Appendix J
Snohomish County
Smith Island Estuarine Restoration
Union Slough Hydraulic Model Study
May 2013
# Snohomish County

**Smith Island Estuarine Restoration**

**Union Slough Hydraulic Model Study**

## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 1. Introduction</td>
<td>.................................................................................................................1</td>
<td>1</td>
</tr>
<tr>
<td>1.1</td>
<td>Modeling Goals and Objectives.................................................................</td>
<td>1</td>
</tr>
<tr>
<td>Chapter 2. Project Approach</td>
<td>.................................................................................................................3</td>
<td>3</td>
</tr>
<tr>
<td>2.1</td>
<td>Modeled Scenarios.................................................................................</td>
<td>3</td>
</tr>
<tr>
<td>2.1.1</td>
<td>Scenario 1—Post-Implementation Conditions for Smith Island Restoration Project</td>
<td>3</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Scenario 2—Post-Implementation Conditions for Smith Island Restoration Project Combined with Blue Heron Slough Project</td>
<td>3</td>
</tr>
<tr>
<td>2.2</td>
<td>Model Selection.......................................................................................</td>
<td>4</td>
</tr>
<tr>
<td>2.3</td>
<td>Elevation Datum .....................................................................................</td>
<td>4</td>
</tr>
<tr>
<td>2.4</td>
<td>Model Description and Development – Union Slough Channel Impacts .........</td>
<td>5</td>
</tr>
<tr>
<td>2.4.1</td>
<td>Model Extents ..................................................................................</td>
<td>5</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Boundary Conditions and Hydrology ..................................................</td>
<td>5</td>
</tr>
<tr>
<td>2.4.3</td>
<td>Calibration and Validation ................................................................</td>
<td>6</td>
</tr>
<tr>
<td>2.5</td>
<td>Model Description and Development – Flood Level Impacts .....................</td>
<td>10</td>
</tr>
<tr>
<td>2.5.1</td>
<td>Model Extents ...................................................................................</td>
<td>10</td>
</tr>
<tr>
<td>2.5.2</td>
<td>Boundary Conditions and Hydrology ..................................................</td>
<td>10</td>
</tr>
<tr>
<td>2.5.3</td>
<td>Calibration and Validation ................................................................</td>
<td>12</td>
</tr>
<tr>
<td>Chapter 3. Model Results</td>
<td>.............................................................................................................15</td>
<td>15</td>
</tr>
<tr>
<td>3.1</td>
<td>Background for Assessing Results........................................................</td>
<td>15</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Flow ................................................................................................</td>
<td>15</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Tide Levels.........................................................................................</td>
<td>15</td>
</tr>
<tr>
<td>3.1.3</td>
<td>Erosion Threshold Evaluation .............................................................</td>
<td>16</td>
</tr>
<tr>
<td>3.2</td>
<td>Flow Velocity Results............................................................................</td>
<td>16</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Existing Conditions.............................................................................</td>
<td>16</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Scenario 1 (Smith Island Restoration Project Implemented)......................</td>
<td>16</td>
</tr>
<tr>
<td>3.2.3</td>
<td>Scenario 2 (Smith Island and Blue Heron Projects Implemented)................</td>
<td>17</td>
</tr>
<tr>
<td>3.3</td>
<td>Bed Shear Stress Results......................................................................</td>
<td>17</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Existing Conditions.............................................................................</td>
<td>17</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Scenario 1 (Smith Island Restoration Project Implemented)......................</td>
<td>17</td>
</tr>
<tr>
<td>3.3.3</td>
<td>Scenario 2 (Smith Island and Blue Heron Projects Implemented)................</td>
<td>18</td>
</tr>
<tr>
<td>3.4</td>
<td>Flood Level Results...............................................................................</td>
<td>18</td>
</tr>
<tr>
<td>Chapter 4. Potential Impacts on Union Slough</td>
<td>.................................................................................................19</td>
<td>19</td>
</tr>
<tr>
<td>4.1</td>
<td>Erosion and Sedimentation .....................................................................</td>
<td>19</td>
</tr>
<tr>
<td>4.2</td>
<td>Buse Timber Company ...........................................................................</td>
<td>19</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Log Delivery and Storage ....................................................................</td>
<td>19</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Effect of Alternatives on Buse Timber Operations ..................................</td>
<td>20</td>
</tr>
<tr>
<td>4.3</td>
<td>Flood Level Impacts................................................................................</td>
<td>21</td>
</tr>
<tr>
<td>References</td>
<td>..............................................................................................................23</td>
<td>23</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Table 1. HEC-RAS Cross sections Used for Boundary Conditions</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Table 2. Model Results Comparison for Water Surface Elevation</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Table 3. FEMA 100-Year water surface elevation Comparison</td>
<td>13</td>
</tr>
</tbody>
</table>

LIST OF FIGURES

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Smith Island Estuarine Restoration Project Vicinity</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Key Elements of Proposed Smith Island Estuarine Restoration Project</td>
<td>back of report</td>
</tr>
<tr>
<td>3</td>
<td>Hydraulic Modeling Mesh and Cross-Sections</td>
<td>back of report</td>
</tr>
<tr>
<td>4</td>
<td>Modeled Hydrographs at Upstream End of Study Area</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Modeled Hydrographs at Downstream End of Study Area</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Model Comparison – Existing Conditions Water Surface Elevations at Cross-Section 5977</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>Model Comparison – Existing Conditions Water Surface Elevations at Cross-Section 7940</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Model Comparison – Existing Conditions Water Surface Elevations at Cross-Section 8906</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Model Comparison – Existing Conditions Water Surface Elevations at Cross-Section 10040</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>Model Comparison – Existing Conditions Water Surface Elevations at Cross-Section 13537</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>Modeled Hydrographs at Upstream End of Study Area</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>Modeled Hydrographs at Downstream End of Study Area</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>Locations of FEMA Cross Sections</td>
<td>back of report</td>
</tr>
<tr>
<td>14</td>
<td>Modeling Results for Flow Velocity and Direction, Existing Conditions</td>
<td>back of report</td>
</tr>
<tr>
<td>15</td>
<td>Modeling Results for Flow Velocity and Direction, Existing Conditions, Upper Project Area</td>
<td>back of report</td>
</tr>
<tr>
<td>16</td>
<td>Modeling Results for Flow Velocity and Direction, Existing Conditions, Lower Project Area</td>
<td>back of report</td>
</tr>
<tr>
<td>17</td>
<td>Modeling Results for Flow Velocity and Direction, Scenario 1 (With Smith Island Restoration Project)</td>
<td>back of report</td>
</tr>
<tr>
<td>18</td>
<td>Modeling Results for Flow Velocity and Direction, Scenario 1 (With Smith Island Restoration Project), Upper Project Area</td>
<td>back of report</td>
</tr>
<tr>
<td>19</td>
<td>Modeling Results for Flow Velocity and Direction, Scenario 1 (With Smith Island Restoration Project), Lower Project Area</td>
<td>back of report</td>
</tr>
<tr>
<td>20</td>
<td>Modeling Results for Flow Velocity and Direction, Scenario 2 (With Smith Island Restoration Project and Blue Heron Slough Project)</td>
<td>back of report</td>
</tr>
<tr>
<td>21</td>
<td>Modeling Results for Flow Velocity and Direction, Scenario 2 (With Smith Island Restoration Project and Blue Heron Slough Project), Upper Project Area</td>
<td>back of report</td>
</tr>
<tr>
<td>22</td>
<td>Modeling Results for Flow Velocity and Direction, Scenario 2 (With Smith Island Restoration Project and Blue Heron Slough Project), Lower Project Area</td>
<td>back of report</td>
</tr>
<tr>
<td>23</td>
<td>Modeling Results for Bed Shear Stress, Existing Conditions</td>
<td>back of report</td>
</tr>
<tr>
<td>24</td>
<td>Modeling Results for Bed Shear Stress, Scenario 1 (With Smith Island Restoration Project)</td>
<td>back of report</td>
</tr>
<tr>
<td>25</td>
<td>Modeling Results for Bed Shear Stress, Scenario 2 (With Smith Island Restoration Project and Blue Heron Slough Project)</td>
<td>back of report</td>
</tr>
<tr>
<td>26</td>
<td>Modeling Results For Water Surface Elevation Comparison Existing Conditions vs. Scenario 1 (Smith Island Restoration)</td>
<td>back of report</td>
</tr>
<tr>
<td>27</td>
<td>Modeling Results For Water Surface Elevation Comparison Existing Conditions vs. Scenario 2 (Smith Island Restoration with Blue Heron Slough Project)</td>
<td>back of report</td>
</tr>
<tr>
<td>28</td>
<td>Buse Log Pocket and Access Ramp</td>
<td>19</td>
</tr>
</tbody>
</table>
CHAPTER 1.
INTRODUCTION

The Smith Island Restoration project proposes long-term conservation of a 400-acre site owned by Snohomish County and the City of Everett. The project entails breaching existing dikes to restore wetlands. The site is adjacent to Union Slough in Snohomish County, Washington (Figure 1). Union Slough is a distributary drainage channel of the delta where the Snohomish River discharges to Possession Sound. Smith Island is located between the Snohomish River and Union Slough east of Everett, Washington and Interstate-5.

This report summarizes the results of the Union Slough Hydraulic Model Study, which evaluated changes to hydraulic conditions in the project area following implementation of two projects: the Smith Island Restoration Project and the Blue Heron Restoration Project. A two-dimensional (2-D) hydraulic computer model developed for this study was used to analyze flow patterns and identify areas where potential erosion or sedimentation may occur after the project is implemented. Post-project impacts to water surface elevations in Union Slough were also modeled to determine whether the project will affect flood levels. Tetra Tech performed the study for Snohomish County’s Surface Water Management Division.

The study also addresses comments from neighboring landowners submitted in response to Snohomish County’s Draft Environmental Impact Statement for the project, which was issued in June 2011. These comments raised concerns about potential Union Slough channel changes that could disrupt business operations and damage property. Two previous hydraulic model studies did not provide sufficient detail to evaluate these concerns.

1.1 MODELING GOALS AND OBJECTIVES

The goal for this study was to provide a detailed analysis of the hydraulic response of Union Slough to the proposed Smith Island Restoration Project and to the combined implementation of the Smith Island Restoration Project and the Blue Heron Slough project, a similar project directly adjacent to the Smith Island Restoration Project on the north side of Union Slough (Figure 1). Objectives include the following:

- Develop hydraulic data that can be evaluated at the project and reach scale to facilitate analysis of impacts.
- Provide information that addresses comments received on the Draft Environmental Impact Statement.
- Given the lack of recorded water surface elevation data in the study area for model calibration, verify the model based on historical observations and comparison against two existing models.
- Use the peak-flow hydrograph from the January 2009 high-flow event (approximately 15-year recurrence interval) to simulate a high flow that has been previously modeled with a one-dimensional (1-D) model.
- Flow velocity and shear stress were evaluated and used to characterize the potential responses of the channel to the proposed scenarios.
- Evaluate potential impacts to water surface elevations in Union Slough during a 100-year flood event.
CHAPTER 2.
PROJECT APPROACH

The Union Slough Hydraulic Model Study used a 2-D hydraulic model, RiverFLO-2D, to estimate hydraulic conditions following implementation of the Smith Island Restoration Project. The computer model simulates river and tidal conditions to illustrate flow patterns in Union Slough and across the project site. It describes major hydraulic attributes such as flow direction, velocity, and water depths in addition to many other minor attributes. Through this simulation and analysis of hydraulic attributes, the nature and magnitude of potential erosion and deposition were determined. The study built upon two previous modeling studies that analyzed hydraulic response to the proposed scenarios:

- A three-dimensional (3-D) hydraulic oceanic model developed by Battelle. This study was undertaken with joint funding provided by Snohomish County, the Tulalip Tribes, the City of Everett, and the Port of Everett. It evaluated the separate and combined effects of estuary restoration projects proposed by each partner. The results are summarized in the report Hydrodynamic Modeling Study of the Snohomish River Estuary: Snohomish River Estuary Restoration Feasibility Study (Battelle, 2007).

- A geomorphic assessment that analyzed results from an unsteady HEC-RAS (1-D) river model. The HEC-RAS model had been previously calibrated by West Consultants to stage data on the Snohomish River for the 2009 water year (October 2008 through September 2009.) The results are summarized in the report Geomorphic Characterization and Channel Response Assessment for Union Slough (GeoEngineers/West, 2011).

2.1 MODELED SCENARIOS

The study addressed existing conditions and the two future-conditions scenarios describe below.

2.1.1 Scenario 1—Post-Implementation Conditions for Smith Island Restoration Project

Scenario 1 includes construction of a new setback dike and breaching of two sections of the existing Diking Improvement District No. 5 dike along Union Slough. The proposed alignment of the new dike will enable restoration of approximately 400 acres of estuarine tidal marsh between the dike and Union Slough. The proposed new dike alignment and the location of the proposed breaches in the existing dike are shown in Figure 2. Note that subsequent to completion of this modeling, Snohomish County adjusted the alignment slightly to the east; this adjustment will not materially affect model results.

The new dike top elevation along Union Slough would be 15 feet (using the North American Vertical Datum of 1988 (NAVD 88). Project site features include one major tidal channel with two offshoot channels within the restoration site.

2.1.2 Scenario 2—Post-Implementation Conditions for Smith Island Restoration Project Combined with Blue Heron Slough Project

The Port of Everett purchased the Biringer Farm in 1993 for use in future wetland mitigation projects. The project site was identified as an area of high potential value for restoring estuarine salmon habitat. The Blue Heron Slough project would breach the existing dikes at several locations and return approximately 360 acres to an intertidal marsh environment.
The current project design for the Blue Heron Slough project calls for four dike breaches along existing dikes at the project site. Three of the four breaches are on the Steamboat Slough side and one on the Union Slough side (Figure 2). The width of the downstream-most breach in Steamboat Slough is 300 feet, and the two at the upstream end of Steamboat Slough are 100 feet. The breach on the Union Slough site has an opening of 150 feet. The interior historical tidal channels would be reconnected to Steamboat and Union Slough and the tidal channels dredged down 6 feet deep.

2.2 MODEL SELECTION

The hydraulic model was selected for this study based on the following criteria:

- A 2D model was necessary to provide sufficient detail regarding flow direction, velocity, and shear stress.
- The study needs to model both river and tidal flow.
- The study requires a detailed model mesh (network) to evaluate site-specific project impacts.

The modeling program RiverFLO-2D was selected based on these criteria. RiverFLO-2D is a hydrodynamic, mobile bed model for rivers and estuaries that uses a finite-element method to compute high-resolution flood hydraulics, including supercritical and subcritical flows over dry or wet river beds. Use of a flexible triangular mesh allows the flow field to be resolved around key channel and floodplain features. RiverFLO-2D estimates water surface elevations and two components of velocity, providing detailed two-dimensional channel hydraulics and overbank flooding predictions (Garcia et al. 2006, Garcia et al. 2009). The resulting model has more flexibility and detail (higher density model mesh) than the 3D model (Battelle, 2007), and provides much more information than the 1-D HEC-RAS model.

RiverFLO-2D provides a GIS software environment that allows linking the physical data in GIS layers to mesh nodes and elements. The software provides a variety of mesh generation options to optimize the mesh creation around topographic characteristics such as river banks, dikes, etc. This enables the model to resolve flow issues in a rapidly varied unsteady flow field.

These model capabilities allow the model to analyze the complex flow patterns that currently exist in the lower Snohomish estuary, and how construction of the Smith Island Restoration Project will cause changes to the existing flow patterns. The resulting detailed information enables us to make specific predictions about the magnitude and location of potential channel impacts.

The RiverFLO-2D model was also utilized to compare predicted 100-year flood levels under existing conditions with post-construction conditions for the Smith Island and Blue Heron Slough projects. This model was used instead of the FEMA-effective HEC-RAS model because of the RiverFLO-2D model’s superior ability to analyze the complex flow patterns that will exist after the project is constructed. We believe this provides the most accurate estimation of project impacts to flood levels.

2.3 ELEVATION DATUM

Elevations reported in this document are all referenced to the North American Vertical Datum of 1988 (NAVD88), including tide levels.
2.4 MODEL DESCRIPTION AND DEVELOPMENT – UNION SLOUGH CHANNEL IMPACTS

2.4.1 Model Extents

The model extents (spatial area included in the model) are the same for both the channel impacts and flood level impacts elements. They were chosen to minimize the impacts of boundary conditions and to capture enough of the system to provide accurate results and to model projects in the slough system beyond the Smith Island area. To capture the hydraulic complexity of the area, the model included Steamboat Slough and Ebey Slough in addition to Union Slough. The upstream model extent is approximately 9,000 feet upstream of the Smith Island project area and the downstream extent is approximately 1000 feet downstream of Interstate-5. The RiverFLO-2D mesh and selected cross sections are shown in Figure 3. The following additional features are represented in the model:

- The City of Everett’s Union Slough project site, immediately south of the Smith Island Restoration Project. There are three dike breaches in the City’s Union Slough project. The breaches all have a length of 180 feet and a bottom elevation of 2.0 feet NAVD 88.
- Existing breaches along dikes on Ebey Island and Spencer Island.

2.4.2 Boundary Conditions and Hydrology

Hydrologic boundary conditions for this study were extracted from the unsteady HEC-RAS model developed previously (GeoEngineers/WEST Consultants, 2011). Table 1 lists the HEC-RAS cross sections that were used for each slough, along with the type of information (flow or stage) extracted at each cross section. Note that the downstream boundary stage is the tide height (reported in NAVD88). The study examined flow conditions over a five-day period that included a major storm. A storm from the 2009 water year that represented about a 15-year event was selected. This storm was selected because it was a storm large enough to evaluate the system’s response to a high flow event, it was based on actual historical data rather than being analytically derived, and it had been previously modeled so a reality-check comparison could be made to both observed and previously modeled data. The 5-day length of the hydrograph was selected to balance the model run, but still capture the full storm effects. Upstream and downstream hydrographs for that storm are shown in Figures 4 and 5.

The modeled flood event provides a representative prediction of extreme in-channel erosion forces for Union Slough, as well as overbank flooding. Larger floods would have more widespread inundation, but would not likely result in significantly more erosion in the channel.

<table>
<thead>
<tr>
<th>Table 1. HEC-RAS Cross Sections Used for Boundary Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Selected Cross Section</strong></td>
</tr>
<tr>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Union Slough</td>
</tr>
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<td>Ebey Slough</td>
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<tr>
<td>Steamboat Slough</td>
</tr>
</tbody>
</table>
2.4.3 Calibration and Validation

A good reproduction of water level measurements is generally an acceptable criterion for assessing the validity of a hydraulic model. When actual measurements are not available, 2-D models may be validated by comparison with simplified 1-D models. In doing this comparison, care should be taken because the two approaches represent hydraulic conditions in different ways, leading to approximate but different results. The methods to represent the bed topography and the evaluation of global head-loss relationships in compound channels and floodplains are very different in 1-D and 2-D models:
• One-dimensional models provide a simplified representation of complex flows, linearly interpolating the floodplain boundary between cross sections, and defining the floodplain by subtracting topographic data from the water surface elevations. This often results in a discontinuous floodplain.

• The Manning’s n coefficient for regular head losses is a global measure that accounts for grain and form roughness, variations in shape and size of the channel cross section, obstructions, vegetation, meandering and internal dissipation (Ven Te Chow, 1959). 1-D models are more sensitive to variation in Manning’s n because the roughness factor accounts for internal momentum exchange plus all the above mentioned factors in each cross section.

• Two-dimensional models are able to capture a continuous floodplain represented by a series of mesh elements where flow can occur in both the lateral and longitudinal directions, resulting in a more realistic representation of the flow in the floodplain. Two-dimensional models can resolve finer-scale losses because the 2-D equations incorporate momentum exchanges within the cross section; this intrinsic internal friction tends to generate higher water elevations than 1-D models results (Belleudy, 2000).

For this study, initial model results were compared to results of the calibrated unsteady HEC-RAS model (GeoEngineers/WEST Consultants, 2011), as shown in Figures 6 to 10.

Figure 6. Model Comparison – Existing Conditions Water Surface Elevations at Cross Section 5977, downstream from I-5
Figure 7. Model Comparison – Existing Conditions Water Surface Elevations at Cross Section 7940, downstream end of lower Smith Island proposed breach

Figure 8. Model Comparison – Existing Conditions Water Surface Elevations at Cross Section 8906, upstream end of lower Smith Island proposed breach
Figure 9. Model Comparison – Existing Conditions Water Surface Elevations at Cross Section 10040, at Blue Heron proposed breach

Figure 10. Model Comparison – Existing Conditions Water Surface Elevations at Cross Section 13537, at upper Smith Island proposed breach
Table 2 summarizes the results of the comparison. Within the project area, the difference in modeled water surface elevation between the HEC-RAS and RiverFLO-2D model varies from 0 to 1 foot. The elevations computed by the 2-D model were higher than those computed by the HEC-RAS model.

<table>
<thead>
<tr>
<th>Cross Section Station</th>
<th>Average Modeled Water Surface Elevation (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RiverFLO-2D</td>
</tr>
<tr>
<td>Below I-5 (5977)</td>
<td>6.3</td>
</tr>
<tr>
<td>Downstream end of lower Smith Island breach (7940)</td>
<td>7.5</td>
</tr>
<tr>
<td>Upstream end of lower Smith Island breach (8906)</td>
<td>8.0</td>
</tr>
<tr>
<td>Blue Heron Slough breach (10040)</td>
<td>8.7</td>
</tr>
<tr>
<td>Upper Smith Island breach (13537)</td>
<td>10.5</td>
</tr>
</tbody>
</table>

A notable difference between the two models is that the existing-conditions HEC-RAS model does not contain storage areas. In a non-tidally influenced system, omitting storage is assumed to provide more conservative results. However, in a tidally influenced basin, the tides provide an unlimited volume of water that can fill storage areas and result in higher water surface elevations for a given storm. This result is shown in the results of the Smith Island analysis described below. The RiverFLO-2D model does contain floodplain storage, which could be one reason water surface elevations are higher for the peak event than in the HEC-RAS model.

The RiverFLO-2D model was determined to be valid, because the water surface elevations are within an acceptable range for comparing a 2-D model to 1-D model results. In addition, the hydraulic response of the slough system matches the historical observations as well as the results of previous modeling efforts – including predicted ranges and expected changes in shear stress and velocities.

### 2.5 MODEL DESCRIPTION AND DEVELOPMENT – FLOOD LEVEL IMPACTS

#### 2.5.1 Model Extents

As mentioned previously, the model extents (spatial area included in the model) are the same for both the channel impacts and flood level impacts elements. They were chosen to minimize the impacts of boundary conditions and to capture enough of the system to provide accurate results and to model projects in the slough system beyond the Smith Island area.

#### 2.5.2 Boundary Conditions and Hydrology

The 100-year hydrographs and tidal boundary conditions were extracted from the existing FEMA model at the same locations and using the same methodology described above for the January 2009 storm. The cross sections used for the boundary conditions are presented in Table 1.
This flood hydrograph, used in the effective FEMA model, is the basis for current Flood Insurance Rate Maps (FIRM) used by Snohomish County for flood risk determinations. The flood occurs over a ten-day period, with the peak flow rate occurring on the third day.

The flow and stage hydrographs used in the boundary conditions are shown in Figures 11 and 12. To reduce the model run time, we did not model the entire 10-day storm; the model was run long enough to capture the peak flows and water surface elevations. This is illustrated in Figures 11 and 12 by the abrupt end of hydrographs.

Figure 11. Modeled Hydrographs at Upstream End of Study Area
2.5.3 Calibration and Validation

To determine the effectiveness of the 2-D model for use with the 100-year flood, the model results for the existing conditions were compared to the effective FEMA 100-year flood elevations at cross sections in the project area. Actual calibration data for the 100-year flood was not available as there are no high water marks or surveyed water surface elevations on Union Slough. Because our analysis was focused on comparing post-project flood levels to existing conditions, the uncalibrated model was adequate as long as it represented expected flow conditions and compared well with the established FEMA model.

A comparison of the 2-D water surface elevations with the effective FEMA water surface elevations is show in Table 3; Figure 13 shows the approximate location of the FEMA cross sections. The 2D model shows a greater backwater effect caused by the I-5 bridge than the effective FEMA model, and as a result the water surface elevations computed are up to 1.4 feet higher upstream of the I-5 bridge. Further upstream the water surface elevations in the 2-D model more closely match the effective FEMA model – differing by approximately 0.6 feet. Downstream of the I-5 bridge, the water surface elevation computed by the 2-D model was 0.3 feet higher. We determined that these results validated use of the 2-D model for comparative purposes in estimating project impacts to flood levels.
<table>
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<th>FEMA Cross Section Letter</th>
<th>FEMA Effective water surface elevation (feet)</th>
<th>2-D water surface elevation (feet)</th>
<th>Difference (feet)</th>
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<tr>
<td>H</td>
<td>15.5</td>
<td>16.1</td>
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</table>
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CHAPTER 3.
MODEL RESULTS

This chapter presents water surface elevation, flow velocity, and bed shear stress for each modeled scenario. These parameters are indicative of how the Smith Island Restoration Project will change channel conditions and flood levels within Union Slough and on the project site.

3.1 BACKGROUND FOR ASSESSING RESULTS

3.1.1 Flow

Results described in this report represent extreme conditions during high-flow periods:

- Union Slough channel impacts were evaluated using the January 2009 storm event. The January 2009 storm event represents the highest flow event of the modeled period, an approximately 15-year recurrence interval flood event. High flows were modeled for this study instead of low flows to provide a conservative illustration of potential project impacts on the Union Slough channel. Modeling of average flow conditions, presented in the GeoEngineers/WEST study (2011), indicated that the high flow period would be most appropriate for evaluating potential erosion impacts.

- Flood level impacts were evaluated using the 100-year flood hydrograph that was used as a basis for FEMA flood risk mapping. This flow level was selected because it is widely recognized as the base flood for floodplain management.

3.1.2 Tide Levels

The flows in Steamboat and Union Sloughs interact extensively during normal flows and flood flows. During typical river flows, the tide cycle dominates flow patterns and water levels. The incoming tide causes upstream flow in Union and Steamboat Sloughs. During ebb tides, water in Steamboat Slough utilizes the Buse Cut as a shortcut through Union Slough to Puget Sound. This unusual flow pattern results in a condition in which more water flows out through Union Slough on the ebb tide than flows in on the flood tide. Following implementation of the Smith Island Restoration Project, the volume of water that flows into Union Slough on the flood tide will increase because of the tidal momentum created by the restored tideland (Battelle, 2007).

Channel Impacts Analysis

The tide levels modeled over the five-day period of the flood are incorporated in the downstream hydrographs shown in Figure 5. Previous studies have indicated that the maximum velocity and shear stress will be downstream from the project site, and will be highest during ebb tides when all of the water on the project site will exit to the west in Union Slough (GeoEngineers/WEST 2011), hence that flow condition was our focus. The peak flow of the January storm event occurs during an ebb tide. The water surface elevation at the downstream boundary is approximately 5.8 feet at the peak of the storm.

Flood Level Impacts Analysis

The tide levels modeled for the flood level impacts analysis are shown in Figure 12. The tides were extracted from the FEMA model – which used a tidal elevation based on FEMA protocol. FEMA protocol provides a conservative downstream boundary that represents a high tide scenario. The water surface elevation at the downstream boundary is approximately 10.6 feet at the peak of the storm.
3.1.3 Erosion Threshold Evaluation

Shear stress is the primary flow parameter used to estimate where erosion will occur. Shear stress increases as flow velocity and water depth increase. The shear stress threshold for erosion is determined primarily by the size and cohesiveness of sediment in the channel and channel banks. Vegetative cover, including roots can also influence when and where erosion will actually occur.

The Union Slough geomorphic evaluation (GeoEngineers/WEST, 2011) recommended a bed shear stress threshold of 0.220 pounds per square foot to estimate when erosion may occur. This value was selected based on field observations regarding the cohesive nature of the channel bed and bank material. The current study did not include a geomorphic assessment, and utilizes the GeoEngineers/WEST study to source the recommended erosion threshold.

Velocity is also a significant indicator of erosion potential. The 2011 geomorphic characterization recommended flow velocities exceeding 6.5 feet per second as a threshold for potential erosion.

3.2 FLOW VELOCITY RESULTS

Results for modeled flow velocities at the peak of the January 2009 flood are shown in Figures 14 through 22. Flow direction and magnitude are illustrated by arrow direction and color. Note that concentrations of velocity arrows do not indicate areas of flow concentration, but rather areas where the model grid is more fine-grained to provide more detailed, closely-spaced results.

Although areas of erosion are predicted more accurately through shear stress, velocity is also a significant indicator. Areas with flow velocities exceeding the proposed 6.5-foot-per-second velocity threshold for potential erosion are shown in orange and red on the maps of model results.

3.2.1 Existing Conditions

Results from the existing conditions model run show that flow is contained within the Union Slough channel except in the mid-Spencer Island reach where some flow diverts east to Steamboat Slough through mid-Spencer Island. Flow velocities are within the range where erosion could be expected along the south side of the channel on the outside of the meander bend at the north end of the project site, and downstream from I-5 just below the Buse log ramp. The meander bend location did experience erosion during the 2009 event, and the levee has recently been repaired.

3.2.2 Scenario 1 (Smith Island Restoration Project Implemented)

Comparison of flow velocity results from existing conditions (Figures 14 – 16) and Scenario 1 (Figures 17 – 19) illustrate how the Smith Island dike breaches would alter the velocity distribution. Figure 17 shows flow entering the project site through the upstream breach and spreading out across the project site. Flow entering through the southern portion of the upstream breach will spread to the south and west, eventually turning back north to flow out the downstream breach. Flow velocities throughout the project site, and within Union Slough, are slow (less than 2 feet per second) and would not cause erosion. Notably, the flows within Union Slough upstream from the lower breach are reduced to the 0.2 foot per second range from existing conditions because of the additional area within the project site for the water to spread.

Within Union Slough downstream from the lower breach, modeling for Scenario 1 indicates a similar velocity magnitude and pattern to existing conditions as flow exits from the project site and flows west through Union Slough. During the modeled flood, these velocities fall within the range where erosion could occur. The velocity pattern is also similar to existing conditions near the Buse Timber Company log
ramp downstream from the I-5 bridge. The velocity increase that occurs under both existing and with-
project conditions at that location could be caused by flow accelerating through a constriction at the log
ramp.

3.2.3 Scenario 2 (Smith Island and Blue Heron Projects Implemented)
The hydraulic modeling indicates an altered flow pattern of flow velocities if the Smith Island and Blue
Heron Slough projects are both implemented (Figures 20 – 22). In the upper portion of the Smith Island
Restoration Project and Union Slough, above the upstream breach, the flow velocity pattern and
magnitude would be similar to those of Scenario 1. Below that point, flow velocities are slightly higher
for Scenario 2, though still lower than levels at which erosion could be expected.

The biggest change over Scenario 1 is shown at the Smith Island Restoration Project downstream breach.
Where all flow would have to exit out through Union Slough under Scenario 1, with Scenario 2 a portion
of flow from the lower Smith Island breach would flow upstream in Union Slough to the Blue Heron
Slough breach, then flow across the Blue Heron site and exit out Steamboat Slough.

Within Union Slough downstream from the lower breach, modeling for Scenario 2 indicates a similar
velocity magnitude and pattern to existing conditions as flow exits from the project site and flows west
through Union Slough. During the modeled flood, these velocities fall within the range where erosion
could occur. The velocity pattern is also similar to existing conditions near the Buse Timber Company log
ramp downstream from the I-5 bridge. The velocity increase that occurs under both existing and with-
project conditions at that location could be caused by flow accelerating through a constriction at the log
ramp.

3.3 BED SHEAR STRESS RESULTS

Figures 23 through 25 illustrate model results for bed shear stress, a primary indicator for erosion
potential. The potential erosion threshold of 0.221 pounds per square foot recommended in the Union
Slough Geomorphic Characterization (GeoEngineers/WEST, 2011) is noted in these figures to delineate
where that threshold is exceeded: areas that exceed the threshold are shown in red, orange, and yellow.

3.3.1 Existing Conditions

The results indicate that under existing conditions, shear stress is within the range for potential erosion
throughout much of Union Slough during a flood such as the January 2009 event. Highest shear stresses
occur just downstream from the I-5 bridge. Areas of lower shear stress occur within channel embayments
along the south bank just below the Smith Island Restoration Project lower breach location, and below the
Buse log ramp where the Union Slough channel widens.

3.3.2 Scenario 1 (Smith Island Restoration Project Implemented)

Under the Smith Island Only scenario, bed shear stresses in Union Slough upstream from the lower
breach are reduced, compared to existing conditions, to below the potential erosion threshold. Shear stress
patterns are similar to existing conditions in the reach just below I-5 where existing conditions modeling
indicates possible erosion. The model results show additional areas where the potential erosion threshold
may be exceeded:

- Within the project site near the lower breach—this is caused by the convergence of flow at
  the lower breach.
- At the mouth of the tidal channel within the project site—this may indicate enlargement of
  the lower portion of the tidal channel.
• In Union Slough downstream from the lower breach and above I-5 along the right (north) bank.

• Starting from the vicinity of the Buse log ramp and extending downstream. The existing constriction in the channel at the Buse log ramp (see Figure 28) likely creates this situation currently. With project implementation, the increased flow through this reach on an ebb tide will magnify the effect. The model predicts new areas of bed shear stresses in the 0.221-0.500 pounds per square foot range (just above the predicted erosion threshold) downstream from the Buse log ramp, and centered within the channel.

3.3.3 **Scenario 2 (Smith Island and Blue Heron Projects Implemented)**

The modeled Smith Island plus Blue Heron Slough scenario illustrates similar results to Scenario 1, with the following differences:

• Above threshold shear stresses at the lower breach are more widespread across the Smith Island Restoration Project, and higher on the eastern (upper) portion of the breach. This is related to the flow in this area going toward the Blue Heron Project breach, which is located just upstream.

• In Union Slough downstream from the Buse log ramp, the increased shear stresses are slightly more widespread across the channel, but not increased in magnitude.

3.4 **FLOOD LEVEL RESULTS**

Figures 26 shows the increase or decrease in predicted water surface elevation for Scenario 1 compared to existing conditions; Figure 27 shows the difference from existing conditions for Scenario 2. Areas shown in blue would have reduced water surface elevation with the implemented scenario; areas in green would have higher water surface elevations.

For both scenarios, the water surface elevations decrease in Union Slough and the Smith Island project area. This may be attributed to the following:

• Under existing conditions during the 100-year flood, the model predicts widespread flooding, including the Smith Island and Hima Farms property. Without the proposed Smith Island setback dike in place, the Interstate-5 bridge causes a backwater effect, which raises water surface elevations. This backwater effect is focused just upstream from the I-5 bridge, as flow through the bridge is concentrated directly at the bridge opening.

• Under Scenario 1 (Smith Island project only), the proposed project dike moves the hydraulic bottleneck upstream to the terminus of the proposed dike, slightly decreasing the backwater effect and lowering water surface elevations through the project area. The decrease in water surface elevations in Scenario 1 is on the order of a few tenths of a foot within the project area. The decrease in Union Slough near the I-5 bridge is on the order of 1 to 2 feet. The large decrease in water surface elevations in the area landward of the proposed dike is caused by the protection provided by the new setback dike.

• For Scenario 2 (Smith Island project and Blue Heron Slough project), the water surface elevation within the project area is still lower than existing conditions. However, the breach in the North Spencer Island dike for Blue Heron project effectively adds another outlet on Union Slough, which increases water surface elevations in North Spencer Island, Ebey Island, and Steamboat Slough.
CHAPTER 4. POTENTIAL IMPACTS ON UNION SLOUGH

The hydraulic modeling conducted for this study indicates that Union Slough hydraulics are likely to be changed by implementation of the Smith Island Restoration Project and the combined implementation of the Smith Island and Blue Heron Slough projects. These alterations include changes in flow velocities, flow directions, and bed shear stresses. Potential impacts from the altered flow hydraulics include erosion, sedimentation, and increased inundation from higher water surface elevations.

4.1 EROSION AND SEDIMENTATION

The model indicates that increased shear stresses during high flow events could cause erosion within the project site at the lower breach and within Union Slough downstream from the lower breach. Downstream from the Buse log ramp, this erosion would likely be distributed across the channel and could cause some erosion of existing dikes. As reported in previous model studies, the infrequency of these high flow conditions and the historically stable channel position suggest that erosion will be minor and readily mitigated through bank protection.

Sedimentation is not indicated by the model results. Although flow velocities in Union Slough above the lower breach will decrease, this will not inhibit the slough’s sediment transport capacity, particularly given the fine-grained nature of the sediment load through this reach (primarily fine sand and silt). Based on these results, channel depth in Union Slough is not likely to be reduced due to sediment deposition. Under lower flow conditions, not modeled as part of this study, localized areas of deposition may occur adjacent to the project site, particularly in back-eddies of tidal channel and breach connections to Union Slough. Higher shear stresses below the Buse log ramp will prevent sediment deposition and may help flush existing sedimentation at this location.

4.2 BUSE TIMBER COMPANY

The Buse Timber Company is located on the south bank of Union Slough immediately west of Interstate 5. Buse has logs delivered to the site by log rafts via Union Slough. The option of delivering logs by water is critical to Buse’s business, as rafting logs is an economical transport method and logs can be sourced by water when truck transported logs are not available. Buse Timber has been in business for decades and has adapted its operations to the existing conditions. The existing hydraulic conditions in Union Slough do not currently pose a significant restriction to the company’s operations.

4.2.1 Log Delivery and Storage

Rafted logs are delivered to the site by a towing company. Logs are delivered during a high tide from Puget Sound, up Steamboat Slough, through the Buse Cut and down Union Slough (see Figure 1). Log delivery is timed to coincide with normal timber operations: Monday through Friday during daylight hours. Logs cannot be delivered to the site up Union Slough at high tide due to the low rise of the Highway 529 bridge over Union Slough, west of I-5. Only rarely during storm events or extremely high river flow events can logs not be delivered at high tide.

Rafted logs are deposited in a chained-log and timber pile crib on the south bank of Union Slough called the pocket (see Figure 28). Buse Timber has a 10-year renewable Aquatic Lands Commercial Lease for the pocket through the Washington State Department of Natural Resources. The current lease expires in December 31, 2014. A Buse Timber work boat pushes or pulls logs within the pocket toward a quarry-spall-surfaced access ramp in the southwest corner of the pocket (see Figure 28). A loader picks logs from the water and deposits them on the shore or directly onto trucks that ferry the logs to the log yard. The
The loader is electrically powered, without hydraulic machinery, to avoid the risk of fuel or hydraulic fluid spills.

Figure 28. Buse Log Pocket and Access Ramp

Removal of logs from the pocket typically takes 2 to 3 hours. Log removal is halted until the next high tide when the water level in Union Slough drops to the bottom of the rocked portion of the access ramp, below which the loader would be unstable, or at dusk due to worker safety. Ideally all logs are removed from the water during one period as logs can float out of the pocket during the next low tide and be lost.

4.2.2 Effect of Alternatives on Buse Timber Operations

Based on the hydraulic modeling conducted for this study, the altered hydraulics in Union Slough may impact the Buse Timber Company log delivery in the following ways:

- Flow velocities and flow direction changes within Union Slough are not of a magnitude that would impede log delivery.
- The portion of the channel used by Buse for log storage—the pocket—will continue to be a protected area, with the force of flow in Union Slough on the north side of the channel. Logs left in the pocket during ebb tides may be subject to stronger current action, increasing the risk of escapement.
- Buse is limited mostly by low water levels when removing logs at the log ramp. Water levels will be the same following project implementation.
- Buse does not receive or unload logs during flood events when flow conditions may be less predictable and unsafe.
4.3 FLOOD LEVEL IMPACTS

The modeling conducted for this study indicates that there will be generally lower flood levels following construction of the Smith Island Restoration Project. Flood levels will be lowered by 1 to 2 feet in Union Slough near the I-5 bridge and by a few tenths of a foot elsewhere in Union Slough and in the Smith Island project area. The effect of this will be reduced flooding on adjacent properties during an extreme flood. Localized hydraulic effects around the new setback dike show a very minor impact on flood levels.

Modeling results also indicate that flood levels will be further reduced on the project site following construction of both the Smith Island and Blue Heron Slough projects. This would be caused by the diversion of flow that is currently exiting through Union Slough. Following construction of the Blue Heron Slough project, a portion of that flow will divert to the north, across North Spencer Island to Steamboat Slough. As shown on Figure 27, water surface elevations on North Spencer Island would increase by several feet, which is expected due to the proposed dike breaches.
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REFERENCES


Cook, A.C. Comparison of one-dimensional HEC-RAS with Two-Dimensional FESWMS model in flood inundation mapping. MSc Thesis. Purdue University. May 2008.


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Figure 2. SMITH ISLAND ESTUARINE RESTORATION PROJECT COMPONENTS
Figure 13. APPROXIMATE LOCATION OF FEMA CROSS-SECTIONS USED FOR 2D MODEL VALIDATION
Figure 14. JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR FLOW VELOCITY AND DIRECTION, EXISTING CONDITIONS
Figure 15. JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR FLOW VELOCITY AND DIRECTION, EXISTING CONDITIONS, UPPER PROJECT AREA
Figure 16. January 2009 15-Year Event Modeling Results for Flow Velocity and Direction, Existing Conditions, Lower Project Area
Figure 18.

JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR FLOW VELOCITY AND DIRECTION, SCENARIO 1 (WITH SMITH ISLAND RESTORATION PROJECT), UPPER PROJECT AREA
Figure 19.
JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR FLOW VELOCITY AND DIRECTION, SCENARIO 1 (WITH SMITH ISLAND RESTORATION PROJECT), LOWER PROJECT AREA

Snohomish County
Smith Island Estuarine Restoration
UNION SLOUGH HYDRAULIC MODEL STUDY
Figure 20. JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR FLOW VELOCITY AND DIRECTION, SCENARIO 2 (WITH SMITH ISLAND RESTORATION PROJECT AND BLUE HERON SLOUGH PROJECT)
Figure 21. JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR FLOW VELOCITY AND DIRECTION, SCENARIO 2 (WITH SMITH ISLAND RESTORATION PROJECT AND BLUE HERON SLOUGH PROJECT), UPPER PROJECT AREA.
Figure 22. JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR FLOW VELOCITY AND DIRECTION, SCENARIO 2 (WITH SMITH ISLAND RESTORATION PROJECT AND BLUE HERON SLOUGH PROJECT), LOWER PROJECT AREA
Figure 23.
JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR BED SHEAR STRESS, EXISTING CONDITIONS
Figure 24. JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR BED SHEAR STRESS, SCENARIO 1 (WITH SMITH ISLAND RESTORATION PROJECT)
Figure 25.

JANUARY 2009 15-YEAR EVENT MODELING RESULTS FOR BED SHEAR STRESS, SCENARIO 2 (WITH SMITH ISLAND RESTORATION PROJECT AND BLUE HERON SLOUGH PROJECT)

Bed Shear Stress (lb/sq. ft.)

- 0.000 - 0.220
- 0.221 - 0.500
- 0.501 - 0.800
- 0.801 - 1.100
- 1.101 - 1.400
- 1.401 - 1.700
- 1.701 - 2.100
- 2.101 - 2.400
- 2.401 - 2.700
- 2.701 - 3.000

Proposed Setback Dike Alignment

Units:
- Feet
- Meters
Figure 26. MODELING RESULTS FOR WATER SURFACE ELEVATION COMPARISON, EXISTING CONDITIONS VS. SCENARIO 1 (SMITH ISLAND RESTORATION)