



**US Army Corps
of Engineers®**
Engineer Research and
Development Center

ERDC
INNOVATIVE SOLUTIONS
for a safer, better world

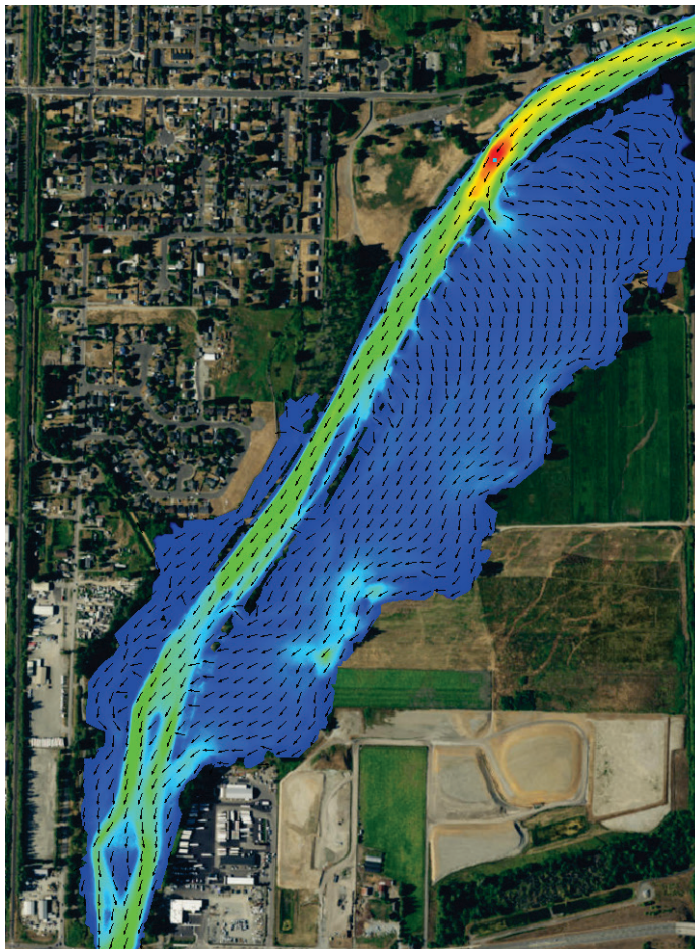
Flood and Coastal Systems Research and Development Program

Modeled Sedimentation in the Lower White River Countyline Levee Setback, Washington State

Comparison of 1D (HEC-RAS) and 2D (AdH) Results

Keaton E. Jones, Travis A. Dahl, and Zachary P. Corum

July 2018



The U.S. Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdc.usace.army.mil.

To search for other technical reports published by ERDC, visit the ERDC online library at <http://acwc.sdp.sirsi.net/client/default>.

Modeled Sedimentation in the Lower White River Countyline Levee Setback, Washington State

Comparison of 1D (HEC-RAS) and 2D (AdH) Results

Keaton E. Jones, Travis A. Dahl

*Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS 39180-6199*

Zachary P. Corum

*U.S. Army Corps of Engineers, Seattle District
4735 E. Marginal Way South
Seattle, WA 98134*

Final report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Project 454633, "Evaluation of Levee Setbacks and River Restoration Projects
for Flood Risk Reduction"

Abstract

The design of the Lower White River Countyline Setback Project in Washington State includes lowering an existing levee and constructing a new setback levee to allow the river to reconnect to an existing wetland. This study used two hydrodynamic and sediment transport models, Hydrologic Engineering Center-River Analysis System (HEC-RAS), and Adaptive Hydraulics (AdH), to model the river and compare the ability of one-dimensional (1D; HEC-RAS) and two-dimensional (2D; AdH) models to simulate hydraulic and sediment behavior in a levee setback project. Overall, both the 1D and the 2D model are well calibrated and indicate that the setback project will increase deposition within the reach. The spatial location of aggradation differs between the two models due to fundamental differences between the 1D and 2D approaches. The 1D model assumes that the river will avulse into the setback area and projects deposition in both the setback and former channel while the 2D model results show most of the aggradation occurring in the setback area. This study shows that, while 1D models can be valuable screening tools for levee setbacks, 2D models of setbacks should be considered when multiple channels may develop, there are lateral processes, or the difference between channel and setback gradations is important.

DISCLAIMER: The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. All product names and trademarks cited are the property of their respective owners. The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

Contents

Abstract	ii
Figures and Tables.....	iv
Preface	vi
Unit Conversion Factors	vii
1 Introduction.....	1
1.1 Objective	1
1.2 Background.....	1
1.3 Approach	5
2 One-Dimensional (1D) Hydrologic Engineering Center-River Analysis System (HEC-RAS) Sediment Transport Modeling.....	7
2.1 Model geometry.....	7
2.2 Boundary conditions	11
2.3 Sediment data and sediment transport modeling approach.....	13
3 Two-Dimensional (2D) Adaptive Hydraulics (AdH) Model.....	17
3.1 Mesh development.....	17
3.2 Hydraulic boundary conditions	22
3.3 Sediment data	24
4 Calibration Period Results	26
4.1 HEC-RAS calibration	26
4.2 AdH calibration	29
5 Water Years (WY) 2006–2007 Results	33
5.1 HEC-RAS WY 2006–2007 results.....	33
5.2 AdH WY 2006–2007 results.....	36
6 Discussion	46
7 Conclusions.....	49
References	50
Appendix A: Starting Sediment Distribution	51
Appendix B: Final Sediment Distribution	55
Report Documentation Page	

Figures and Tables

Figures

Figure 1. Lower White River Countyline Levee Setback Project location.....	2
Figure 2. White River Channel aggradation from 1984 to 2009.	3
Figure 3. Proposed levee setback project design.	4
Figure 4. Representative GI Study HEC-RAS cross section. The blue line is the original elevation of the bed and banks, and the red line is the elevation after 50 years of simulation, showing the potential for significant aggradation of both the channel and the levee setback area.	5
Figure 5. HEC-RAS model extents.	8
Figure 6. 8th Street bridge lidded cross section.	9
Figure 7. Levee lowering at cross section 31266 with 1,000 cubic feet per second (cfs) flow (looking downstream with stationing starting on the left descending bank on the left side of the image).....	10
Figure 8. Geometry change in area of setback with 1,000 cfs flow (view is looking upstream, with the right descending bank on the left side of the image).	11
Figure 9. Upstream boundary condition for calibration period.....	12
Figure 10. Upstream boundary condition for WY 2006–2007.....	12
Figure 11. Downstream boundary condition.....	13
Figure 12. Bed sample gradations.	14
Figure 13. Location of applied gradations.....	15
Figure 14. Total load gradations.....	16
Figure 15. AdH model extents.	18
Figure 16. Existing conditions elevations.....	19
Figure 17. 8th Street bridge pier represented in mesh.....	20
Figure 18. Material types (in the legend, DS = downstream; US = upstream).....	21
Figure 19. Proposed conditions geometry change.....	22
Figure 20. Hydraulic boundary conditions for 2012–2014 ADH calibration.....	23
Figure 21. Hydraulic boundary conditions for 2006–2007.....	23
Figure 22. Longitudinal cumulative volume change.	27
Figure 23. Thalweg comparison.....	27
Figure 24. 8th Street bridge comparison.....	28
Figure 25. A Street bridge comparison.	28
Figure 26. Channel aggradation from 2012 to 2014.	30
Figure 27. Channel degradation from 2012 to 2014.....	31
Figure 28. AdH 8th Street bridge comparison.	32
Figure 29. AdH A Street bridge comparison.	32
Figure 30. Existing conditions sedimentation from 1D HEC-RAS model.....	33
Figure 31. Proposed conditions sedimentation from 1D HEC-RAS model.....	34

Figure 32. Water surface elevation at cross section 31266.77 (immediately downstream from the proposed levee notch).	35
Figure 33. HEC-RAS existing conditions cross section.	36
Figure 34. HEC-RAS proposed conditions cross section.	36
Figure 35. Existing conditions aggradation for WY 2006–2007.	37
Figure 36. Existing conditions degradation for WY 2006–2007.	38
Figure 37. Proposed conditions aggradation for WY 2006–2007.	39
Figure 38. Proposed conditions degradation for WY 2006–2007.	40
Figure 39. AdH existing conditions cross-section change.	41
Figure 40. AdH proposed conditions cross-section change.	41
Figure 41. AdH water surface elevation change (just downstream from the proposed levee notch)	42
Figure 42. Main levee cut plan view before and after 2-year model run.	43
Figure 43. Main levee cut profile before levee lowering, immediately after levee lowering, and after 2-year model run.	43
Figure 44. Velocity map of levee notch at 6,100 cfs flow.	44
Figure 45. 6,100 cfs velocities.	44
Figure 46. 13,100 cfs velocities.	45

Tables

Table 1. Flow to total load relation.	16
Table 2. Roughness values.	21
Table 3. Grain class fractions in initial bed layers.	24

Preface

This study was conducted for the U.S. Army Corps of Engineers, Flood and Coastal Systems Research and Development Program, under “Evaluation of Levee Setbacks and River Restoration Projects for Flood Risk Reduction.” The program manager was Dr. Cary Talbot, Technical Programs Office (CEERD-HT).

The work was performed by the River Engineering Branch of the Flood and Storm Protection Division (CEERD-HF), U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL). At the time of publication, Mr. Keith W. Flowers was Chief, River Engineering Branch (CEERD-HFR); Dr. Cary A. Talbot was Chief, Flood and Storm Protection Division (CEERD-HF); and Dr. Julie D. Rosati was the Technical Director for Flood and Coastal Storm Protection (CEERD-HT). The Acting Director of ERDC-CHL was Mr. Jeffrey R. Eckstein.

The authors acknowledge Mr. Chris Brummer and Mr. Terry Butler of King County and Mr. Brendan Comport for their support in providing information about the Countyline Setback Project.

The Commander of ERDC was COL Bryan S. Green and the Director was Dr. David W. Pittman.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1,609.347	meters
millimeters	0.0393701	inches
square feet	0.09290304	square meters

1 Introduction

1.1 Objective

The study was conducted to examine the potential hydrodynamic and sediment transport behavior for the Lower White River Countyline Levee Setback Project in Washington State. The study made use of both a one-dimensional (1D) Hydrologic Engineering Center-River Analysis System (HEC-RAS) model and a two-dimensional (2D) Adaptive Hydraulics (AdH). The study effort examines a coarse bedded and highly dynamic site.

The study compared models' abilities to replicate observed hydrodynamic and sediment trends for existing conditions from 2012 to 2014. Then, post-project impacts were compared. Ultimately, the effort provides recommendations and general guidance on levee setback modeling situations where 2D simulations perform better than 1D.

1.2 Background

The White River is a glacially fed river that begins at Mount Rainier and flows into the Puyallup River. The Lower White River Countyline Levee Setback Project is located on the White River at the border of King and Pierce Counties, WA, near the towns of Pacific and Sumner, 5.5 miles upstream of the confluence with the Puyallup River. The project is scheduled to be completed by King County in the fall of 2017.

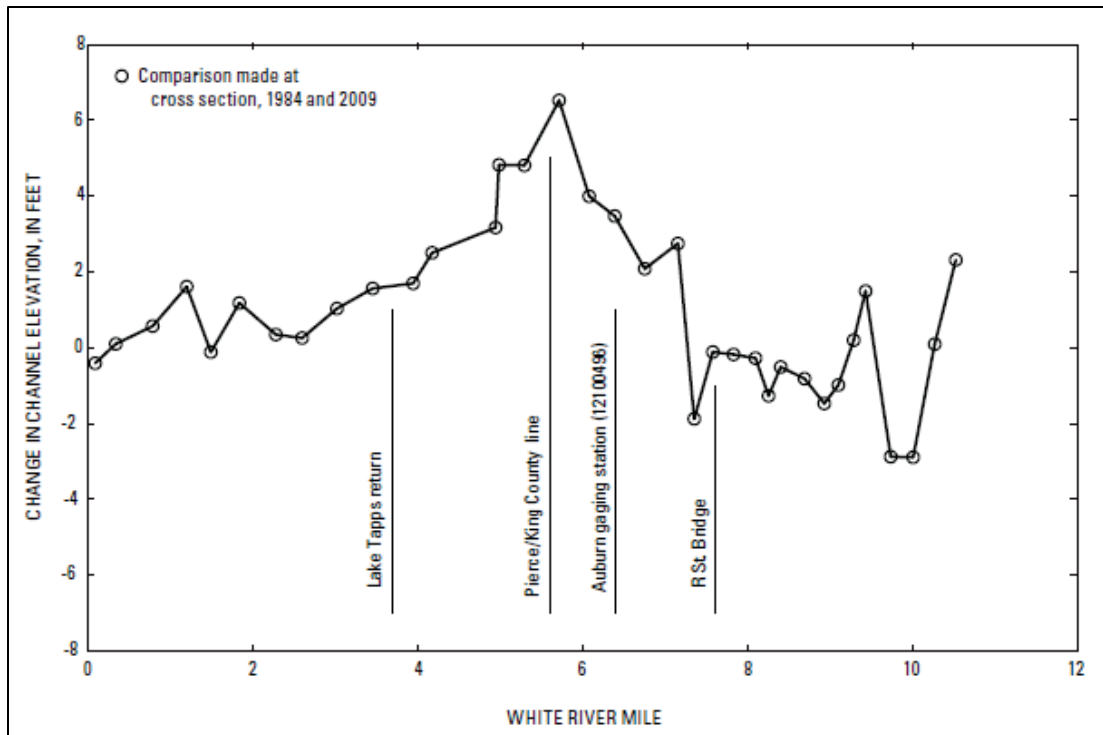
Figure 1 shows the project site's location relative to Mount Rainier and the city of Seattle.

Figure 1. Lower White River Countyline Levee Setback Project location.



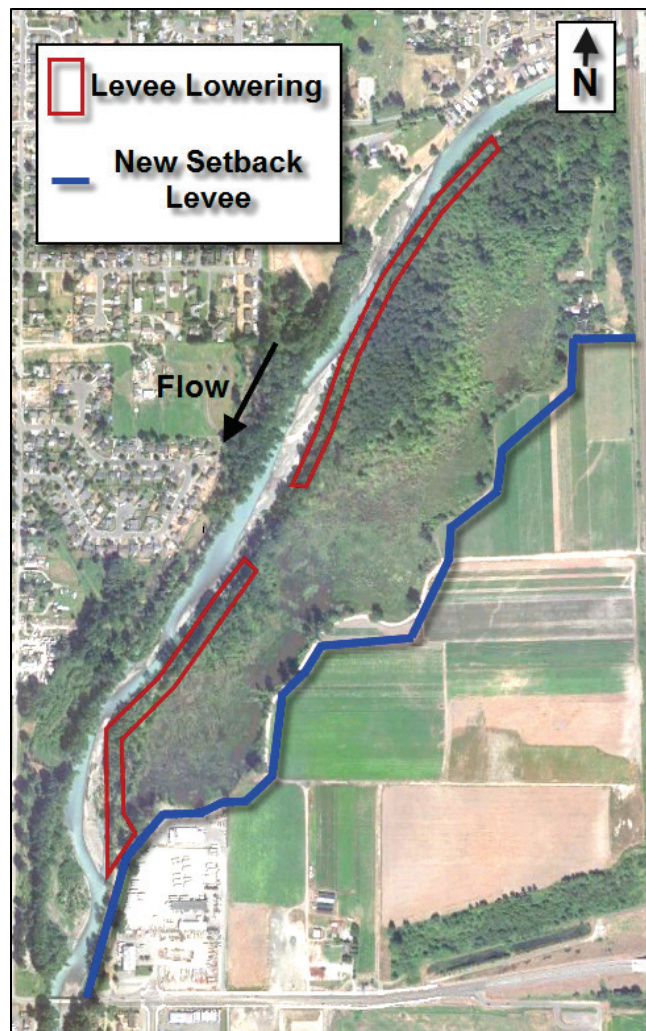
The portion of the river near the Countyline site is a historically channelized anabranch of an alluvial fan where the valley gradient slope is in the process of transitioning from a gradient of 30 feet (ft) per mile to 5 ft per mile. This location was dredged on a regular basis until the mid-1980s. This reach has continued to aggrade significantly since the dredging stopped. According to the U.S. Geological Survey (USGS 2010), the average channel elevation increased over 6 ft at the Countyline site from 1984 to 2009. Figure 2 shows the aggradation from 1984 to 2009 along the lower 11 miles of the White River (USGS 2010).

Figure 2. White River Channel aggradation from 1984 to 2009.



The significant deposition in the Countyline reach between river mile (RM) 6.5 and 5 has decreased in-channel conveyance capacity, increasing flood risk. The setback project's main goal is to reduce flood risk, but the project also received interest and funding for its potential beneficial ecological impact by improving habitat. The design proposes a new setback levee and removes a significant portion of an existing levee to allow the river to reconnect with 121 acres of wetland occupying a former relict river channel. Figure 3 shows a simplified representation of the project's design.

Figure 3. Proposed levee setback project design.



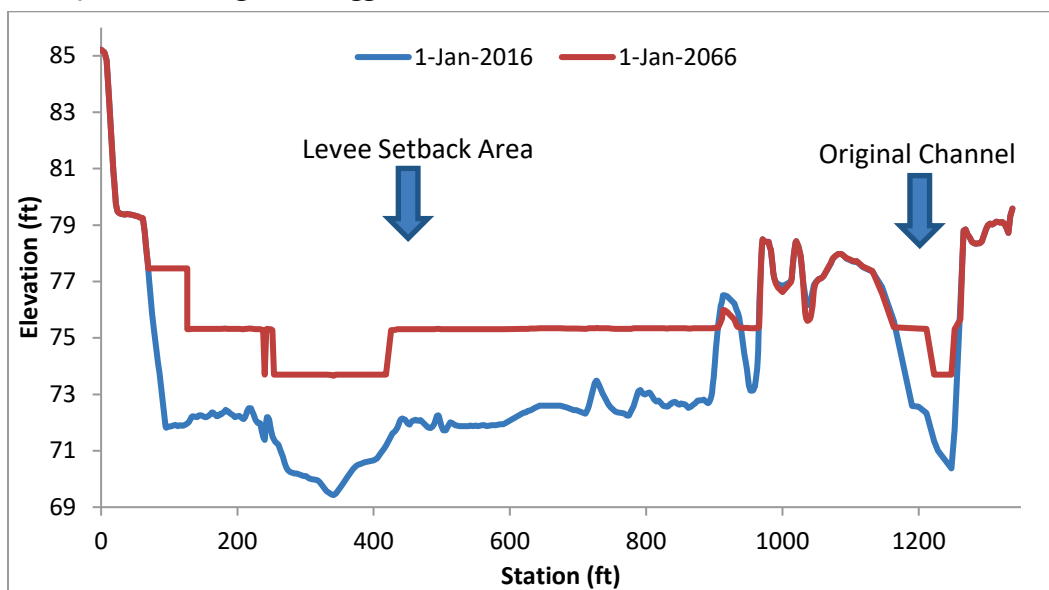
This site was previously included in the Puyallup River General Investigations (GI) Study that used 1D HEC-RAS models for a basin-wide sediment transport analysis of the Puyallup watershed¹ (Gibson et al. 2017). The GI Study model predicted that the levee setback would induce aggradation downstream of the diversion, eventually filling in portions of the channel and the setback area over a 50-year period². Over time, the initial flood conveyance capacity increase created by the setback was predicted to be reversed by continued aggradation due to the high sediment load and valley gradient change. Figure 4 shows an image of the results taken from the GI Study report. The blue line represents a cross

¹ Corum, Z. P. Unpublished. Documentation of 2016 Lower White River HEC-RAS Sediment Studies Baseline Files.

² U.S. Army Corps of Engineers. In preparation. *Puyallup River Basin Flood Risk Reduction Feasibility Study*.

section in the setback reach, and the red line represents that cross section after a 50-year simulation. Aggradation of the channel bed in both the setback area and the original channel can be seen. The setback area is the low land to the left of the levee near station 1000 ft.

Figure 4. Representative GI Study HEC-RAS cross section. The blue line is the original elevation of the bed and banks, and the red line is the elevation after 50 years of simulation, showing the potential for significant aggradation of both the channel and the levee setback area.



The original study team applied a 1D, HEC-RAS, mobile bed model to satisfy the very tight schedule and budget constraints. However, they recommended 2D analysis to evaluate both the assumptions required by the 1D analysis and the results that emerged from those conclusions, particularly significant aggradation predicted in both the channel and setback downstream of the diversion. Thus, a 2D model of the same area was constructed to determine if the increased dimensionality, which allows the model to select its own flow path, would produce more physically realistic results.

1.3 Approach

This study consisted of developing a 1D HEC-RAS sediment model and a 2D AdH sediment model. Both models were calibrated to replicate measured volumetric change between 2012 and 2014. Both models were then used to simulate future conditions both with and without project design elements. The model outputs for these scenarios were then analyzed and compared between the two models.

This report is organized as follows:

- Section 1 consists of an introduction of this study and a background of the project and site that is being used as a test case.
- Section 2 describes the setup of the 1D HEC-RAS model.
- Section 3 discusses the 2D AdH model development.
- Section 4 contains results and discussions of the calibration for both the 1D and 2D models.
- Section 5 consists of the results of the proposed conditions test for both the 1D and 2D models.
- Section 6 is a discussion of model differences and results of the proposed levee setback simulations.
- Section 7 is a brief summary of the study.

2 One-Dimensional (1D) Hydrologic Engineering Center-River Analysis System (HEC-RAS) Sediment Transport Modeling

The HEC-RAS is a hydrodynamic model with 1D and 2D capabilities (Brunner 2016b). It also has moveable bed sediment transport capabilities, which are limited to one dimension. The 1D HEC-RAS sediment transport models used in this study were created from a baseline model used for the Puyallup GI Study to determine future bed elevations for levee design. The GI Study calibrated the HEC-RAS models to 1984–2009 bed change and then simulated 50-year future conditions models for multiple portions of the Puyallup River watershed, including the White River. The effort described in this document consists of a 2012 existing conditions model and a proposed design model.

To develop the HEC-RAS models for this study, the White River model from the GI Study was updated with 2012 survey data and run to simulate the longitudinal cumulative volumetric changes observed between 2012 and 2014. This 2012-to-2014 period run was used as a validation run. Water Year (WY) 2006 to 2007 (October 2005 through September 2007) was also simulated with the existing geometry and proposed geometry to determine the potential effects of the levee setback. This time period was chosen because it included the highest flood during the 25 years and was expected to show significant geomorphic change.

2.1 Model geometry

The models include the lower portion of the White River from RM 8.5 down to its confluence with the Puyallup River at RM 0 and consists of 74 cross sections. The 2009 cross sections from the original GI Study model were updated with 2012 bathymetry data. This stretch of river contains 10 bridges, but only 2 are included in the sediment transport model, the A Street bridge and the 8th Street bridge, since these bridges have potential to impact hydraulics and sediment transport in the area of concern. The reach between these two bridges is the project location. The remaining eight bridges have a negligible impact due to their distance from the project site. The bridge functionality in HEC-RAS can cause instabilities in sediment transport due to the close cross-section spacing. Therefore, HEC-RAS sediment models often simulate bridges as lidded

cross sections. The bridge geometry was merged into the cross sections as follows: bridge piers are added as cross-section points, assumed debris on the piers is added as blocked obstructions, and the deck is inserted as a lid. Figure 5 displays the extents of the model along with the river miles, bridges, and cross sections that are later referenced. Figure 6 shows the 8th Street bridge represented as a lidded cross section in HEC-RAS. Manning's n values throughout the channel ranged from 0.035 to 0.048. Overbank roughness coefficients ranged from 0.03 to 0.1, with most being approximately 0.08 in the area of the setback.

Figure 5. HEC-RAS model extents.

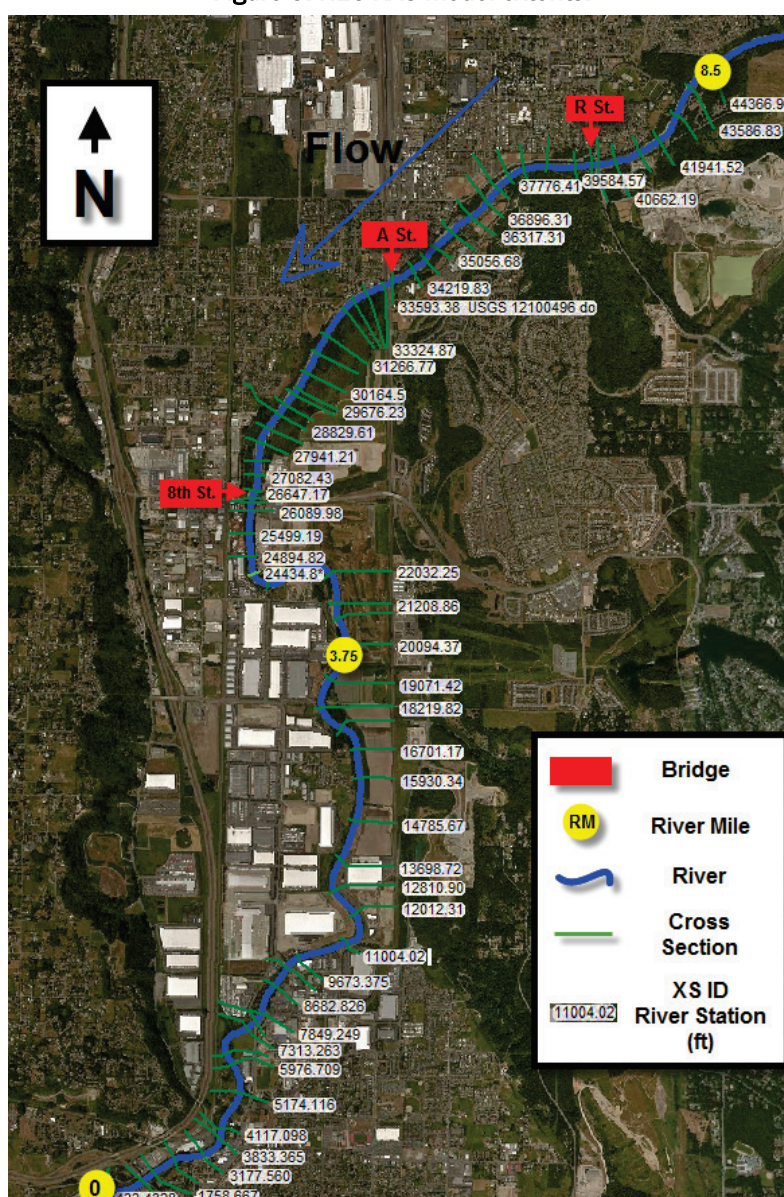
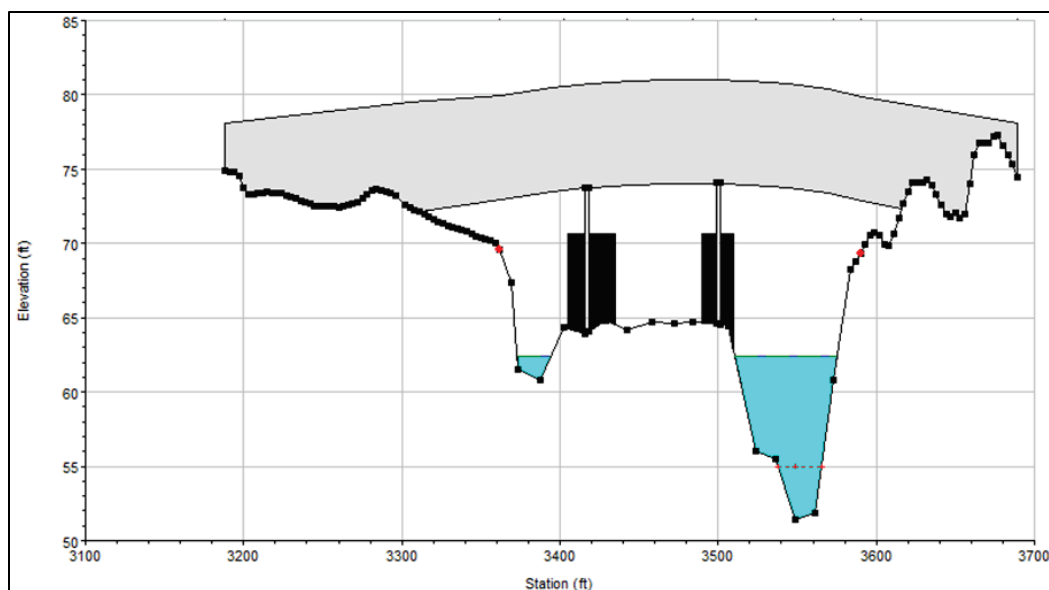


Figure 6. 8th Street bridge lidded cross section.



The only difference between the existing and proposed models is reflected in the cross-section geometry. The proposed model geometry depicts the design elements of the Countyline Levee Setback Project as follows:

- Portions of the existing cross sections were lowered to represent areas of levee removal. Model levee stations were also removed at these points.
- Blocked obstructions were added to represent new revetments and flow-deflection structures.
- A new setback levee was added.
- Reach lengths and ineffective flow limits were also modified to better represent the flow pattern expected after levee removal.

Figure 7 shows an example of the levee lowering and setback at cross section 31266.77, which is the beginning of the planned excavation just downstream of the A Street bridge. The geometry of the entire setback area between the A Street bridge and the 8th Street bridge for pre- and post-development conditions is shown in Figure 8. As shown in Figure 8, the model allows water to access the entire left-bank floodplain once the levee is lowered. This change in the model is based on the assumption that the river will erode the higher ground between the existing channel and restored area to access the lower topography adjacent to the perched river channel. The validity of this assumption is critical to both model performance and predictions of long-term depositional trends in this aggrading reach.

Figure 7. Levee lowering at cross section 31266 with 1,000 cubic feet per second (cfs) flow (looking downstream with stationing starting on the left descending bank on the left side of the image).

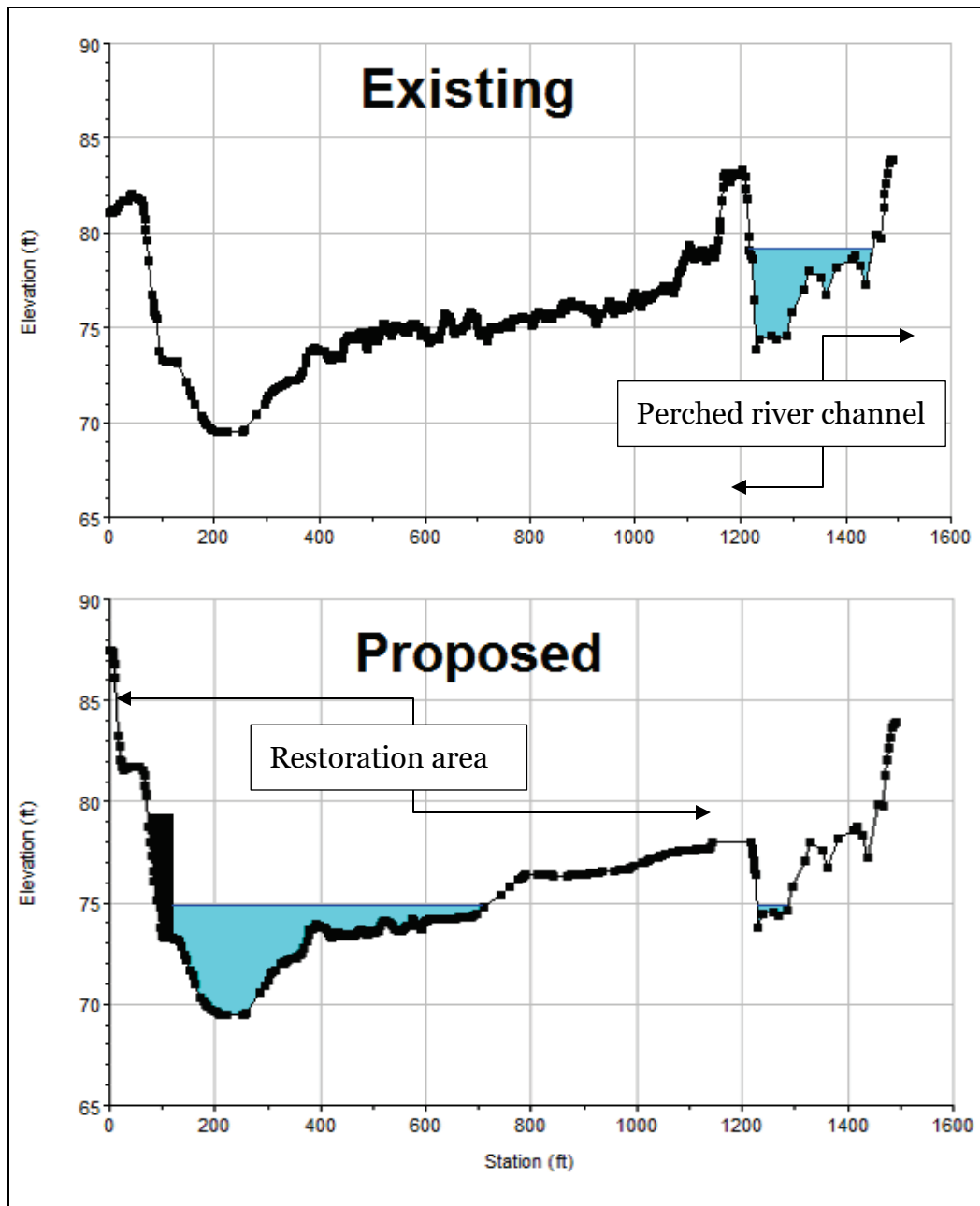
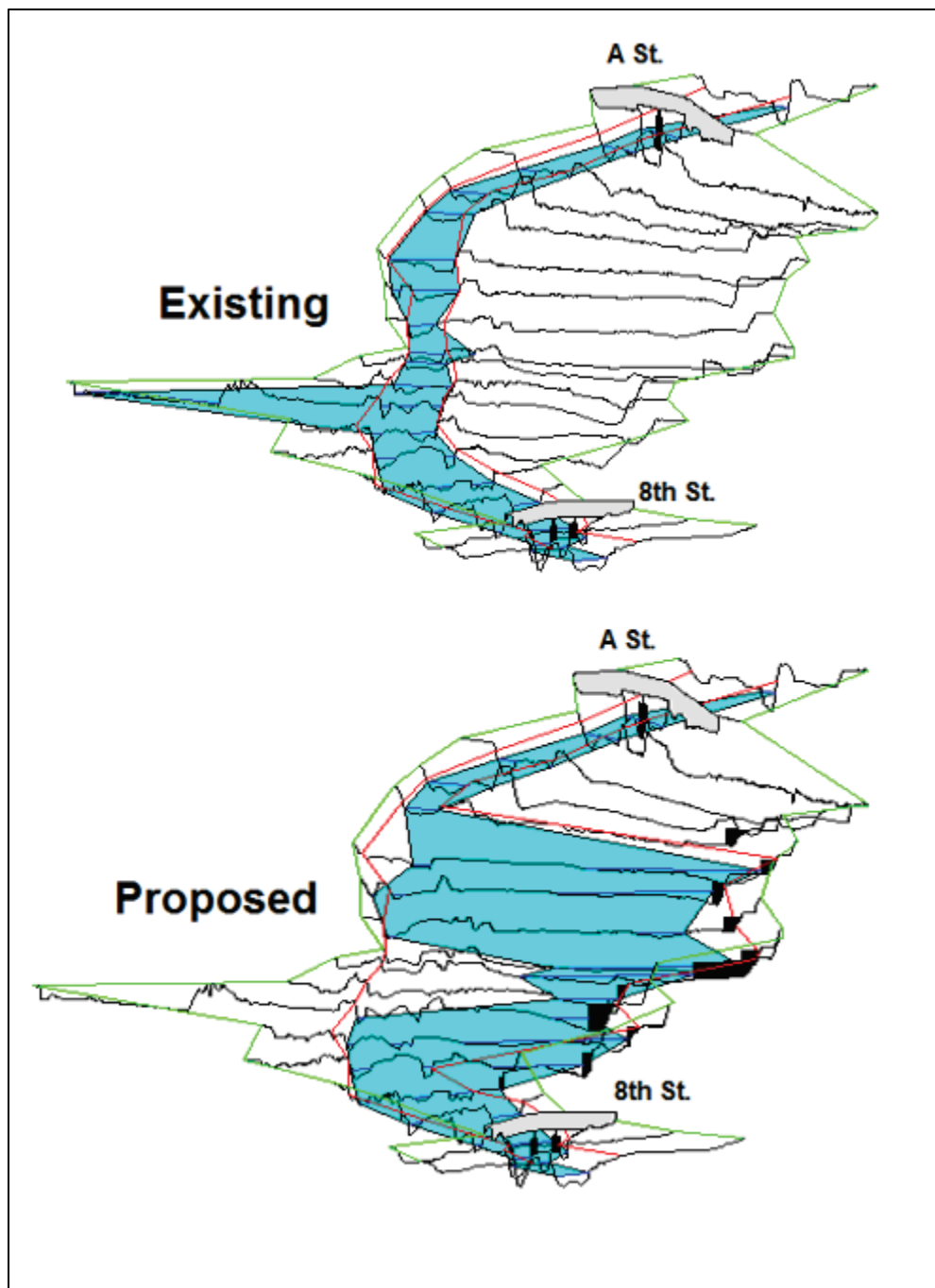


Figure 8. Geometry change in area of setback with 1,000 cfs flow (view is looking upstream, with the right descending bank on the left side of the image).



2.2 Boundary conditions

The upstream boundary condition at cross section 44366.96 was generated by combining flow values from USGS gage 12099200 (White River above Boise Creek) and USGS gage 12099600 (Boise Creek at Buckley). For the 2012 to 2014 calibration period, hourly flows from

1 October 2012 to 15 December 2014 were smoothed using a 3-hour average and then converted to a quasi-unsteady hydrograph (Figure 9). The same method was used for WY 2006–2007 (Figure 10).

Figure 9. Upstream boundary condition for calibration period.

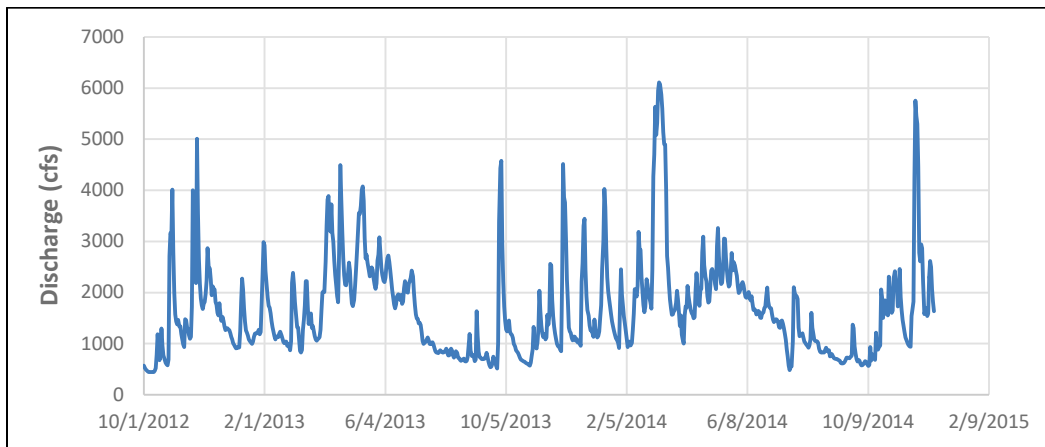
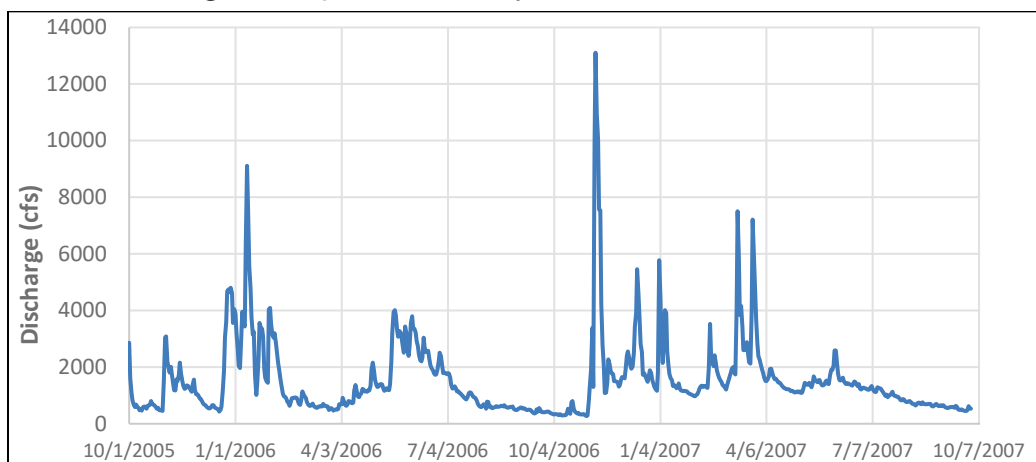
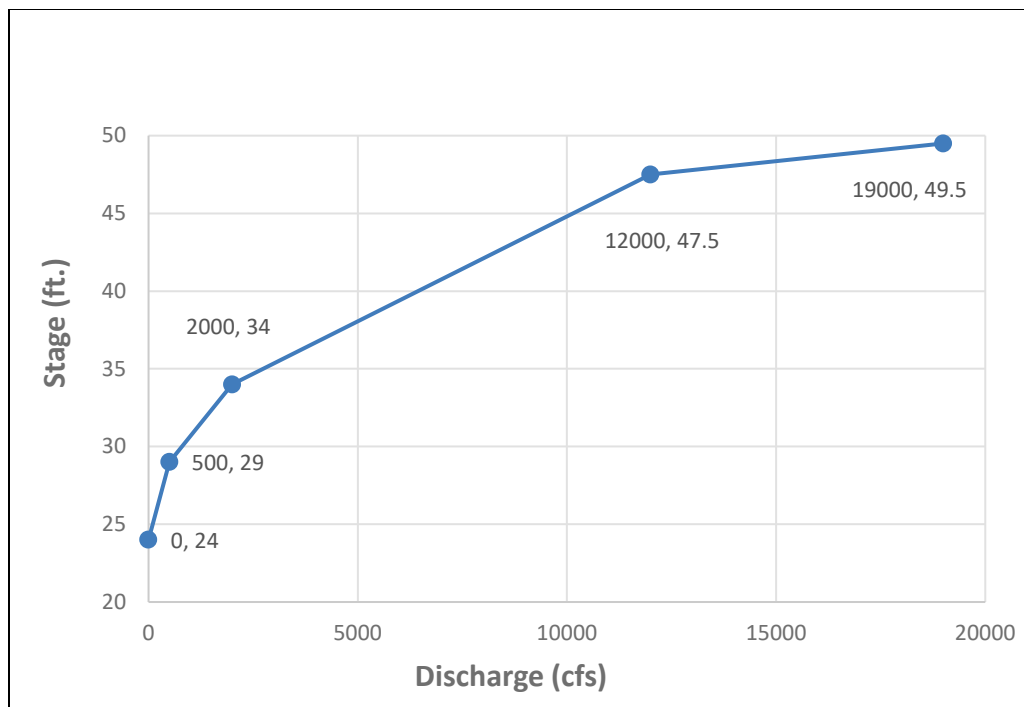


Figure 10. Upstream boundary condition for WY 2006–2007.



A rating curve relating discharge to stage was applied at cross section 433.4328 as the downstream boundary condition (Figure 11). The rating curve was taken from the GI Study's calibrated White River Model. The curve was created using data obtained from the GI Study's larger-scale, basin-wide unsteady flow model.

Figure 11. Downstream boundary condition.



2.3 Sediment data and sediment transport modeling approach

Sedimentation within the HEC-RAS model framework uses a control volume (sediment reservoir) and sediment continuity approach where the river is broken into a network of adjacent control volumes. The longitudinal bounds of an individual control volume are the midpoints between adjacent 1D cross sections, and sediment is either stored or eroded and routed between control volumes based on the balance of sediment supply and transport capacity (the Exner equation). Erosion and deposition are allowed within user-defined *movable bed* limits. The default behavior in HEC-RAS, and the one used in this study, is to raise and lower all wetted parts of each cross section uniformly within the movable bed limits (a significant limitation in dynamic environments). The bed gradation is uniform within a cross section. Hydrodynamics are explicitly coupled with sediment calculations, meaning that once the model reaches a stable step-backwater solution, sediment continuity is computed, the cross-section geometry is adjusted, and then the hydrodynamics are recomputed. As long as small time-steps are used, this is generally not a significant issue. (Refer to Chapter 13 of the HEC-RAS Hydraulic Reference Manual [Brunner 2016a] for more background on the theoretical basis of the software, transport equations, and model setup.)

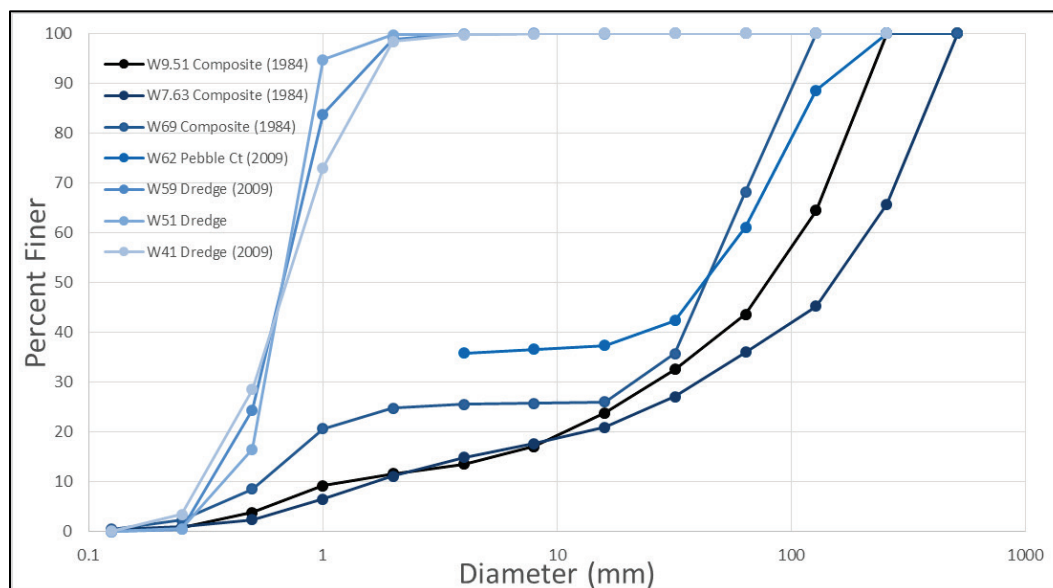
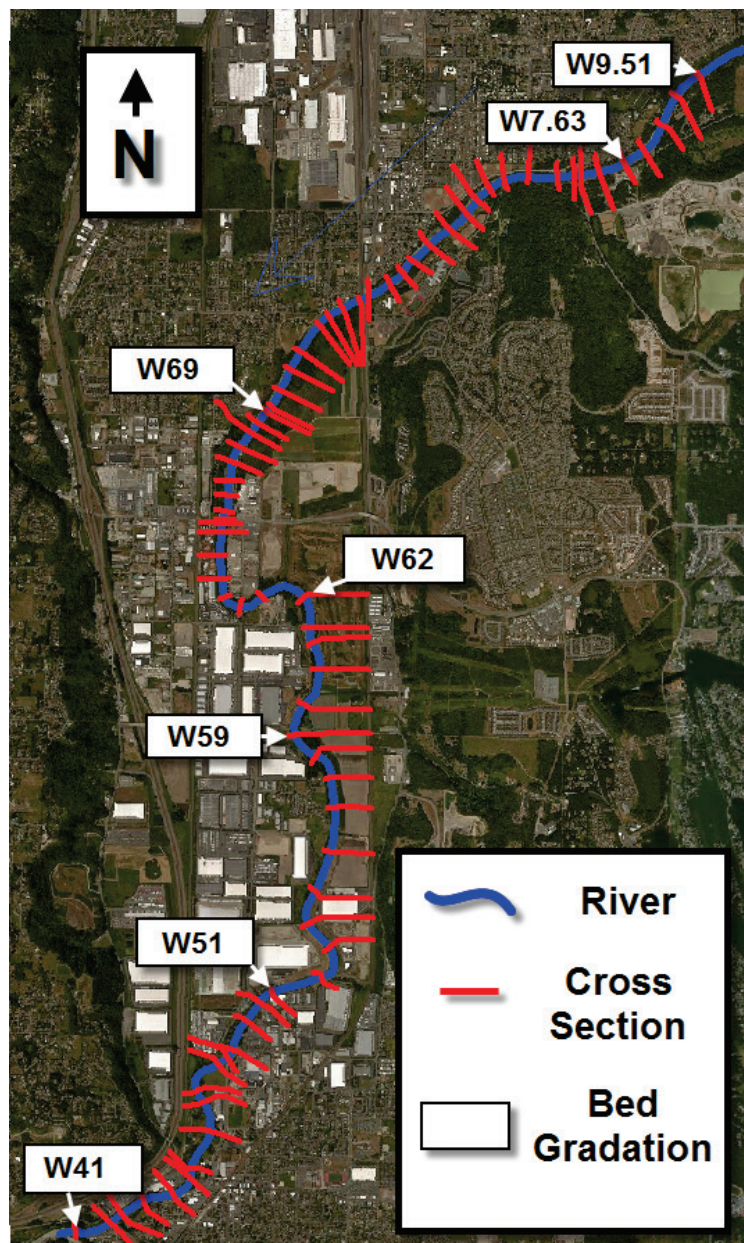


Figure 13. Location of applied gradations.

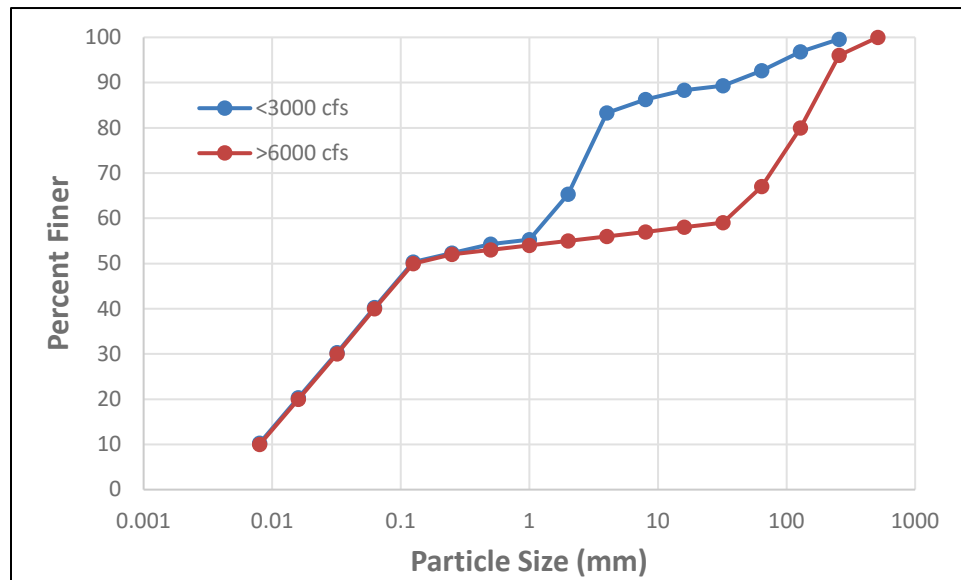


Multiple sets of bedload and suspended load samples were taken between 1955 and 2011. These were used to create a sediment rating curve for the GI Study model. This curve was then used as a calibration parameter, and slight adjustments were made to match observed data for the GI model. The GI Study's final calibrated sediment rating curve was used here as the upstream sediment boundary condition for the HEC-RAS models in this study. The bilinear rating curve relates flow to a total load (Table 1) and flow to total load gradations (Figure 14) to determine the incoming load for each grain size.

Table 1. Flow to total load relation.

Flow (cfs)	600	3,000	6,000	15,000
Total Load (tons/day)	13	2,000	18,000	40,000

Figure 14. Total load gradations.



3 Two-Dimensional (2D) Adaptive Hydraulics (AdH) Model

The AdH model is a finite element model developed by the U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. It can model 3D and 2D shallow water flows coupled with constituent transport. AdH can spatially and temporally adapt during the simulation where more numerical resolution is needed to achieve computational error tolerances. AdH also has the ability to allow wetting and drying in the system (ERDC CHL 2015) and is a vital capability for the Countyline Levee Setback study where floodplains are fluctuating between dry and inundated conditions.

AdH was selected for this study since it has the ability to model fine and coarse sediment transport in two and three dimensions. AdH links with SEDLIB to perform sediment transport. SEDLIB is a sediment transport library that is capable of solving transport related to multiple grainsizes, multiple layers, and cohesive and noncohesive sediments (Brown 2014). Since the river's dominant flow condition transitions from 1D to 2D at the upstream extent of levee removal and continues through the site, the 2D morphodynamic capability of the AdH model was used as it is expected to provide better insights on post-project geomorphic conditions in this complex setting.

The AdH models were used to simulate the same conditions as the HEC-RAS models, 2012–2014 calibration period and WY 2006–2007 for the existing and proposed geometry. For AdH to compute sediment transport, all unit specifications must be metric. All reported results have been converted to English units.

3.1 Mesh development

AdH uses a finite element triangulated mesh as the computational domain. The mesh covers 1,116 acres and consists of 45,087 elements and 22,772 nodes. The upstream boundary of the mesh begins at approximately RM 8.5, the same location as the HEC-RAS model. The downstream end of the mesh is at RM 3.75. Thus, the downstream boundary was moved upstream from the location of the HEC-RAS downstream boundary to shorten the model and reduce computational time. (This is discussed in more detail in Section 3.2.) The mesh includes

all land that flood waters could potentially reach. Figure 15 shows the model extents and the area it encompasses. The projection of the model was State Plane North American Datum of 1927 (NAD27), Washington South (FIPS 4602), and the vertical datum was North American Vertical Datum of 1988 (NAVD88).

Figure 15. AdH model extents.



The AdH model used 2014 light detection and ranging (lidar) data provided by the Seattle District for the overbank elevations and the channel cross section data from the 2012 Existing Conditions HEC-RAS model for bathymetry. The mesh bathymetry was created by interpolating cross sections every 10 ft between the existing cross sections within HEC-RAS. The lines of interpolation between existing cross sections were carefully drawn to capture mid-channel bars and braided portions of the channel. Once all the new cross sections were added, they were exported as an xyz file and merged into the lidar scatter set. A temporary levee composed of fabric-lined gabions along portions of the right bank in the

area of the setback was also added into the lidar scatter set. This created the final scatter set that was interpolated to the mesh. Figure 16 shows the elevations of the existing conditions mesh. Note: The A Street bridge cross section in the HEC-RAS model had not been updated to the 2012 geometry at the time the mesh was created, so the elevation of the mesh at the bridge represents the 2009 survey. (This is discussed further in Section 4.2.) This was the only cross section that was not updated. Portions of the mesh were removed to represent the piers of the R Street, A Street, and 8th Street bridges (Figure 17). A constant zero velocity was assigned to the nodes on the bridge piers to create a no-slip surface that would act as friction on the piers.

Figure 16. Existing conditions elevations.

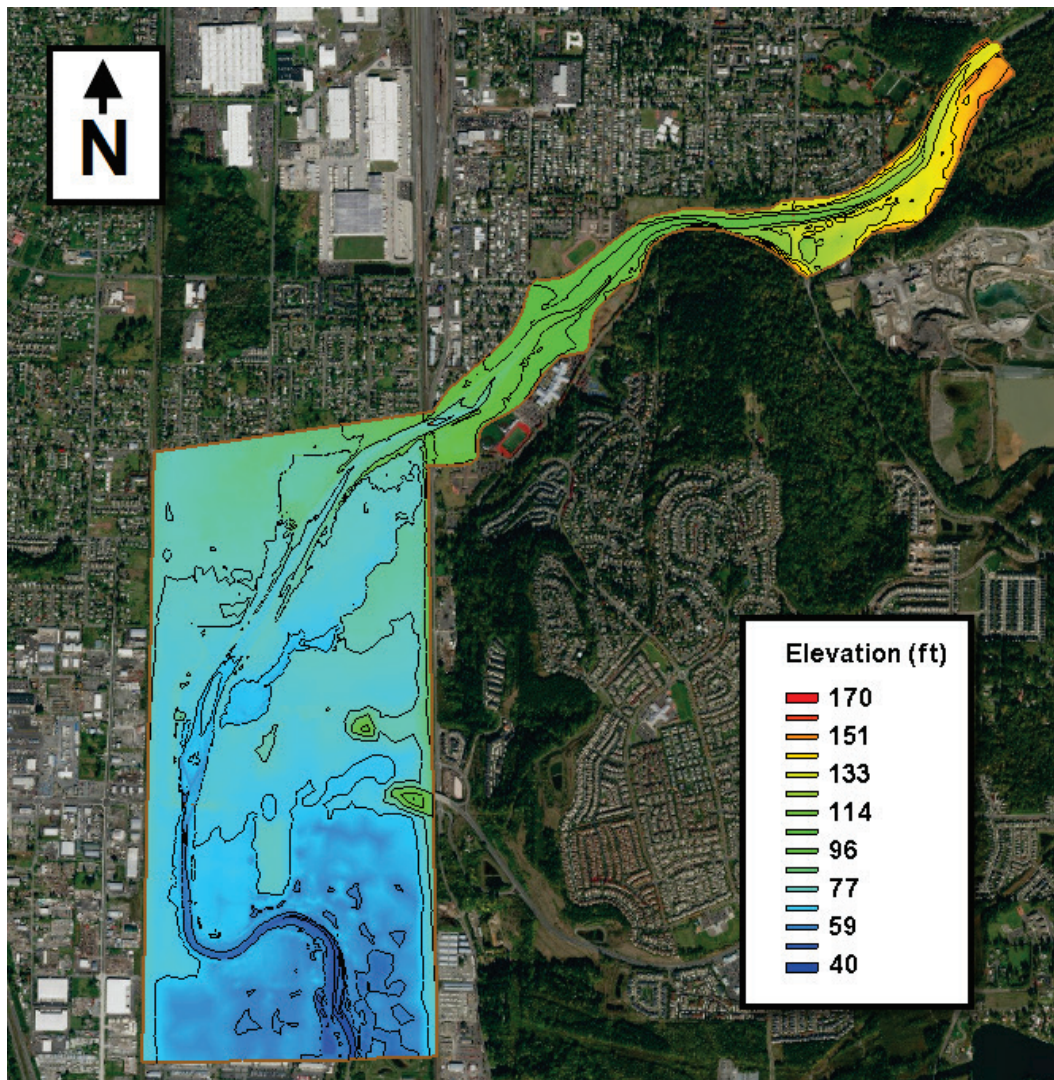
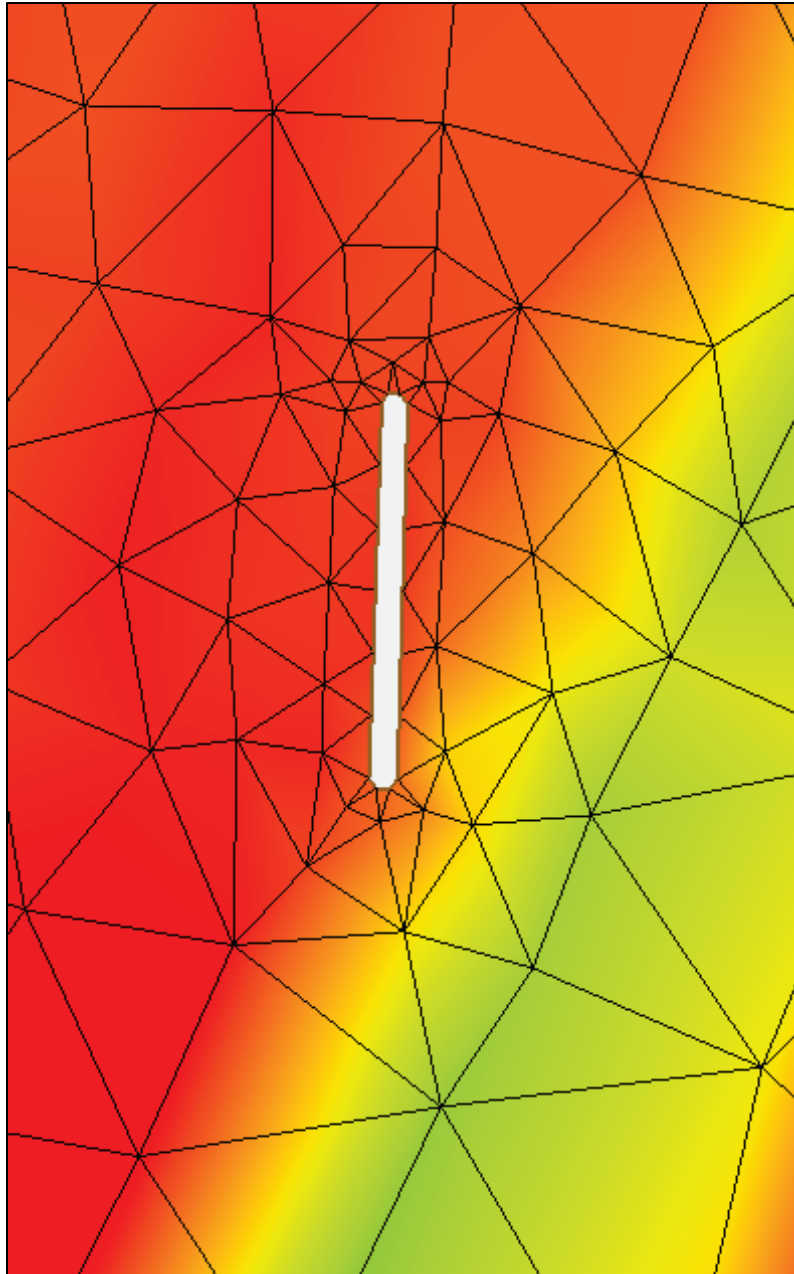


Figure 17. 8th Street bridge pier represented in mesh.



Ten different material types were created to assign portions of the mesh different roughness values and bed gradations. Additionally, for hard points or areas where bed change would not occur, materials spatially defined areas of no elevation change. The different material types are shown in Figure 18 along with each material type's roughness in Table 2. The disabled material type represents a portion of the mesh that is turned off, preventing flow from entering.

Figure 18. Material types (in the legend, DS = downstream; US = upstream).

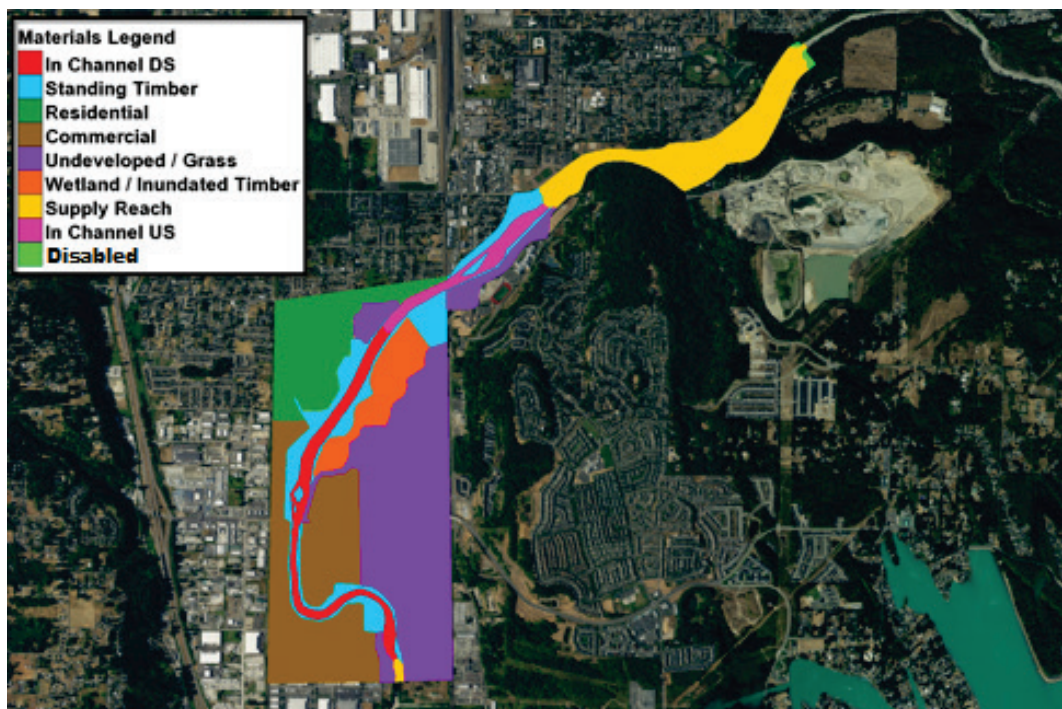
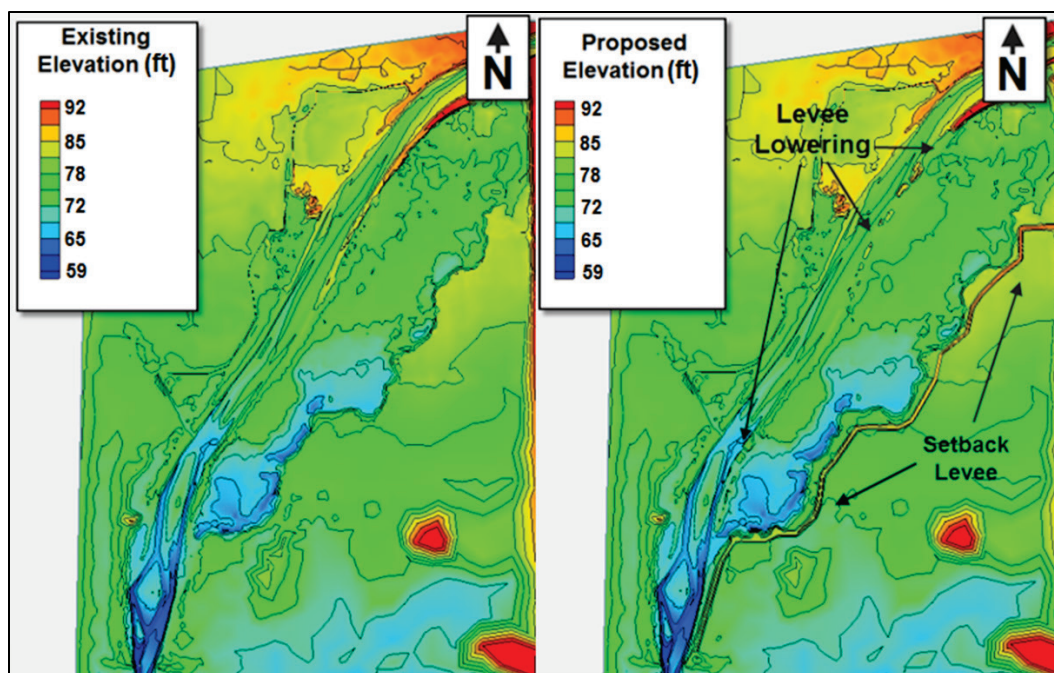


Table 2. Roughness values.

Material Type	Manning's n
In-channel DS	0.03
Standing Timber	0.05
Residential	0.025
Commercial	0.025
Undeveloped/Grass	0.025
Wetland/Inundated Timber	0.06
Supply Reach	0.03
In-channel US	0.03

Like the HEC-RAS models, the only difference between the existing AdH and proposed AdH model is the geometry. The geometry was adjusted to represent post project conditions. This includes lowering portions of the existing levee and building a new setback levee (Figure 19).

Figure 19. Proposed conditions geometry change.



3.2 Hydraulic boundary conditions

The AdH models have the same upstream boundary as the HEC-RAS models. The assigned flow values were the same combination of flows (USGS Gauge 12099200 White River above Boise Creek at Buckley, WA, and USGS Gauge 12099600 Boise Creek at Buckley, WA). Due to the high energy and steep channel slope at the boundary, a small, flat-bottom head bay was added to allow flow to be evenly distributed across the channel. This head bay created a smoother initial hydraulic transition.

The downstream end of the model was moved upstream from the end of the HEC-RAS model to RM 3.75, which is approximately 1.25 miles downstream of 8th Street bridge. This was done to reduce computational time by limiting model boundaries closer to the area of interest. Runs were performed to ensure that the 1.25 miles are sufficient to prevent the downstream boundary from impacting the hydraulics near the setback site. A tail water rating curve was created for the new location by running a series of steady flows with the HEC-RAS model to find the corresponding water surface elevations at that new location. This rating curve was then used to create a daily water surface time series that was used as the final downstream boundary condition for 2012–2014 and 2006–2007, Figure 20 and Figure 21, respectively.

Figure 20. Hydraulic boundary conditions for 2012–2014 ADH calibration.

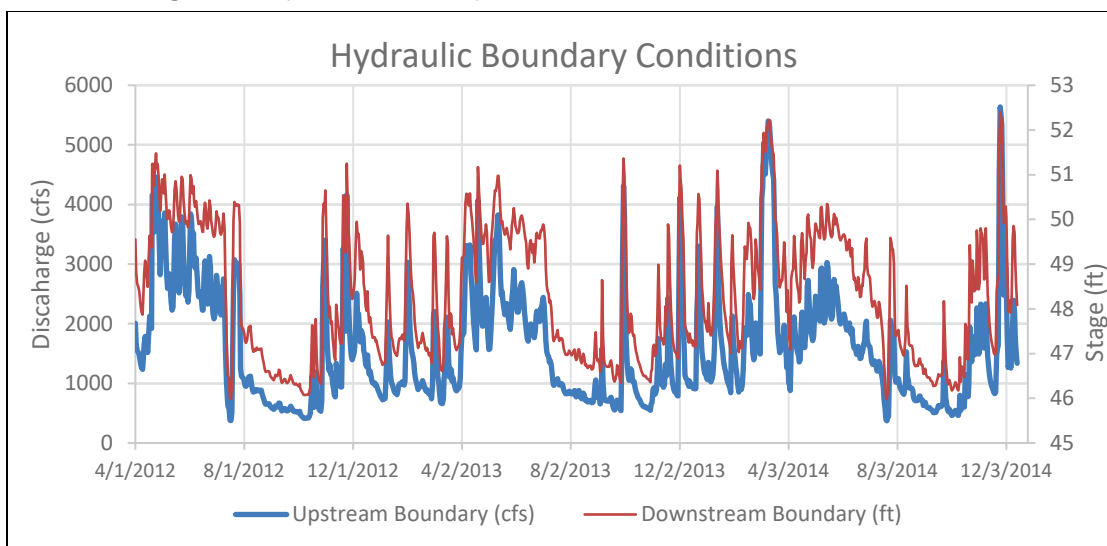
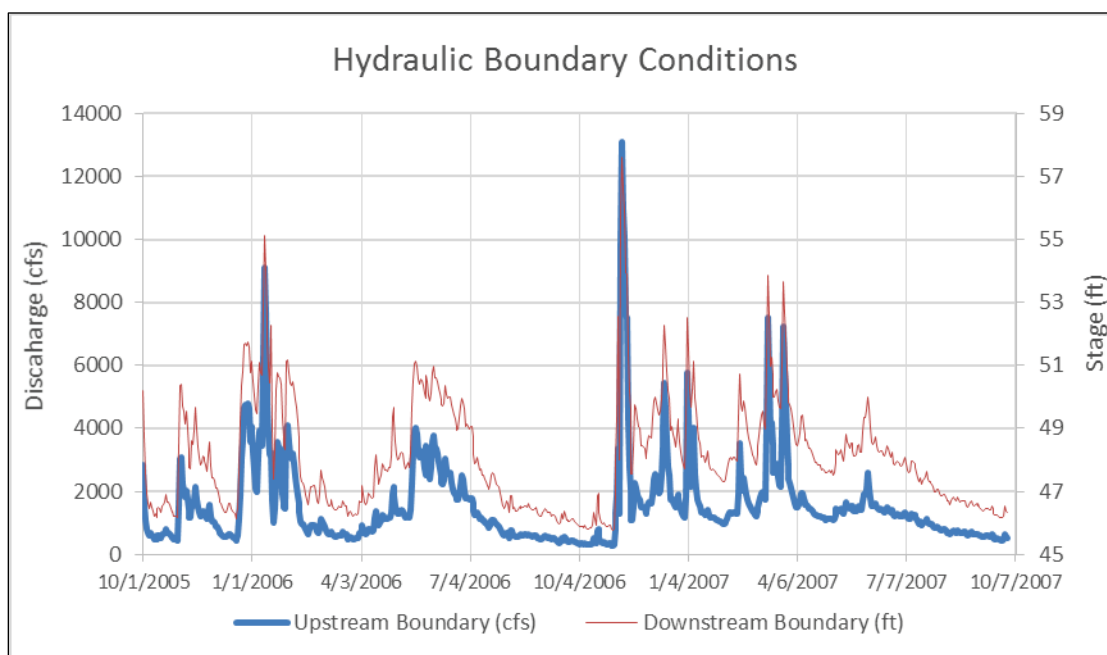


Figure 21. Hydraulic boundary conditions for 2006–2007.



Although the setback could potentially reduce water surface elevations at the downstream boundary, the same tail water was still used for the proposed geometry. The impact that far downstream is assumed to be minimal, and the boundary was placed so that any reasonable backwater impacts caused by the boundary could not propagate the entire distance upstream to the area of concern.

3.3 Sediment data

The AdH model uses Wright-Parker noncohesive suspended entrainment equations and the Meyer-Peter Müller bedload entrainment equations with the Wong-Parker correction. The model also uses the Egiazaroff noncohesive hiding factor. A bed initialization was first conducted to create a sediment hot-start file that was used for the AdH models. The number of bed layers, bed layer thickness, and bed layer gradations were assigned for each material type. Grain class fractions for very coarse silt up through small boulders were assigned to each layer for each material type. A consistent base layer was placed across the entire model domain. A finer gradation was then placed on top of the base layer. This was done so the model would have an abundant supply of finer sediment and would be able to relocate this sediment to the appropriate locations. A third source material gradation was placed at the upstream end of the model where the flows entered. This gradation is where the sediment equilibrium boundary condition was applied, and it controlled what sediment entered the model. A flood hydrograph was then run through the model while not allowing the bed to displace to initialize the bed and to allow the sediment to be sorted. All starting bed gradations before initialization are listed in Table 3. Appendix A includes figures showing the distribution of sediment after the bed initialization runs.

Table 3. Grain class fractions in initial bed layers.

Grain Class	Geometric Mean Grain Size (millimeter)	Class Fraction in Base Layer	Class Fraction in Top Fine Layer	Class Fraction in Upstream Source Material Layer
Coarse Silt	.045	.004	.004	.000
Fine Sand (FS)	.177	.005	.015	.004
Medium Sand (MS)	.354	.015	.185	.012
Coarse Sand (CS)	.707	.041	.537	.035
Very Coarse Sand (VCS)	1.41	.046	.070	.040
Very Fine Gravel (VFG)	2.83	.038	.014	.033
Fine Gravel (FG)	5.66	.028	.015	.023
Medium Gravel (MG)	11.3	.032	.016	.028
Coarse Gravel (CG)	22.6	.062	.018	.054
Very Coarse Gravel (VCG)	45.3	.089	.035	.078
Small Cobble (SC)	90.5	.092	.091	.080
Large Cobble (LC)	181	.205	0	.235
Small Boulder (SB)	362	.343	0	.378

Just downstream of the inflow boundary, a sediment equilibrium boundary condition was applied. This means that the model calculates an equilibrium concentration based on the shear stress. The estimated concentration is used to determine the incoming sediment load at the boundary. This equilibrium is normally applied at the hydraulic boundary, but with the addition of the head bay, the model shear stresses were no longer representative of those expected to control sediment entering from upstream. The sediment boundary was moved just downstream of the head bay to where the water enters into the river channel and the shear stresses are more representative of the natural conditions. A suspended load was also specified at the sediment boundary. The suspended load was a specified concentration time series. The time series was created by using a rating curve relating concentration to flow that was created from measured suspended data taken by the USGS at the R Street bridge in 2011 and 2012. The entire incoming suspended load was specified to be a coarse silt so that it acts as a wash load in the channel and will only fall out of suspension and be deposited in the overbank, thereby not impacting the bed elevations in the main channel.

4 Calibration Period Results

Both models were calibrated to match observed total deposition from 2012 to 2014 in the reach between A Street and 8th Street. The observed total deposition was calculated by using the end area method with 2012 and 2014 surveyed cross sections that were taken in channel. This method estimated a total observed deposition of 32,230 cubic yards (cy) in the reach.

4.1 HEC-RAS calibration

The 2012-to-2014 existing-conditions HEC-RAS model accurately matched observed bed changes. The model was calibrated to match longitudinal volume change. It was able to produce total deposition in the setback area between A Street and 8th Street of 30,881 cy, which is within 5% of the observed change. Figure 22 shows the cumulative volume change in the model along with the observed end area method. The reason for the departure of the model from observed trends downstream of 8th Street could be related to effects from the bridge or the two sharp bends just downstream of the bridge. The conditions through the bridge varied significantly from 2012 to 2014 as woody debris buildups occurred over time around the bridge piers. This is also an area of a gravel/sand transition that Gibson et al. (2017) previously demonstrated was very sensitive to model parameters like the downstream boundary condition.

The thalweg elevations and multiple cross sections between the bridges (Figure 23–Figure 25) were also checked to see how closely they match the 2014 surveyed data. All match reasonably well. The total deposition is within 5% in the setback reach and the thalweg has a root mean square error of 1.84 ft across all cross sections of the reach. The model results in a 3% decrease in channel capacity at the 8th Street bridge (Figure 24) while the 2014 survey results in a 12% decrease in capacity. The figure shows that the model is able to replicate the increase in the thalweg on the right side of the bridge piers and the erosion that occurred between the piers. At the A Street bridge, the surveys resulted in a 17% decrease in area between 2012 and 2014 while the model only produces a 3% reduction.

Figure 22. Longitudinal cumulative volume change.

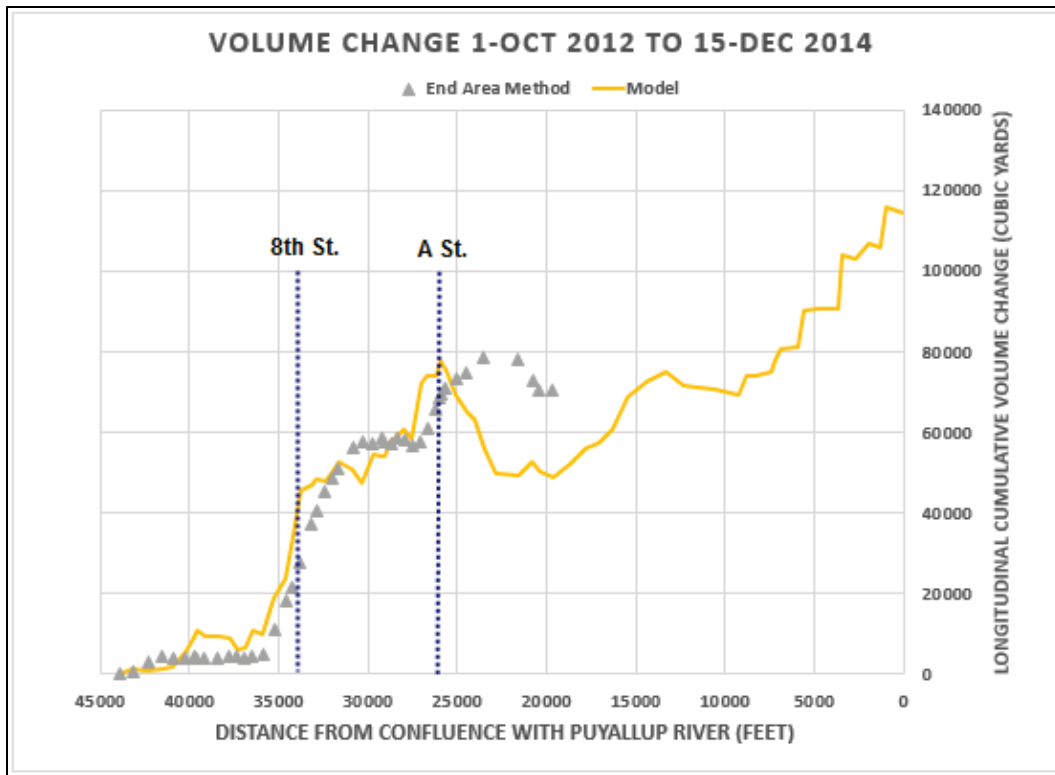


Figure 23. Thalweg comparison.

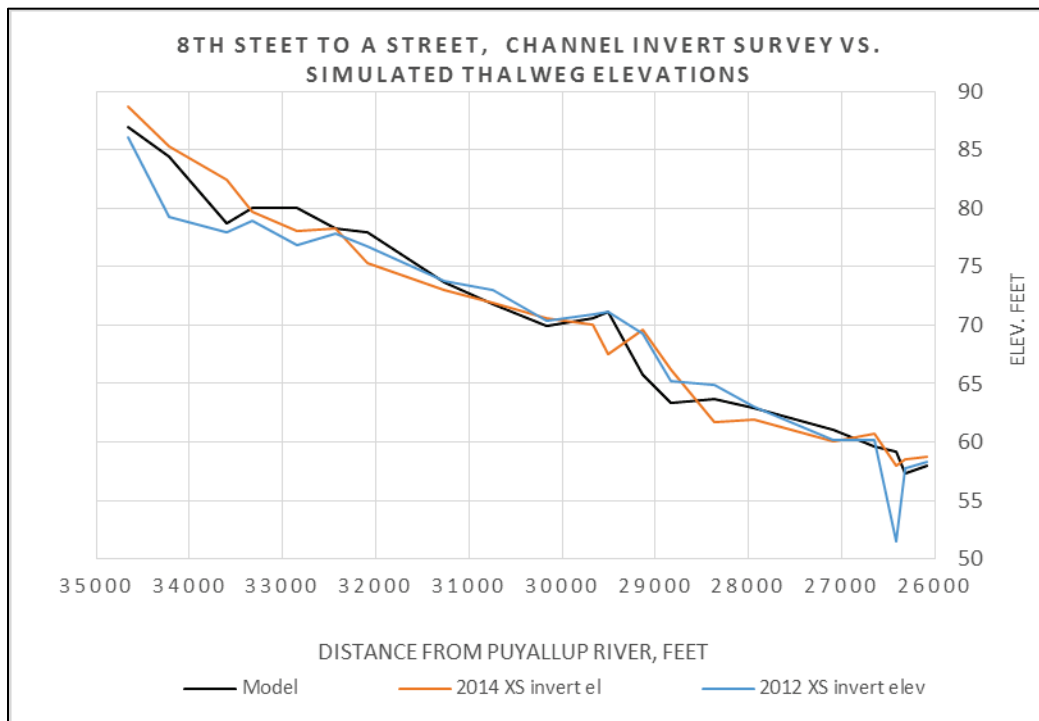


Figure 24. 8th Street bridge comparison.

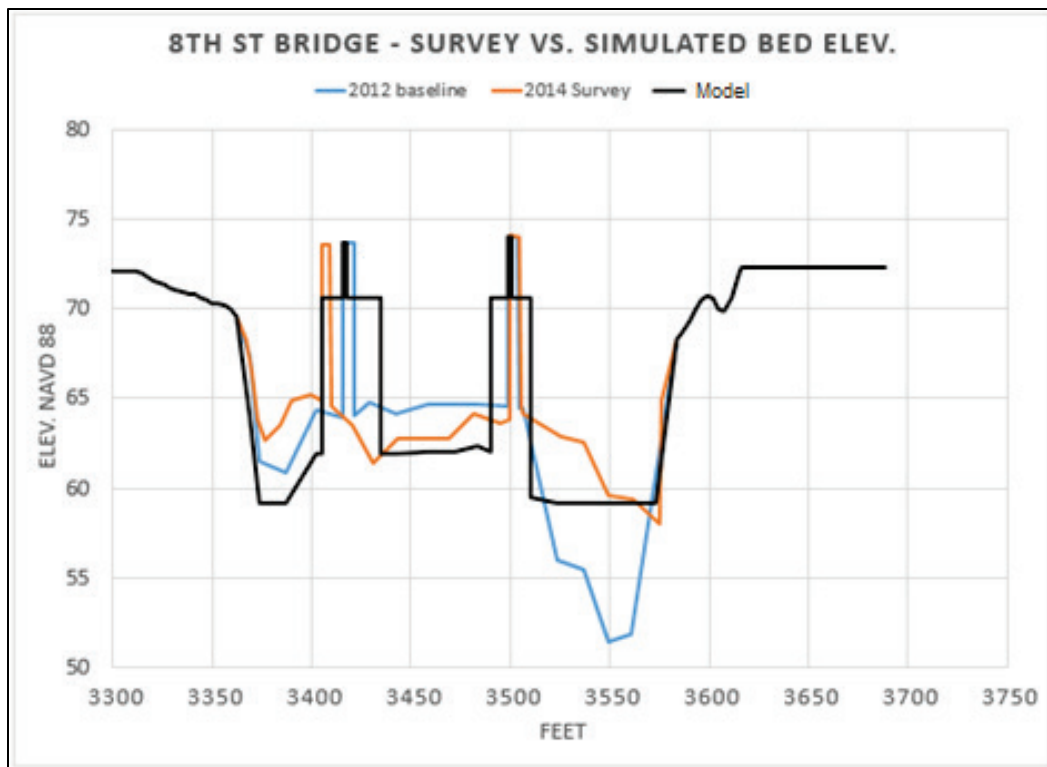
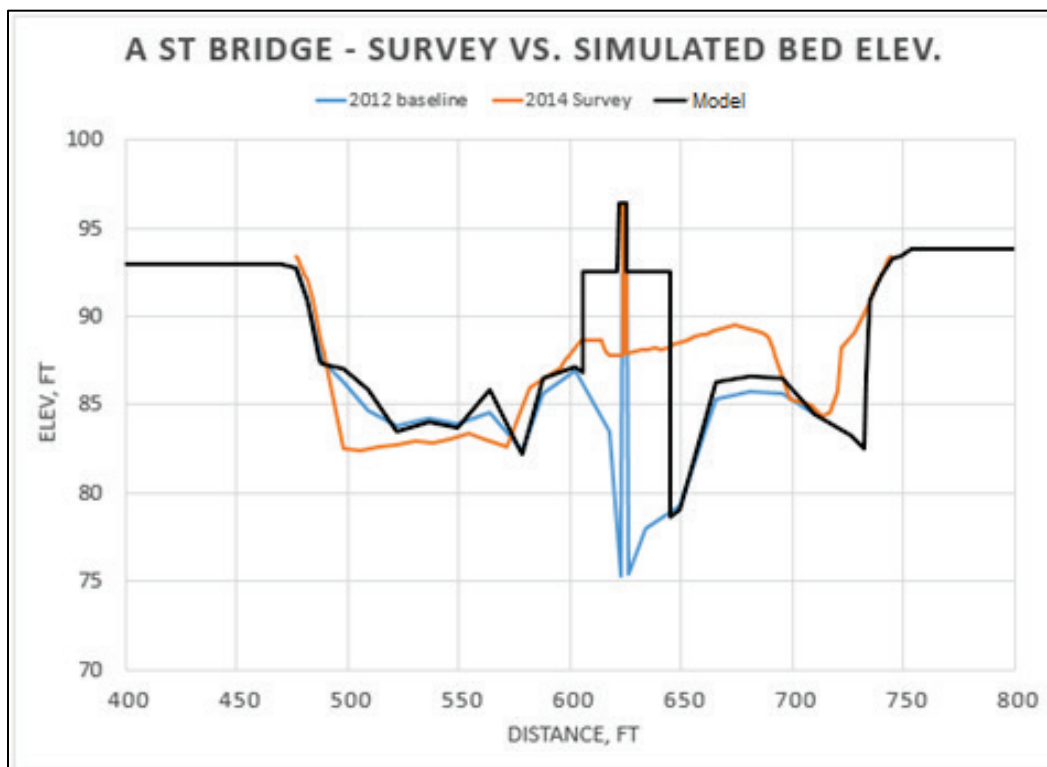


Figure 25. A Street bridge comparison.



4.2 AdH calibration

The final calibrated AdH model indicates 34,200 cy of deposition between A Street and 8th Street, 6% more than the observed 32,230 cy. In early runs there were high amounts of erosion and deposition very early in the simulations. It was hypothesized that this was a result of the model trying to create a smoother, more natural channel. Due to the interpolation method used to create the bathymetry data between surveyed cross sections, the initial model channel was very linear. A 6-month period (1 January 2012 to 30 September 2012) was added to the beginning of the run to allow initial corrections to the channel to occur. Total displacement and volumetric change were then measured between the end of the run (15 December 2014) and 6 months into the run (1 October 2012) to represent the calibration period. The aggradation that occurred during this period is shown in Figure 26 while Figure 27 shows the degradation.

Final elevations at 8th Street and A Street were compared to the 2014 surveyed cross sections (Figure 28 and Figure 29, respectively). The model is able to replicate the depositional trends at both locations. As noted earlier, the starting elevations at the A Street bridge were representative of 2009 surveyed data. Significant aggradation occurred between the 2009 and 2012 cross sections and continued through 2014. The model shows the channel evenly filling up while the surveyed data show a bar forming on the left side in 2012 and then the right side of the channel filling in 2014. The lateral change is likely driven by woody debris building around the piers, which is a dynamic problem that the model does not capture. The model is still able to replicate the general depositional trend at this location, however.

Figure 26. Channel aggradation from 2012 to 2014.

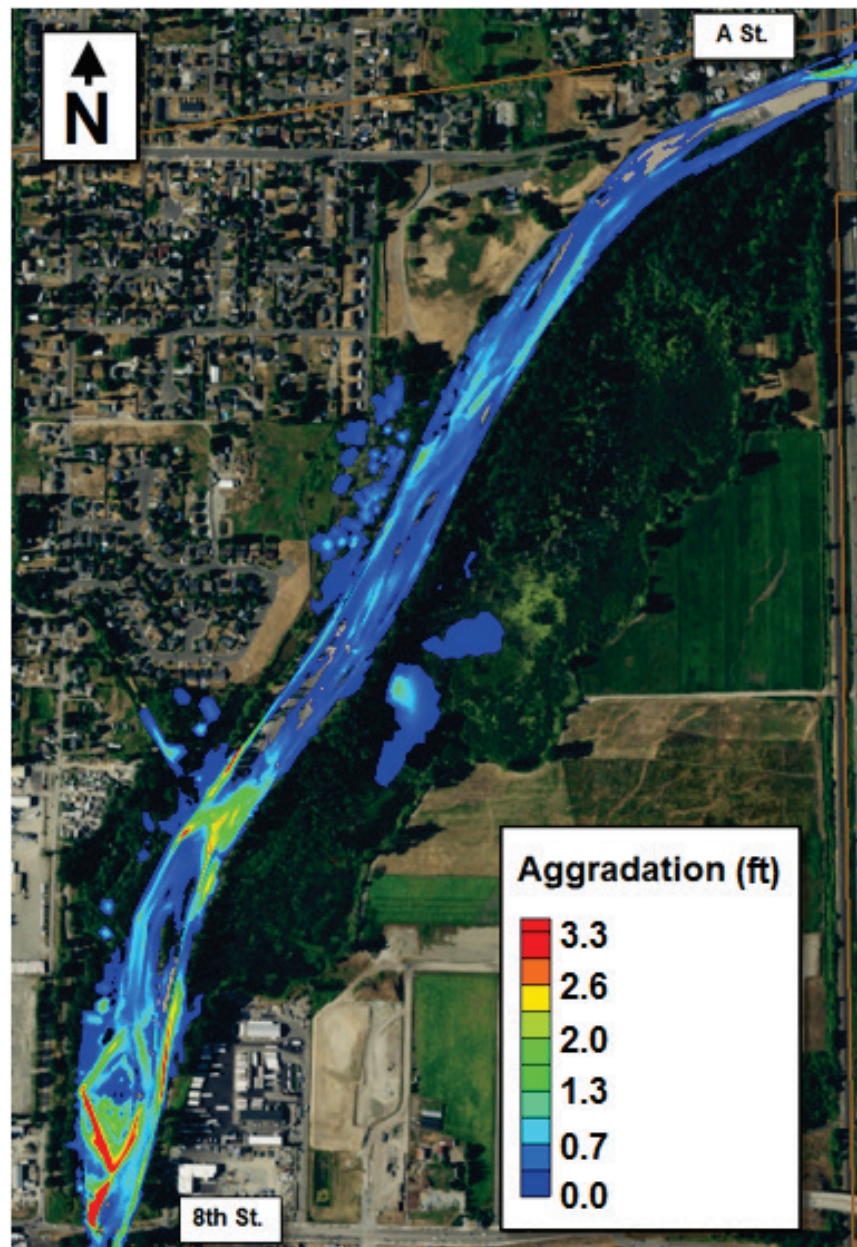


Figure 27. Channel degradation from 2012 to 2014.

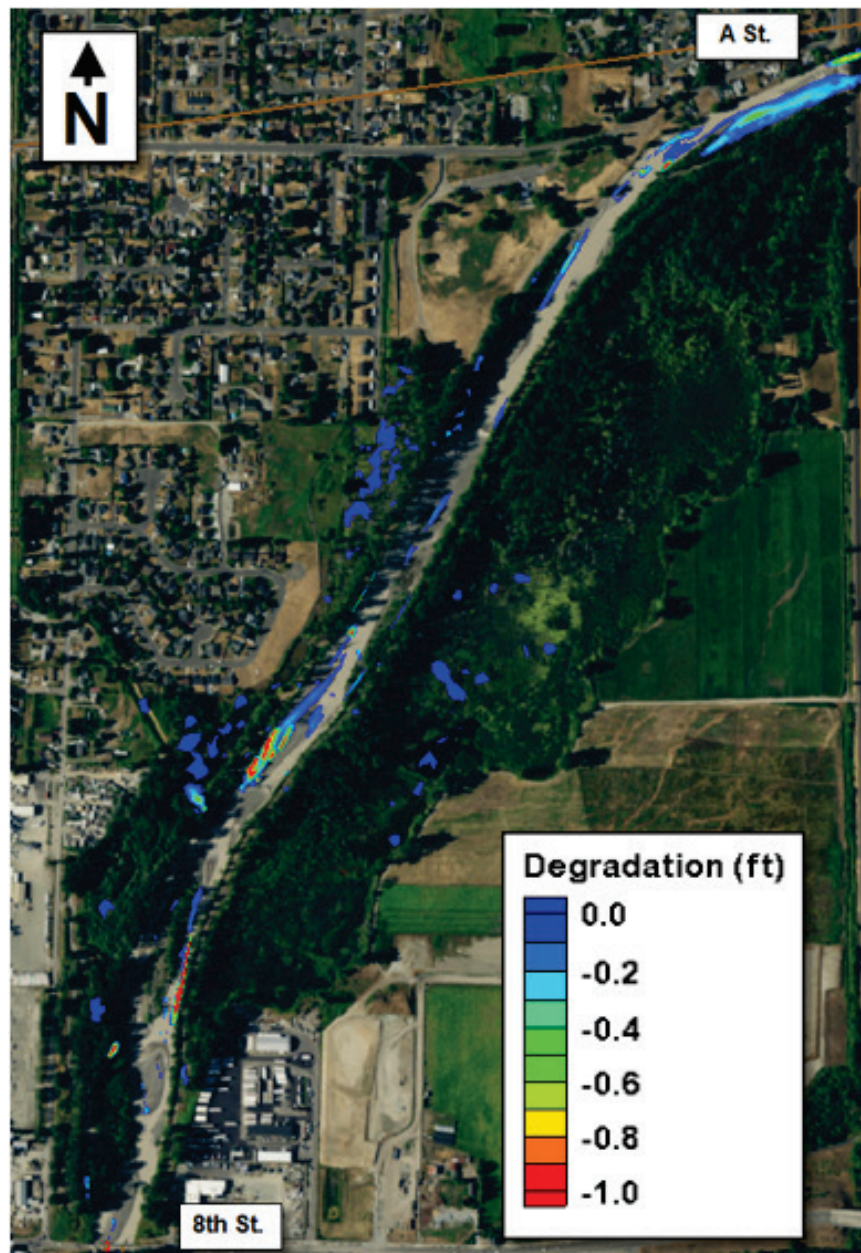


Figure 28. AdH 8th Street bridge comparison.

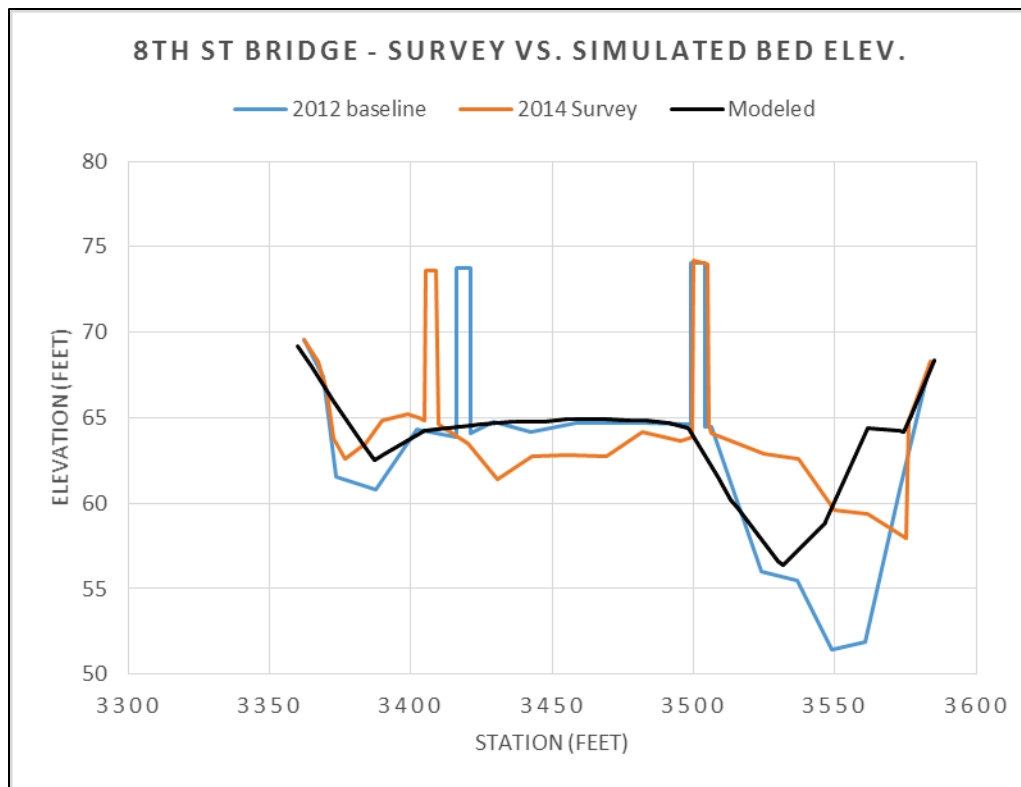
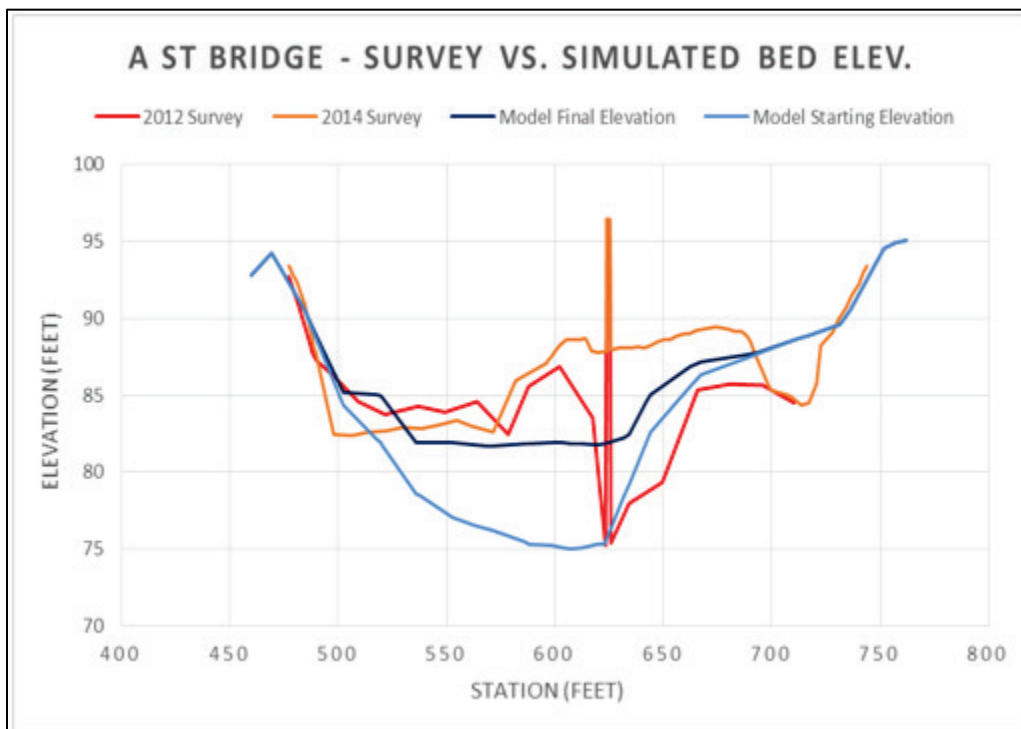


Figure 29. AdH A Street bridge comparison.



5 Water Years (WY) 2006–2007 Results

WY 2006 and 2007 were run with the existing conditions models and the proposed conditions models to determine the effects the setback could have.

5.1 HEC-RAS WY 2006–2007 results

The existing conditions HEC-RAS model deposited 70,000 cy. A majority of the deposition happens outside of the moveable bed limits. The moveable bed limits consist of the main channel and the setback area for both the existing and proposed scenarios. The other area refers mostly to the right overbank. Figure 30 shows the sedimentation broken down by grain size for the existing conditions run.

The proposed levee setback model shows much more deposition. This geometry produced a total deposition in the reach of 176,000 cy (Figure 31). In this scenario, most of the deposition occurred inside of the moveable bed limits. This increased deposition is induced by the spreading of the flow across the setback area. This reduces depths and velocities, resulting in less sediment transport capacity.

Figure 30. Existing conditions sedimentation from 1D HEC-RAS model.

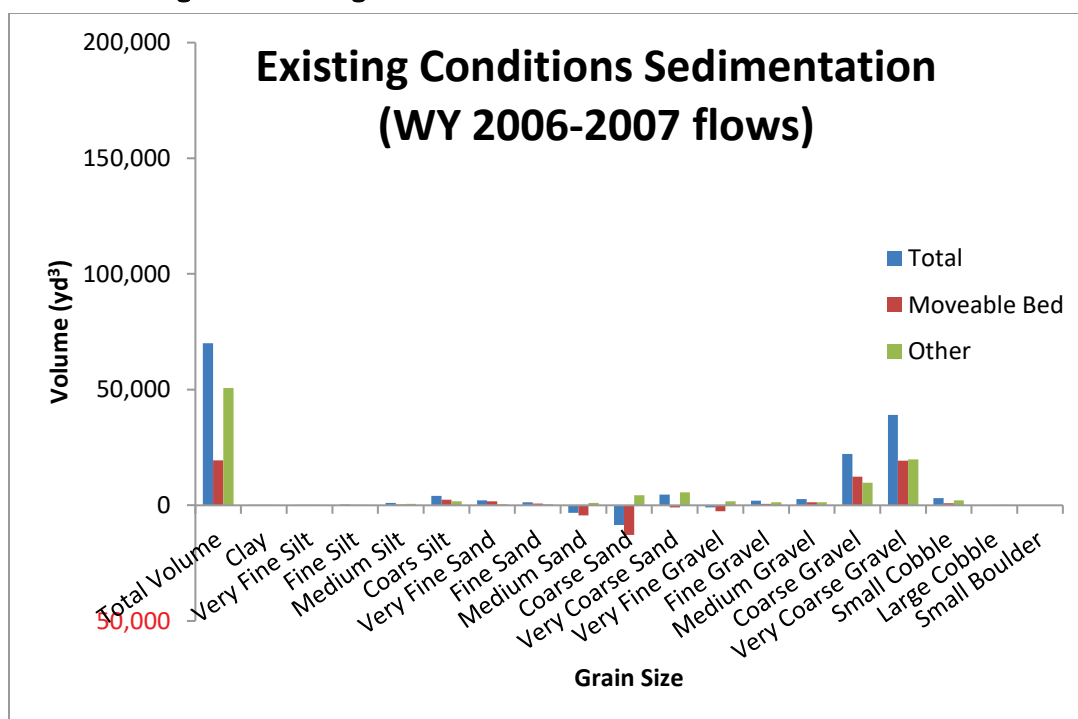
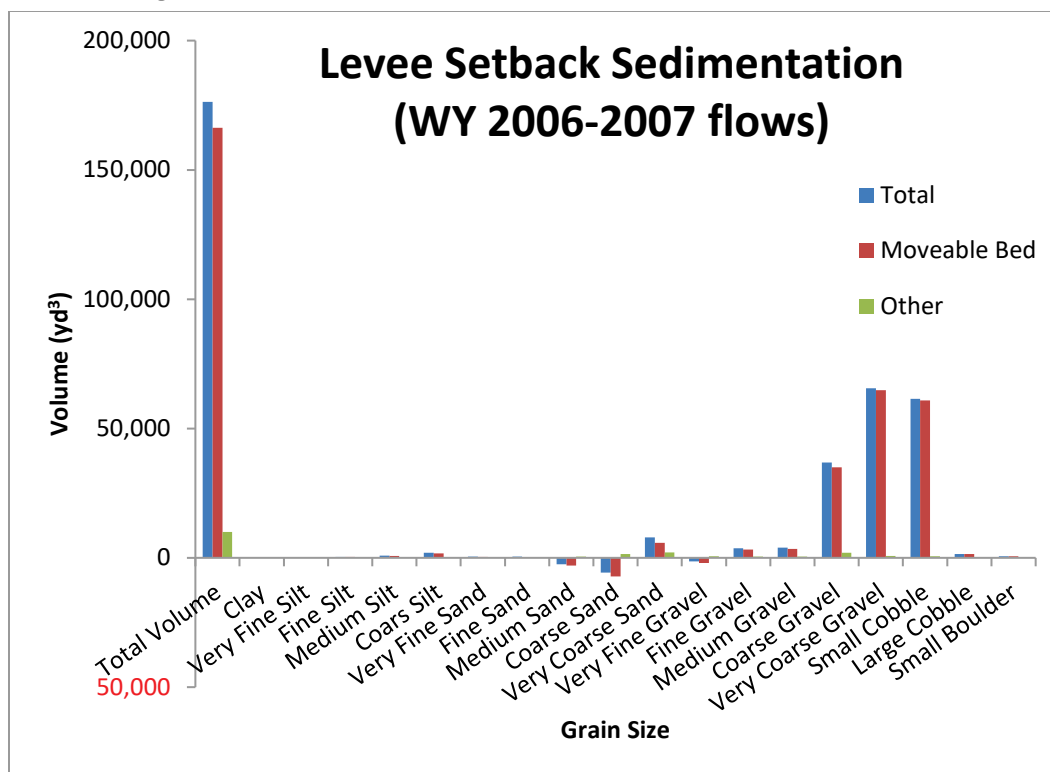
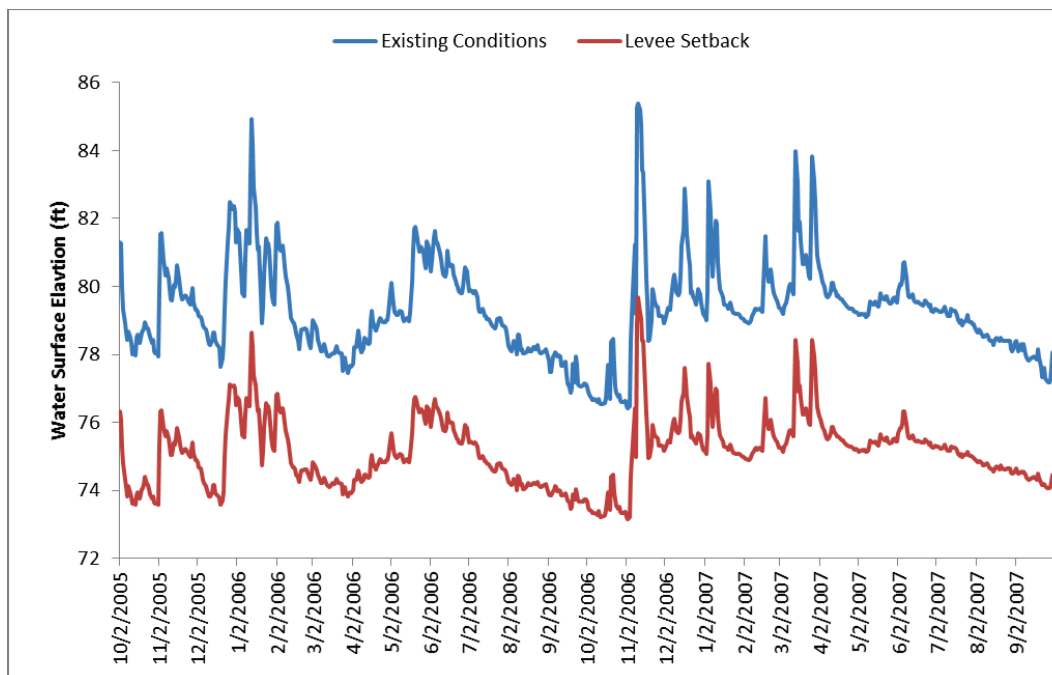


Figure 31. Proposed conditions sedimentation from 1D HEC-RAS model.



The levee setback consistently reduced water surface elevations by approximately 4 to 5 ft immediately downstream of the levee notch throughout the run (Figure 32). This is primarily because the model assumed the river will avulse into the lower setback area. Although the setback will give extra channel capacity, this is not a realistic representation of the water surface impacts it will have at all flows if the river does not avulse through the remnant levee into the site. If the river does not avulse into the site, the river stage will not be high enough at low flows to have access to the setback area, and the water surface reduction will not be seen at lower flows.

Figure 32. Water surface elevation at cross section 31266.77 (immediately downstream from the proposed levee notch).



Cross-sectional changes are shown in Figure 33 and Figure 34 for the existing and proposed conditions, respectively. Both models resulted in aggradation in both the main channel and the setback area, but the amount of deposition increased significantly in the proposed scenario. Due to high flows, overtopping of both the left bank and the right bank occurs in the existing conditions model. This is the cause of the deposition in the setback area for the existing conditions model, although it is not a common occurrence and only happens at high flows. The proposed conditions model, which gives the river easier access to the setback area, shows much more deposition occurring in the area of the setback and at lower flows. The proposed geometry also causes a significant increase in aggradation in the main channel at this location. This is likely a result of the flow being distributed across the entire cross section and reducing the depths and shear stresses in the main channel, thus reducing the transport capacity.

Figure 33. HEC-RAS existing conditions cross section.

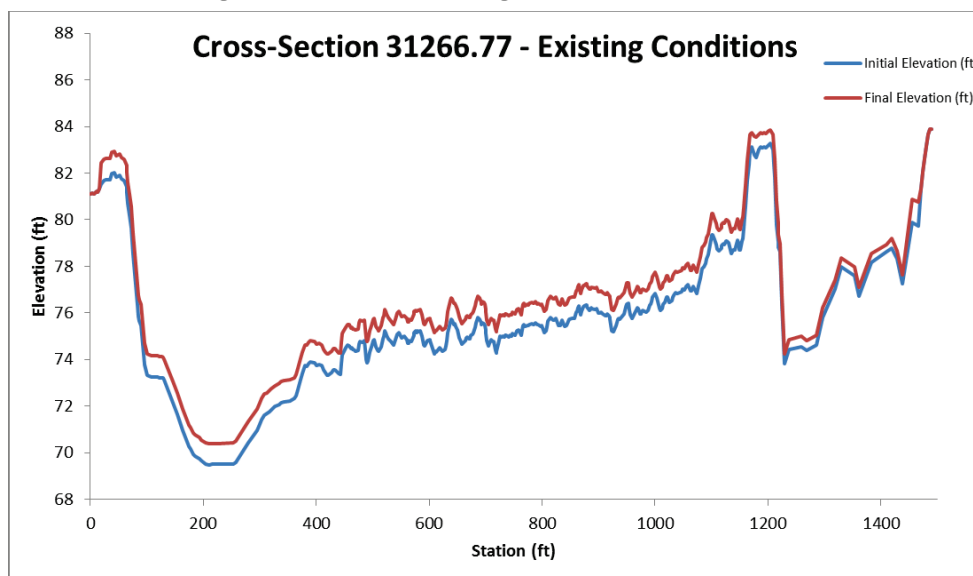
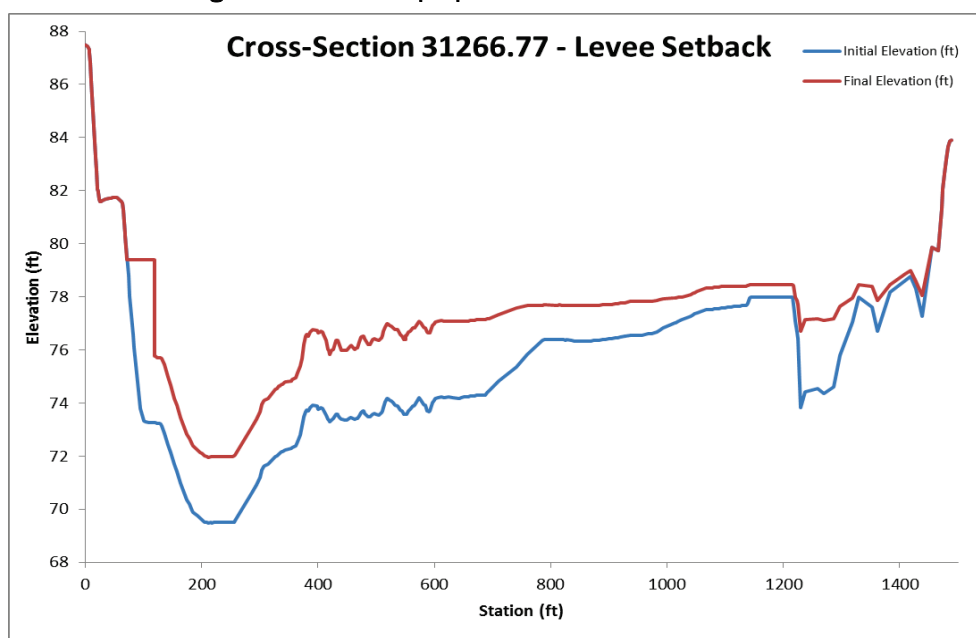


Figure 34. HEC-RAS proposed conditions cross section.



5.2 AdH WY 2006–2007 results

The existing conditions AdH model for the WY 2006–2007 flows followed the same in-channel depositional trend as the calibration period. The entire reach was depositional, with 68,000 cy of deposition between the two bridges. A total of 53,000 cy of the deposition occurred in the channel. This period of flows included much higher and more frequent overbank flows than the calibration period, resulting in more overbank deposition. The

higher incoming flows also meant more incoming sediment, resulting in more in-channel deposition. Figure 35 and Figure 36 show the aggradation and degradation that occurred during the 2-year period, respectively.

Figure 35. Existing conditions aggradation for WY 2006–2007.

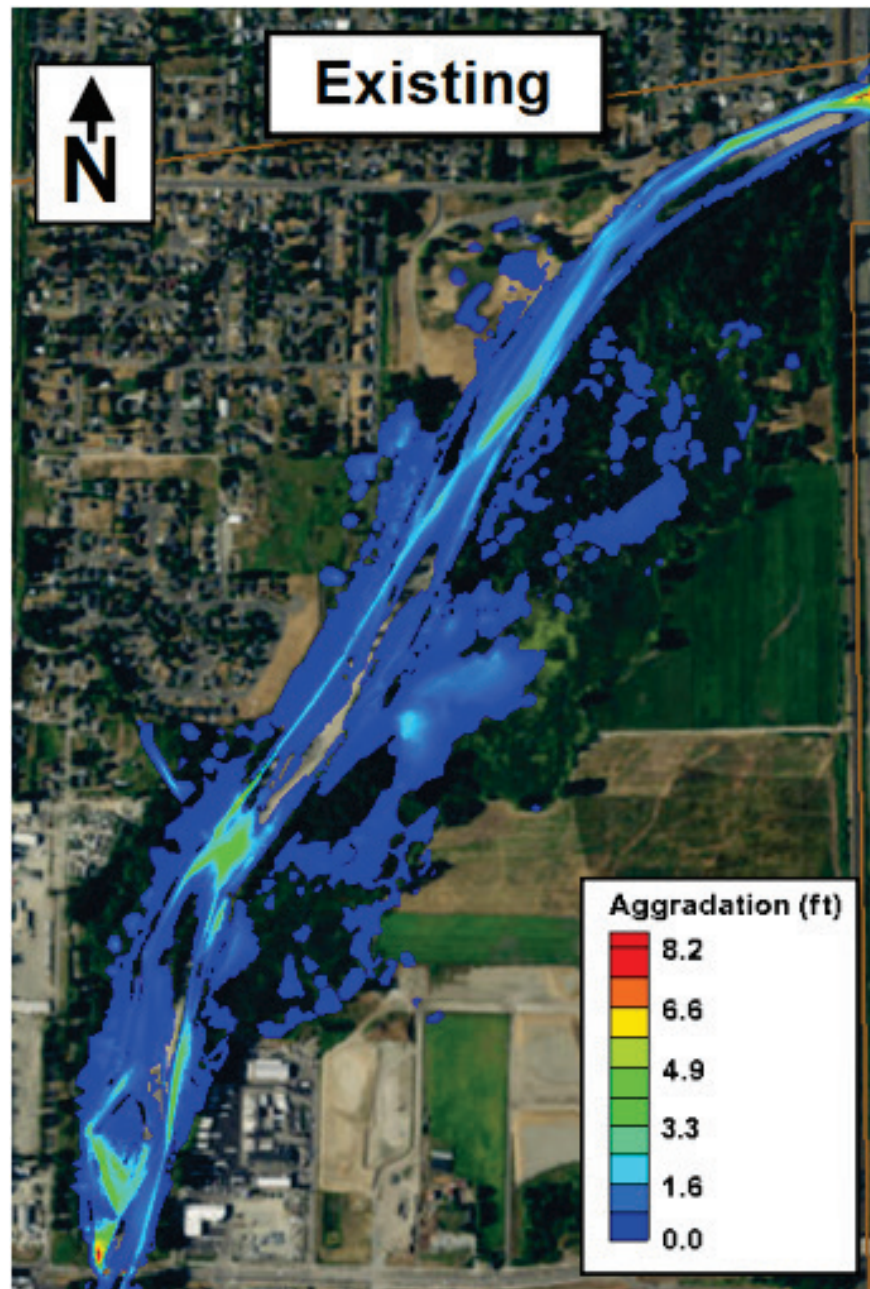
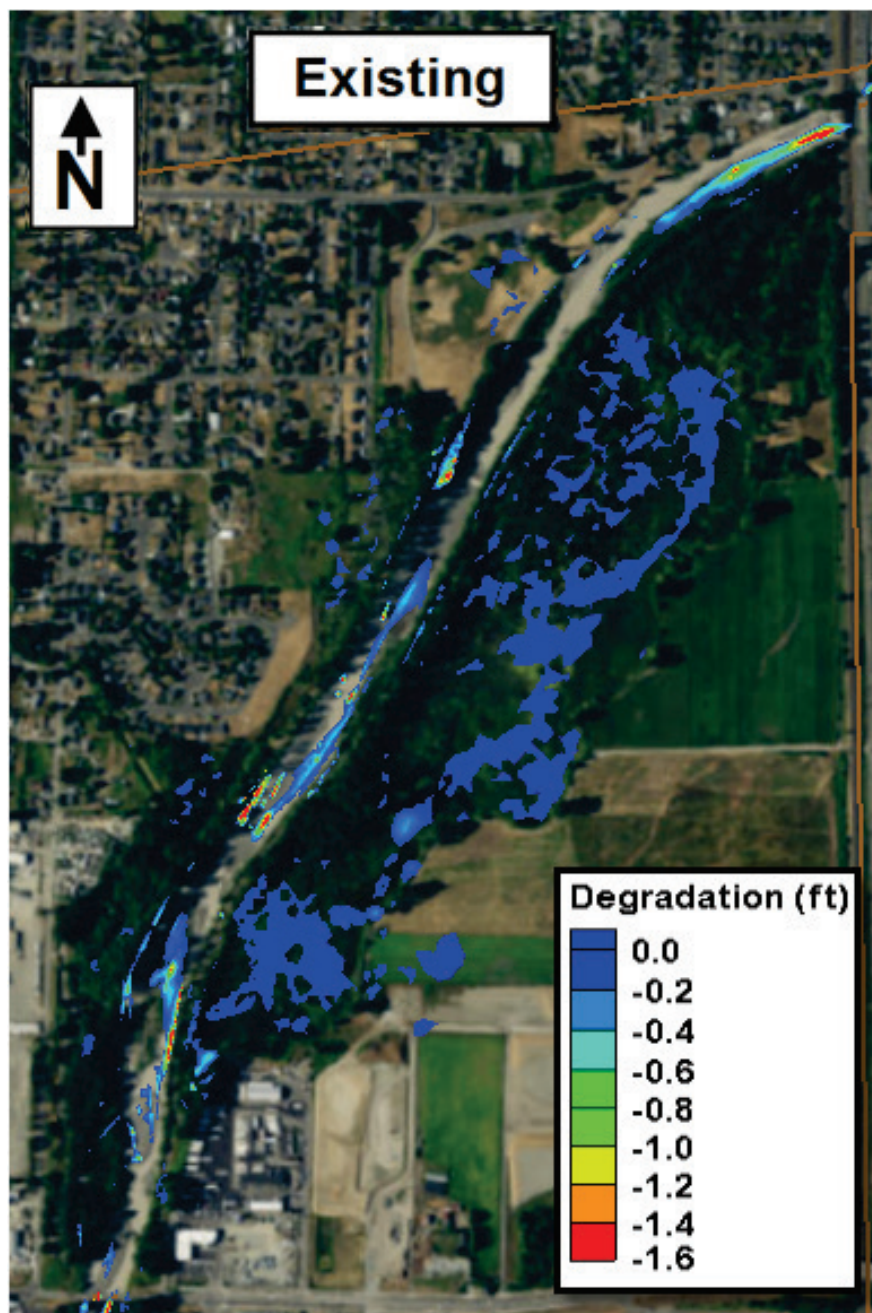


Figure 36. Existing conditions degradation for WY 2006–2007.



The proposed levee setback model had a total deposition of 143,000 cy, with 47,000 cy occurring in the main channel. Although the total in channel deposition by the end of the run was lower, this mostly occurred downstream of the last levee notches. Downstream of the setback, once the water returns to the main channel, there is nearly the same flow as in the existing conditions model. The total sediment load, however, is lower due to the sediment dropping out in the setback area. This results in less deposition in areas downstream of the return flow. Figure 37 shows the

aggradation for the proposed conditions. The areas with the highest aggradation are all located near where the levee lowering occurred. The main levee cut at the beginning of the setback area shows the most deposition. Degradation is shown in Figure 38.

Figure 37. Proposed conditions aggradation for WY 2006–2007.

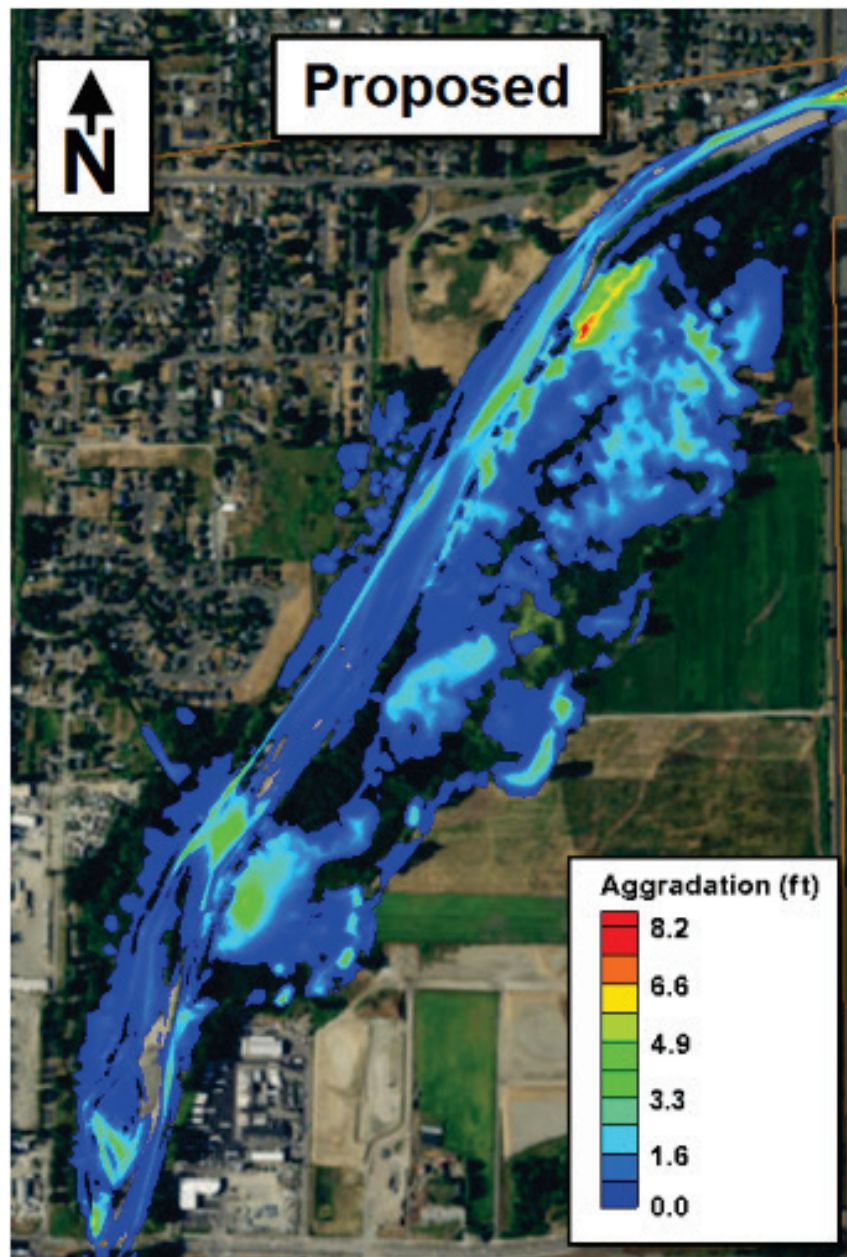
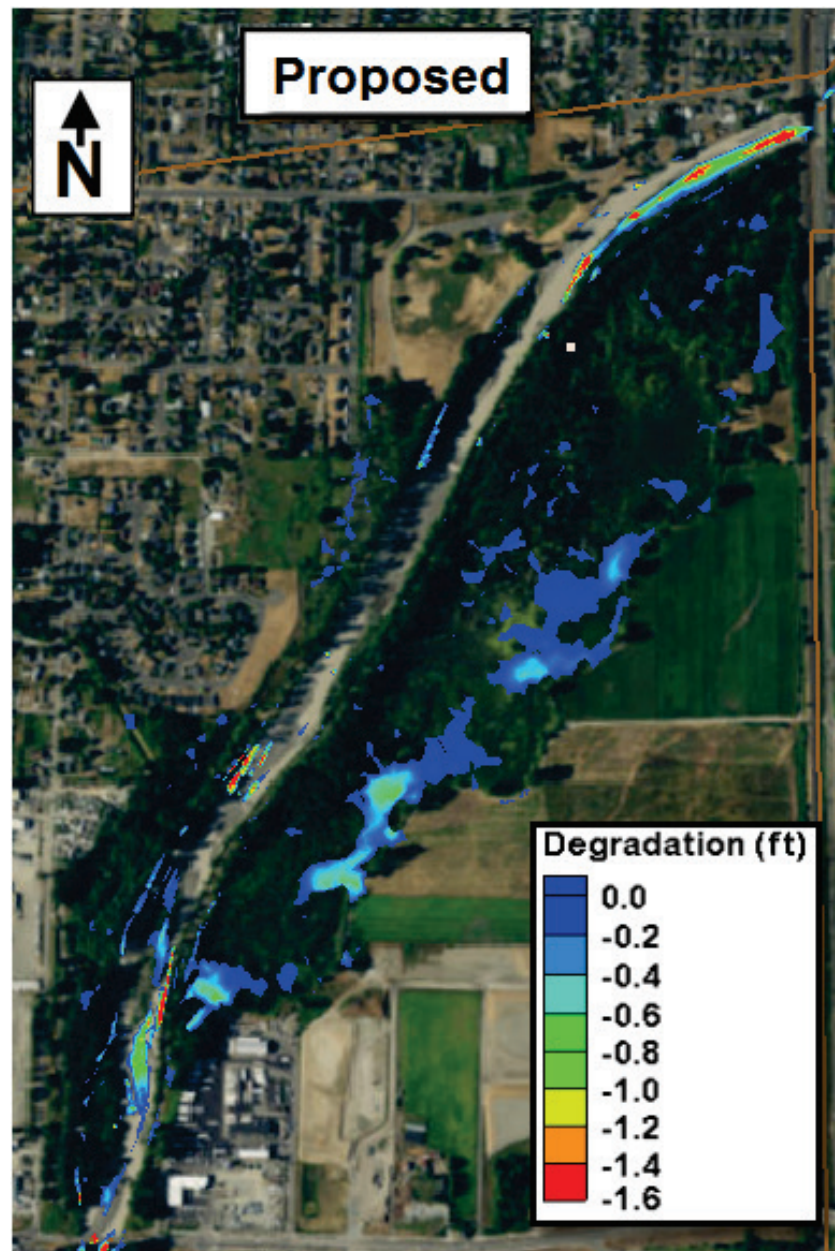


Figure 38. Proposed conditions degradation for WY 2006–2007.



The cross sections below (Figure 39 and Figure 40) were extracted from the AdH mesh for both the existing and proposed conditions models in the same location as the HEC-RAS cross sections shown in Figure 33 and Figure 34, respectively. Both the with and without project conditions show the bottom of the main channel aggrading along with some deposition in the left overbank area. The most noticeable difference is the amount of deposition that occurs on top of the left-bank levee where it was lowered in the proposed scenario. This was a common occurrence at all locations where the levee was lowered and flow was able to overtop it.

Figure 39. AdH existing conditions cross-section change.

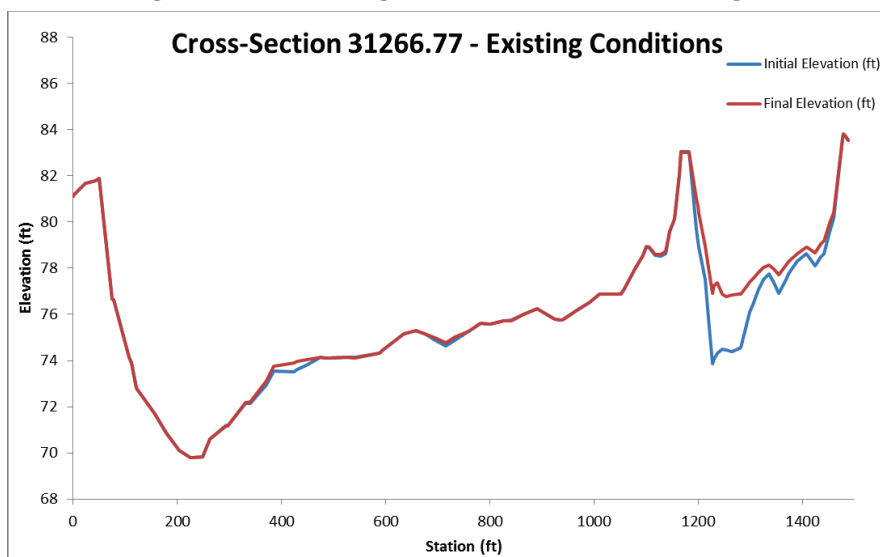
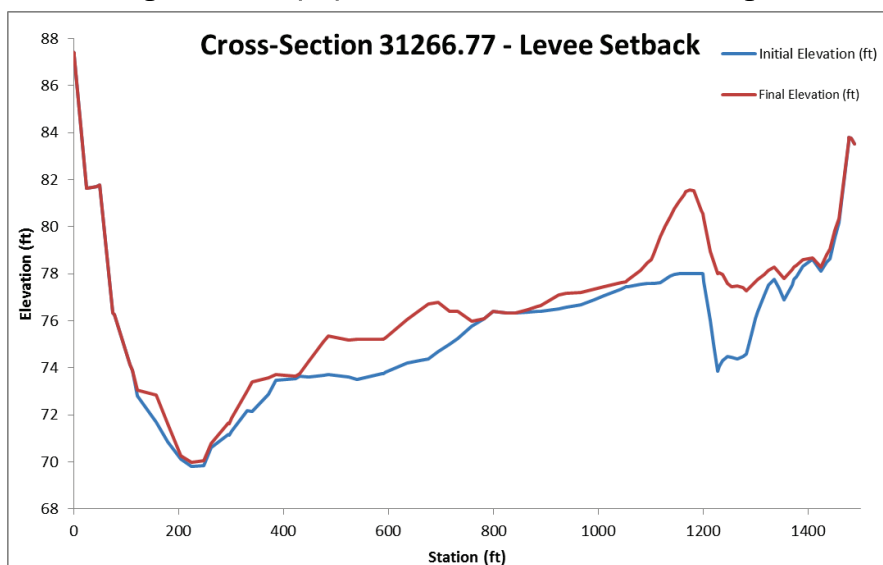
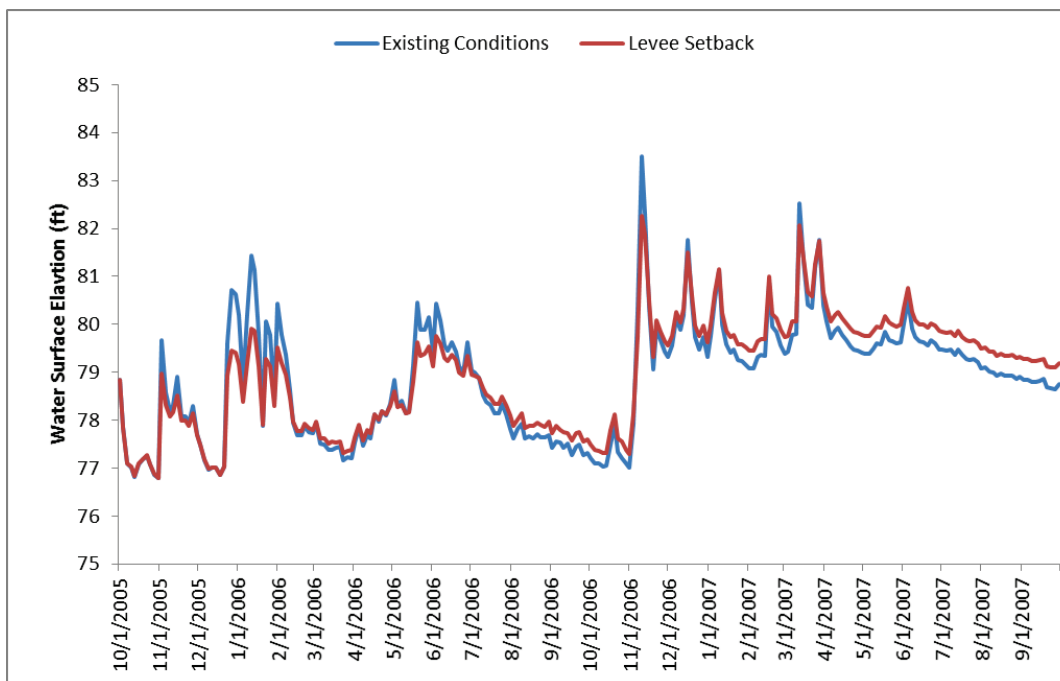


Figure 40. AdH proposed conditions cross-section change.



The reduction in flood elevations throughout the run is obvious when looking at the water surface time series in Figure 41 below. This benefit only occurs when flows are high enough to enter the setback area at the first main levee cut. The graph shows that this benefit is reduced through time as the levee notch fills. The increase in water surface at lower flows between the proposed and existing models shows that the setback is causing the channel to aggrade slightly faster at this location. This is possibly due to the decrease in depth at higher flows causing more in-channel sedimentation at this location.

Figure 41. AdH water surface elevation change (just downstream from the proposed levee notch)



The main upstream levee notch is a critical aspect of this model. The notch is meant to give the river access to the wetland behind the levee and the opportunity to create a secondary channel or migrate into the setback area. The model results show that large amounts of sediment could deposit in the cut initially and then more deposition could occur every time flow overtops the notch, building back a natural levee. A plan view and profile view of the deposition at the levee notch are shown in Figure 42 and Figure 43, respectively. Velocities for the first high flow (6,100 cfs) that causes most of the initial deposition in the notch are shown in Figure 44. This image of the velocity shows that the flow comes through the cut and immediately loses energy. This is the reason the flow can no longer move the sediment through the system and deposition occurs at that location. Figure 45 shows a broader view of the entire project site for the same 6,100 cfs flow. Figure 46 is a velocity snap shot of the highest flow that was run (13,100 cfs). By the time this flow arrived, the channel notch had already filled in significantly. Due to this, the image shows that there was not much conveyance through the setback area even at this extremely high flow.

Figure 42. Main levee cut plan view before and after 2-year model run.

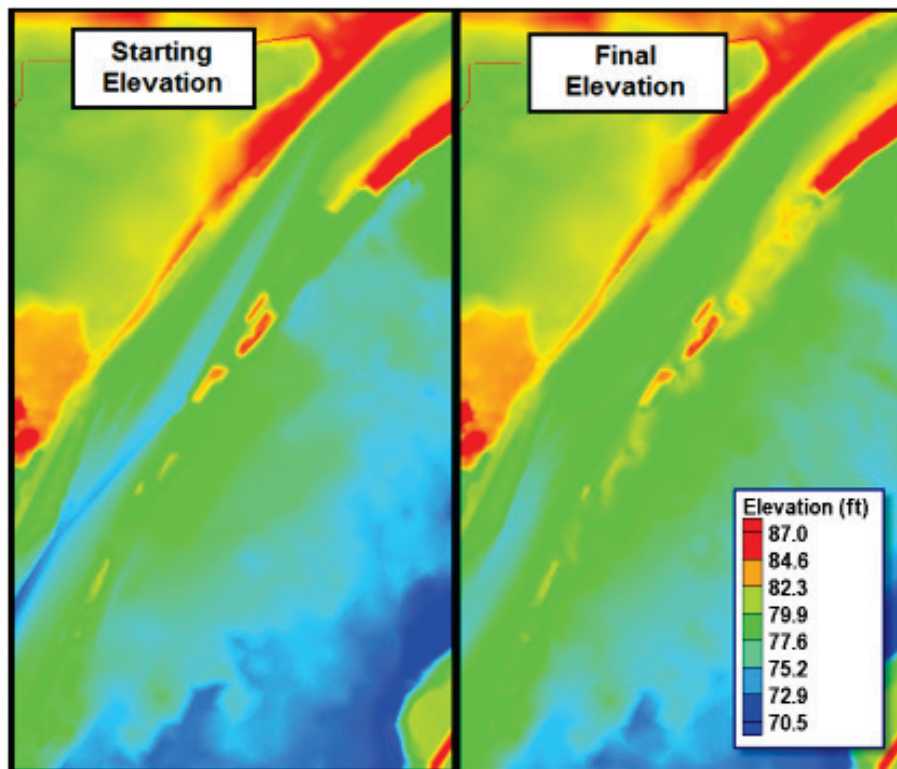


Figure 43. Main levee cut profile before levee lowering, immediately after levee lowering, and after 2-year model run.

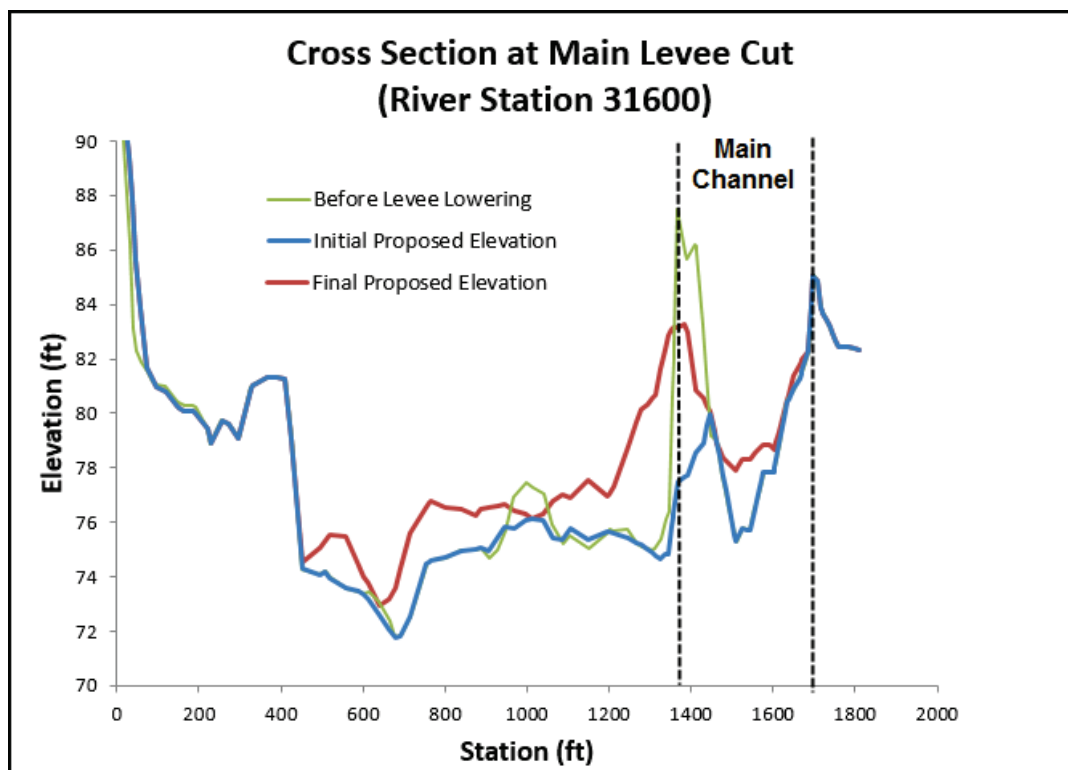


Figure 44. Velocity map of levee notch at 6,100 cfs flow.

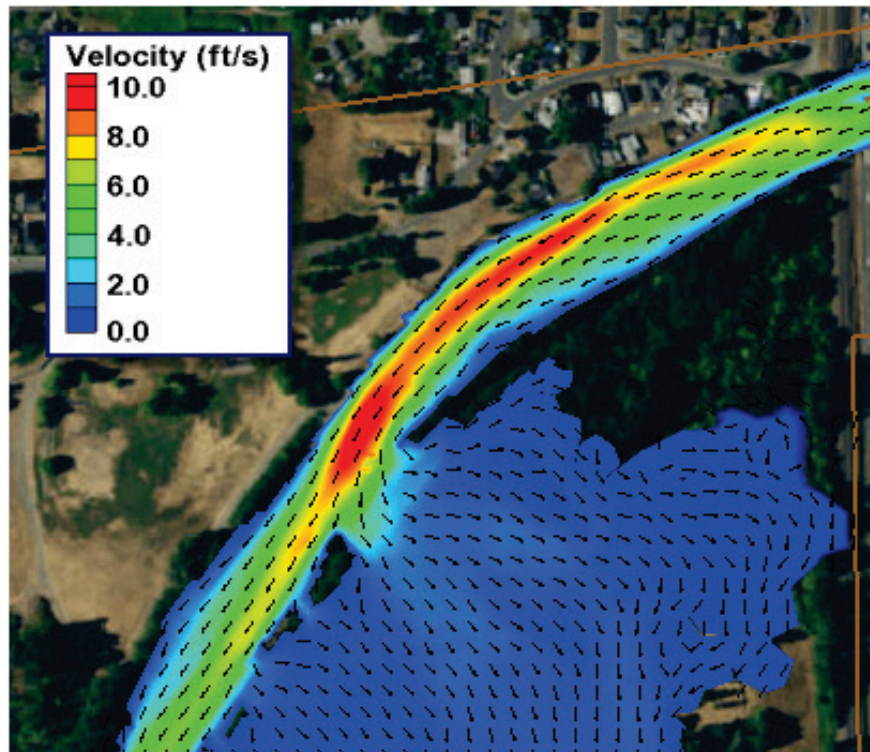


Figure 45. 6,100 cfs velocities.

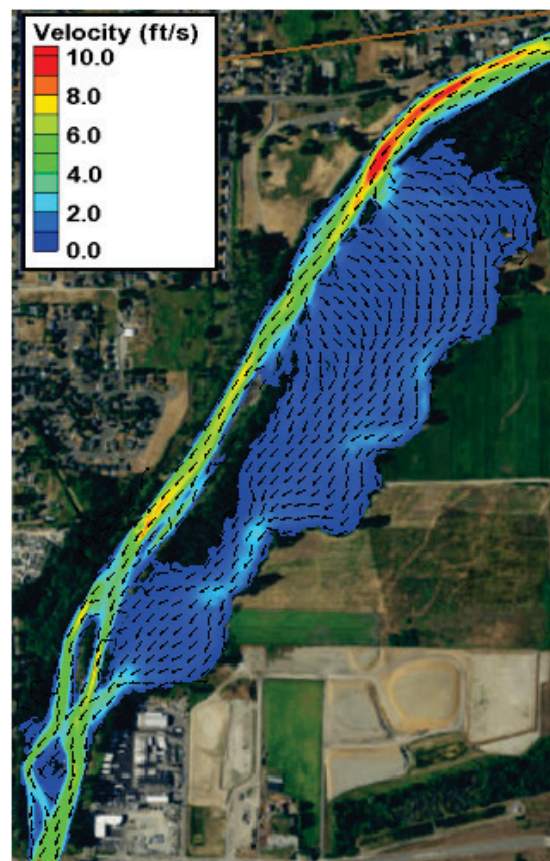
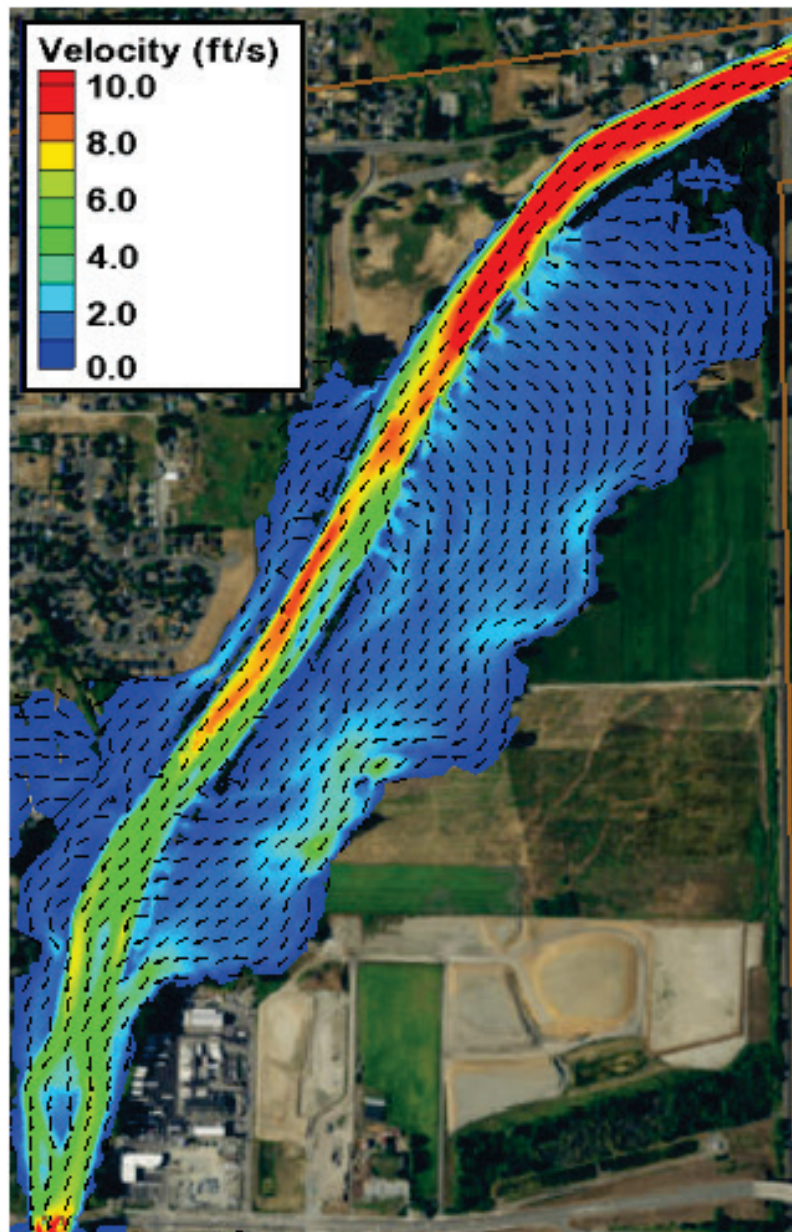


Figure 46. 13,100 cfs velocities.



6 Discussion

The HEC-RAS and AdH models were calibrated to the observed deposition volumes from 2012 to 2014. Both models predict that the proposed levee setback will alter the existing sediment transport regime within the reach resulting in more aggradation. The issues of concern are where the deposition will occur and how it will impact channel conveyance over time.

A major concern and unknown for the Countyline Setback Project is how the river will react when given easier access to the setback area. The reaction could range from fully avulsing and abandoning the current channel to not having much geomorphic change and only using the setback as extra storage at high flows. The two different models produce results on two opposite ends of the spectrum. The AdH model shows no avulsion into the setback area and even builds back a natural levee while the HEC-RAS model required modelers to select a flow path at the beginning of the model and assume complete avulsion. The avulsion assumption is critical but was the expected result during design. However, AdH did not require an initial channel path assumption and did not compute an avulsion.

The levee lowering was assumed to cause the river to migrate into the setback or create a secondary channel. The HEC-RAS model immediately reroutes the flow through the setback area when the proposed design geometry is applied. This is because the setback area is lower than the existing river channel in some cross sections, and HEC-RAS distributes the flow across the entire cross section inundating the lowest elevations first. Rerouting could be unrealistic if the high flows do not erode the remnant portion of the levee sufficiently. If a migration of the river into the setback area occurred, two mechanisms are possible. First, a gradual effect as lateral flows overtop the levee cuts and slowly forms a new channel. Second, a quick response in the form of a head-cut could erode upstream through the remnant levee. The HEC-RAS model is unable to capture either transition in morphology due to the 1D limitations and must either assume that a complete avulsion occurs or modify the geometry to assume that it does not.

The AdH model can simulate an avulsion without pre-defining it, but did not compute a complete avulsion. Not only does the river not migrate into the setback area, the levee notches begin closing off due to deposition.

Large amounts of deposition occur at the levee notches as water and sediment move laterally from the main channel across the levee notches to the setback area. Once the sediment passes through the main levee cut, the river does not have enough energy to continue transporting the sediment through the setback area, resulting in deposition. This deposition is due to a higher roughness in the setback area and a larger area for the flow to be distributed. Currently, the main channel is straight between the proposed diversion, and the point the flow would return to the main channel. A diversion would require a much longer flow path, and flows would have to make a nearly 90 degree turn to enter the setback through the proposed levee notch (Figure 44). These circumstances support the likelihood of the physical river behaving similarly to the AdH model's results.

However, there is also evidence at the site that the system would be able to avulse and maintain the levee cut. Abrupt deposition is present on site where extensive crevasse splays have formed on the landward side of failed sections of the levee (where river is able to flow into the restoration site frequently). These splays are bisected by channels and have yet to close off (as predicted by the AdH model at the proposed levee cuts). Because these breaches currently exist on the site and have not closed off, there is concern with the validity of the AdH model's results. Review of model results in the vicinity of these breaches suggests that the model does capture the deposition because the mesh was not built with fine enough resolution to accurately capture the small channels forming within the splays. The deposition at this location in the model is fines (silts and clays) and fine sands. There is likely not enough energy available to transport coarser material into the crevasse splay to close off the small channels, unlike in the proposed conditions model where sands and coarser material deposit to plug the upstream levee notches.

In the 2-year simulation, the AdH model predicts that deposition could form a natural levee where the existing levee was cut. If the river behaved similarly to the AdH results, with natural levee building and no avulsion occurring, it would not be a poor design. The natural levee would likely reach a stable height at a much lower elevation than the current existing levee. The lower level would allow the river to remain in its current channel without decreasing the transport capacity at non-flood flows and have access to a large storage area in the setback at higher flows. Increased storage would reduce stages during floods and not significantly increase the current existing aggradation rates.

The study was conducted to compare 1D and 2D model simulations of a levee setback and not to influence the project design. If other design options such as adjusting the levee notching or implementing a pilot channel were investigated with the purpose of directly impacting design, sensitivity analysis would need to be conducted on multiple variables. These variables could include overbank roughness, overbank bed gradations, and flow hydrographs.

The 1D model performed well in the channelized reach. However, the 2D model presents several advantages that make it the appropriate level of complexity for a setback levee analysis like this one. Multi-dimensional models should be considered for levee setbacks if one or more of the following situations is anticipated:

1. Generality. 1D models require users to make a priori decisions about flow path and the transporting channel. In cases where the channel alignment is not known or may change over the course of the simulation, the 2D model presents a more *general* solution (Gibson and Pasternack 2016).
2. Separate Conveyance Reaches. Balancing flow and sediment between two reaches is a fundamentally 2D process. For example, the two channels discussed in this report have separate and longitudinally continuous flows, water surface elevations, and sediment loads. The 1D model confounds these, computing them new at each cross section. Split flow could approximate this in a 1D model (Gibson and Pasternack 2016), but the 2D model can calculate complex split flow and bed change without explicitly specifying the channel configuration.
3. Lateral Sediment Diversion. The concerns surrounding the design of the Countyline Levee Setback emerged from detailed lateral sediment diversion dynamics at the junction between the main channel and potential avulsion. Both 1D and 2D models must consider vertical suspension effects at a diversion. However, a 2D model computes this flow and sediment split much more precisely than a 1D model (even a 1D model with split flow).
4. Lateral Bed Gradation Definition. 2D models allow the bed gradation to vary in all directions. The 1D model only allows bed gradation to vary longitudinally and vertically. In floodplain deposition or scour scenarios, particularly where lateral deposition of coarse sediment is the potential failure mode, the lateral gradation definition in a 2D model is an important feature.

7 Conclusions

This study highlights some of the potential differences between one-dimensional (1D) and two-dimensional (2D) models, especially with respect to modeling of setback levees. When modeling a multiple channel situation with a single cross section, the 1D model is restricted to a single water elevation and velocity at each cross section, computes transport for the whole cross section based on a pre-defined channel, and does not keep flow or sediment confined to each channel. 2D models determine water elevations and velocities at each node in the model mesh and maintain flow and sediment continuity in sub-channels without requiring modelers to define them before the simulation. This fundamental difference allows the 2D model to capture more complex behaviors of flow and sediment transport but at the expense of computational time and data requirements. For a complex levee setback, that tradeoff may be necessary to capture the lateral flows common in setback projects due to the floodplain inundation. Sediment movement into the levee setback area is driven by lateral flows, rather than just the general downstream movement that is simulated in a 1D model.

1D models can be valuable screening tools for levee setbacks, especially in situations where the channel is not expected to migrate out of its current path. However, multi-dimensional models should be considered for levee setback studies if they are expected to generate multiple discrete, dynamic channels (especially potential avulsions), are driven by lateral hydrodynamic or sediment process, or if the difference between channel and setback gradations are important for the model objectives.

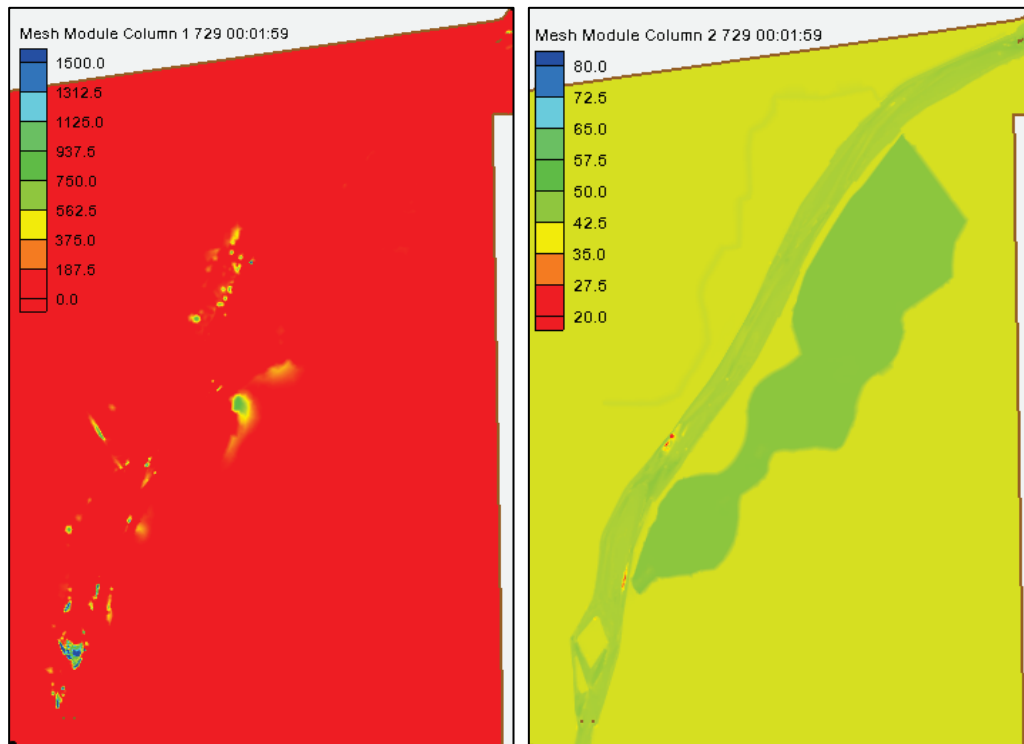
References

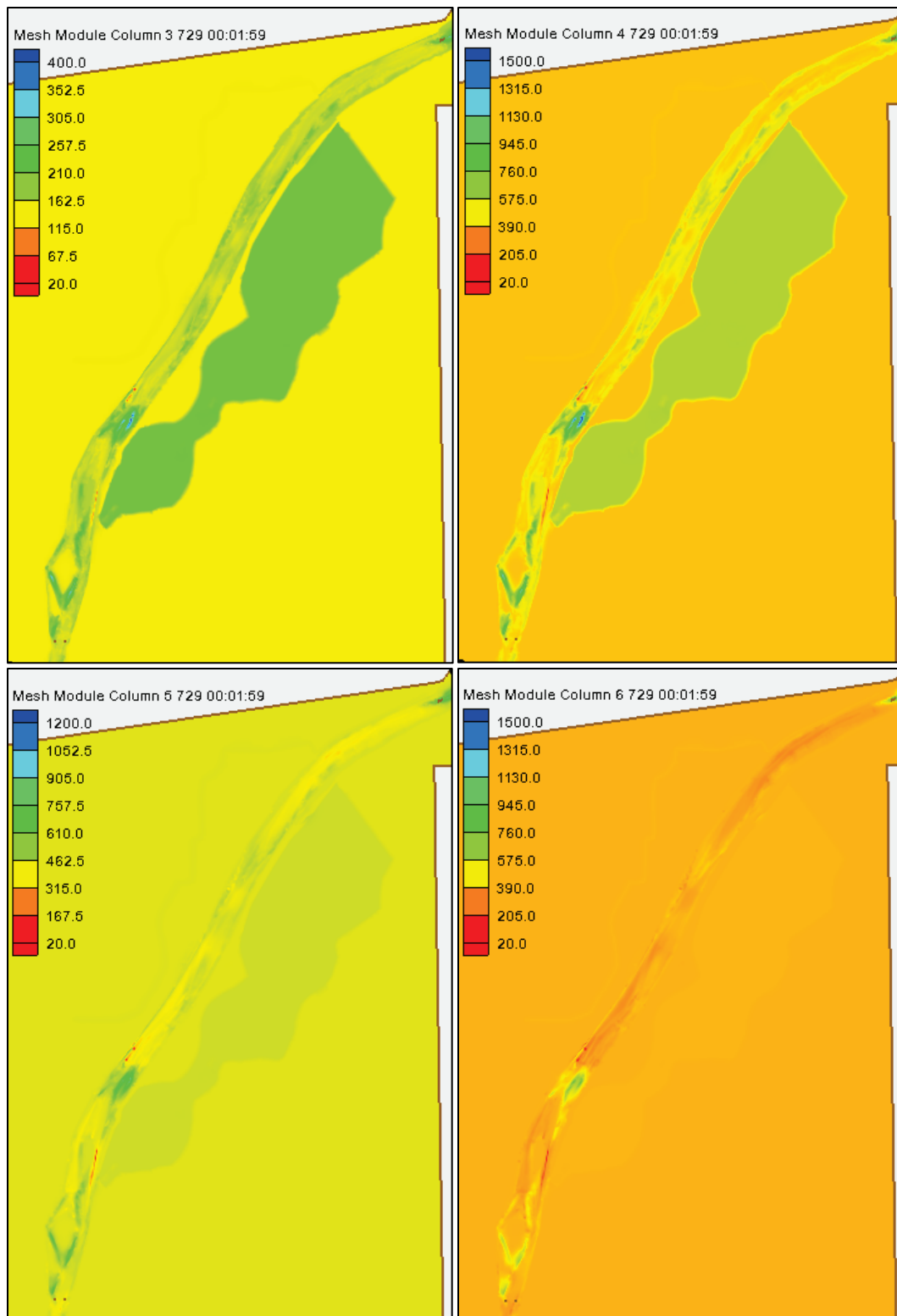
- Brown, G. L., J. N. Tate, and G. Savant. 2012. *SEDLIB Multiple Grain Size Mixed Sediment Library: Technical Manual*. Coastal and Hydraulics Laboratory. Vicksburg, MS: U.S Army Engineer Research and Development Center. https://chl.erdrc.dren.mil/adh/documentation/SEDLIB_Manual-Version1.2.pdf.
- Brunner, G. W. 2016a. *HEC-RAS River Analysis Hydraulic Reference Manual Version 5.0*. U.S. Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center, Davis, CA. <http://www.hec.usace.army.mil/software/hecras/documentation/HEC-RAS%205.0%20Reference%20Manual.pdf>.
- Brunner, G. W. 2016b. *HEC-RAS River Analysis System User's Manual Version 5.0*. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.
- Gibson, S., B. Comport, and Z. Corum. 2017. "Calibrating a Sediment Transport Model through a Gravel-Sand Transition: Avoiding Equifinality Errors in HEC-RAS Models of the Puyallup and White Rivers." In *Proceedings, ASCE EWRI World Environmental & Water Resource Congress*.
- Gibson, S. A., and G. B. Pasternack. 2016. "Selecting between One-Dimensional and Two-Dimensional Hydrodynamic Models for Ecohydraulic Analysis: Comparing 1D and 2D Ecohydraulic Models." *River Research and Applications* 32(6): 1365–1381.
- U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC CHL). 2015. *Adaptive Hydraulics (AdH) Version 4.5 Hydrodynamic User Manual*. Vicksburg, MS: U.S. Army Engineer Research and Development Center. https://chl.erdrc.dren.mil/adh/documentation/AdH_Manual_Hydrodynamic-Version4.5.pdf.
- U.S. Geological Survey (USGS). 2010. *Channel-Conveyance Capacity, Channel Change, and Sediment Transport in the Lower Puyallup, White, and Carbon Rivers, Western Washington*. Scientific Investigations Report 2010-5240. Reston, VA: U.S. Geological Survey.

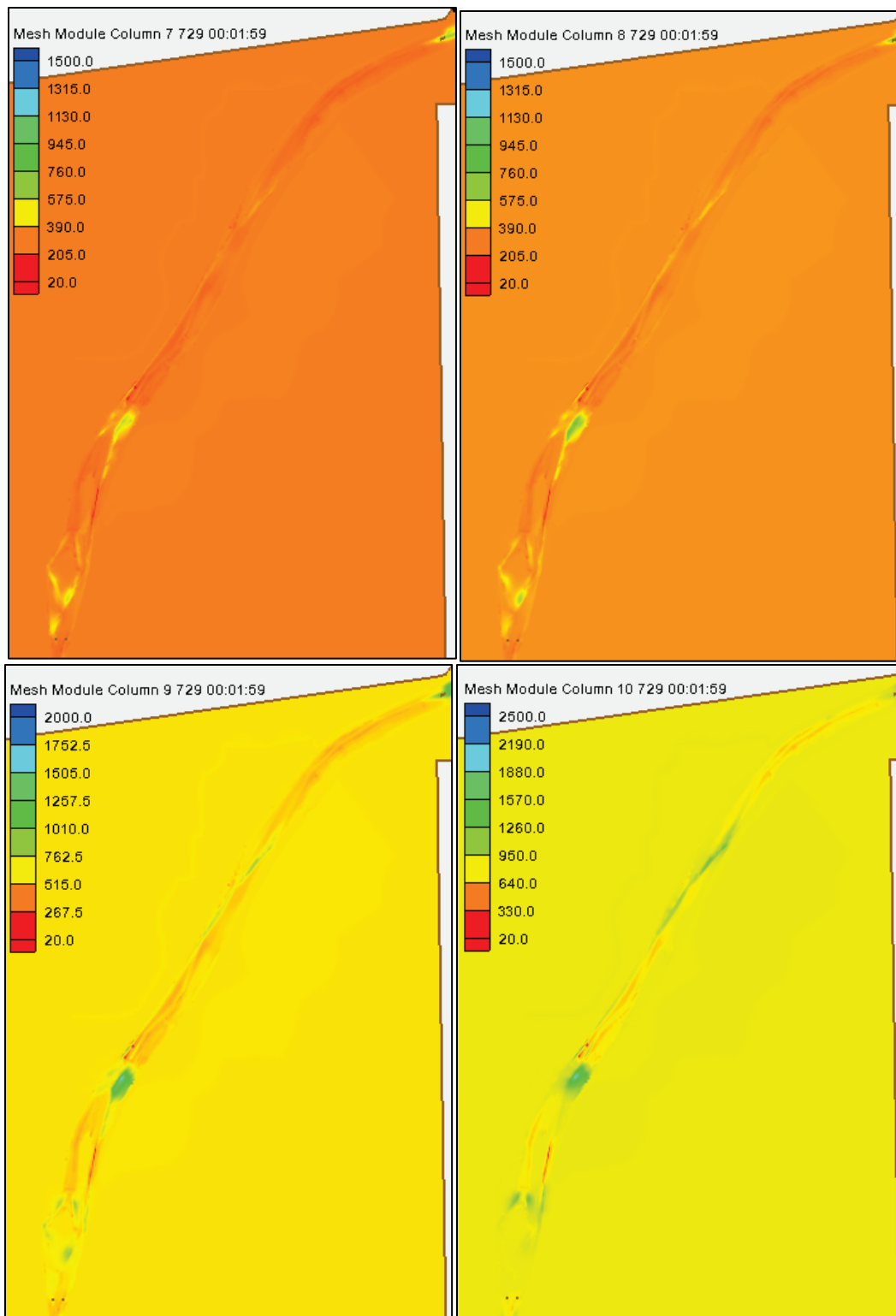
Appendix A: Starting Sediment Distribution

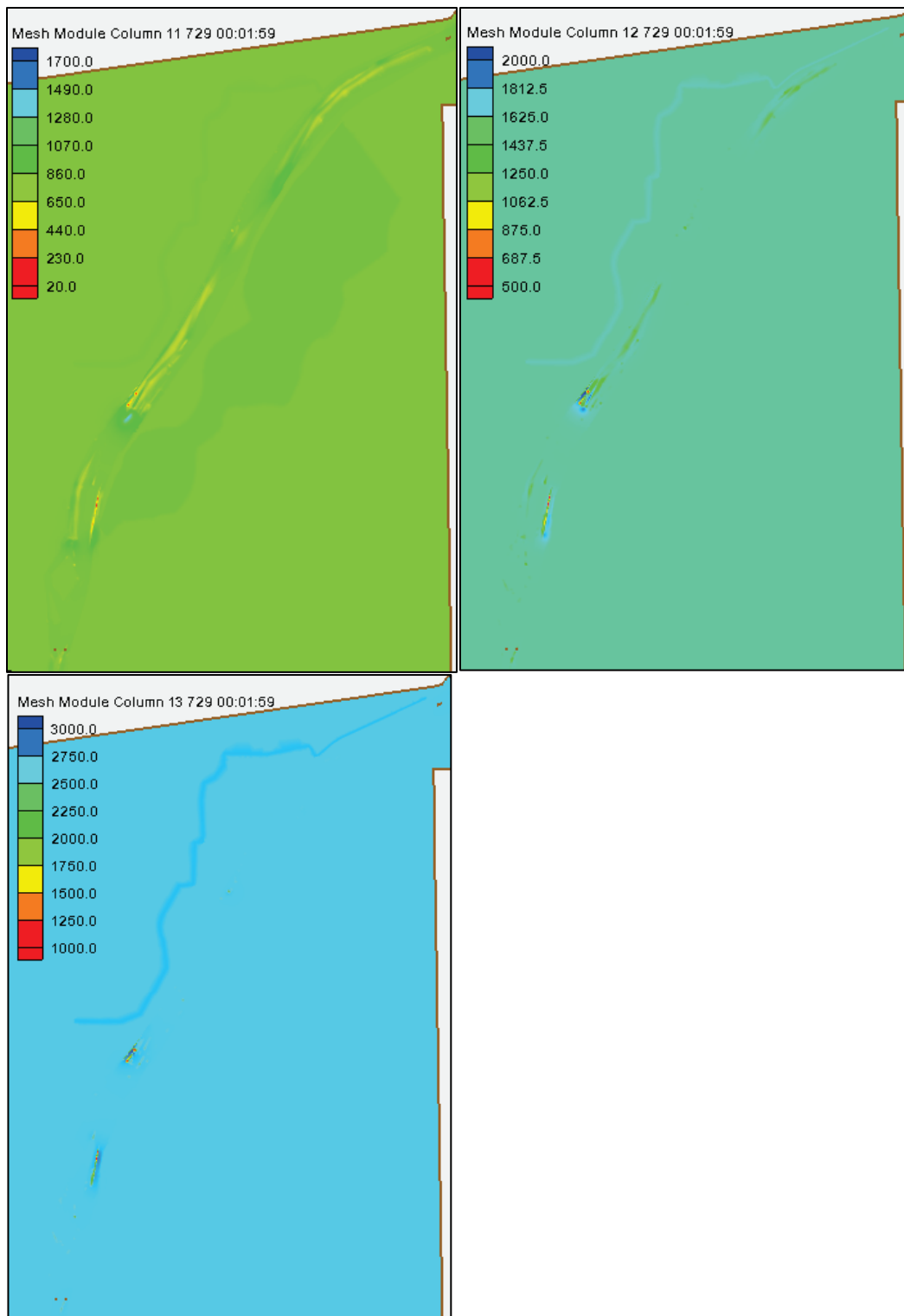
The following figures show the spatial distribution after bed initialization runs in kilograms per square meter for each grain class from coarse silt through small boulders. The column number is located in the text in the top left corner of each image.

Column	1	2	3	4	5	6	7	8	9	10	11	12	13
Grain Class	Csilt	FS	MS	CS	VCS	VFG	FG	MG	CG	VCG	SC	LC	SB





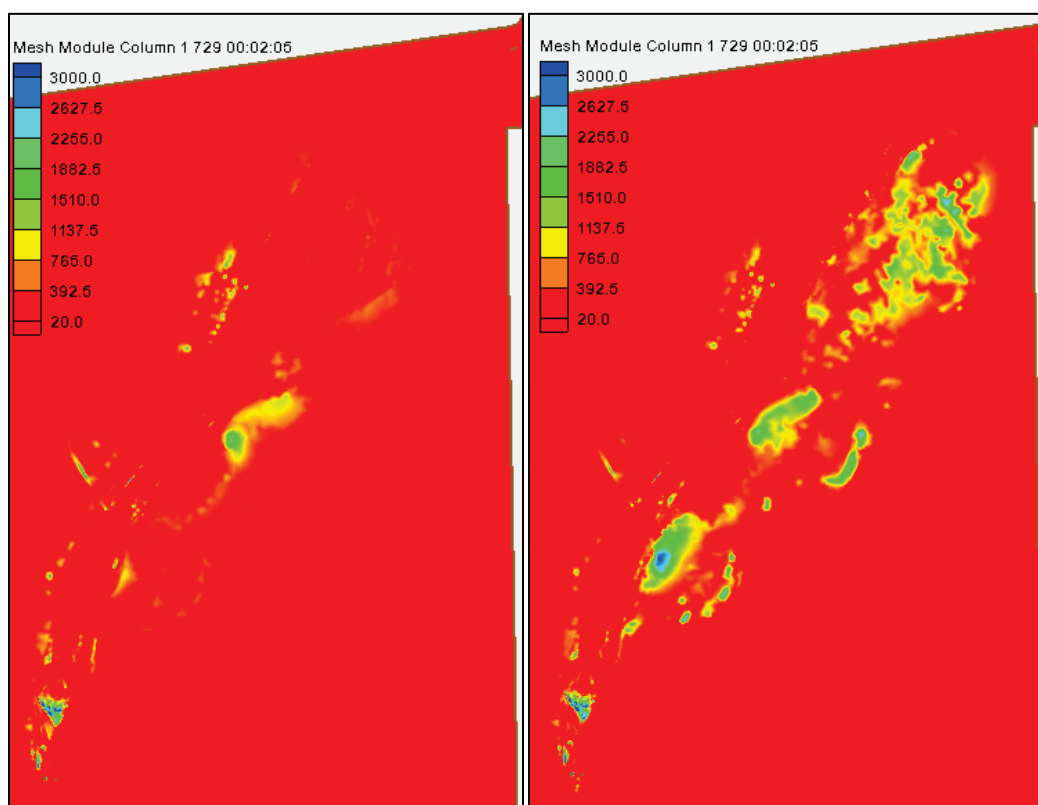


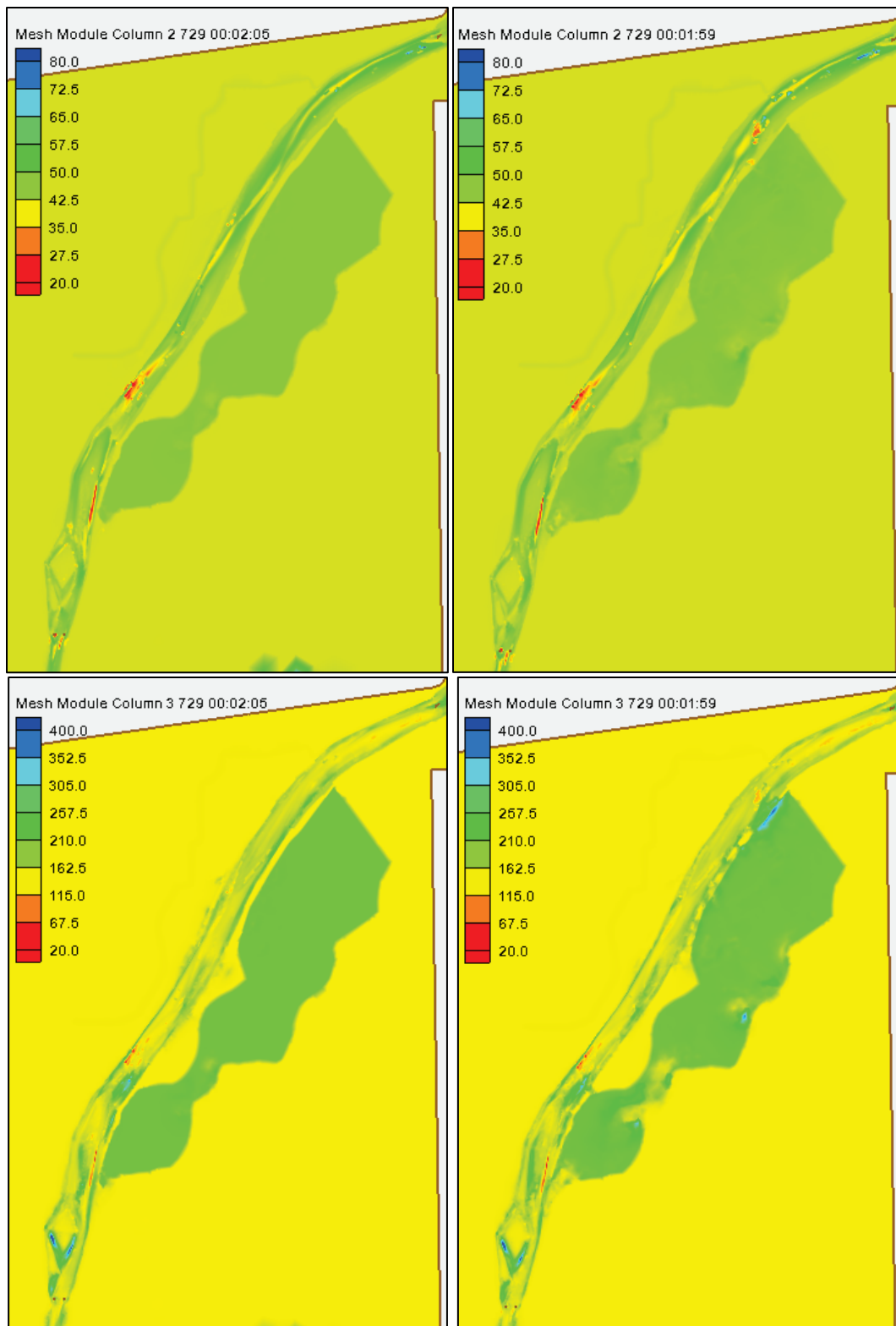


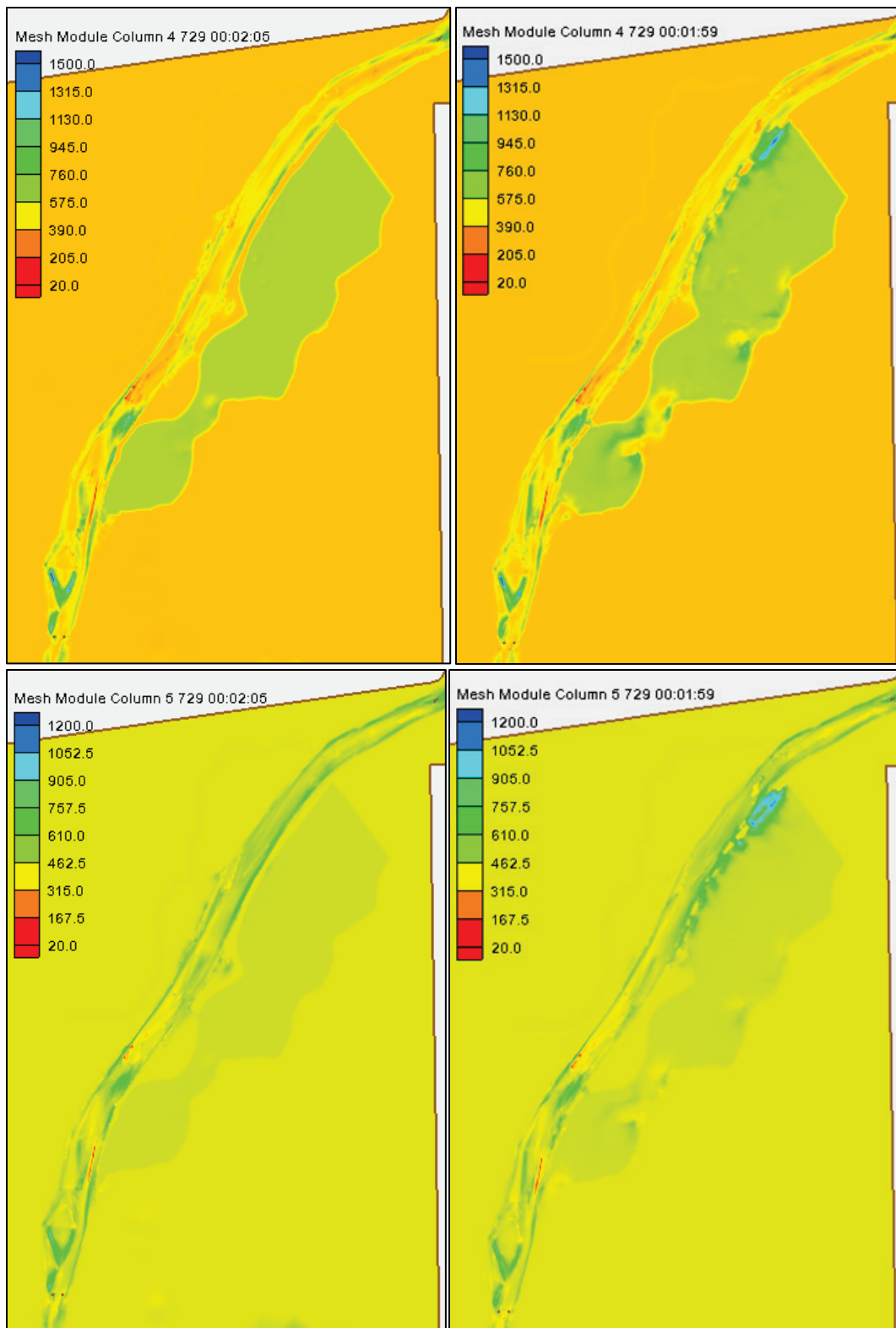
Appendix B: Final Sediment Distribution

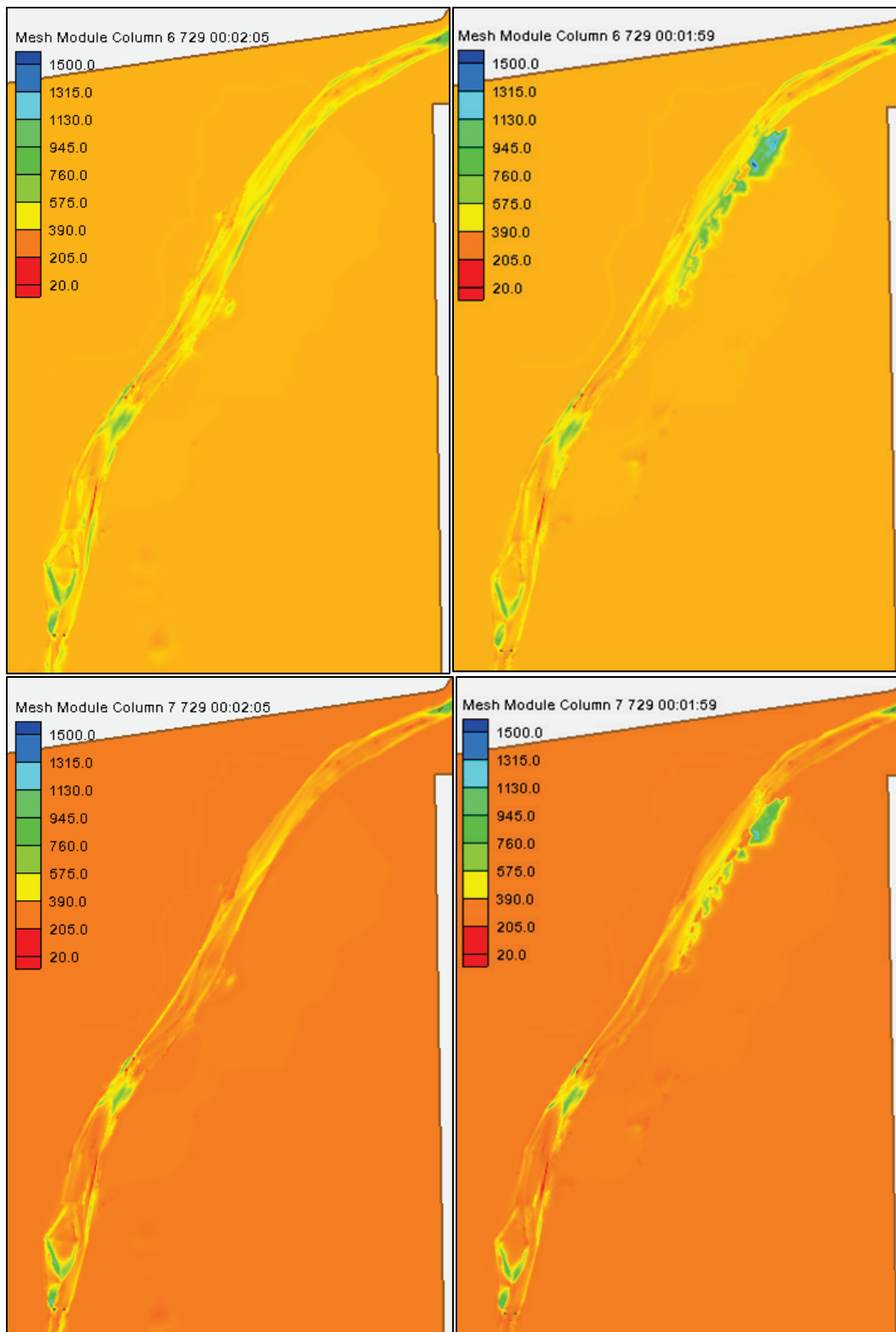
The following images show the sediment distribution at the end of the WY 2006–2007 runs for both the existing and the proposed conditions AdH models. The images on the left are from the existing conditions run, and the images to the right are from the proposed conditions.

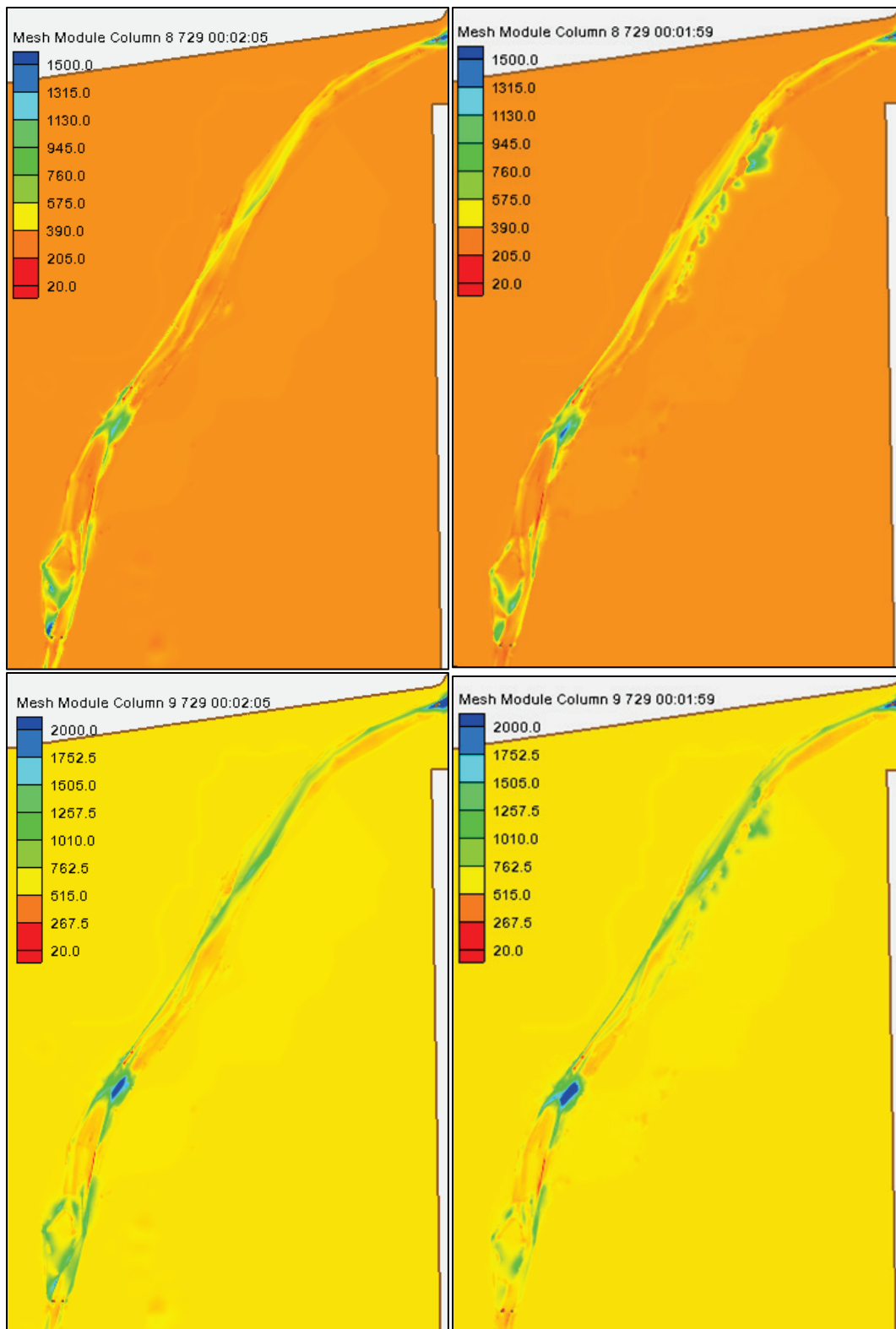
Column	1	2	3	4	5	6	7	8	9	10	11	12	13
Grain Class	Csilt	FS	MS	CS	VCS	VFG	FG	MG	CG	VCG	SC	LC	SB

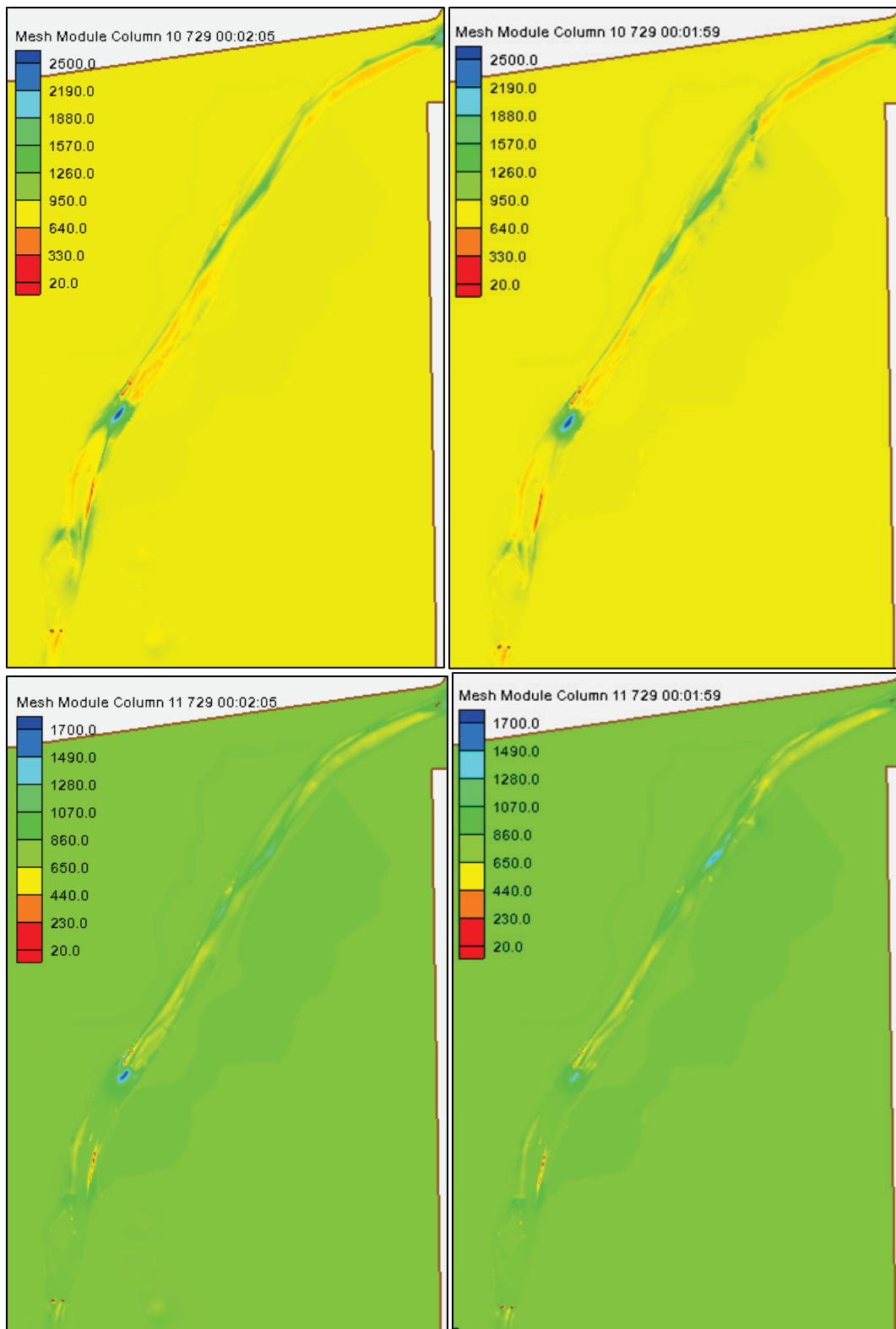


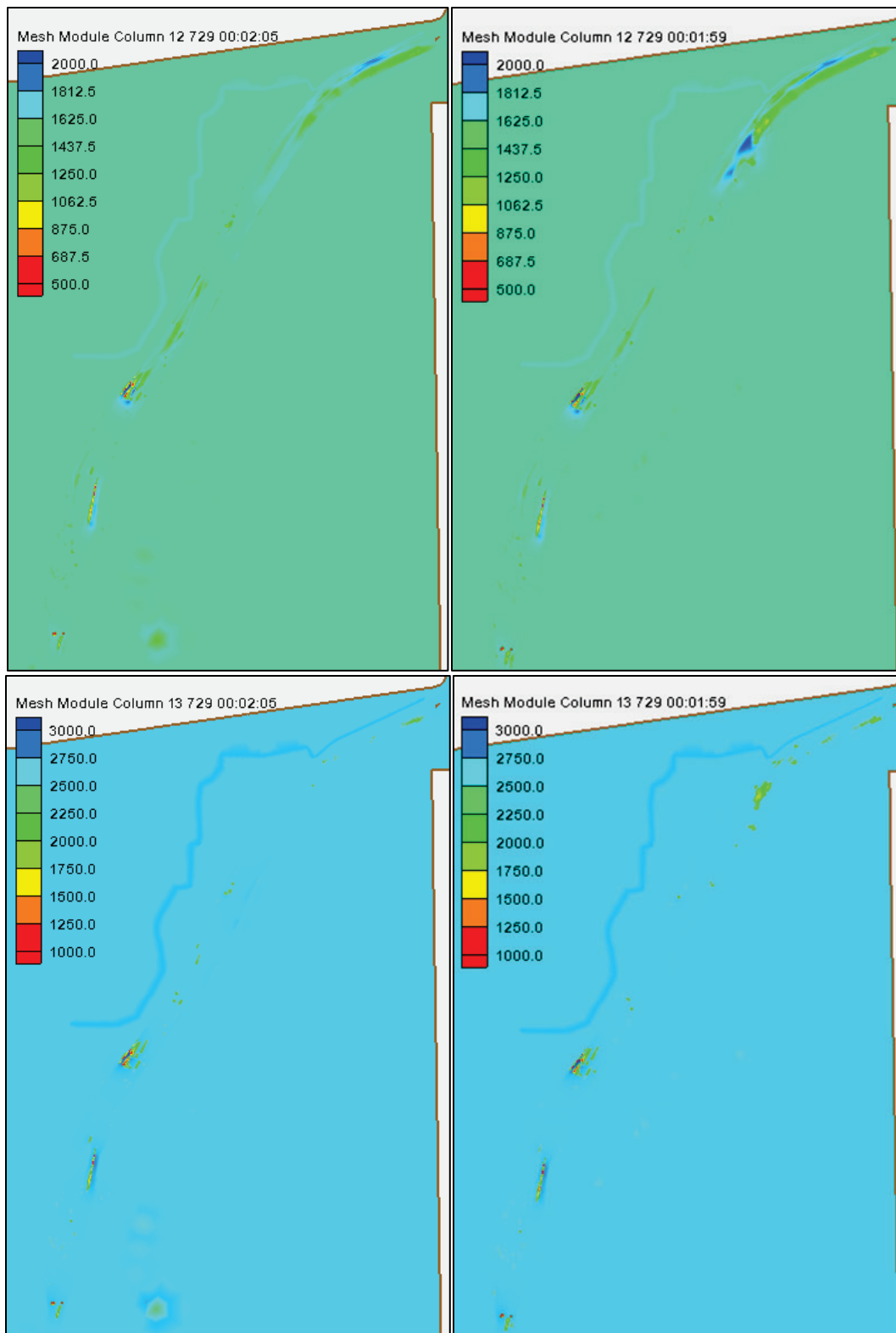












REPORT DOCUMENTATION PAGE					Form Approved OMB No. 0704-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.						
1. REPORT DATE July 2018		2. REPORT TYPE Final Report		3. DATES COVERED (From - To)		
4. TITLE AND SUBTITLE Modeled Sedimentation in the Lower White River Countyline Levee Setback, Washington State: Comparison of 1D (HEC-RAS) and 2D (AdH) Results				5a. CONTRACT NUMBER		
				5b. GRANT NUMBER		
				5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Keaton E. Jones, Travis A. Dahl, and Zachary P. Corum				5d. PROJECT NUMBER 454633		
				5e. TASK NUMBER		
				5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Coastal and Hydraulics Laboratory U.S. Army Engineer Research and Development Center 3909 Halls Ferry Rd Vicksburg, MS 39180-6199		U.S. Army Corps of Engineers, Seattle District 4735 E. Marginal Way South Seattle, WA 98134		8. PERFORMING ORGANIZATION REPORT NUMBER ERDC/CHL TR-18-9		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Corps of Engineers Washington, DC 20314-1000				10. SPONSOR/MONITOR'S ACRONYM(S) USACE		
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT The design of the Lower White River Countyline Setback Project in Washington State includes lowering an existing levee and constructing a new setback levee to allow the river to reconnect to an existing wetland. This study used two hydrodynamic and sediment transport models, Hydrologic Engineering Center-River Analysis System (HEC-RAS), and Adaptive Hydraulics (AdH), to model the river and compare the ability of one-dimensional (1D; HEC-RAS) and two-dimensional (2D; AdH) models to simulate hydraulic and sediment behavior in a levee setback project. Overall, both the 1D and the 2D model are well calibrated and indicate that the setback project will increase deposition within the reach. The spatial location of aggradation differs between the two models due to fundamental differences between the 1D and 2D approaches. The 1D model assumes that the river will avulse into the setback area and projects deposition in both the setback and former channel while the 2D model results show most of the aggradation occurring in the setback area. This study shows that, while 1D models can be valuable screening tools for levee setbacks, 2D models of setbacks should be considered when multiple channels may develop, there are lateral processes, or the difference between channel and setback gradations is important.						
15. SUBJECT TERMS Floodplains, Restoration ecology, Sedimentation and deposition, Sediment transport, White River (Wash.)—Flood control, White River (Wash.)--Levees						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT	b. ABSTRACT	c. THIS PAGE			Keaton Jones	
Unclassified	Unclassified	Unclassified	SAR	69	19b. TELEPHONE NUMBER (Include area code) 601-634-3558	