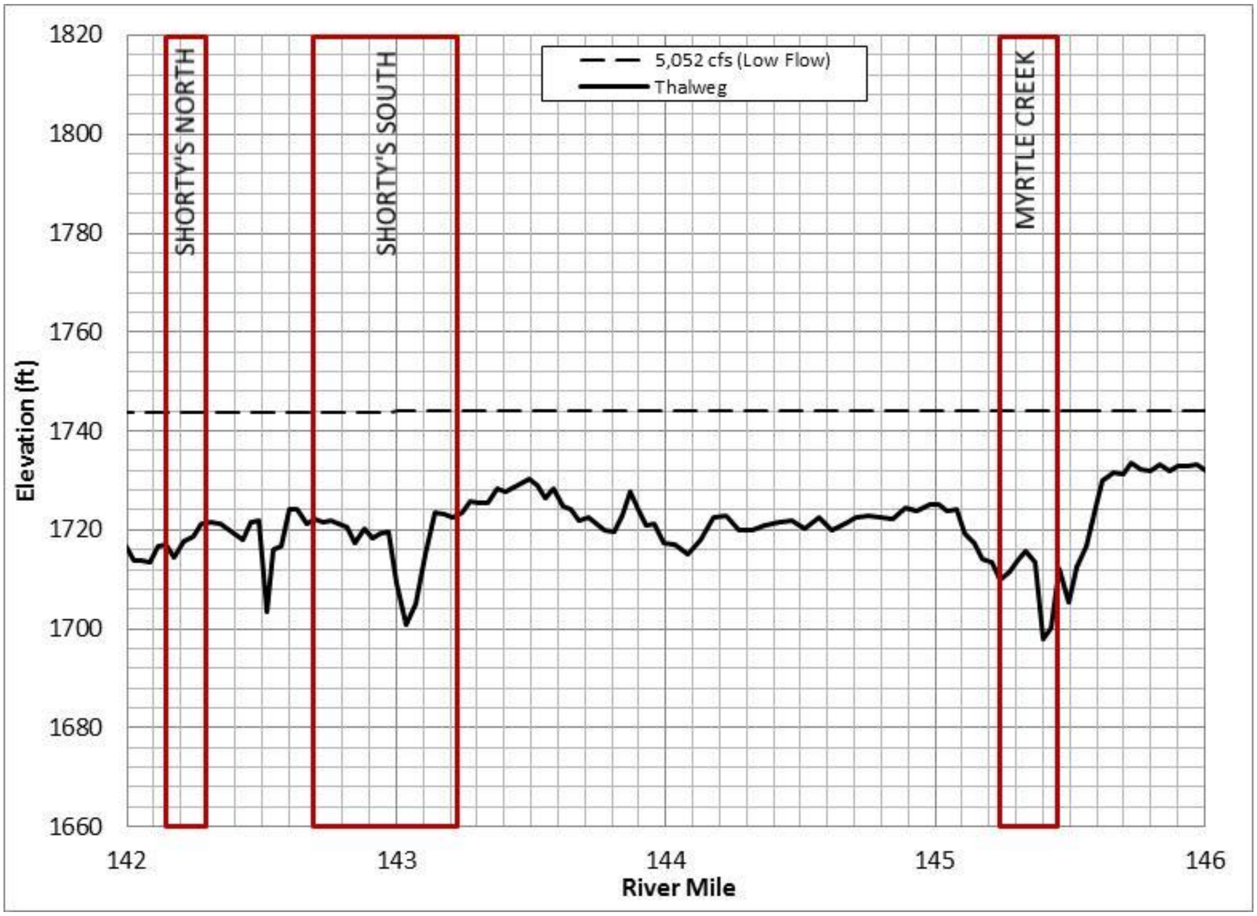

Figure 3-6. Low flow Conditions (5,052 cfs through the project site) Water Surface Elevations Under Existing Without Project Conditions.

Table 3-3. Low flow Conditions (5,052 cfs through the project site) Water Surface Elevations Under Existing Without Project Conditions.

XS	Location	Existing Without Project
142.21	Shorty's North	1743.86
142.311		1743.87
142.757		1743.90
142.972	Shorty's South	1743.91
143.073		1743.92
143.179		1743.93
143.276		1743.94
145.243	Myrtle Creek	1744.13
145.368		1744.13
145.46		1744.13

3.2.3 DETERMINATION OF THE TENTATIVELY RECOMMENDED PLAN EFFECTS ON FLOODING CONDITIONS

The impact of the project on water surface elevations is important for two reasons. First, there should not be an impact on the 100-year water surface elevation to meet floodplain regulation requirements. Secondly, water surface elevations during high flows smaller than the 100-year are still of considerable interest to those with property outside the levees, since seepage and high groundwater in fields is a concern. A significant increase in the water surface elevations for high flows could result in increased seepage and elevated groundwater tables and needs to be avoided.

One-dimensional hydraulic analyses along the Kootenai River were carried out to determine the hydraulic conditions at each proposed placement site. The purpose of the analysis was to determine the effects of the substrate placements on flood elevations for conditions ranging from the typical flows during the spawning period up to the 100-year flood. The water-surface elevations were compared for the existing without project and existing with project conditions.

Results of the analysis are shown graphically in Figure 3.7 which plots the longitudinal profile of the Kootenai River from Porthill at the downstream end to the Montana border at the upstream end. Figure 3.8 focuses on the project area to display the water surface profiles through the project sites. Note that even at the lowest flow, the entire project site is under heavy backwater influence from the Kootenay Lake downstream. Table 3.4 shows a selection of cross-section results from both existing without project and existing with project model runs. Additionally, a cross-section upstream and downstream of all the sites is included to affirm that water surface elevation changes are minimal upstream and downstream of the project site. Water surface elevation differences from the upstream end of Myrtle Creek through the downstream end of Shorty's North are insignificant at a maximum of 0.02 feet or less. The maximum elevation difference of 0.02 feet occurs between Shorty's North and Myrtle Creek during typical KRWS spawning flow of 27,810 cfs. For the 100-year flood peak of 65,000 cfs, the maximum increase is 0.01 feet. Based on the modeling results, the proposed substrate placements will not have an adverse effect on flooding or groundwater conditions *(Note: The model results are conservatively high since the 8-feet thick beds have been redesigned in June 2012 to be only 2-feet thick and will have even less influence on channel hydraulics and water surface elevations.)*.

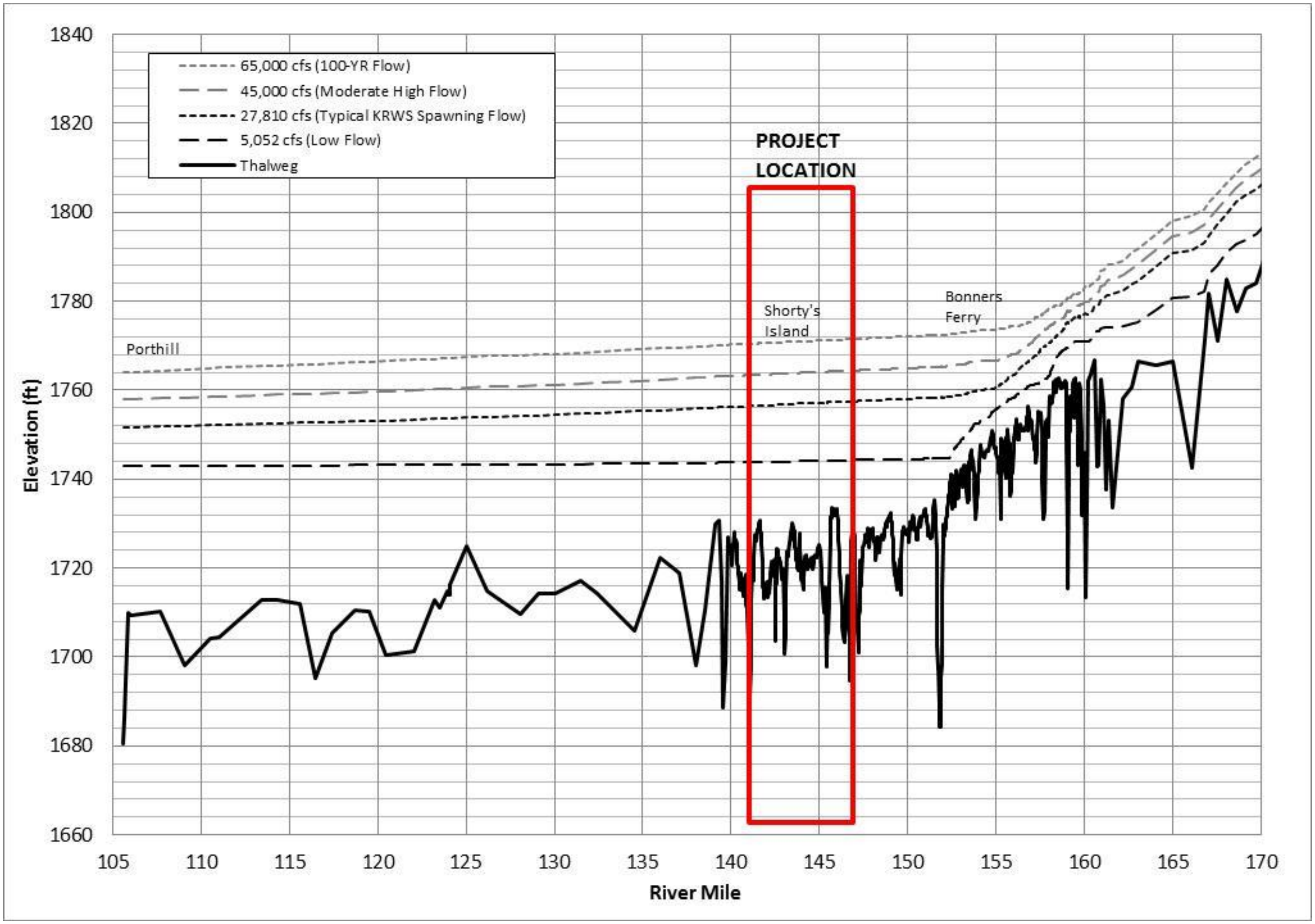

Figure 3-7. Water Surface Profile of Kootenai River Model from Porthill to the Montana Border.

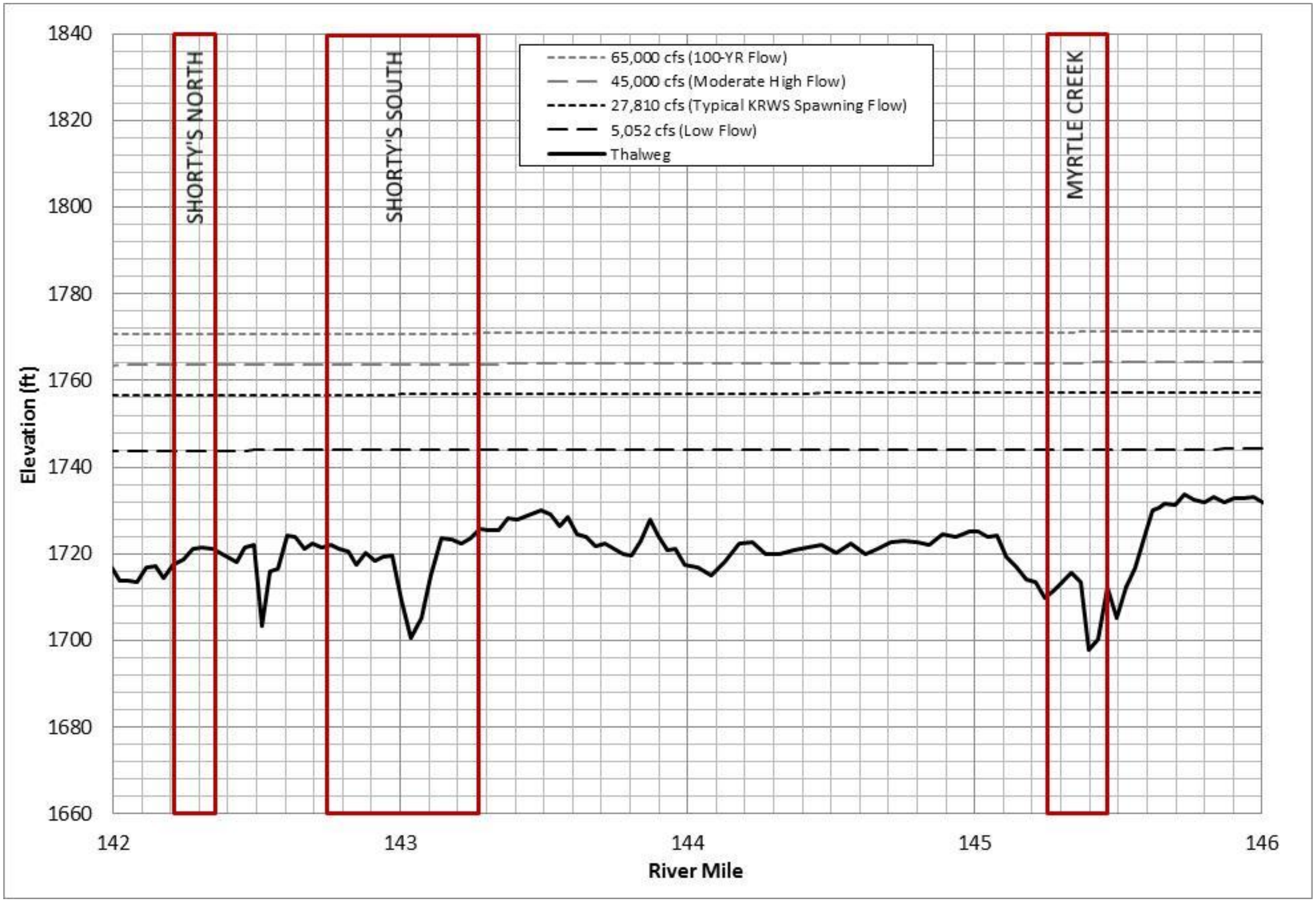

Figure 3-8. Water Surface Profile of Kootenai River Model Through Each Placement Site for Each of the Four Study Flows.

Table 3-4. Comparison of Water Surface Elevations (feet) for the Existing Without Project and Existing With Project Conditions.

Cross-Section Number	Location	5,052 cfs (Low Flow)			27,810 cfs (Typical KRWS Spawning Flow)			45,000 cfs (Moderate High Flow)			65,000 cfs (100-yr Flow at Bonners Ferry)		
		Existing Without Project	Existing With Project	Change (ft)	Existing Without Project	Existing With Project	Change (ft)	Existing Without Project	Existing With Project	Change (ft)	Existing Without Project	Existing With Project	Change (ft)
141.747	D/S of Sites	1743.84	1743.84	0.00	1756.53	1756.53	0.00	1763.49	1763.49	0.00	1770.58	1770.58	0.00
142.21	Shorty's North	1743.86	1743.86	0.00	1756.61	1756.61	0.00	1763.57	1763.57	0.00	1770.64	1770.64	0.00
142.277		1743.87	1743.87	0.00	1756.64	1756.64	0.00	1763.59	1763.59	0.00	1770.67	1770.67	0.00
142.345		1743.87	1743.87	0.00	1756.65	1756.65	0.00	1763.61	1763.61	0.00	1770.68	1770.68	0.00
142.941	Shorty's South	1743.91	1743.91	0.00	1756.76	1756.76	0.00	1763.7	1763.7	0.00	1770.77	1770.77	0.00
143.003		1743.92	1743.92	0.00	1756.78	1756.78	0.00	1763.71	1763.72	0.01	1770.78	1770.79	0.01
143.073		1743.92	1743.92	0.00	1756.81	1756.81	0.00	1763.76	1763.75	0.01	1770.83	1770.83	0.00
143.143		1743.92	1743.92	0.00	1756.80	1756.80	0.00	1763.74	1763.74	0.00	1770.82	1770.81	0.01
143.276		1743.93	1743.94	0.01	1756.84	1756.85	0.01	1763.79	1763.8	0.01	1770.87	1770.88	0.01
145.243	Myrtle Creek	1744.12	1744.13	0.01	1757.19	1757.2	0.01	1764.08	1764.09	0.01	1771.16	1771.17	0.01
145.307		1744.12	1744.13	0.01	1757.2	1757.21	0.01	1764.08	1764.09	0.01	1771.15	1771.16	0.01
145.399		1744.13	1744.13	0.00	1757.23	1757.24	0.01	1764.13	1764.13	0.00	1771.2	1771.21	0.01
145.46		1744.13	1744.14	0.01	1757.24	1757.25	0.01	1764.14	1764.15	0.01	1771.23	1771.24	0.01
146.201	U/S of Sites	1744.25	1744.25	0.00	1757.38	1757.39	0.01	1764.25	1764.26	0.01	1771.34	1771.35	0.01

One of the primary reasons the changes are so small for the with project condition is the substrate placements are relatively small compared to the size of the Kootenai River. The change in cross-sectional area due to the placements is generally small in relation to the flow area for the entire cross-section. At cross-section 143.143, a substrate placement on clay bed, the area was decreased a maximum of 12% of the total flow area due to the substrate placement at low flow conditions. At cross-section 143.073, a substrate placement on clay shelf, the area was decreased a maximum of 11% at low flows. Both cross-sections showed a 6% decrease in total flow area at typical KRWS spawning flows. Table 3.5 shows the total flow area changes at these two representative cross-sections at all flow profiles.

Table 3-5. Decrease in Total Flow Area Due to Substrate Placement at Two Representative Cross-Sections.

Cross-Section	Substrate Placement	5,052 cfs	27,810 cfs	45,000 cfs	65,000 cfs
143.073	Clay Shelf	-9%	-5%	-4%	-4%
143.143	Clay Bed	-12%	-6%	-5%	-4%

Another reason for the insensitivity of the surface elevations to the reduction in area associated with the with project substrate placement is the low energy of the Kootenai River. The energy gradient (essentially the water surface elevation slope through the reach) across each placement site is shown in Table 3.6. The gradient is on the order of ½-ft per mile or less across each placement site. HEC-RAS also calculated flow distributions across each cross-section. The maximum velocity at each cross section was overall very small, and generally in the thalweg of the channel. The highest velocity for typical KRWS spawning flows occurred in Shorty's South and was 3.23 ft/s.

Table 3-6. Energy Gradient Across Each Placement Site (Based on HEC-RAS Water Surface Elevations and Total Distance Across Each Site), and Maximum Velocity in Each Site.

Site	Energy Gradient (ft/ft)				Max Velocity (ft/s)			
	5,052 cfs	27,810 cfs	45,000 cfs	65,000 cfs	5,052 cfs	27,810 cfs	45,000 cfs	65,000 cfs
Shorty's North	0.000008	0.000033	0.000033	0.000033	1.0	3.0	3.8	4.5
Shorty's South	0.000014	0.000045	0.000042	0.000035	1.5	3.2	3.7	4.1
Myrtle Creek	0.000013	0.000066	0.000079	0.000093	1.1	3.0	3.6	4.0

The low change in cross-sectional area, combined with extensive backwater effects from Kootenay Lake and the mild channel gradient, each play a part in minimizing the effects from the substrate placements. Even at the lowest flow at Porthill, 5,450 cfs (5,052 cfs at the project site), combined with the lowest Porthill stage, 1743 feet, the Kootenai River is backwatered through the city of Bonners Ferry, well upstream of the entire project area. At such low flows, the water surface elevation at the site is mostly determined by the downstream boundary condition, not the channel geometry or channel flows. At higher flows, the channel flow is more influential on the water surface elevation, but the substrate placements comprise such a small amount of the total flow area, and the velocity and gradient of the channel is so low, that there is still virtually no effect on the water surface elevation in the project area.

3.2.4 Incipient Motion Calculations to Determine Mobility of Placed Substrate

One of the key design elements for the substrate placements is the substrate particle size. It is critical that the placements remain in place over time and must be sized accordingly to withstand flood events in the

Kootenai. The Kootenai River System has no ability to replenish the substrate material naturally, so the material must stay in place even through high flows. Incipient motion of the substrate was determined along both the flat surfaces of the placements and on the placement sideslopes.

3.2.4.1 METHODOLOGY

The concept of incipient motion was applied to substrate placements on clay beds. Incipient motion is taken to be the threshold of mobilization, the condition where the erosive force of the flow in the channel is balanced by the resistive force of the weight of the pebble. The total channel shear stress was calculated to quantify the erosive force, which is more conservative than just considering the particle shear stress. The dimensionless Shields parameter was applied to the submerged weight of a particular size fraction of the bed to quantify the resistive force. Comparing total shear stress calculated for different flows to the resistive force provides a method for identifying the flow corresponding to conditions of incipient motion. Since shear stress typically increases as the flow rate increases, all flows greater than the flow at incipient motion can be assumed to be erosive.

Determining the flows associated with incipient motion for the proposed placement materials on the Kootenai River provides a basis for assessing the relative mobility and stability of the substrate placements. The minimum particle size to withstand the incipient motion threshold was calculated for two cases: 1) on the horizontal top of the substrate placements, and 2) on the side slopes of the placements. The relationship for stable particle size, below (Julien 1998) and a Shields Parameter of 0.03 was used for this analysis.

$$\tau = \gamma R_h S \qquad \text{Eqn 1}$$

$$\tau_* = \frac{\tau}{(\gamma_s - \gamma)\, d_s} = 0.03 \qquad \text{Eqn 2}$$

Where:
τ = total shear stress (lb/ft^2)
γ = specific weight of water (lb/ft^3)
R_h = hydraulic radius of the channel (ft)
S = energy slope (ft/ft)
τ_* = Shields parameter
γ_s = specific weight of sediment (lb/ft^3)
d_s = particle size (ft)

The stability of the substrate on the side slopes of the placement is as important as the stability on the flat surface of the placement. For this reason, moment-stability analysis was performed for material along the placement side slopes. The stability of the material depends on the stability of individual particles subjected to the hydrodynamic forces of the placement configuration. This analysis considered placement configurations with 2:1 side slopes.

On the side slope of the placement, substrate material is subject to the forces of gravity, as well as lift, drag, and buoyancy. The submerged particle has a side slope component, θ. The streamline deviates from the horizontal at an angle, λ, along the embankment. Once in motion, the particle follows a direction at an angle β from the downward direction. Stability against the rotation of a particle determines incipient conditions of motion when the equilibrium of moments about the point of rotation is satisfied (Julien 1998).

The factor of safety, FS, of the particle against rotation is defined as the ratio of the moments resisting particle rotation out of the bank to the submerged weight and fluid force moments tending to rotate the particle out of its resting position (Simons and Senturk 1992). The factor of safety for submerged particles on side slopes where the flow has a non-horizontal velocity vector is described in the following four equations:

$$SF = \frac{\cos\theta \tan\phi}{\eta' \tan\phi + \sin\theta \cos\beta} \qquad \text{Eqn 3}$$

$$\beta = \tan^{-1}\left\{\frac{\cos\lambda}{\frac{2\sin\theta}{\eta \tan\phi} + \sin\lambda}\right\} \qquad \text{Eqn 4}$$

$$\eta = \frac{21\tau_s}{(S_s - 1)\gamma d_s} \qquad \text{Eqn 5}$$

$$\eta' = \eta\left\{\frac{1+\sin(\lambda+\beta)}{2}\right\} \qquad \text{Eqn 6}$$

Where: *SF* = factor of safety
θ = bank angle (degrees)
ϕ= angle of repose for sediment particle (degrees)
β= particle motion angle (projection of a vertical on the embankment plane, degrees)
η = stability number
η'= stability number for the particles on the embankment side slope
λ= deviation of streamline from the horizontal along the embankment plane (degrees)
τ_s= shear stress on the sideslope of angle θ (lb/ft^2)

The variable η' is called the stability number for the particles on the side slope and is related to the Shields Parameter. Given a particle size d_s of submerged specific weight γ' and angle of repose ϕ and given a velocity field at an angle θ, the set of four equations above can be solved to obtain the safety factor *SF*. An *SF* value of 1 is the boundary value for incipient motion. *SF* values greater than 1 indicate stability of the particles (Simons and Senturk 1992). These calculations were performed for the case of both angular (ϕ=40°) and rounded (ϕ=33°) stone.

3.2.4.2 Results

The analyses yielded minimum grain sizes that will withstand each of the larger study flows. The shear stress calculations were applied to a set of representative cross-sections deemed typical for the study site. Table 3.7 shows the results for both the horizontal flat top of the placement as well as the 2:1 side slopes of each placement. Results are shown for each of the three larger study flows: 27,810 cfs (typical KRWS spawning flow), 45,000 cfs (moderate high flow) and 65,000 cfs (100-year flow at Bonners Ferry).

Table 3-7. Summary of Incipient Motion Results for Existing With Project Conditions on the Placement Top and Side Slopes.

XS	Stable Particle Size (mm)					
	27,810 cfs		45,000 cfs		65,000 cfs	
	Placement Top	Side Slopes	Placement Top	Side Slopes	Placement Top	Side Slopes
145.399	3	16	5	17	6	19
143.073	4	14	5	16	6	19
142.277	5	12	5	15	6	21

The stable particle size at each placement site is generally much smaller than the d_{50} of the proposed placement substrate (d_{50} for the ideal placement is on the order of 100 mm). The largest erodible particle calculated on the side slopes, 21 mm, fall within 7% and 17% of the lower end of the ideal substrate envelope (Figure 3.9). This indicates that particles comprising the ideal substrate envelope should be stable under all conditions up to and including the 100-Year flow.

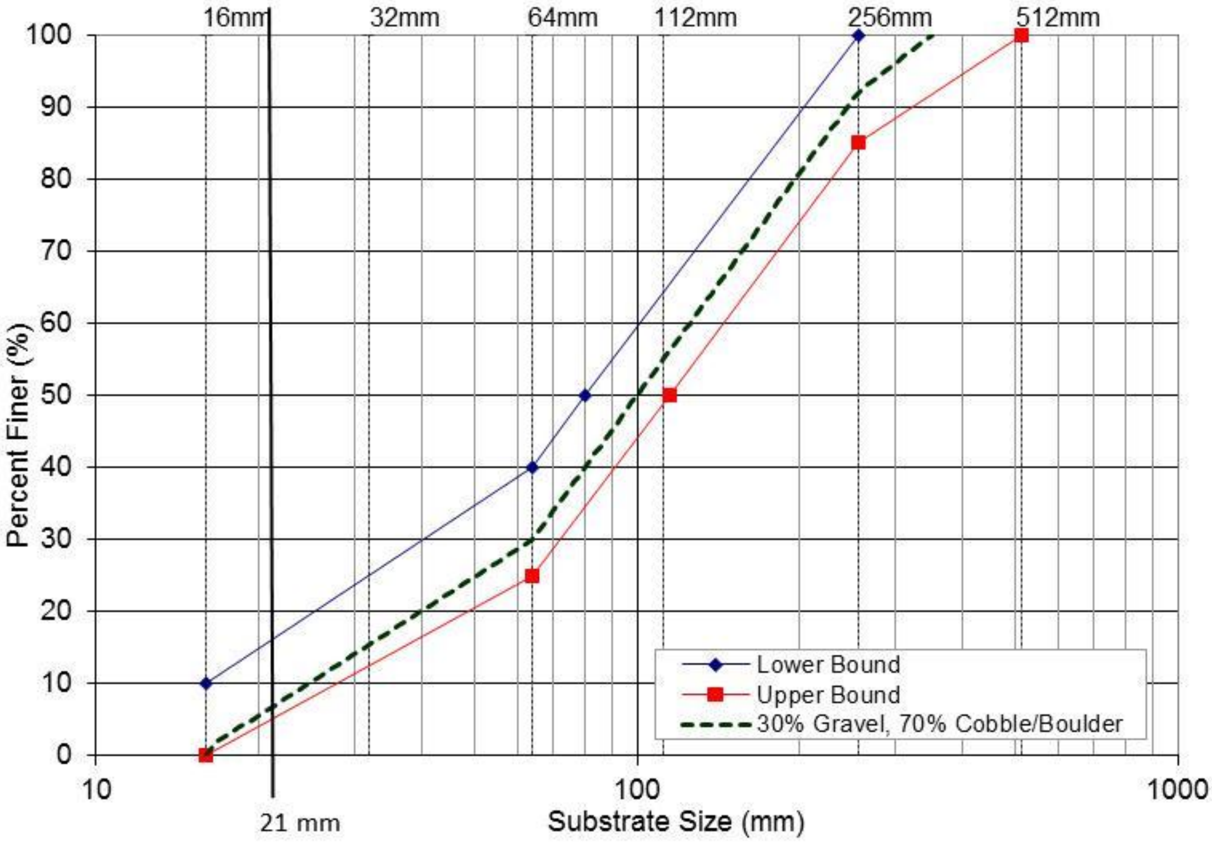

Figure 3-9. The Ideal Placement Substrate in Relation to the Calculated Stable Particle Size.

4 USGS TWO-DIMENSIONAL MODEL (FASTMECH)

The 2D model, Flow and Sediment Transport with Morphologic Evolution of Channels (FaSTMECH) contained in the iRIC modeling system was used for all two-dimensional analyses performed by the USGS in support of the Shorty's Island 1135 Project analyses. FaSTMECH was developed at the USGS and a thorough description of the model can be found in Nelson and McDonald (1996) and Nelson et al. (2003).

4.1 4.1 General Description of FaSTMECH

A brief introduction to FaSTMECH is presented here to provide context to its application to the 1135 Project. This description of taken from McDonald et al. (2010).

FaSTMECH includes two flow calculation components. The first component is a solution of the shallow water equations, with a closure for bed stress that incorporates a drag coefficient. The second component is a submodel that calculates the vertical distribution of the primary flow and the secondary flow about the streamlines of the vertically averaged flow. The full governing equations used in the computational solution are cast in a channel-fitted curvilinear coordinate system described in Nelson and Smith (1989). In the first part of the model, the shallow water equations are used to compute the vertical structure of flow along the vertically averaged streamlines as well as the cross streamline components of both the vertically average velocity and the bottom stress. Inputs to the vertically averaged model are discharge, topography, and roughness. The second part of the model computes the cross-stream components of velocity and Reynolds shear stress, yielding the vertical structure of secondary flows and the modification to the bottom stress associated with secondary flows. Inputs to the vertical-structure component of the model are eddy viscosity structure functions and the results of the vertically averaged model. The approach uses the assumptions that the flow is steady and hydrostatic, and the turbulence can be treated adequately by relating Reynolds stresses to flow shear using an isotropic eddy viscosity. This so-called quasi-three-dimensional approach has been shown to adequately simulate the velocity field, bed shear stress, and resulting patterns of erosion and deposition where secondary flows are significant, such as meander bends, without the complexity of a fully three-dimensional model Nelson et al. (2003).

The numerical solution technique employed in FaSTMECH solves the full vertically averaged equations on a curvilinear orthogonal grid using relatively standard methods. First, an explicit solution of the streamwise and cross-stream momentum equations is obtained for the vertically averaged velocity subject to a known guessed water-surface elevation and velocity fields. The initial guess is taken from a simple steady 1D flow solution. Second, the water-surface elevation is calculated using the semi-implicit method for linked equations (SIMPLE) (Pantankar 1980), which comprises an alternating-direction implicit scheme with operator splitting and a tridiagonal matrix solver. Water-surface elevation and velocity fields are updated in an iterative cycle using differential relaxation, and iteration continues until both mass and momentum conservation are satisfied to a high degree of accuracy at every point in the computational grid. Using solutions from the vertically averaged model, an assumed eddy viscosity structure from Rattray and Mitsuda (1974), and a spatial distribution of roughness lengths or drag coefficients, the vertical-structure component of the FaSTMECH model yields a full three-dimensional flow solution.

4.2 MODEL GEOMETRY

The description of the model geometry presented in this subsection as well as the description of the model geometry and boundary conditions were taken from a memo prepared by the USGS (Pers. Com. Brandy Logan, June 18, 2011).

To construct multidimensional flow and sediment-transport models for the 1135 sites, we used topography that is a combination of bathymetry provided by Gary Barton, USGS Water Science Center, Tacoma, WA and LiDAR coverage of above water topography from the report "LiDAR Remote Sensing Data Collection: Columbia River Survey Delivery 9", dated July 29, 2010. These two data sets were stitched together by first subsampling the LiDAR data on to a 5 meter grid and then removing all LiDAR points representing water-surface elevation. Second, the bathymetry data that overlapped the resulting LiDAR data from the first step was removed. The two subsequent data sets were combined to form one complete data set of topography for the meander reach.

Three models have been developed for the 1135 Project and other ongoing studies. The first is the Braided Reach model that extends from just downstream of the Kootenai – Moyie River confluence to the Tribal Hatchery downstream near Bonners Ferry. The second is the Meander Reach model that extends from the US HWY 95 bridge at Bonners Ferry to the USGS Klockman Ranch gage. The third is the short Meander Reach model (a subset of the previous model) that extends from just above the Myrtle Creek Bend to downstream of Shorty Island. The two long reach models (Braided and entire Meander) used a discretization of approximately 10 meters and the short Meander Reach used a finer discretization of approximately 5 meters. The results presented in this Appendix are from the short Meander Reach model with the finer grid, as it was judged to be more appropriate for the more detailed questions addressed.

4.3 MODEL CALIBRATION

The two long-reach models were calibrated to synoptic water-level measurements made throughout the Meander and Braided Reaches. During 2006, the gage locations included the Tribal Hatchery, Bonners Ferry, and five temporary gages upstream of Bonners Ferry. In 2010, the gage locations included Klockman Ranch, Tribal Hatchery, Bonners Ferry, and 6 temporary gages of which one was at Ambush Rock, and 5 were upstream of Bonners Ferry. During the period of time in 2006 and 2010 that flows were selected for model calibration, the flow was usually unsteady. The length of the Braided and Meander Reaches are long enough that the flow was not expected to be constant over the entire reach at any one period of time. To determine a set of stages for a steady flow condition we chose to average the flow over a period of 12 to 24 hours, and to average the stage at each of the measuring locations over the same period (Table 4.1).

The USGS first calibrated the Braided Reach model and subsequently calibrated the Meander Reach model. The resulting meander reach calibration was used for computations from the short Meander Reach model. Because detailed measurements of grain-size and vegetation on bars and banks are not available, the USGS originally attempted to keep the calibration simple by using a single value of roughness for the entire reach. However, using this simple treatment for roughness, it was not possible to get a good correlation between measured and simulated water-surface elevations. Therefore, the USGS divided the roughness into three regions with division points at Ambush Rock (effectively the point at which the river transitions from gravel/cobble substrate upstream and sand downstream) and at the Tribal Hatchery. To set the roughness for the Meander Reach model (which overlaps with the Braided Reach model between the US 95 bridge and the Tribal Hatchery) the USGS used the calibrated values from the Braided Reach model for the upstream section between the US HWY 95 bridge and Ambush Rock, and Ambush Rock to the Tribal Hatchery, and calibrated the reach below the Tribal Hatchery to Klockman Ranch (Table 4.1).

Table 4-1. Dates of Flows Used to Calibrate the Models, the Calibrated Roughness (Cd-drag coefficient), and the Lateral Eddy Viscosity Used (LEV).

Date (mm/dd/yy)	Q_{ave} (cfs)	Q_{min} (cfs)	Q_{max} (cfs)	Drag Coefficient (Cd)			Lateral Eddy Viscosity (LEV)
				Meander Below Tribal Hatchery	Meander Tribal Hatchery to Ambush Rock	Meander Tribal Hatchery to Ambush Rock	
5/2/10	9,902	9,517	10,463	0.0048	0.0064	0.0048	0.0170
5/23/10	21,351	20,275	22,690	0.0030	0.0037	0.0037	0.0310
6/4/10	31,777	30,256	33,931	0.0026	0.0029	0.0038	0.0340
6/13/10	41,198	37,809	43,911	0.0017	0.0027	0.0038	0.0400
6/10/2006	50,758	50,497	50,905	0.0012	0.0010	0.0030	0.0547

4.4 APPLICATION OF THE TWO-DIMENSIONAL MODEL

The USGS performed two-dimensional modeling of the proposed substrate placement areas for both the existing without project and existing with project conditions using the calibrated FaSTMECH model *(Note: As discussed in Section 3.1.1, the existing with project condition was based on the 8-feet thick substrate placements originally proposed for the clay beds in the November 2011 35 percent design. The thickness was reduced to 2-feet in the June 2012 revision of the 35 percent design.)*. The model applied was the short reach with the finer grid discretization of 5m that extends from just above the Myrtle Creek bend to downstream of Shorty's Island. The USGS provided two memos documenting the results (Pers. Com. USGS, June 2011 and Pers. Com. USGS September 26, 2011).

4.4.1 EXISTING WITHOUT PROJECT CONDITION RESULTS

Example of the model results for the existing without project condition including velocity, depth, and bed shear stress, for the highest discharge modeled (50,758 cfs) are shown in Figures 4.1, 4.2 and 4.3, respectively. In reviewing these figures, the areas of highest velocity, depth and shear stress are in the areas of the proposed substrate placements at the three projects sites. This is consistent with the need for these areas to exhibit hydraulic complexity as well as have conditions conducive to scouring sediments and minimizing the likelihood that the placed substrate will be buried by deposited sand and finer sediments.

Additional figures showing the maximum mobile grain-size, maximum suspended grain-size and the erosion pattern and rate for each of the five modeled flows determined by the USGS are presented in Figures 4.4, 4.5 and 4.6, respectively. Each plot shows the typical conditions at the three restoration sites, Myrtle Creek, Shorty's South and Shorty's North.

In reviewing Figure 4.4, the largest grain size moving are at Shorty's South with the size ranging from about 1.5 mm at 10,000 cfs to 4mm at flows of approximately 30,000 cfs and larger. Both Myrtle Creek and Shorty's North start at 1.5mm at 10,000 cfs, but do not increase in size as rapidly as Shorty's South. At 30,000 cfs, the maximum grains size mobilized is 3mm at Myrtle Creek and 2mm at Shorty's North. At the largest flow modeled of about 50,000 cfs, both sizes are still smaller than for the corresponding discharge at Shorty's South; with Myrtle Creek being 3.5mm and Shorty's South being 3mm. These values are similar to the general reach average values for the Meander Reach reported in Chapter 3 of the Main Report that indicated mobilization of bed sediments up to 2.5mm for 30,000 cfs and 4mm for 65,000 cfs. Comparing to the 1-D model results in Section 3 of this appendix, the 1-D results showed mobilization of 3 to 5mm particles at approximate 30,000 cfs and 6 mm particles at 65,000 cfs. The one-dimensional modeling shows larger particles moving, which is likely due to picking a relatively low critical shear stress parameter of 0.03. The conservative value was chosen for the application in Section 3 since these results were being used for design.

Figure 4.5 provides the results for the three sites in terms of the maximum grain size the flow is capable of suspending. For the three sites, the results are identical from 10,000 cfs up to and including 40,000 cfs. For flows from 10,000 to 30,000 cfs, the maximum suspended grain size is 0.13mm to 0.15mm at just over 40,000 cfs, the maximum suspended size is 0.19 mm. For Shorty's North, the size does not increase as flows climb to over 50,000 cfs; however, the maximum suspended grain size does increase to 0.22m for Myrtle Creek and 0.25 mm for Shorty's North. The median bed material size (D_{50}) reported by the USGS in the project area is 0.22 mm. Comparing this size with the maximum grains size that would be suspended indicates that the vast majority of sediment would be traveling as bed load.

Estimated erosion rates are presented in Figure 4.6 for the three sites. These are primarily useful as a qualitative assessment of whether an area would be eroding or depositional, rather than a quantification of actual erosion rates. The results at all three sites indicate erosion as the likely response at the three proposed project sites for flows above 20,000 cfs. This is consistent with these sites scouring the bed to expose the lacustrine clay layer on which the substrate placements are proposed.

4.4.2 EXISTING WITH PROJECT CONDITION RESULTS

To help evaluated whether the placement of 8 feet of substrate *(as proposed in November 2011, but reduced to 2-feet in June 2012)* at the Shorty's South and Shorty's North sites has the potential to adversely impact the hydraulics conditions that both contribute to the hydraulic conditions that attract the KRWS and maintain the clay bed scoured free of sand, the USGS performed two-dimensional hydraulic modeling of these sites using FaSTMECH.

To model the with project condition at Shorty's South and Shorty's North, Tetra Tech provided the USGS with shapefiles of the substrate placement locations as well as topographic breaklines representing the intended geometry of the originally proposed 8 feet of suitable substrate placement. Figure 4.7 shows the locations of the proposed substrate placements including both the 8 foot substrate placement on clay beds (cross sections 1, 3, 4 and 5) and the 2 foot substrate placement on the clay shelf (cross section 2). Figure 4.7 also shows the location of cross sections later used to illustrate changes in velocity. The shapefiles and topographic breaklines were converted from English to Metric units for the analysis. The USGS constructed topography representing the substrate placements by first deleting the surveyed topographic points within the amendment locations then inserting the topographic breakline topography representing the placement geometry. To model the clay shelf at Shorty's South (cross section 2 on Figure 4.7) the USGS added two feet to the original surveyed topography at the "Shelf" location rather than using the topographic breaklines.

The USGS performed two model simulations using (1) the original surveyed topography and (2) the topography representing the substrate placement, for a flow rate of 30,000 cfs. The USGS plotted the maximum mobile grain size (mm), maximum suspended grain size (mm), and erosion rate (inches per day) for each simulation in Figures 4.8, 4.9 and 4.10. The simulations with project condition show very small increases in each of the three values over the without project condition. The increased values are a result of the small decrease in cross-sectional area of the channel due to the substrate amendment. The results indicate that in the with project condition 3 mm sediment is mobile in a few locations over the substrate placement and 2 mm sediment is mobile throughout the thalweg (Figure 4.8). This represents an increase in sediment mobility over the without project condition and provides an indicator that the placements create conditions slightly more conducive to scouring of sediments. The maximum suspended grain size is 0.19 mm which is slightly smaller than the mean grain size of 0.22 mm so most of the existing mobile sediment would be moving as bedload at this flow rate. It is noted that the area with 19 mm sediment suspended is slightly increased for the with project condition (Figure 4.9). The pattern of erosion and deposition is patchy, and the erosion and deposition rates are small. At the modeled flow rate an erosion or deposition rate of 0.00001 meters per 600 second would result in 0.06 inches of erosion or deposition over a 24 hour period. Comparing the without and with project conditions show a slightly higher potential erosion rate for the with project condition over the areas of substrate placement (Figure 4.10). These are represented by the darker orange areas in the with project condition that does not show up in the without project condition.

For each of the five substrate placement locations at Shorty's Island the USGS plotted the without and with project topography with the resulting velocity for each cross section (Figures 4.11, 4.12, 4.13, 4.14 and 4.15). Again, the results suggest only a very small change in velocity. The USGS also computed the change in cross-sectional area by integrating the depth across each cross-section. The with project topography at each of the five cross-sections results in very small percentage change to the cross-sectional area of 4.26, 1.0, 2.8, 2.4, and 1.8 percent for cross-sections 1 through 5, respectively. In general it would be expected that changes to the velocity would be on the same order as changes to the cross-sectional area *(Note: the changes are conservatively high since they are based on the original 35 percent design consisting of 8-feet thick substrate placements on the clay beds which were later reduced to 2-feet thick).*

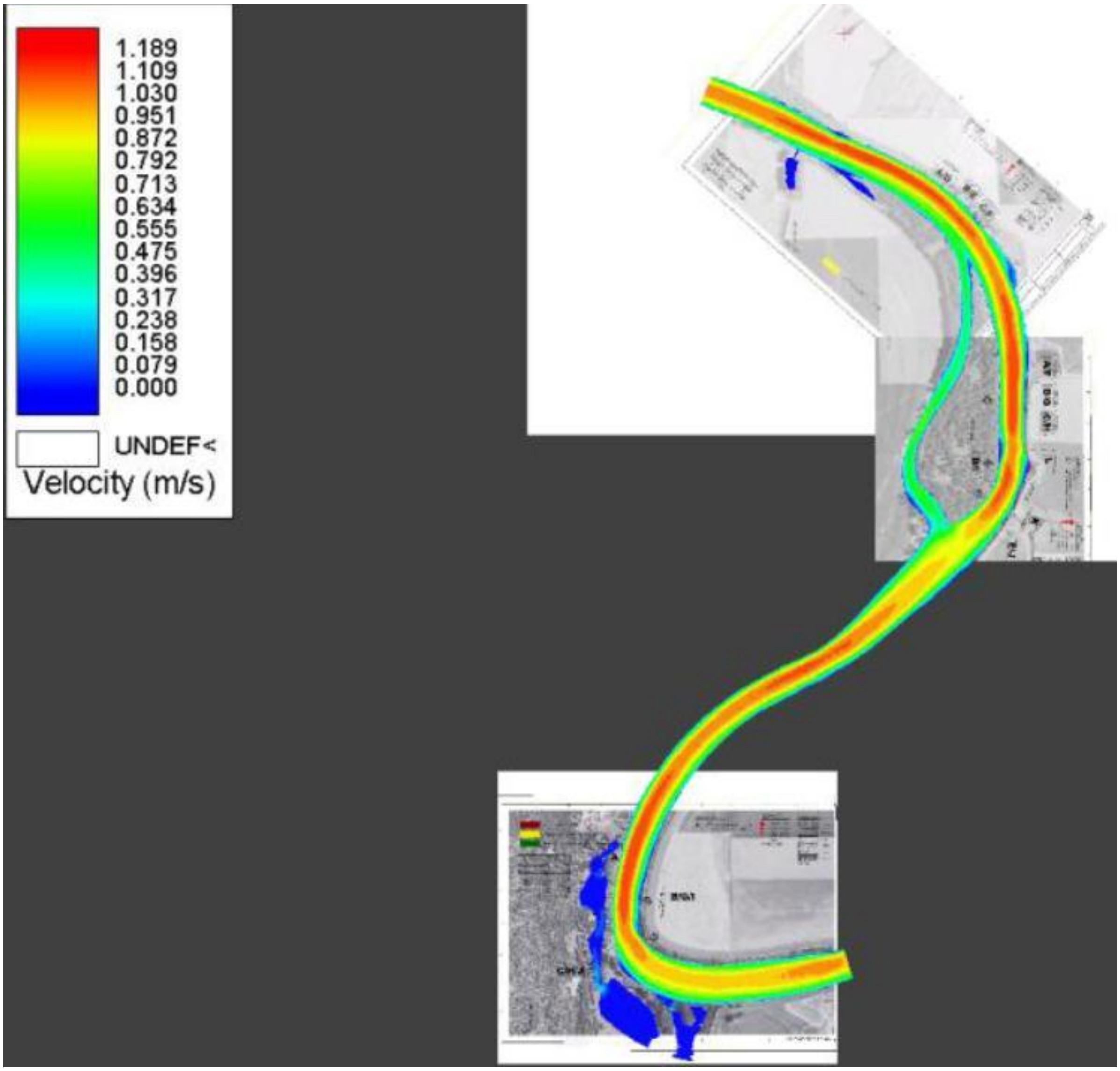

Figure 4-1. Example FaSTMECH Model Results for Velocity (in meters per second) from Myrtle Creek Downstream to below Shorty's Island at a Discharge of 50,758 cfs (USGS)

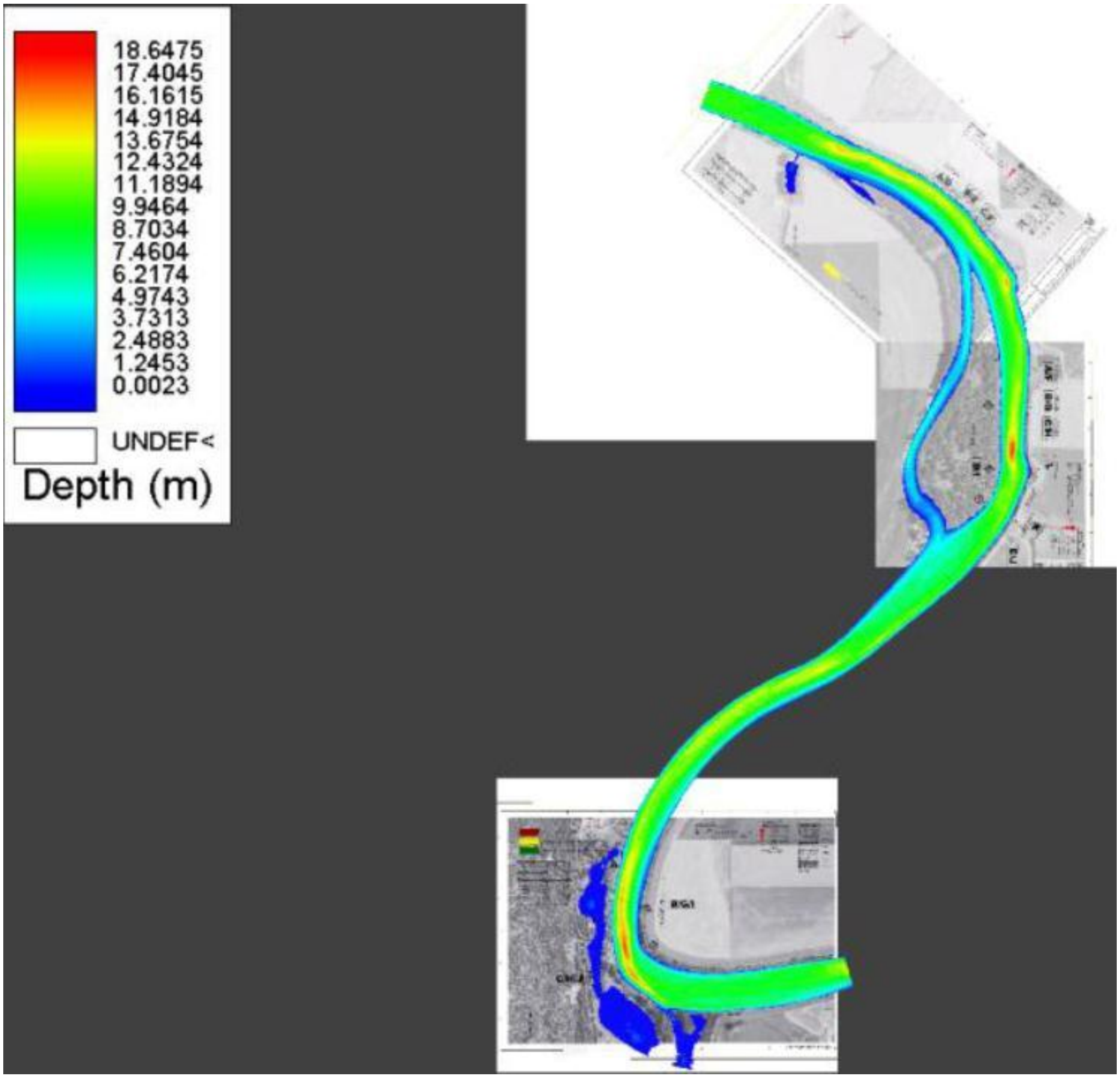

Figure 4-2. Example FaSTMECH Model Results for Depth (in meters) from Myrtle Creek Downstream to below Shorty's Island at a Discharge of 50,758 cfs (USGS)

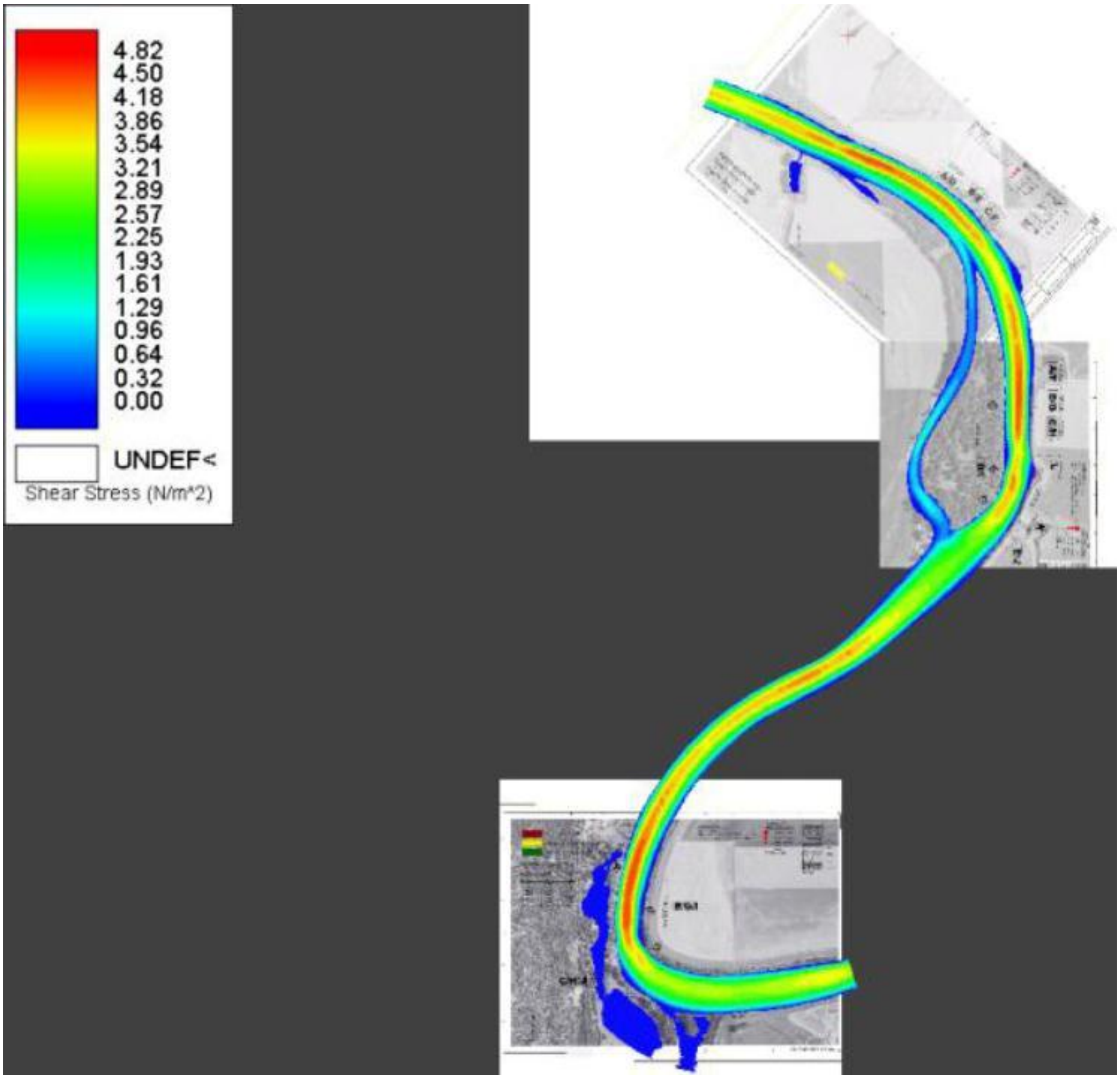

Figure 4-3. Example FaSTMECH Model Results for Depth (in Newtons per square meter) from Myrtle Creek Downstream to below Shorty's Island at a Discharge of 50,758 cfs (USGS)

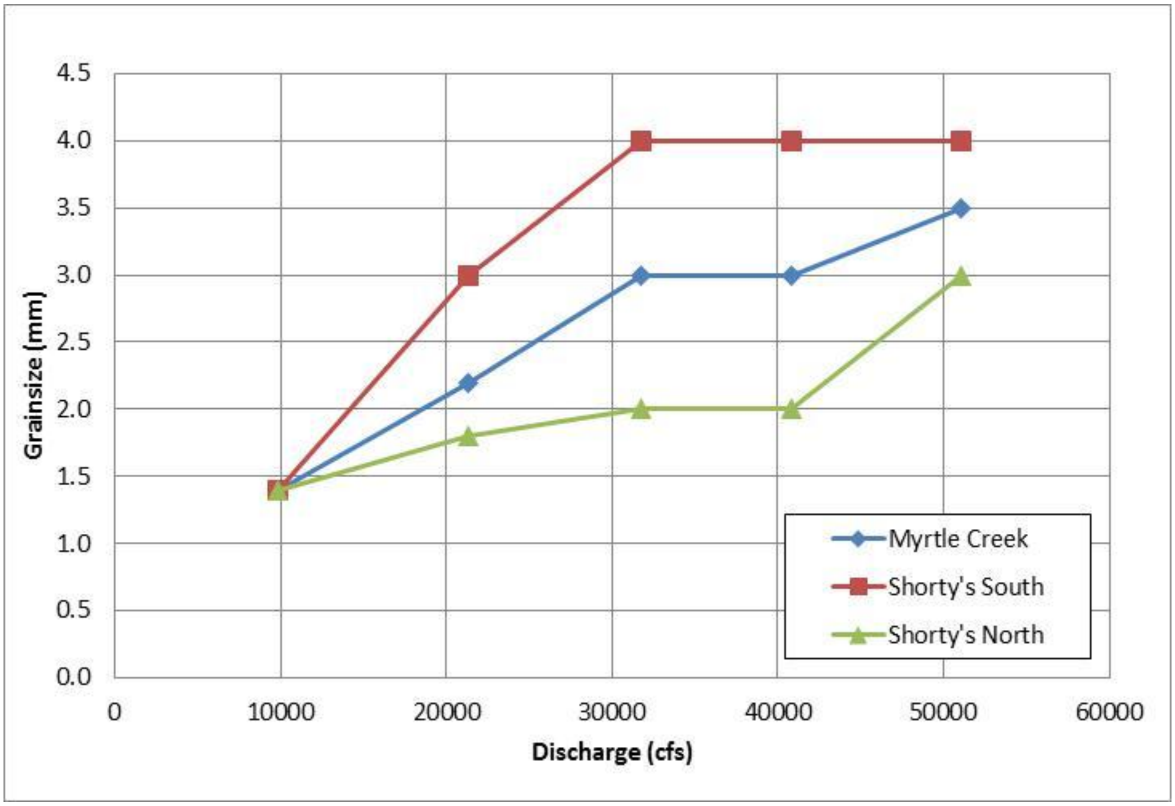

Figure 4-4. Maximum Mobile Grain-Size at Myrtle Creek, Shorty's South, and Shorty's North (USGS)

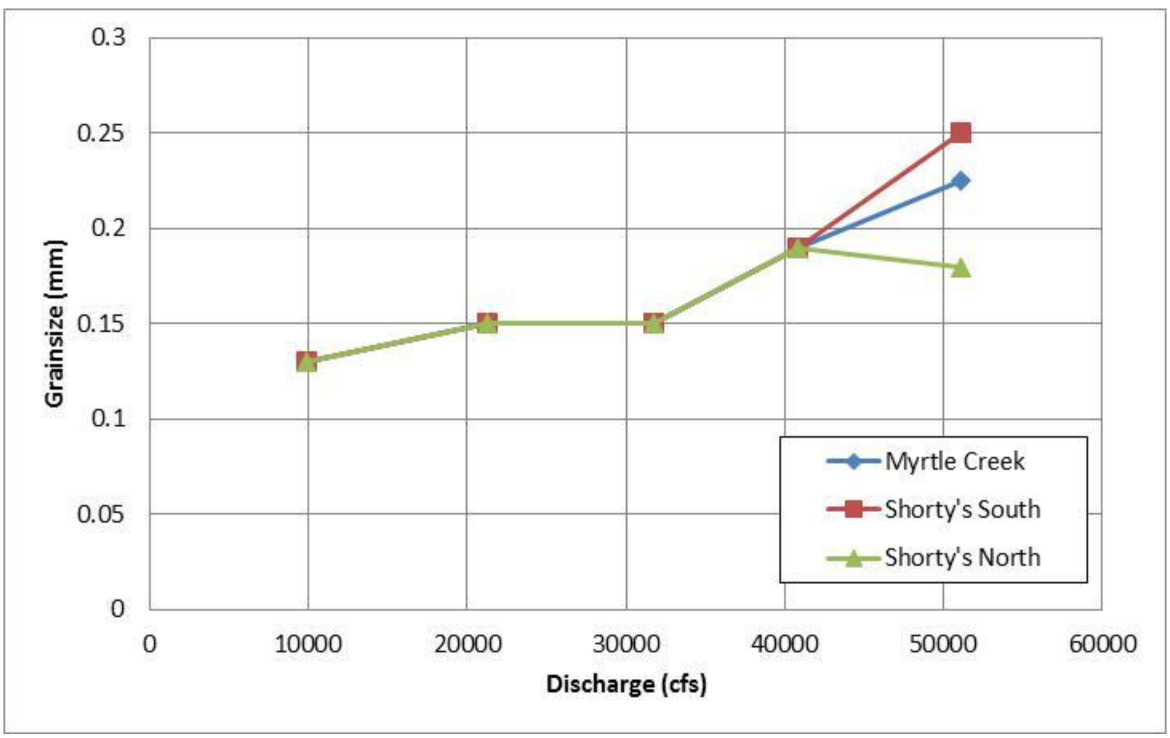

Figure 4-5. The Maximum Suspended Grain-Size at Myrtle Creek, Shorty's South and Shorty's North (USGS)

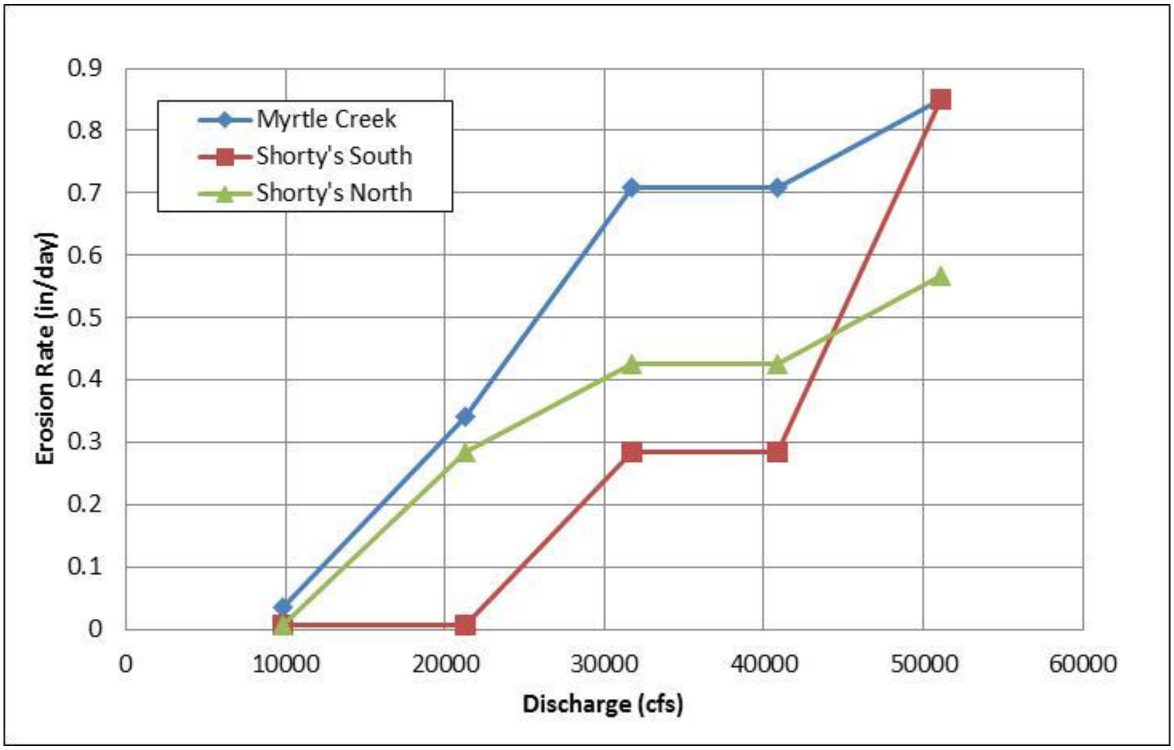

Figure 4-6. The Erosion Rate at Myrtle Creek, Shorty's South and Shorty's North (USGS).

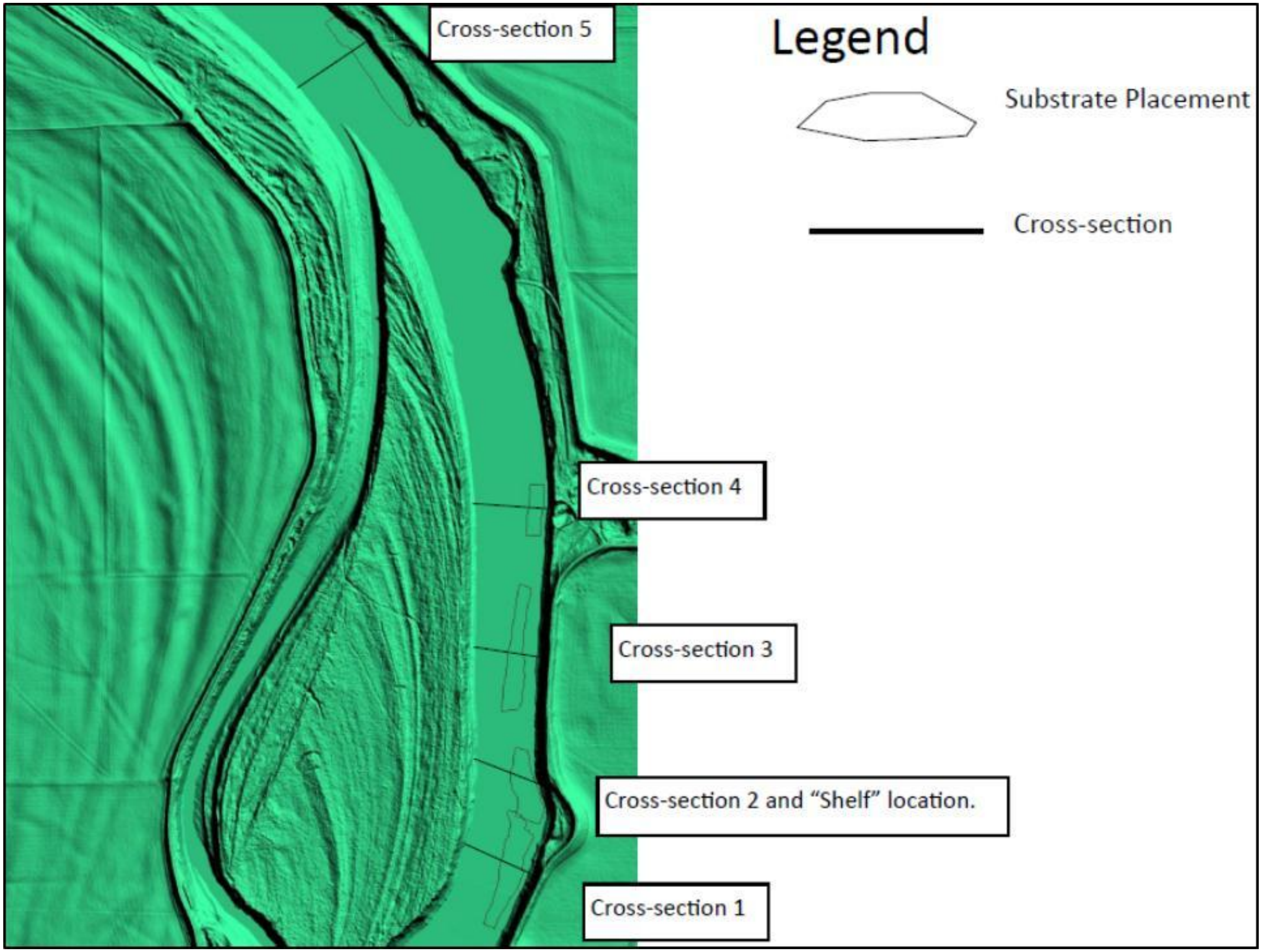

Figure 4-7. Substrate Placement and Cross Section Locations for Shorty's South and Shorty's North (USGS)

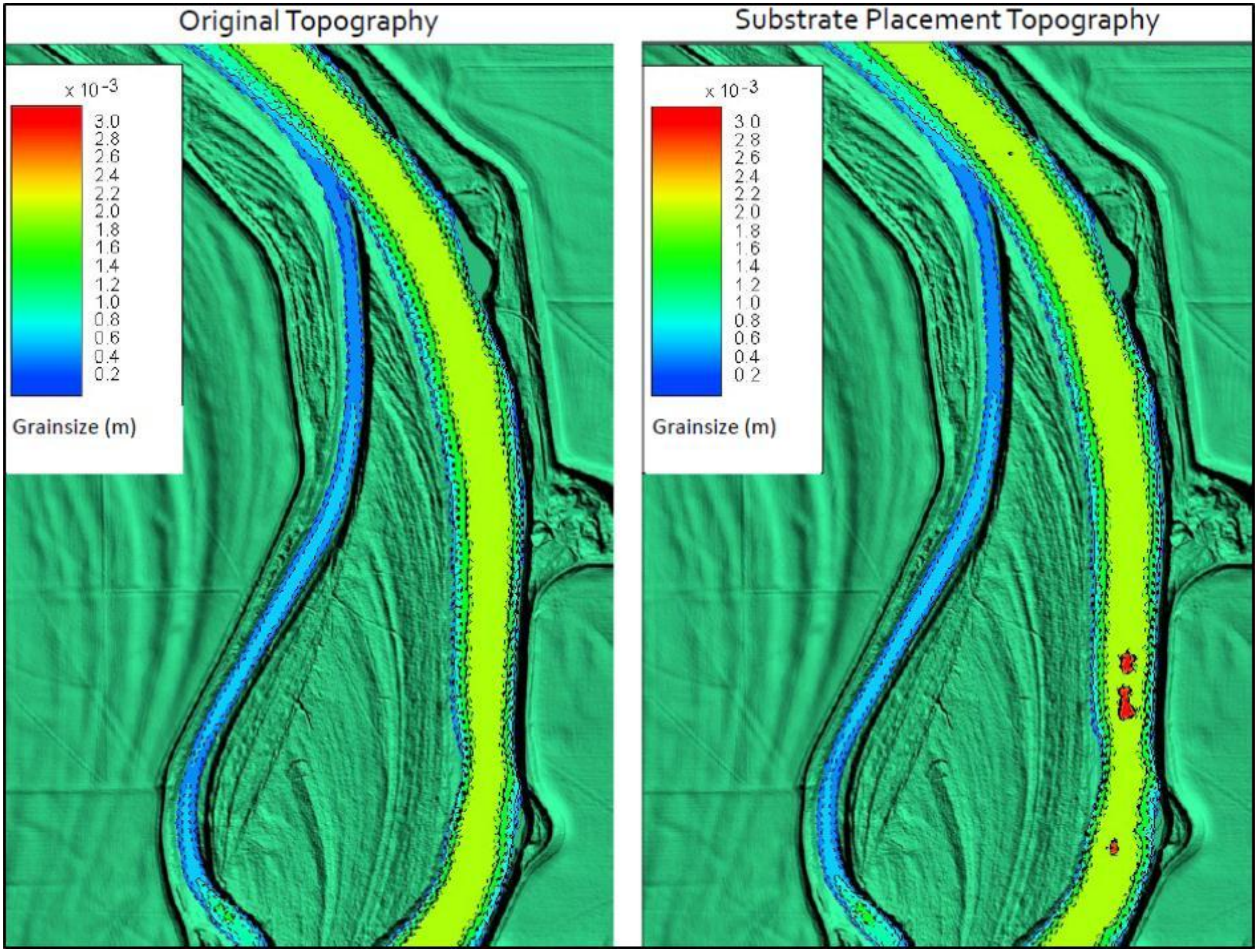

Figure 4-8. Maximum mobile bed material size for Without Project (original topography) and With Project (Substrate Placement Topography) at 30,000 cfs, Shorty's Island (USGS)

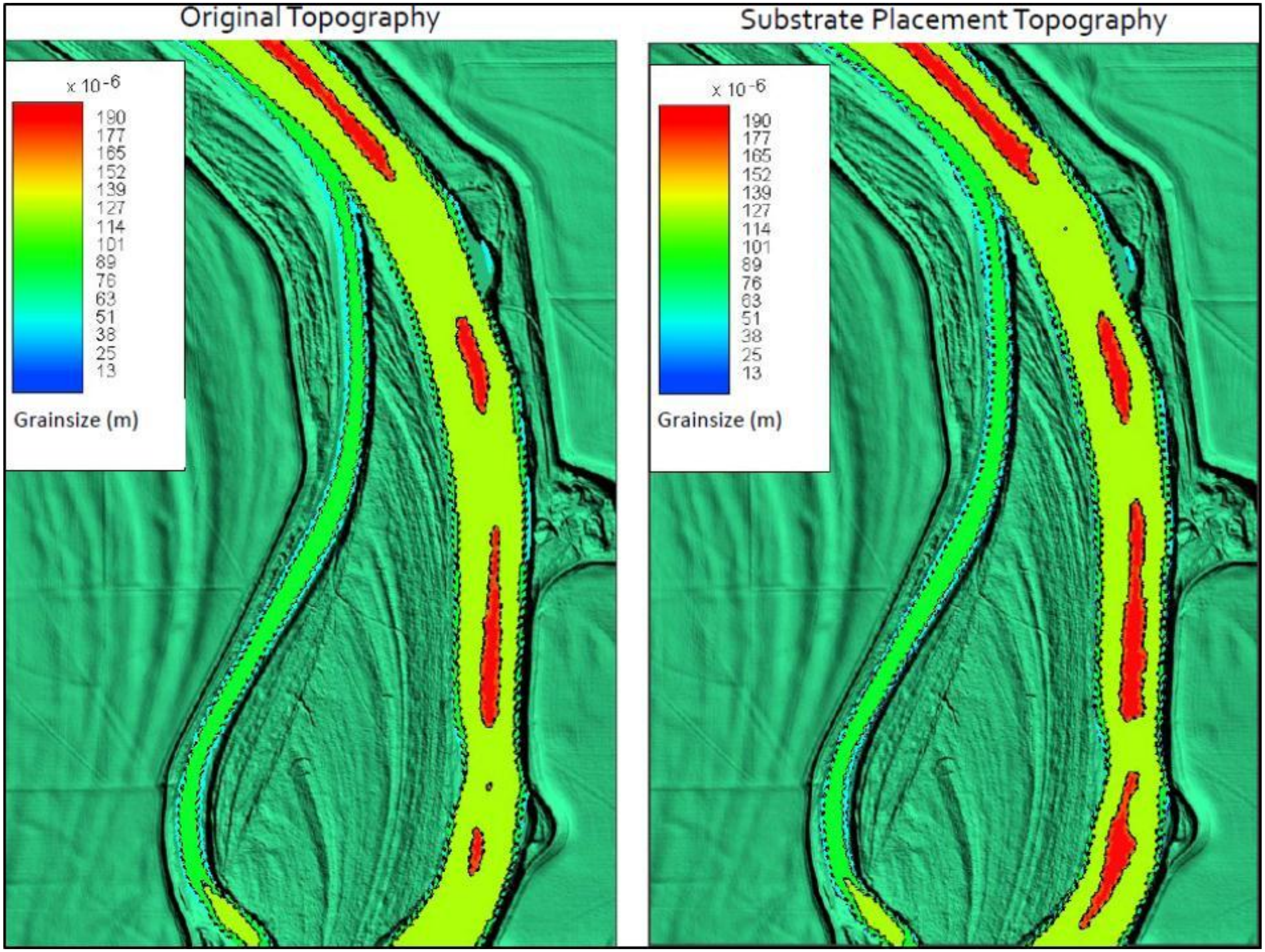

Figure 4-9. Maximum Suspended Sediment Size for Without Project (original topography) and With Project (Substrate Placement Topography) at 30,000 cfs, Shorty's Island (USGS)

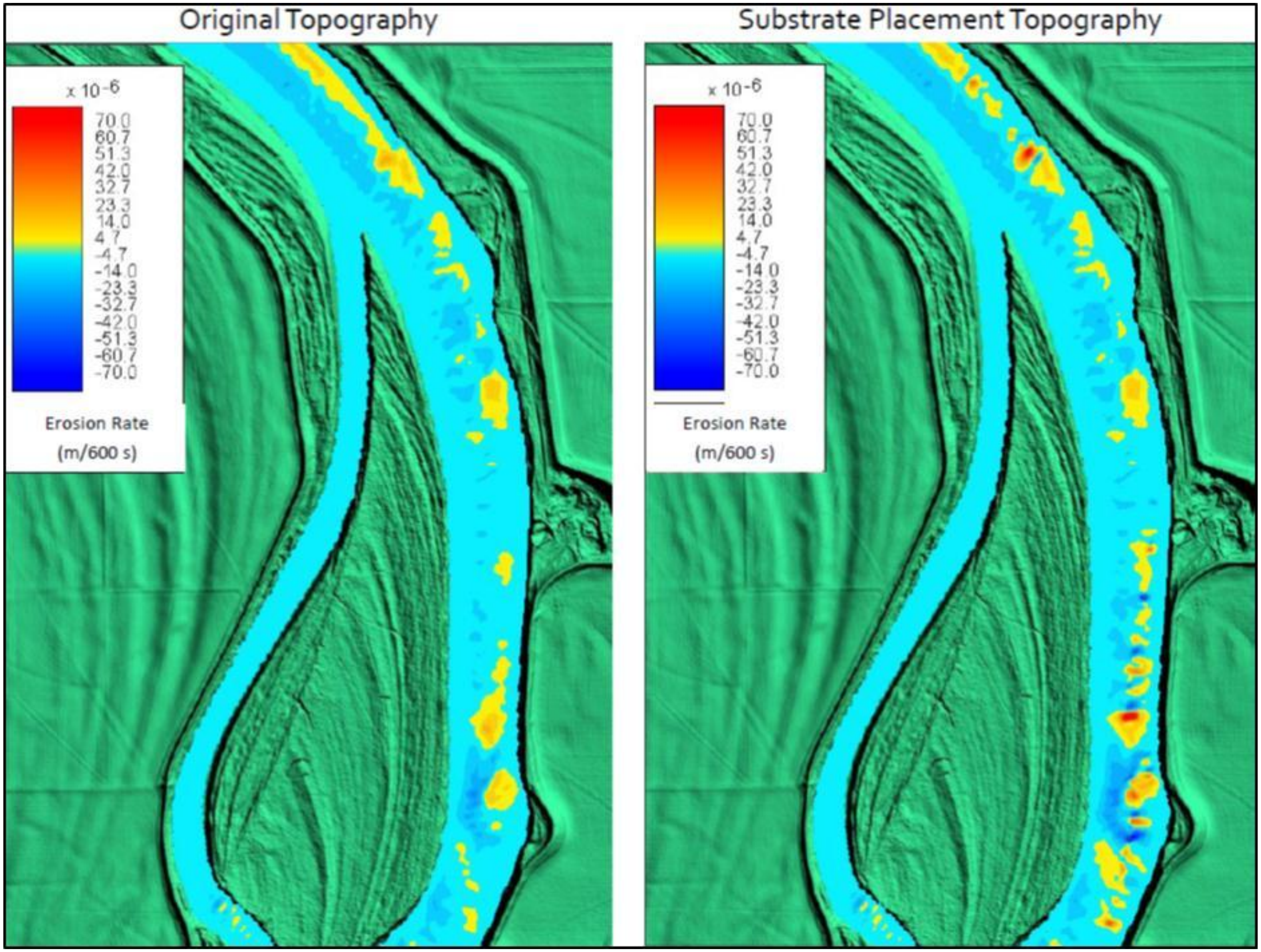

Figure 4-10. Estimated Erosion Rage for 0.22 mm Sediment for Without Project (original topography) and With Project (Substrate Placement Topography) at 30,000 cfs, Shorty's Island (USGS)

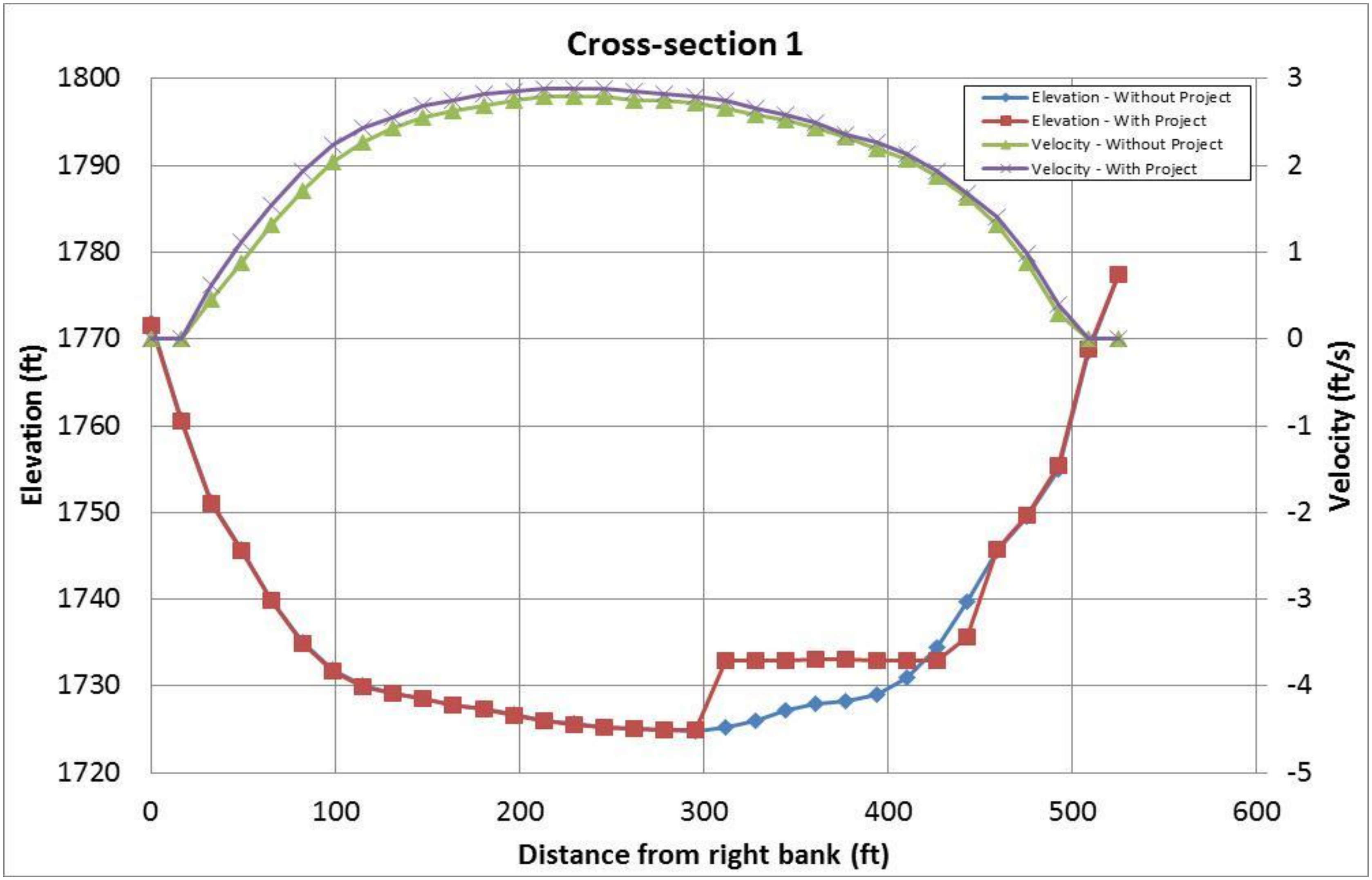

Figure 4-11. Bed Elevation and Simulated Velocity Distribution for the Without and With Project Conditions, Cross-Section 1, Shorty's South (USGS)

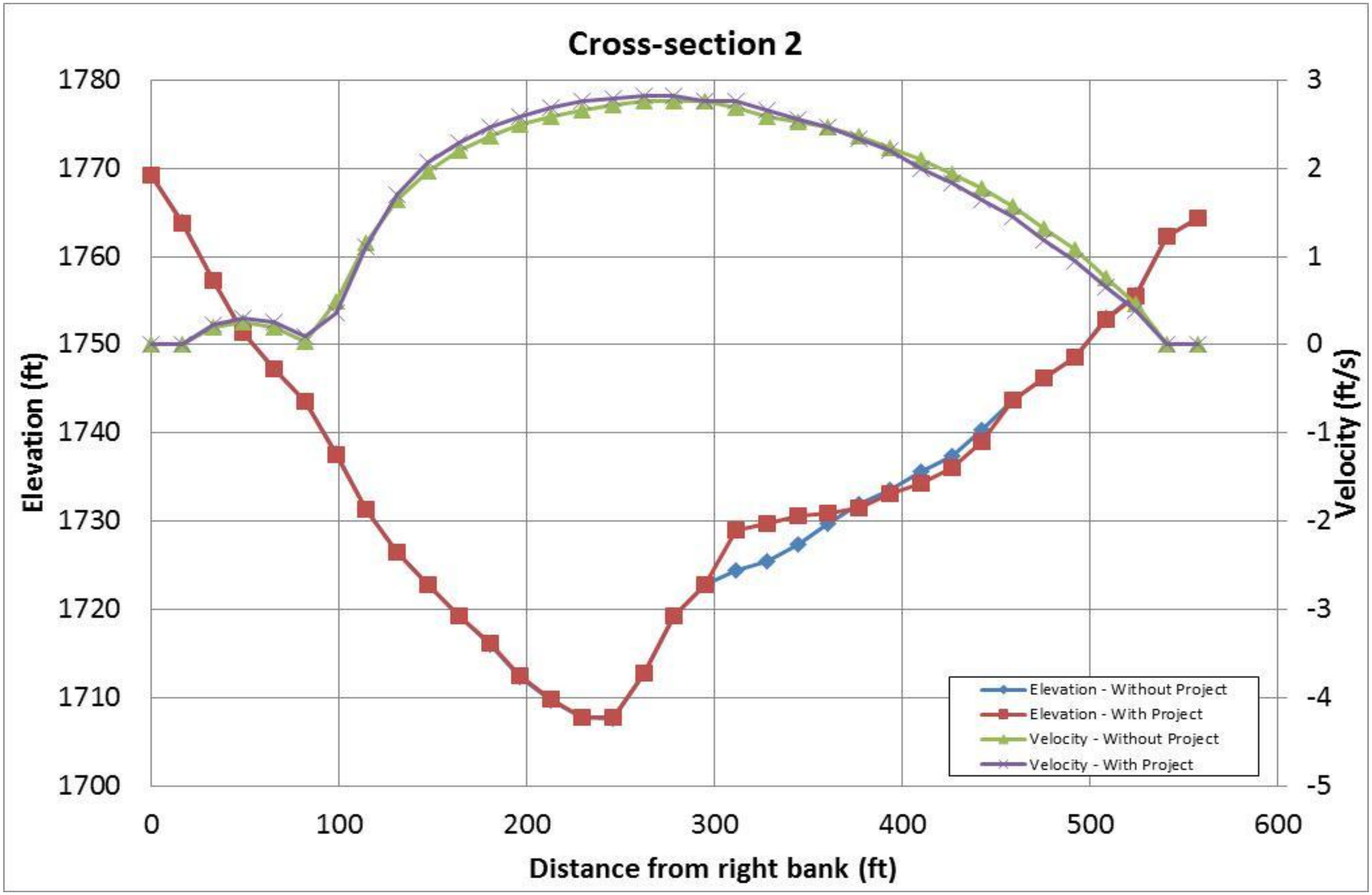

Figure 4-12. Bed Elevation and Simulated Velocity Distribution for the Without and With Project Conditions, Cross-Section 2, Shorty's South (USGS)

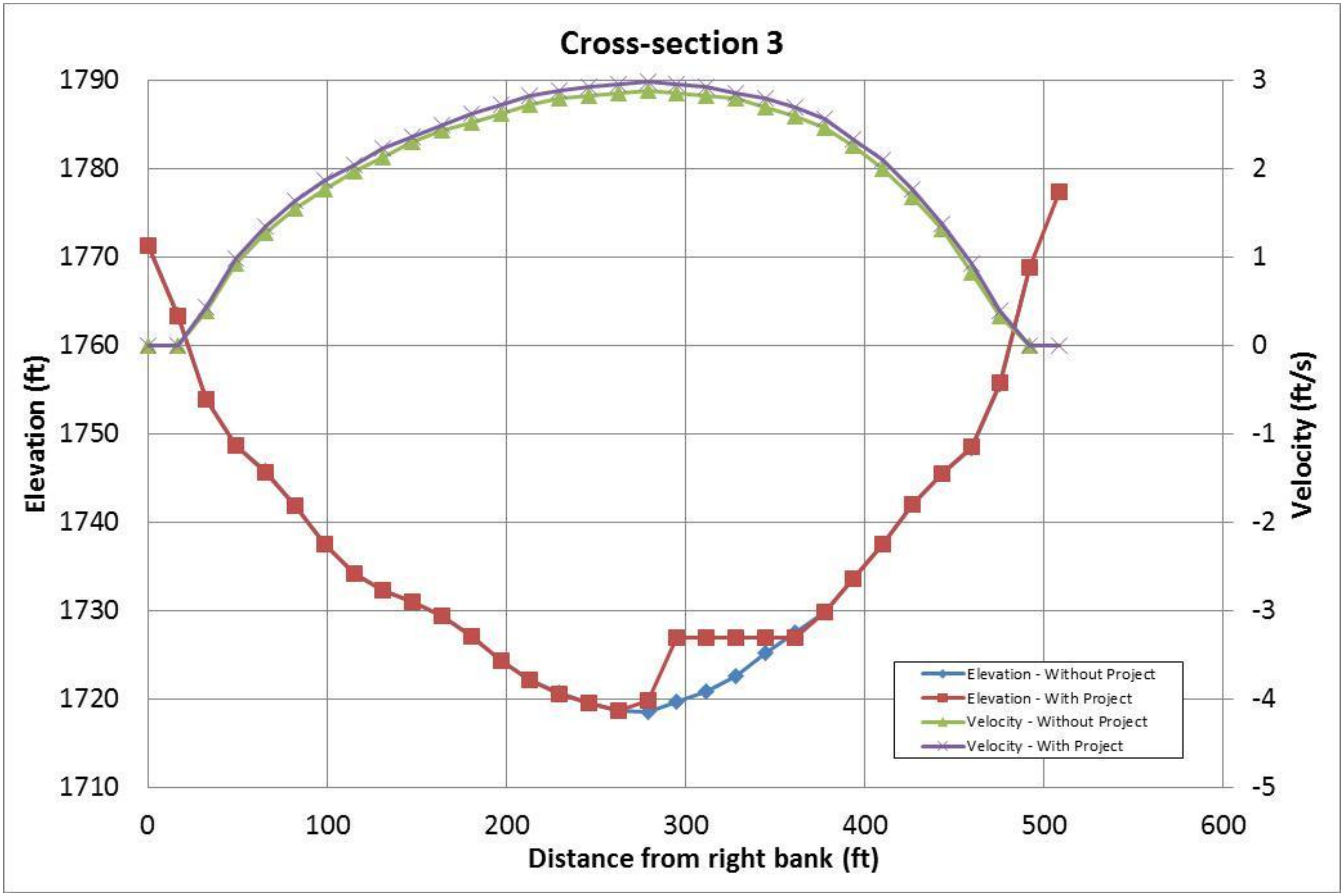

Figure 4-13. Bed Elevation and Simulated Velocity Distribution for the Without and With Project Conditions, Cross-Section 3, Shorty's South (USGS)

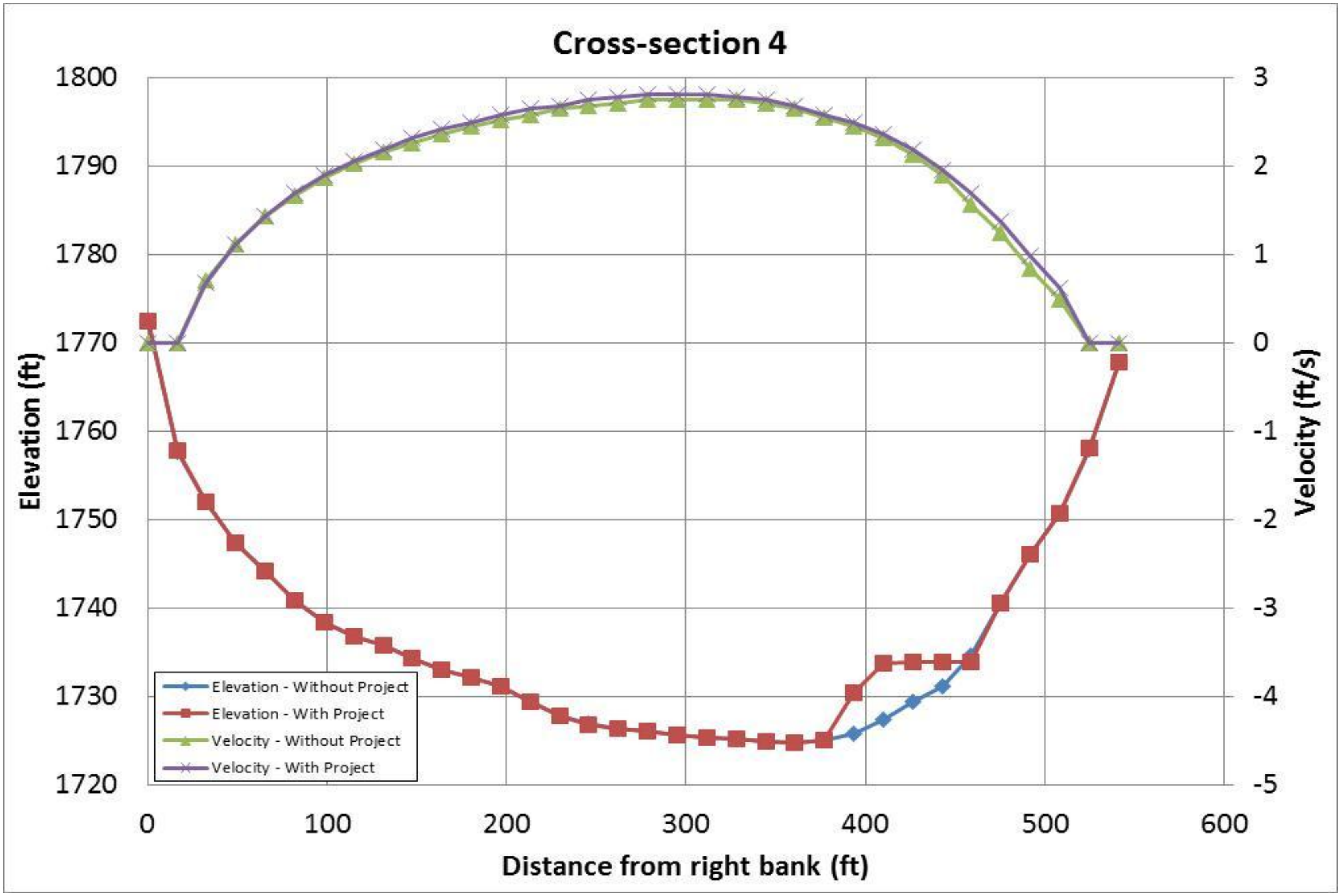

Figure 4-14. Bed Elevation and Simulated Velocity Distribution for the Without and With Project Conditions, Cross-Section 4, Shorty's South (USGS)

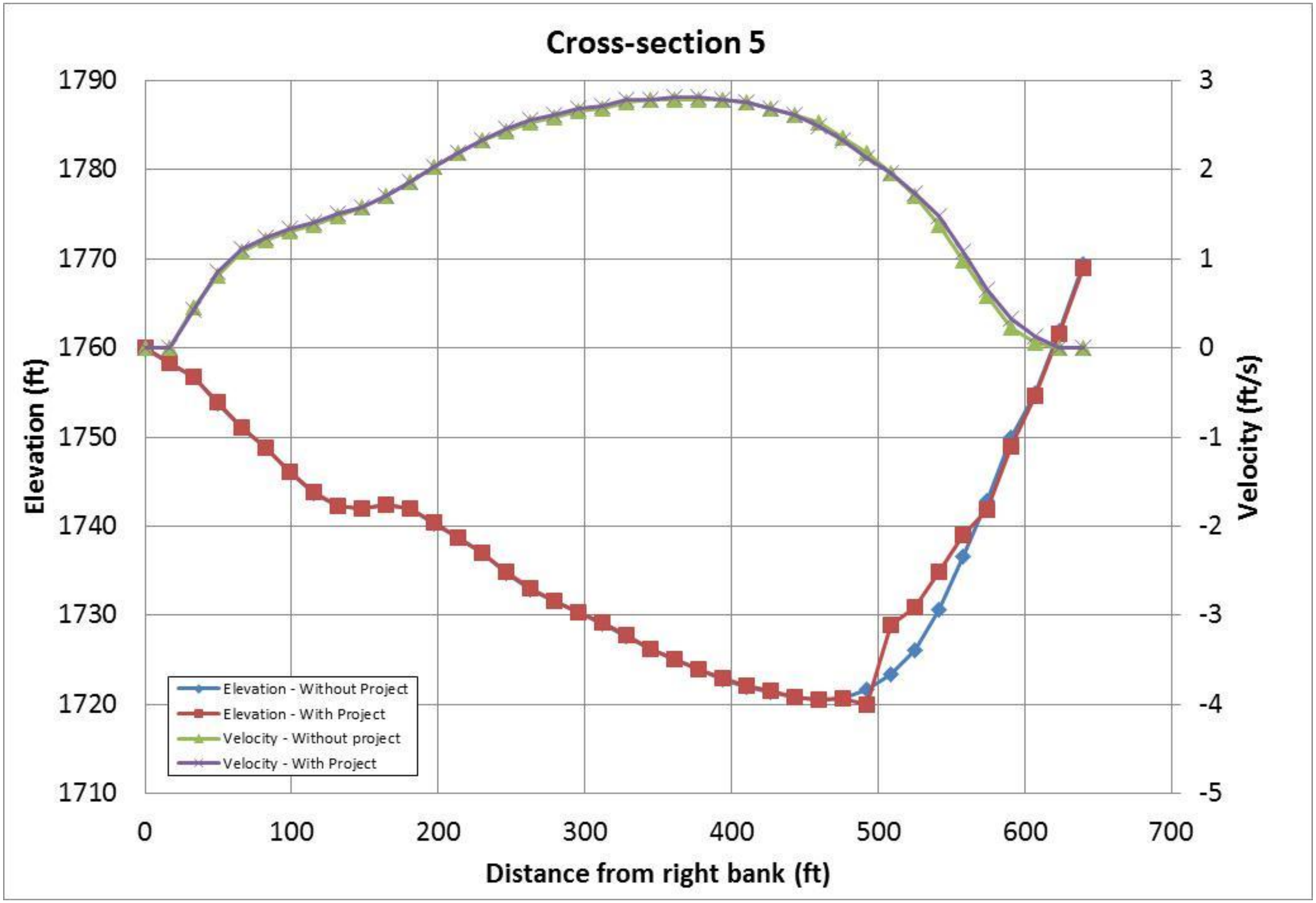

Figure 4-15. Bed Elevation and Simulated Velocity Distribution for the Without and With Project Conditions, Cross-Section 5, Shorty's North (USGS)

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