December 2013

To Whom It May Concern:

To aid in understanding the technical document review process, the involvement in the process by Diking Improvement District #5, and to track the various documents involved in that process, the following are appended for consideration:


3. County’s Response to Smith Island Restoration Project; Tasks 1-4 Report Review; Comments, Findings, and Recommendations Report, prepared by SNR COMPANY.

If there are questions or concerns regarding this compilation, please contact Bob Aldrich, 425-388-6424, Project Manager, Smith Island Restoration Project.

Thank you,

Bob Aldrich
Project Manager
Smith Island Restoration Project
Smith Island Restoration Project; Tasks 1-4
Report Review; Comments, Findings, and
Recommendations Report
Based on Exhibit A – Scope of Services for the Diking Improvement District 5 Related
to Smith Island Restoration Project Technical Studies and Analysis

FINAL DRAFT

Prepared for:
Diking Improvement District Number 5

Prepared by:

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April 2013
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1 INTRODUCTION

SNR has been retained by the Diking Improvement District Number 5 (DD5) Commissioners to conduct peer reviews and prepare comments for technical reports being used by Snohomish County for a project that will include the seasonal and tidal flooding of approximately 400 acres of Snohomish County owned (as of 2002), levee protected farmland. The County proposes to construct a setback levee to protect private properties located west of the proposed project prior to breaching the existing levees at two locations with the goal of creating a tidally influenced fluvial environment as part of a salmon habitat restoration program. The proposed setback levee and restoration project is located within the northeastern portion of Smith Island (Figure 1-1 – Site Location on Google Earth Professional, July 2012 Air Photograph).

Figure 1-1 - Site Location on Google Earth Professional, July 2012 Air Photograph

The studies and reports prepared for or by Snohomish County and other reports the county is using were used to obtain several types of information, such as existing and potential changes in surface water drainage in the areas located landward of the proposed setback levee, potential impacts to ground water quality from saltwater intrusion after the existing levees are breached, and the impacts to the Union Slough after the breaching of the existing Smith Island levee system currently maintained by the DD5.

The studies conducted to identify potential impacts to Union Slough also focused on impacts to water elevations in Union Slough, increased river bed and bank scour, and the potential for channel migration. These studies predict potential flood elevations, including different flooding scenarios. However, none of these studies (including modeling) focused on what the flooding impacts would be if all of the existing unmaintained DD5 levees in the proposed restoration area are gone.

None of the reports SNR reviewed address what will happen to the remaining unmaintained levees after the breaches have been conducted. The erosion from high river flows, tidal currents, and from wind driven wave action (fetch) is not discussed. Additionally, the affects of the proposed restoration activities, such as the placement of large woody debris and the “sculpting” of the proposed restoration area were not discussed in the channel migration reports.
Another reason Snohomish County performed studies, had studies conducted, and is referencing other studies conducted for the proposed Smith Island Restoration project is to provide the information necessary for a SEPA EIS that must be completed (finalized) to determine all of the potential environmental impacts the proposed Smith Island Restoration Project may have.

1.1 TASKS

SNR’s contract with the DD5 includes four (4) specific tasks with each task including subtasks. This draft report is a required subtask component of all four tasks. The four tasks are described in the contract as:

- Task 1 – Review of Studies of Drainage for Landward Side of Proposed Dike
- Task 2 – Review of Studies of Impacts to Union Slough
- Task 3 – Review of Study of Potential Dike Overtopping
- Task 4 – Review of Study of Potential Salt Water Intrusion

Because the studies conducted for Tasks 2 and 3 are similar and both included surface water modeling, these tasks and a review of financial impacts to the DD5 were specifically excluded from commenting, but not from review for reference purposes.

The subtasks for each Task included a site visit, however, it was determined that one site visit would be sufficient to meet the requirements for all tasks. Based on this SNR’s hydrogeologists and engineering geologist’s tasks included a site visit, the review of the documents Snohomish County provided on their FTP site, the preparation of questions developed by SNR during the document review, attendance of a meeting with the Commissioners and with the Commissioners, Snohomish County representatives, and the County consultants to discuss SNR’s questions.

As a result of the meeting with the Commissioners, Snohomish County and its consultants, SNR requested additional information and documentation from Snohomish County. The additional information and documents the County agreed to provide were eventually provided (with some exceptions) to SNR on the Snohomish County FTP site.

This draft report provides a summary of SNR’s comments for the documents Snohomish County provided to SNR. SNR’s comments in this draft report also consider the County’s limited answers to SNR’s questions (provided to Snohomish County by the DD5 on February 6, 2013) during the February 7, 2013 meeting held at the Buse Lumber meeting room. SNR’s comments also consider additional information and documents provided by Snohomish County per SNR’s request in an e-mail to Peter Ojala dated February 8, 2013. SNR’s comments also consider the June 2011, Draft Environmental Impact Statement (DEIS) prepared by Snohomish County, which SNR also reviewed but did not provide comments per instructions from the DD5 commissioners.

SNR’s findings and conclusions are presented as separate sections of this draft report. These findings and conclusions are provided to meet the requirements of the subtasks and are based on the comments SNR has provided for each report reviewed by Task...
2 DOCUMENTS REVIEWED

A total of 10 reports were provided by Snohomish County on its FTP site (of which was the DEIS, which was reviewed by SNR, however, SNR was directed to not provide comments on the DEIS). Snohomish County divided these reports into four “tasks” for SNR’s licensed hydrogeologists and engineering geologists to review as defined in SNR’s contract with the DD5. The purpose of the Task 1 was to review surface water “drainage” reports; Tasks 2 and 3 (combined into one task) was the review of geomorphic and “floodplain” modeling reports of the Union Slough and vicinity, including modeling conducted to determine potential scouring and flooding potential; Task 4 was a review of reports prepared to address the potential for saltwater intrusion. The following is a list of the documents for each of the review tasks1 (1 through 4):

2.1 Task 1

1. Draft Snohomish County Smith Island Drainage Analysis, Second Draft, November 2012, prepared by TetraTech


2.2 Tasks 2 and 3


2. Smith Island Levee Analysis for [the] Everett Water Pollution Control Facility and Diking District No. 5, Prepared for the City of Everett, October 2007, prepared by ESA Adolfsen


4. Draft, Snohomish County, Smith Island Estuarine Restoration Union Slough Hydraulic Model Study, November 2012, prepared by TetraTech

5. Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared for CH2M Hill, prepared by West Consultants

2.3 Task 4


It should be noted that some of these reports include other reports as attachments and appendices. In some cases a major portion of the report is the Appendices. For example, the Geologic and Hydrogeologic Field Investigation Report, Smith Island Restoration Project by Bailey includes numerous Appendices for test pit logs, well logs, and laboratory data.

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1 This is the list of contractually listed documents. However, SNR’s also reviewed all other documentation Snohomish County provided as a response to SNR’s February 8, 2013 request for additional information.
As discussed above, Snohomish County provided some of the additional information and reports SNR requested, the following is a listing of the reports and other documents Snohomish County provided and were reviewed by SNR:

2.4 Additional Documents and Information Provided by Snohomish County


3 OVERVIEW

Snohomish County purchased farmland in the northeastern Smith Island area (approximately 2002). As part of the County’s federal salmon recovery effort\(^2\), the County has determined that the Smith Island farmland it had purchased could be used as part of the County’s salmon recovery requirements if the Diking Improvement District 5 levees protecting this portion of the Smith Island are breached and the tidally influenced Union Slough is allowed to flood the farmland. By definition, what Snohomish County has defined as “restoration activities” is the seasonal and tidal flooding of farmland. The justification for determining that this is a restoration project was apparently based on the conclusion by the County that this farmland was an “estuarine” tidal marsh, prior to European settlement of the Everett/Marysville area.

This proposed Smith Island Restoration project would generally include the construction of a setback levee along the Snohomish County eastern property line to protect private property immediately west of the proposed restoration area. After the setback levee is designed and then constructed to meet the U.S. Army Corps of Engineers (USACE) performance standards for levees, the existing left bank levee that bounds the eastern and northern portions of the proposed restoration area would be breached in two locations, to allow, seasonal, tidally influenced “river water” in the Union Slough (east and north of the existing levee system) to flood the farmland with the goal of creating estuarine marsh and/or mudflat conditions presumed to exist prior to the construction of the existing levee system currently owned and maintained by the DD5.

These proposed activities will be conducted within the Snohomish River Delta complex, which includes three channels (sloughs) that branch from the Snohomish River main stem, south and north of Ebey Island (Figure 3-1 – Snohomish River Delta Complex showing Main Stem and Sloughs on 2011 Marysville and Everett Quad Topographic Maps). The three sloughs (Ebey Slough, Steamboat Slough and Union Slough) converge at the mouth of a single channel near the northwestern portion of Smith Island.

As with many Puget Lowland rivers, the Snohomish River and the sloughs (distributary channels) that formed in the delta have been confined by the construction of levees during the late 19\(^{th}\) and early 20\(^{th}\) century, in addition to other modifications, including dredging and the removal of “snags” to make the river and sloughs more navigable (during early settlement of this area, the primary mode of transportation was on the rivers).

As settlement increased and logging activities continued, agriculture became an important industry. Small settlements evolved into towns and eventually cities, with many of these settlements being near or on rivers. Farmland was developed in the river valleys; however, seasonal river flooding was a pervasive problem. Additionally, what was considered to be very good farmland was located in tidally influenced areas that are also subject to seasonal flooding.

To address the river (and in some cases stream) flooding, levees and other flood control measures were constructed by land owners and in some cases, by communities. The Levees (dikes) that were constructed to confined the rivers and streams within their banks to allow farming on agricultural land within the tidally influenced and seasonally flooded areas to be conducted year-round.

Recognizing the need for levee systems and other flood control measures and the need to share the costs associated with this undertaking, the Washington State legislature enacted state codes in 1895 to create drainage districts and diking districts, which were combined into a single code (85 RCW) in 1909. Improvement districts (drainage, diking, and sewerage) were organized in 1913 (Ch. 85.08 RCW, Ch. 85.15 RCW).

\(^2\) Per page 2 of the DEIS: To help meet federal mandates for salmon recovery, the Snohomish County Council unanimously passed Resolution 05-026 in May 2005 supporting the ten-year habitat improvement milestones identified in the Snohomish Basin Salmon Conservation Plan,
Figure 3-1- Snohomish River Delta Complex showing Main Stem and Sloughs on 2011 Marysville and Everett Quad Topographic Maps
The adoption of state codes allowing the creation of drainage and diking districts led to major changes in the hydrology of rivers and tidally influenced areas that not only included the installation of more levees, it also included the diversion of rivers and streams, dredging activities, and the construction of extensive drainage ditch systems. This also included other controls that reduced flooding and made more agricultural land available for farming year-round. These controls if maintained, also significantly constrained channel meander.

Federal agencies also implemented flood control and drainage programs. The United States Army Corps of Engineers conducted (and continues to conduct) flood control activities, including the construction of levees, flood control facilities, including dams (e.g., the Howard Hansen Dam), and dredging activities to reduce the potential for flooding to insure that the waterways remain navigable.

The Soil Conservation Service (now the National Resource Conservation Service – NRCS), a division of the United States Department of Agriculture, also had extensive flood control and drainage programs, many of which continue to the present. In fact, the Soil Conservation Service was so active at conducting drainage and diking programs during the 1960s that the need for many diking and drainage districts became somewhat unnecessary, which resulted in many of the Diking Districts being suspended.

However, since the conversion of the Soil Conservation Service to the NRCS, virtually all drainage programs in the Puget Lowlands have been eliminated and the agency has greatly limited levee construction and maintenance activities. This has led to a resurgence of “reactivated” drainage and diking districts to protect farmland and in many cases, developed areas (e.g., the DD5 levees provide more protection to non-farmland areas than to farmland).

The Snohomish River and the delta distributary channels (sloughs) have had levee protection for a long time (many predating 1911, including the levees on Smith Island) per the 1911 USGS Topographic Map of the Mount Vernon Quadrangle and these levees (and associated drainage systems) have generally been maintained as necessary to insure that they function correctly. This system of maintained levees has essentially sequestered the Snohomish River and the associated distributary channels on the Snohomish River delta to the confines of these levees. These conditions are now considered to be the “normal” river hydrology and as with any hydrologic system, any changes in the system, will result in changes in the hydrology and the fluvial geomorphology of the system.

Snohomish County realized that the proposed restoration activities will result in potential impacts that could create changes the hydrology and fluvial geomorphology of Union Slough. These changes may also result in impacts to ground water, surface water, and an increase the flooding potential of the private properties landward of the proposed setback levee.

Additionally, the proposed Smith Island Restoration project would change how surface water drains from the private properties that would be located immediately west of the proposed setback levee because one of the tidal channels located in this area will be cut off by the proposed setback levee (Tidal Channel A – eastern tidal channel).

This tidal channel is currently part of the drainage system used by the landowners on the private properties. If the proposed restoration activities are conducted Tidal Channel A will be located east of the proposed setback levee, eliminating existing drainage to this tidal channel from these private properties.

It is believed that the reason several studies were conducted by or for Snohomish County since 2003 was to evaluate the potential impacts the proposed restoration project would have on the Union Slough, the surrounding properties, and on the navigability of the Union Slough. These studies were used in the initial SEPA process to identify potential environmental impacts; however, this apparently led to the County developing a SEPA Environmental Impact Statement (EIS) to address the potential environmental and other impacts in more detail.
The potential impacts to private property and local industry associated with the proposed restoration project were identified by stakeholders and others during the initial SEPA EIS review process. To address the concerns raised during the EIS review process, Snohomish County used existing studies, had additional studies conducted, and the County conducted a study to determine how the proposed restoration project may impact surface water drainage landward of the proposed setback levee, assess the potential impacts to the hydrology and fluvial geomorphology of the Union Slough, evaluate the potential of dike overtopping (of the proposed setback dike), and to evaluate potential impacts to ground water quality by saltwater intrusion.

This draft report has been prepared as a condition of SNR’s contract with the DD5 and summarizes SNR’s independent peer review comments on the studies and reports provided to SNR on the Snohomish County FTP site or January 25, 2013 and additional information and documents from Snohomish County requested in a SNR e-mail, dated February 8, 2013 per the February 7, 2013 meeting where Snohomish County discussed some of the 178 questions SNR generated during the initial document review. This report also provides SNR’s findings and recommendations in separate sections to address the other subtask requirements.

The following sections summarize SNR’s comments for each task, which are followed by sections on SNR’s findings and recommendations.
4 Task 1 Comments

SNR’s contract describes this as the “Review of Studies of Drainage for the Landward Side of Proposed Dike”. Task 1 includes the review of two documents, a document prepared by TetraTech entitled Draft Snohomish County Smith Island Drainage Analysis, Second Draft, November 2012, and a document prepared by Steven Cahill, PE entitled, Smith Island Restoration Project, West Side Drainage, Preliminary Report, March 2011, Snohomish Conservation District; however, the Cahill report is included as an Appendix B in the TetraTech report, therefore this review focuses on the TetraTech report because SNR reviewed the Cahill report included in the TetraTech report.


The unauthored TetraTech Technical Memorandum (it is customary to include the name of the author(s) even in draft documents that are submitted for independent peer review) states (page 1):

This analysis builds upon the drainage system description developed by the Conservation District, provides analysis of impacts to the drainage system that will be caused by construction of the Smith Island Restoration project, and provides conceptual recommendations to address drainage needs created by the project.

TetraTech is referencing the drainage system description developed by the Snohomish Conservation District, which is actually a reference to the Cahill, 2011 report.

The TetraTech Technical Memorandum states (page 1):

An existing perimeter levee prevents tidal and river flooding of Smith Island, therefore surface water runoff due to rainfall is the primary drainage concern. Currently surface water drains via subsurface drains and a network of channels and ditches to three remnant tidal channels.

This assumes that precipitation is the primary drainage concern, however, it does not apparently consider WSDOT drainage from Interstate 5 into the area landward of the proposed setback levee, including direct drainage into Tidal Channel B via a 15” tightline3 (Asif Iqbal, Hima Nursery, personal communications, 2013) nor does it apparently consider that the surface water and subsurface drainage system from the Hima Nursery that currently drains to the tidal channels (Figure 4-1 – Tidal Channel Locations) that are filled with water year around (the source of the water in these channels, especially during the dry season, was not determined in any report Snohomish County provided to SNR).

Additionally, the hydraulic connectivity of these tidal channels has not been evaluated nor has Tidal Channel B’s (or Tidal Channel C’s) potential hydrologic response to the inundation of Tidal Channel A been evaluated. Tidal Channel A will be located waterward of the proposed setback levee and Tidal Channels B and C are located landward of the proposed setback levee.

If the three tidal channels are hydrologically connected, then it is possible that when Tidal Channel A is inundated during high tides and/or flood conditions that this will influence the water levels in the other tidal Channels, including Tidal Channel B.

3 This WSDOT tightline was not addressed in the either drainage report.
The TetraTech drainage analysis also does not discuss the hydrologic relationship of the tidal channels and the hydrology of the feature known as the “borrow ditch” bounding the landward side of the existing levee system filled with water year-round.

The “borrow ditch” drains to Tidal Channel A; Tidal Channel A then drains through a tide gate into Union Slough. The source of the water in the borrow ditch has not been evaluated and is presently unknown. However, it is known that this ditch drains toward Tidal Channel A, which discharges to the Union Slough through the tidal gate and the borrow ditch remains full of water throughout the year.

The borrow ditch will continue to bound the remaining DD5 levees along the northern boundary of the area inside of the proposed setback levee. However, if water has been present in the existing borrow ditch year-round and this borrow ditch will still be present landward of the section of the DD5 levee that will tied into the setback dike, it is unclear why the water in the remaining borrow ditch is not apparently factored in as a drainage issue after the setback levee is built or factored in as a source of water in the proposed storm water storage area that would bound the landward side of setback levee to the north.

Although precipitation is one of the primary sources of potential runoff on the Hima property, precipitation may not be the primary source of the runoff, or the only potential surface water on the Hima property. The landward side of the levee as underflow seepage, through-flow seepage, and/or an event or breach of the existing dike system.
Dike overtopping or a breach will typically occur during major flooding events, which is when the drainage system landward of the proposed setback levee will typically be at or near capacity. It is unclear what will happen to the private properties landward of the proposed setback levee, if a dike overtopping and/or a breach occur during a major storm event.

If an overtopping or breach occurs on the existing levee system there at least 400 acres of buffer storage for this water to be stored in areas that are topographically lower than the developed portions of the private properties. If the proposed restoration activities are conducted as discussed in the TetraTech document, there will be little or no storage for overtopping or levee breaches. It is unclear why this was not discussed in the TetraTech report or the DEIS.

Additionally, as discussed above, WSDOT diverts its permitted, point source, municipal separate storm system (MS4) storm water from I-5 onto the Hima Nursery owned drainage system along the western property line; some of this storm water enters a Hima owned 15” tightline that discharges directly into Tidal Channel B. The remaining MS4 storm water flows to the south and is pumped into Tidal Channel C at the point where a 24” culvert drains Tidal Channel C directly under the I-5 freeway. This surface water hydrology, which includes permitted, point source, municipal separate storm sewer system (MS4) water was not included in the Cahill report or the TetraTech report. Additionally, the drainage report does not discuss what would happen if a major flood event is accompanied by a power outage that would effectively stop pump that moves water from the western ditch owned by Hima into Tidal Channel C.

The ability to convey surface water from the land side of the proposed setback levee is a primary drainage concern. The proposed drainage design relies on Tidal Channel B to be the primary “storm water conveyance” on the landward side of the proposed setback levee (as is Tidal Channel C in the southern drainage basin). However, this proposed design assumes that the 42” WSDOT culvert that was installed to allow Tidal Channel B to drain to the Union Slough will not function; this why the design of the proposed drainage system factors in the storm water storage capacity for Tidal Channel B.

However, page 81 of the DEIS states; “Although they are isolated from Union Slough by dikes and tide gates, the remnant tidal channels and drainage ditches are considered fish-bearing waters.” This suggests that these are also considered to be waters of the State and possibly waters of the United States pursuant to 33CFR328 which may affect the use of the Tidal Channel B as proposed by TetraTech and Cahill. It is unclear if federal and state codes regarding the regulatory status of the tidal channels have been evaluated for the proposed designs discussed in the Tetra Tech report.

Additionally, the tidal channels are filled with surface water year-round reducing the storage capacity in these channels, suggesting that these channels may be receiving ground water base flow (this is unknown because no studies were included in any of the reports reviewed by SNR address the hydrology of the tidal channels). Additionally, the potential rate of base flow during the winter months is unknown nor is it known how direct inundation of Tidal Channel A will affect the ground water or based flow in Tidal Channels B and C.

Ground water and potential unsaturated zone flow were not included in the analysis even though the ground water is known to have a potentiometric surface elevation that is at or above the ground surface on the Hima property (Bailey, 2012). Unsaturated zone flows are known to occur within 4 feet of the ground surface within sand lenses and in peat deposits. It is possible that the unsaturated zone flow (interpreted by Bailey, 2012 as ground water) observed in the test pits excavated for the Snohomish County saltwater intrusion studies may be linked to the surface water hydrology in the Union Slough. This may explain why the borrow ditch is filled with water year-round, which would suggest there is a potential for under seepage and/or through seepage for the existing levee system and the proposed setback levee.
Most of the Hima property has subsurface and ditched drainage systems that divert surface water discharges to Tidal Channel B and indirectly to Tidal Channel A. If the setback levee is constructed, the Hima drainage system will be directly discharged to Tidal Channel B exclusively.

The existing Hima property subsurface drainage system is designed prevent ponding and “drain” the near surface soils meaning that there is minimal infiltration to ground water or the unsaturated zone in these areas. The models used by TetraTech and Cahill assume some of the precipitation will infiltrate to ground water (the Cahill models used “C” type soils – forest, flat), which means there are potential errors in the modeled storm water volumes that will enter the drainage system.

Additionally, without knowing the characteristics of the subsurface hydrology it is difficult to design a subsurface anc surface drainage system, especially one that will be dependent on an unlined storm water storage area that will be excavated into upper sediments that include sand lenses and peat deposits that are known to be water bearing (Bailey, 2012), immediately landward of the proposed setback levee.

The existing DD5 levee system is approximately 3,000 feet east of the “developed” private properties that will be protected by the proposed setback levee (the DD5 levee system is located approximately 1,400 feet north of Tidal Channel B). This 3,000 foot “buffer” is up to 5 feet lower in elevation than the surrounding private properties.

It is unclear how the proposed setback levee will affect the unsaturated zone and ground water hydrology beneath the privately owned properties if the Union Slough will be “lapping” at the toe of the proposed setback levee. It is also unclear how the subsurface hydrology will be affected when Tidal Channel A is inundated with tidal and seasonal flooding if the setback levee is moved to the vicinity of the easterly property lines of the private properties, especially the hydrology of Tidal Channel B.

The TetraTech document divides the Smith Island Restoration area and the private properties located west of this restoration area into “drainage basins” and then estimates the amount of storage required in the tidal channels for each basin. However, the document also states that for the purposes of this study it is assumed that Tidal Channel B has zero drainage because the 42-inch culvert that conveys water in this channel under the I-5 freeway is partially blocked and it is unclear what WSDOT will do to prevent the culvert from becoming completely blocked.

TetraTech suggests that Tidal Channel B can be used to store storm water and that supplemental storage can be created in an area located northwest of the proposed setback levee to manage storm water generated from significant storm events. This assumes that Tidal Channel B can store storm water without impacting the Hima drainage system and that there are no regulatory issues associated with all of the Tidal channels (A, B, and C) being classified as fish bearing waters (which would suggest these features are identified as waters of the State) as indicated in the DEIS.

The TetraTech Memorandum states (page 10):

A second approach using a rainfall-based runoff analysis was utilized to estimate drainage system needs. This approach is standard methodology for sizing stormwater facilities, including storage and conveyance. While not typically applied to agricultural sites, it provides a conservative analysis, and also provides a comparison for the rainfall-based approach utilized in the Snohomish Conservation District study.

The rainfall-based storm water runoff analysis models are intended to be used in the design of storm water systems and facilities. This model cannot accurately tidal channels as storm water conveyances (or storm water storage) nor can it factor in subsurface drainage systems or accurately model the effects of near surface ground water or unsaturated zone flow landward of a levee system.
The model also does not factor in WSDOT’s direct discharge into Tidal Channel B via the Hima 15” tightline. Additionally, Best Management Practices cannot typically be applied to “fish bearing waters” as suggested by the DEIS.

The TetraTech Technical Memorandum states (page 10):

\[
\text{WWM accounts for the absorption of water by the soil, but does not explicitly include groundwater contribution. However, groundwater contribution would be minimal with the fine-grain soils that occur in the project area.}
\]

The WWM does have a High Groundwater/Wetland element; however, it is experimental and cannot be calibrated for underground drainage systems, such as those installed on the Hima Nursery. The DEIS suggests extensive wetland complexes are present in the proposed restoration area and that near surface ground water is present. Bailey, 2012 suggests that “ground water seeps were identified within 4 feet of the ground surface. Bailey also suggests and the static ground water level measured in the wells he constructed is at or above the ground surface. This suggests that shallow ground water may be present (wetland hydrology is ground water hydrology) in the proposed restoration area.

Because the hydrology of the tidal channels has not been studied, it is unknown if tidal channels are receiving ground water base flow or if saturated soil conditions are present in the tidal channels. If ground water is the source of the hydrology in the Tidal channels, this would suggest that the tidal channels are “connected” hydrologically (ground water is a hydraulic system at or above one atmosphere in pressure).

None of the drainage studies (or other studies reviewed by SNR for this project) include studies that identify the source of the tidal channel hydrology or what will happen to the hydrology of Tidal Channels B and C if Tidal Channel A is inundated with tidal and 1% storm event flooding (this is when drainage on the private properties is critical). The drainage analysis is relying on Tidal Channel B storing a significant amount of storm water, however, it is unclear how much storage will be available if the tidal channels are hydrologically connected and Tidal Channel A is inundated with combined high tide and significant flooding on the Union Slough.

Additionally, Bailey, 2012 never conducted any testing on the upper sediments for permeability, hydraulic conductivity, or hydraulic transmissivity. These soils are described as being loose to very loose, with relatively high permeability sand units and peat deposits. Until more is known about the hydrologic properties of the upper sediments it is difficult to generate an accurate drainage model.

The TetraTech Technical Memorandum states (page 10):

\[
\text{Figures 5 and 6 illustrate the outflow through the tide gate for Scenarios 1 and 2. The figures show the amount of time the tide gate is open represented by the flow through the tide gate. Tidal elevations are also shown illustrating that flow through the tide gate typically occurs several hours each day when the tide is low. For example during day three of Scenario 1, a peak flow of approximately 16 cfs flows through the tide gate during that day’s low tide. The tide gate is open for approximately 3 hours total during that period of outflow.}
\]

It is unclear where Figures 5 and 6 came from, including the tide and river flow elevation data that is presented in these figures, or how the determination that the tide gate will be open for approximately 3 hours total during “that period of outflow.” SNR is unaware of this functionality in the WWM model or the model’s ability to factor in tide gates, tides, or high flows at outfalls to the waters of the State and United States (receiving waters). The source of the data used in these figures is not provided and is unsupported by references, calculations, or any supporting documentation.
The TetraTech Technical Memorandum states (page 14):

The resulting storage volume available in Tidal Channel B was estimated at approximately 384,000 cubic feet, or 8.8 acre-feet. For a conservative estimate based on the assumption that vegetation would reduce the estimated available storage in Tidal Channel B, the volume estimate was reduced by 20% to approximately 7.1 acre-feet.

This assumes that storm water, including permitted, point source, WSDOT MS4 storm water in the Hima 15” tightline can be stored in “fish bearing waters” and that Tidal Channel B is not hydrologically connected to Tidal Channel A. It also assumes that once the setback levee is relocated to the west, the underflow that is apparently occurring with the existing levee system will not occur with the setback levee. However, there have been no studies conducted to make these determinations; therefore, it is unclear how a conclusion can be made that 7.1 acre feet of storm water can be stored in Tidal Channel B.

Additionally, if Tidal Channel B is considered to be “fish bearing waters” as stated in the DEIS, it is unclear if the regulatory considerations associated with using “fish bearing waters” to store storm water, including permitted point source storm water generated by WSDOT have been addressed. Additionally, it is unclear why WSDOT will not maintain the 42” culver that was apparently installed to allow “fish bearing waters” to drain to the Union Slough as they have historically (historic maps indicate that Tidal Channel B formed a confluence with a tidal channel that linked the mainstem of the Snohomish River to the Union Slough).

What is curious is that all drainage evaluations only consider the use of pumps as a backup during major flooding events rather than as an alternative to the excavation of storm water storage facilities, using Tidal Channel B to store storm water, and the “relocation” of a tide gate. It is unclear why TetraTech did not include an evaluation that only uses pumps (electric pumps with power backup), rather than excavated detention facilities and relocated tide gates, to remove water from Tidal Channel B and from the borrow ditch that bounds the landward side of the remaining, maintained DD5 levee.

Regardless, TetraTech assumes that the hydrology will not change due to the inundation of approximately 400 acres of farmland if the proposed restoration project is conducted. However, there are no hydrologic studies that have been conducted that demonstrate that there will be no changes to the hydrology, including the hydrology of the tidal channels what will be located landward of the proposed setback dike.

4.2 General Discussions Task 1

The TetraTech Report does not discuss the “borrow ditch” water that currently drains to Tidal Channel A. This ditch will continue to generate water along the northern DD5 levee that will remain as part of the post restoration levee system. It is unclear how this water will be managed after the proposed setback levee is constructed. Will there be a similar “drainage ditch” excavated landward of the proposed setback levee and will this ditch fill with water as the current ditch system does? How will this water be managed and what is the volume of water that will be generated during high tides and significant storm events (and river flow events)?

What is the source of the elevation data used for the drainage studies? The only topographic maps for the private properties are prepared by Cahill. However, these maps are relatively low resolution maps with LiDAR generated contours without topographic elevation data being provided. Snohomish County did provide SNR with a topographic “survey” map in PDF format; however, this map was difficult to read and does not apparently include survey data for the private properties. Therefore, SNR cannot evaluate the accuracy of the elevation data used for the Cahill or TetraTech studies. In areas with relatively low topographic relief, accurate elevation is critical when designing a storm water drainage system.
It is clear that TetraTech did not conduct field studies on the private properties and relied on the Cahill report, however, it is unclear where some of the TetraTech data came from, including figures, tide data, river gauge data for the Union Slough and other data that would not be provided by the WWHM3 or the SWMM models and is necessary to run these models. Additionally, it is unclear how the subsurface drainage system on the Hima site was addressed and it is unclear what portion of the surface water was allocated to infiltration to ground water. It is also unclear how the drainage north of Tidal Channel B was addressed. This property is now owned by the Hima Nursery and will be used as part of the nursery operations. This will likely include the installation of additional subsurface drainage systems.

It is unclear how the subsurface drainage system on the Hima site was included in the model, how the Hima 15-inch tightline that conveys WSDOT permitted point source, MS4 storm water into Tidal Channel B were incorporated into the WWHM3 or SWMM model and it is unclear how the WSDOT storm water diverted into the Hima owned western ditch system was incorporated into these models.

The water in the Hima western ditch system is pumped to Tidal Channel C and if this pump system ceases to function during a major flooding event (the pump is electric), it is unclear how this will affect drainage on the site, including storm water flows to Tidal Channel B. It is also unclear why WSDOT is using the Hima ditch system to manage its permitted point source MS4 storm water and why Hima must convey this MS4 storm water through its tightline system to Tidal Channel B.

Additionally, it is unclear how the WWHM3 addresses the “borrow ditch” water that will continue to be generated behind the remaining northern segment of the DD5 levee that currently drains to Tidal Channel A or similar water that may be generated landward of the proposed setback levee.

It is difficult to interpret drainage issues with no data and without having conducted comprehensive field studies, preparing detailed survey maps that have accurate elevation datum and controls, a complete understanding of all potential sources of surface water, and an understanding of the subsurface geology and hydrogeology.

This difficulty is compounded when all of the surface water and most likely, subsurface water on the site drains into a natural feature that has been identified in the DEIS as “fish bearing waters” and the site is located on a major river delta adjacent to a delta channel (Union Slough) in a tidally influenced area. It becomes even more difficult when the site drainage has been significantly altered by human activities and the site is located landward of a very old levee system (believed to have been built prior to 1911). When existing hydrologic conditions are difficult to interpret it can make the interpretation of changes in the existing conditions difficult, especially with subsurface hydrology.

The existing drainage on the proposed restoration site and the private properties that bound the western portion of the proposed restoration site have been altered historically to meet the agricultural use of this portion of Smith Island. This includes the construction of the levee system, the excavation of agricultural drainage ditches, the installation of tide gates, the construction of subsurface drainage systems (this may include tile lines on the farmland in the proposed restoration area), and when Interstate 5 was constructed, the installation of culverts under the I-5 to allow the tidal channels to continue to flow and form confluences with the Union Slough (Tidal Channels A and B) and the Snohomish River (Tidal Channel C) and a bridge over the Union Slough.

The 1911 USGS topographic map of the Mount Vernon Quadrangle (Figure 4-2) shows that the 1911 levee system is similar to the existing levee system and also suggests the that the tidal channels had different geomorphology (and may have levees rather than tide gates). This topographic map also suggests that Tidal Channel C may have had manmade modifications (connection to a manmade drainage ditch) since 1911.
Regardless, the current drainage relies on the three tidal channels to drain the area inside the existing levee system. This includes the private properties west of the proposed restoration project (and setback levee). The proposed setback levee will eliminate existing drainage to the east, including the drainage from the private properties and the borrow ditch landward of the existing levee system that currently drain east into Tidal Channel A. However, Tidal Channels B and C will be located landward of the proposed setback levee.

All of the existing tidal channels have surface water present year-round however; the source of this hydrology has not been investigated or explained. Bailey, 2012 suggests that the proposed restoration area is inundated with up to several feet of water during the winter months; however, Bailey does not discuss the source of this inundation on farmland that is drained with agricultural drainage ditches that historically kept this farmland dry enough to farm. It is unclear why Bailey reports that this farmland is now flooded extensively during the winter months, or why Bailey apparently did not conduct any studies to determine the source of this reported hydrology (such as emergent groundwater).

The recommendations in the TetraTech Technical Memorandum indicate that Tidal Channel B will be used as the primary storm water drainage conveyance and storage facility for the Hima property and that a 5 acre, four foot deep unlined storm water detention facility would be used to store storm water in the northeastern portion of the area that would be landward of the proposed setback levee. TetraTech suggests two possible configurations (page 25):

The storage channel could be built as an extension of Tidal Channel B, discharging to Union Slough through the tide gate. As an alternative, a culvert with backflow preventer could connect Tidal Channel B to the storage channel, permitting gravity flow into the...
storage channel and allowing Hima Farms to continue pumping from Tidal Channel B to the storage channel as an operational option.

Both configurations appear to perform adequately according to the drainage criteria, and the pipe connection could be placed at an intermediate elevation as well.

The tide gate on the north end of Smith Island would be relocated to the end of the proposed storage channel as shown on Figure 21. It is assumed that the outlet pipe size and invert elevation will be unchanged. The rate at which the storage area drains would vary depending on the tidal water surface elevation in Union Slough, similar to the way Tidal Channel A drains at present.

Either of these options will impact Tidal Channel B and will change the location of this channel's confluence with the Union Slough. In addition, it is unclear how the proposed drainage plan will address drainage in drainage basin B2 draining to the north, presumably into the borrow ditch drainage system that currently drains to Tidal Channel A and the northwestern portion of drainage basin A2 that appears to drain east toward Tidal Channel A. Both of these areas are inside the proposed setback levee and the all of the property in these drainage areas is owned by Hima. Hima purchased this property to expand its nursery operations and it is reasonable to assume that the subsurface drainage system will be extended into these areas.

There are several issues that pertain to the proposed drainage system, including a lack of understanding of the subsurface hydrology anywhere on the private properties and in the proposed restoration area. It is known that the tidal channels and the borrow ditch drainage system are full of water year around. This suggests that there is a subsurface source of the hydrology for these features, especially during the dry season. Additionally, the elevation data for the private properties is limited to LiDAR generated topography that SNR could not verify and is not certified by a licensed surveyor (SNR was not provided with any elevation maps certified by a licensed surveyor).

There is no proposed drainage system in drainage basin B2 or the northwestern portion of drainage basin A2 or for the drainage in the borrow ditch that bounds the landward side of the remaining section of the existing DD5 levee. The flow from the Hima tightline that transports WSDOT permitted point source MS4 storm water that discharges directly into Tidal Channel B is also not apparently factored in models.

The TetraTech Technical Memorandum assumes that the only surface water hydrology that needs to be addressed is precipitation. It is clear that there are other sources of surface water, including but not limited to the unsaturated zone flow and potential ground water baseflow into Tidal Channel B, potential underseepage and/or through-seepage from the City of Everett sewage treatment ponds, the borrow ditch drainage system, and known discharges from the WSDOT.

The evidence of subsurface hydrology in the ditch systems and in the tidal channels suggests that any unlined storm water storage facility or conveyance system can be impacted by the subsurface hydrology. Additionally, it is unclear how the subsurface hydrology will change when the existing levees are breached and tidally influenced Union Sough water backs up against the proposed setback levee.

In summary, SNR believes that additional studies (including subsurface, hydrogeologic studies) need to be conducted and all potential surface water sources need to be addressed, including permitted point source MS4 storm water from WSDOT. Accurate topographic data is required for the area landward of the proposed setback levee (this should also include the area the setback levee will be built on) and this data should include accurate elevation data for tidally influenced flows in the Union Slough based recent measurements in Union Slough to the nearest 1/100th of a foot.
The drainage in drainage basin B2 and the northwestern portion of drainage basin A2 should also be characterized, including flows in the borrow ditch for the remaining DD5 levee section bounding the northern portion inside of the proposed setback levee area.

The potential impacts that subsurface hydrology will have on the surface water drainage needs to be evaluated, as well as the inundation of the proposed restoration area, especially in Tidal Channel B and any drainage system associated with the setback levee. It is known that the borrow ditch drainage system landward of the existing levee system has water in it year around, and run-on controls may be required landward of the proposed setback levee. This needs to be studied and addressed in the drainage plan.

There are potential regulatory issues that may need to be addressed. Tidal Channel B is considered to be “fish bearing waters” which suggests that federal and state codes that regulate these types of water bodies would need to be evaluated, especially since permitted MS4 point source water from I-5 is directly discharged into Tidal Channel B which is proposed to be used for storage (and it is unclear how this will affect the regulatory status of the proposed 5 acre storm water detention facility).

Apparently, TetraTech did not conduct any field studies on the surface water hydrology of the private properties or the restoration area, nor were subsurface studies conducted to characterize the subsurface hydrology, including the hydrology of the tidal channels. The only field studies that were conducted were conducted by Steven Cahill, PE and these studies were limited in scope and did not include subsurface investigations or those that that include subsurface hydrologic studies. This may be why Mr. Cahill describes Tidal Channel B as “Drain Ditch B” on the Project Site Map drawings (tidal channels are natural features).

Additionally, the WWHM and SWMM models may not be the most appropriate models to use for surface water drainage analysis for the existing conditions and the proposed conditions if the setback levee is constructed. These models are specifically designed for storm water system design and do not factor in subsurface drainage systems, tidal channels being used as storm water conveyances, nor will these programs include potential hydrologic issues with near surface ground water, unsaturated zone flow and hydrology potentially affected by levees.

TetraTech should conduct actual surface water hydrology studies on the private properties, including subsurface studies that include testing of the surface sediments for hydrologic properties. Detailed surveying should be conducted to insure that accurate elevations are used in any design and modeling. TetraTech should also look at models that may be more appropriate for the studies that need to be conducted, including those listed by the United States Geologic Survey at: [http://water.usgs.gov/software/lists/surface_water](http://water.usgs.gov/software/lists/surface_water). All of the private property that will be located landward of the proposed setback levee is agricultural land where storm water standards associated with development are not required. TetraTech should consider the option of using pumps exclusively and where necessary, adding drainage ditches and pumps, such as the area north of Tidal Channel B.

The Drainage Plan must also include all other sources of water, such as the water that is present year-round in the “borrow ditch” and may be present in any drainage system associated with the proposed setback dike.
5 TASKS 2 AND 3 COMMENTS

There are five documents that SNR reviewed for Tasks 2 and 3. These documents focus on the geomorphology of the proposed restoration area and vicinity, the surface water hydrology of the Snohomish River Delta in the vicinity of the proposed restoration (including Union Slough), and three different types of modeling of the Snohomish River Delta in the vicinity of the proposed restoration. These models are, the 1 dimensional, unsteady HEC-RAS model (2011, West Consultants and 2007, West Consultants) with both of the West Consultants models being based on 2003 modeling conducted on the mainstem of the Snohomish River; the 2 dimensional RiverFLO-2D model (TetraTech, 2012) based on the West Consultants models; and the 3 dimensional FVCOM model (2007 – Battelle).

It should be noted that Task 3 is described in SNR’s contract as a dike overtopping study; however, the reports in this document do not specifically address dike overtopping for the proposed setback dike; although they do include studies on the top of the levee for the existing levee system. The reason these studies do not directly address the potential for overtopping of the proposed setback levee may be due to the lack of actual setback levee designs considering the design phase is currently being conducted by Snohomish County. It should also be noted that the Corps of Engineers specifications for levees has changed since hurricane Katrina and that the most recent Corps requirements need to be included in the proposed setback levee design.

SNR’s comments for each of the documents reviewed are presented below:

5.1 Geomorphic Characterization and Channel Response Assessment for Union Slough, Smith Island Restoration Project, Snohomish County, Washington, 2011

This document was prepared by GeoEngineers, Inc. for the Snohomish County Surface Water Management Division and includes HEC-RAS modeling conducted by West Consultants (and a report prepared by West Consultants in Appendix A).

Although not specified in the title of this document, the introduction in this document (page 1) indicates that this is a draft report rather than a final report:

This draft report summarizes the results of services completed by GeoEngineers and WEST Consultants (WEST) for Snohomish County Surface Water Management (County) at the proposed Smith Island Restoration Project, which will be located adjacent to Union Slough in Snohomish County, Washington (Figure 1). These services were completed in accordance with our proposal dated January 10, 2011.

This report states (page 1):

Union Slough is a distributary drainage channel of the Snohomish River Estuary Delta. The Delta is situated at the mouth of the Snohomish River where it discharges to Possession Sound.

The term “estuary delta” is somewhat misleading because estuaries and deltas are generally considered to be different as stated by Dalrymple and Choi, 2006:

“For example, estuaries, as defined by Dalrymple et al. (1992; see also Boyd et al., 2006; Dalrymple, 2006), form only under transgressive conditions and thus are represented primarily by transgressive successions, whereas deltas are progradational (Dalrymple et al., 2003).”
“Throughout this review, the terms "estuary" and "estuarine" refer only to transgressive coastal areas and not to those areas with brackish-water! Indeed, as will be noted later, brackish-water conditions also occur in deltas and even in some shelf environments, whereas some transgressing coastal areas have either fully fresh or fully marine salinity.”

In general, the transgressive areas are located along the delta margins in the Possession Sound, there is no evidence that transgressive conditions are present in the Union Slough (this is area exhibits the characteristics of a progradational area and therefore would be identified (geologically) as a delta).

The GeoEngineers report states (page 1):

The Smith Island Restoration Project contains approximately 400 acres of former tidal marsh wetlands proposed to be reconnected through a series of levee breaches.

GeoEngineers does not provide any information in their report that supports this statement, nor do any of the other documents provided by Snohomish County support the statement that the 400 acres of former tidal marsh wetlands were present in the proposed restoration area prior to the construction of the levees. In fact, a Snohomish County Public Works document dated April 2009, entitled “Smith Island Restoration Project” states:

As with most of the Snohomish River estuary, Smith Island was logged, diked and drained for agricultural purposes near the end of the 1800’s and early 1900’s.

This suggests that logging was conducted, then levees were constructed and the areas inside the levees were drained for agricultural purposes. An agricultural drainage system is almost always required in areas where the forest has been removed because the evapotranspiration provided by forest land is now gone (up to 75% of precipitation is removed by this evapotranspiration), the farmland is located inside a levee, and to allow farming to occur during the rainy season when Hortinian storage and runoff will be generated due to the increased runoff after the forest was removed agricultural drainage systems are required. Also, tidal marsh wetlands do not typically support forests that are suitable for logging activities.

Additionally, HistoryLink.org Essay 2965, Smith, Henry A. (1830-1915),

“By the mid-1850s, Smith was farming, nurturing fruit orchards, and investing in real estate. One of his land deals was at the mouth of the Snohomish River, later called Smith Island. This area consisted of unprotected tide flats and was therefore subject to seasonal flooding. Despite building dikes in an effort to replicate the Holland experiment, waters drowned his fruit orchards.”

This suggested that seasonal flooding (and that tidal flooding was not the problem, because he would not have planted the trees if the area was flooded twice a day) occurred on Smith Island and that levees were built sometime around the mid-1850s (these levees can be seen on the 1869 Land Office map). However, what Dr. Smith may have not known at the time, is that unless the water can be removed inside the levees, the area will still flood due to precipitation and levee underflow. This is why there are agricultural drainage ditches, drainage from the “borrow ditch”, and drainage outlets (with tide gates) behind the existing DDS levees.

The GeoEngineers Report states the purpose of the studies and report on page 1, as:

Figure 2 presents the preferred locations for the levee breaches, as provided by the County. The primary purpose of this study is to characterize physical conditions and
The processes governing channel morphology under existing conditions, and to assess potential channel responses resulting from the following proposed scenarios, as requested by the County:

The Smith Island Restoration Project only (Scenario 1); and

The combined effects of the County’s Smith Island Restoration Project together with the proposed Blue Heron project. (Scenario 2).

In other words, the study was conducted to “predict” potential changes in the Union Slough fluvial geomorphology due to the proposed changes that would occur to the existing fluvial geomorphology after the proposed setback levee is constructed and existing levee is breached.

Additionally, the “preferred locations for the levee breaches” presented in Figure 2 do not apparently match what was modeled by West Consultants, because Figure 1 in the West Consultants report showing the cross sections appears to be different than Figure 2 in the GeoEngineers report. It is also unclear why no west to east cross sections are shown to extend into the southern proposed breach area on the West Consultants Figure 1.

The GeoEngineers report (pages 1 and 2) states:

1) assess physical channel characteristics documented in historic and current geologic and geomorphic information regarding the Union Slough channel adjacent to the proposed Smith Island Restoration Project; (2) evaluate hydraulic output from a US Army Corps of Engineers (USACE) Hydraulic Engineering Center, River Analysis Software (HEC-RAS) model prepared by WEST, and (3) complete an evaluation of anticipated channel responses in Union Slough resulting from the two proposed Scenarios. Activities comprising the major scope elements are summarized below:

| Collect information specific to the whole of Union Slough and the proposed Smith Island Restoration Project. This information includes aerial photographs dating from 1938 through 2007, local geology and geomorphology, published literature, available reports, and information from Snohomish County and WEST regarding Union Slough bathymetry and cross-section profiles. |
| Review and evaluate the collected data with respect to historic and current channel behavior. |
| Complete two, one-day field reconnaissance of the Union Slough channel adjacent to the proposed restoration project. The reconnaissance, which extended from downstream of I-5 adjacent to the Buse Timber offices to the upstream extent of the project area included documenting areas of observable bank erosion, sediment production, areas subject to deposition, and general levee conditions. |
| Review results of a hydraulic model developed by WEST (summary memo provided as Appendix A) focusing on the output generated for two primary hydraulic parameters (boundary shear stress and velocity) at five representative cross sections throughout the entire project reach. |
| Synthesize the results of the information/data review and field reconnaissance, characterize past and present geomorphic conditions, identify physical conditions and processes governing existing channel behavior, and describe potential responses of the channel to the two proposed scenarios. |
Although historic air photographs do provide valuable information, they will not provide much information on potential channel meander for distributary channels (sloughs) in a river delta system that has been protected by levees since the late 19th century and is known to have been protected by levees in 1911.

Interestingly the GeoEngineers report references a 1938 air photograph that is not presented in the report (the Wes Report includes a 1947 air photograph). However, even the 1947 air photograph of the area shows that the hydrology was significantly different that it is now, with the distributary channel that connected the Snohomish River to the Union Slough and Tidal Channel B formed a confluence with having been cut off from the Snohomish River by a road. This is not discussed in the GeoEngineers report, even though this did result in a change in the Union Slough and Tidal Channel B hydrology and fluvial geomorphology.

The GeoEngineers report suggests that data on the local geology was collected, however, the report does not discuss any geologic or hydrogeologist studies that were conducted. Based on SNR’s review of the GeoEngineers report, nc test pits, drilling activities, and sample collection activities were conducted. No sediment testing was conducted by GeoEngineers to determine the characteristics of the bank or bed materials in Union Slough, including consolidator and cohesiveness.

The GeoEngineers report only documents field observations that were made along the banks of the Union Slough. However, the studies conducted by Bailey (2012) did include the excavation of the test pits and drilling activities, including the collection of sediment samples using a standard penatrometer. Bailey’s studies suggest that the sediments in the area he studies at best have “normal consolidation” and very little structural strength (N = 0).

What is somewhat surprising is that GeoEngineers did not focus on the unique fluvial geomorphology and hydrology of channels that have been confined by levees for over a century. These channels develop unique geomorphic characteristics because overbanking into a floodplain is restricted by the manmade levees. This typically leads to higher velocity flows in the channel and a deepening of the channel bed, although in this report, GeoEngineers suggests that the channel morphology is relatively unchanged (even since the 2006 bathymetry studies that were conducted by Global Remote Sensing, LLC).

In fact, the Global Remote Sensing, LLC, January 2007 document states:

> It should be noted that riverbed conditions likely changed as a result of the flooding between November 4 and 14, 2006. There were areas surveyed before and after the storm that showed channel changes. GRS hydrographers made every effort to resolve these differences in the channels and to provide the most accurate bathymetric assessment as possible. It should be expected that changes in the channel configuration will occur over time because the river and estuary system is dynamic and active.

It is unclear why GeoEngineers believes that once the levees are breached that the Union Slough will not meander, especially when the remaining, unmaintained DD5 levees are gone due to erosion caused by high water flow, wind driven waves, and changes in the water dynamics as water flows in the southern breach and out the northern breach (the levees will have water on both sides). It is also unclear why none of the modeling includes scenarios where the existing levees are completely gone, which is what the eventual fluvial geomorphology of this area will reflect if the proposed mitigation project proceeds and the levee is breached as planned (none of the reports SNR was given to review addresses this).
Once the levees are breached, the Union Slough will no longer be isolated from its floodplain. The Union Slough flow velocity in this area will drop because the flow is no longer completely confined within the levees (this communication with the floodplain will increase as the remaining unmaintained levees fail). As the flow velocity drops where the levee is breached, sediments that are being transported at higher velocities in the Union Slough to the south, will “drop out” where the velocity drops and will be deposited. This change in the flow velocity and the deposition of sediments is the first step in the process that will lead to a change in the Union Slough fluvial geomorphology, which will typically lead to the normal channel meander associated with distributary channels on river deltas; these areas have low topographic relief which is conducive to “meandering channel” fluvial geomorphology.

The GeoEngineers report (page 2) states:

**The Snohomish River and delta have experienced 100-year floods at intervals of three to ten years (Snohomish County, 2005). The largest floods are typically caused by rain-on-snow events (FEMA, 2005).**

If 100 year (1%) floods are occurring at intervals of every three to ten years why did West Consultants limit the model to what has been determined to be a “predicted” 15 year flood event?

The GeoEngineers report (page 3) states:

**Most of the surficial geology mapped in the project area is composed of the younger alluvium and estuarine sediments. The younger alluvium consists of floodplain deposits, up to 20 meters thick, composed primarily of cohesive and compact silty sand, interbedded with occasional sand or gravel lenses. The younger alluvium is interfingered with the estuarine sediment and composed primarily of silt and clay with organic matter.**

This suggests that GeoEngineers mapped the project area. If this is the case who mapped it and where is the map? Also, it is customary to include an excerpt or copies of the geologic maps the report is referencing, the geologic map(s) are not provided in the report. If this description is from Minard, 1985, this should state that this and that the source is the Geologic Map of the Marysville Quadrangle, Snohomish County, Washington, 1985, Minard, James P., United States Geological Survey.

The GeoEngineers report states (page 3):

**Flows in the slough are heavily influenced by diurnal tides; the diurnal tidal fluctuation (difference in mean higher high and mean lower low tide levels) measured in Everett, Washington (Station 9447659) is about 11 feet (NOAA, 2006). In the vicinity of the Project site, the dominant flow direction in Union Slough is upstream (south) during the incoming phases of high tides and downstream (north) during the outgoing phases of low tides.**

SNR checked the NOAA website for information on the Everett tide gage (9447659) and could not find an active tide gage at this location. NOAA data on station 9447659 suggests that this station was only active for a brief period of time (December 1995 - January 1996). The location of active NOAA tide gages is shown in Figure 5-1 (from http://tidesandcurrents.noaa.gov/gmap3/). Tide gage 9447659 is not shown as being an active gage.
Tide predictions are suitable for navigation on the Puget Sound however; predicted tide elevation data is not the same as actual tide heights in a specific area (especially on deltas and in distributary channels) nor do NOAA tide predictions provide tide current data.

The effect that tides have in rivers and sloughs (and estuaries and bays) can be significantly different than in the open ocean. Tidal currents can interact with the flow in rivers and the river geomorphology to create higher water elevations than the actual predicted tides and this interaction can actually create standing waves called tidal bores. The comparison of predicted tides in open water (Puget Sound) to actual tides in fluvial systems can be misleading and lead to incorrect models.

Although, the height of a tide may be somewhat useful for predicting levee overtopping, the effects of sediment transport, scour, and other fluvial geomorphologic controls on channel morphology and potential meander caused by the movement of water should focus on tidal currents and their interaction with river flow and the fluvial geomorphology of the channel.

NOAA does provide tidal current charts; however, these charts are provided for navigational purposes and should not be used in models or for design purposes as discussed by the United States Army Corps of Engineers publication HEC 25 - Tidal Hydrology, Hydraulics, and Scour at Bridges:

These predicted tidal currents, while very helpful for navigation, are not appropriate for design and should be used with extreme caution, even for model calibration purposes. Partially, the reason for these caveats is because waterway bathymetry can vary even over short distances, so even a waterway segment with essentially the same tidal elevation may have very different amounts of tidal current. If tidal currents are used for model calibration, judgment should be used in their interpretation. As described by NOAA on their tidal current website: “Currents are spatially variable, thus predictions should NOT be extrapolated even to near-by locations. Interpolation between two near-by locations should NOT be attempted. Use of such extrapolations can be hazardous.”
It should be noted that “flow is a relative term”, especially on deltas and in distributary channels such as the Union Slough (these are very complex hydrologic systems). These channels are draining to the Possession Sound across the delta. As the tide rises, the outflow of fresh water is hydraulically controlled by the rising tide, causing a “backwater effect” that will cause the water in the channel to rise.

This is not a flow reversal; a flow reversal will only occur if the “incoming tide” can create greater hydraulic head than is available in the channel (typically during summer months when the height of the water in the channel is low). However, the tidal influence does have an effect on the channel morphology in all cases, including tidal currents that can enter the channel when the tide head is greater than the head of the water in the channel.

The tidal influence combined with changes in channel morphology and hydrology on delta distributary channel systems can create many different channel changes, including the reactivation of “blind” channels (such as Tidal Channels A in the proposed Smith Island Restoration Area) and the creation of new distributary channels (Hood, G. W., 2010). This is why accurate tide information and accurate stream gage information (generated at the same time) is often vital to accurately interpret the conditions for a specific area on a distributary channel on a river delta (this is the best way to develop accurate models).

The GeoEngineers document states (page 3):

> The cohesive, estuarine sediments deposited comprising the Union and Steamboat Slough channels are more resistant to lateral erosion and, as a result, these channels are entrenched.

GeoEngineers did not conduct any studies on the sediments in the stream channels, including test pits and borings nor was any analysis performed on any of the sediments. The 2012 studies conducted by Bailey suggest that these sediments, at best, have “normal consolidation” and have low compressive strength based on standard penatrometer blow counts. Additionally, these deposits have the characteristics of overbank deposits that are layers of sands and silts which is not necessarily an indicator of high erosion resistance. Additionally, the use of the term “entrenched” is unclear because these channels are artificially constrained by the levees (not entrenched).

Once the levees are removed, it is expected that the normal overbanking of a distributary channel would resume. If this were not the case, the proposed restoration area would not become inundated. If the concept of entrenched channels were true, then the channel becomes so deeply incised that it no longer communicates with the floodplain via overbanking (except during major flood events).

The GeoEngineers report states (page 3):

> This section of the report summarizes the results of the geomorphic characterization conducted for this study. The summary is based on the conclusions drawn from review of the 1812 and 1884 General Land Office (GLO) maps . . .

It is unclear why copies of these maps that were used by GeoEngineers in the interpretation of the stability of the distributary channels were not included in the GeoEngineers report as figures, especially the 1812 map considering that the first Land Office opened in the Oregon Territory in 1855 as stated in the Bureau of Land Management Land Office History (http://www.blm.gov/or/pubroom/lohistory.php):

> American traders, trappers, and settlers were drawn to the Pacific Northwest while the Oregon Territory was still claimed by the British Crown. The first large wagon train along
the Oregon trail arrived in 1843. Fortunately for these early settlers, the Oregon Compromise with Great Britain was reached in 1846. This agreement added the area covering the states of Washington, Oregon, Idaho, and western Montana to the public domain and made possible the legalization and patenting of the settlers land claims under U.S. land claim and homesteading laws.

The General Land Office was transferred to the new Department of the Interior in 1849 and continued to establish field offices in the western territories and states. Oregon and Washington Land Offices began with the Oregon City Land Office (1855 to 1905) and were established in many towns including Olympia, Seattle, Walla Walla, Yakima, and Spokane in Washington and Burns, Lakeview, Roseburg, The Dalles, and Vale in Oregon. The local land offices in Oregon and Washington were closed by 1948-1949 and all of the survey and homestead records were consolidated in the Portland office.

SNR checked the GLO maps for this area and found the 1869 map for Township 29, Range 5E (Figure 5 - 2 - 1869 Land Office Map of Township 29, Range 5E). This map suggests that the fluvial geomorphology of the Union Slough and other sloughs in this area, including a connector channel between the Snohomish River and the Union Slough has changed since this survey was conducted. It also suggests that tidal channels were forming and changing since this survey was conducted.

By 1911, the USGS topographic map of the Mount Vernon Quadrangle (Figure 4-2) shows all of the tidal channels and different fluvial geology for the Union Slough than shown in the 1869 Land Office map (although Tidal Channel C did not have the morphology it has today) and the connector channel between the Snohomish River and the Union Slough appears to have different morphology. The Ebey Slough also appears to have different fluvial geomorphology when comparing the 1869 Land Office map to the 1911 USGS topographic map of the Mount Vernon Quadrangle.

The 1943 USGS Topographic Map of the Marysville Quadrangle (Figure 5-3 – From the 1943 USGS Topographic Map of the Marysville Quadrangle) suggests other fluvial geomorphologic changes have occurred since 1911, primarily with the blind tidal channels A, B, and C. It also shows the channel connecting the Snohomish River to the Union Slough being cut off by road building activities.

The 1943 USGS Topographic Map also shows changes in the Ebey Slough channel morphology and changes in the Union Slough channel morphology west of the northern portion of Ebey Island. A new blind channel is also shown to the north of the Union Slough suggesting that a connection with the Union Slough may be present.

The 1956 USGS Topographic Map of the Marysville Quadrangle (Figure 5-4 – From the 1956 USGS Topographic Map of the Marysville Quadrangle) shows differences from the 1943 USGS topographic map of the Marysville Quadrangle, including changes in the blind tidal channels A, B, and C. It also suggests that Tidal Channel B has been completely cutoff from the historic channel that connected the Snohomish River to the Union Slough by a manmade pond and ditch systems. It also suggests a sandbar has been created in the Union Slough under Highway 99.

The 2011 USGS Topographic Map of the Marysville Quadrangle (Figure 5-5 – From the 2011 USGS Topographic Map of the Marysville Quadrangle) shows many changes since the 1956 USGS Topographic Map of the Marysville Quadrangle was published. The construction of Interstate 5 has influenced the hydrology of this area as has the construction of the City of Everett waste water facility (Publically Owned Treatment Works – POTW).
Figure 5-2 - 1869 Land Office Map of Township 29, Range 5E

Figure 5-3 - From the 1943 USGS Topographic Map of the Marysville Quadrangle
Figure 5-4 - From the 1956 USGS Topographic Map of the Marysville Quadrangle

Figure 5-5 - From the 2011 USGS Topographic Map of the Marysville Quadrangle
The 2011 USGS Topographic Map of the Marysville quadrangle indicates that the fluvial geomorphology and hydrology of Tidal Channel B has continued to change, especially west of the Interstate 5 freeway. The surface water hydrology on the west side of the Interstate 5 freeway has been highly modified by human activities (the pond shown in the 1956 USGS topographic map is gone). However, based on air photographs (July 2012), Tidal Channel B flows may be somewhat different than shown on the 2011 USGS topographic Map (some of these flows appear to flow south in a manmade drainage ditch system and some appear to flow into what is left of the channel that used to connect the Snohomish River and the Union Slough (the channel that Tidal Channel B used to form a confluence with).

The 2011 USGS Topographic Map of the Marysville quadrangle also shows a tidal channel to the north of Union Slough (that used to form a confluence with Union Slough) has been cut off. It also shows major changes to the fluvial geomorphology and hydrology of a blind tidal channel to the west of Highway 99. Additionally, there is now a manmade bay north of the mouth of the Steamboat Slough. The fluvial geomorphology of the Ebey Slough mouth has also changes as has the geomorphology of “Isthmus” that separates Steamboat Slough from Ebey Slough (a sand bar shown in the mouth of the Ebey Slough in the 1956 USGS topographic map is also gone).

The 2011 USGS Topographic Map of the Marysville quadrangle indicates that a blind tidal channel to the south of the proposed Smith Island Restoration Areas is completely gone and has been replaced with 160 acre lagoon used by the City of Everett POTW to “oxidize” waste water. It also shows a manmade ditch that discharges to the Snoqualmie River that SNR believes is the City of Everett 2 acre chlorination facility that sanitizes the water in the oxidation lagoon before it is discharged into the Snohomish River.

In general the primary reason the Union Slough channel morphology did not change much is because this slough has had a maintained levee system that has been in place for a long time (at least 110 years). This does not mean that these tidal distributary channels will not meander if levees are removed, especially if the removal results in a decrease in channel flow velocities because in this low gradient area, when the flow changes from high to low, sediments will be deposited and sediment deposition is one of the many mechanisms that can initiate channel meander (Hood, G. W., 2009).

It should also be noted that channels that are confined by levees will be high flow channels that will create high levels of erosion as the channel tries to reach equilibrium. If the levees are not maintained; as the banks get steeper and are undercut, they will collapse creating a wider and shallower channel which will eventually lead to a channel with a floodplain. This combined with other hydrologic forces (including wind driven waves) will result in the eventual removal of the remaining levees. Additionally it is very possible that blind Channel A may eventually connect to the Union Slough to the south. If this happens, the eastern portion of the proposed restoration area could become an island.

The GeoEngineers report states (page 4):

\[
\text{The low flow channel is entrenched, with side walls that typically hold a steep angle. The high flow portion of the channel extends from the top of the low flow channel to a vegetation line marking the approximate ordinary high water line. In most areas, the top of the bank is also the delta/floodplain surface, upon which the levees have been constructed.}
\]
It is somewhat unusual to define the lower portion of a river channel as being entrenched because this term is generally applied to a channel that has become deeply incised, often because of human activities. Channel flow varies seasonally, with the highest flows occurring during the rainy season, especially during the spring when snow melt adds to precipitation events. The channel is not typically filled to the top (without overbanking) to bankfull width flow every year; with these events occurring about every 2-3 years. However, these flows would be below the top of the levees because these levees are for the most part built on the historic floodplain.

Bankfull width flow and high flows are not typically associated with the ordinary high water mark (OHWM), especially in areas that are regulated as shorelines (the Union Slough is regulated as a shoreline) per the State of Washington Shoreline Management Act which defines the OHWM as follows:

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SMA (RCW 90.58.030(2)(b) and WAC 173-22-030(11)) and is the only definition that may be used for administering the Shoreline Management Act:

"Ordinary high water mark" on all lakes, streams, and tidal water is that mark that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation as that condition exists on June 1, 1971, as it may naturally change thereafter, or as it may change thereafter in accordance with permits issued by a local government or the department: PROVIDED, that in any area where the ordinary high water mark cannot be found, the ordinary high water mark adjoining salt water shall be the line of mean higher high tide and the ordinary high water mark adjoining fresh water shall be the line of mean high water.
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This suggests that the high water flow may not be where the OHWM is located. It should also be noted that overbanking cannot occur in a channel system with levees that prevent overbank flows (flood control). The levee system effectively “entrenches” the channel by artificial methods; however, it is unclear if this has resulted in deep channel incision in the Union Slough.

However, channels with levees have higher velocity flows which results in higher erosion which can prevent vegetation from being established on the historic banks, simply because the levees create artificially higher banks. Determining the OHWM in channels with levees must often rely on identifiers other than vegetation to determine where the action of the wasters is “so common and usual and so long continued in ordinary years as to mark upon the soil character distinct from that of the abutting land.”

The GeoEngineers report states (page 4):

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Channel dimensions taken from the bathymetric profile and HEC-RAS model cross sections (Figures 4, 5 and 6) document channel widths ranging from approximately 150 to 250 feet. Channel widths at low flows, bankfull flows (ordinary high), and high flows vary little due to the geometry of the channel, which is defined by a bench roughly 6 to 10 feet wide that extends from low flow channel top-of-bank to the toe of the high flow channel bank.
```
The origin of the bathymetric Channel dimensions obtained from the bathymetric data that was used and how it was developed is not described in the GeoEngineers report. The only bathymetry that SNR is aware of that was conducted on the Union Slough is the study conducted by Global Remote Sensing, LLC in 2006 for the Tulalip Tribes of Washington. The Global Remote Sensing report indicates that it is expected that the bathymetry of the distributary channels will change overtime:

It should be expected that changes in the channel configuration will occur over time because the river and estuary system is dynamic and active.

The HEC-RAS model does not develop topography or channel dimensions without having data input into the model, therefore the source of the HEC-RAS data should be stated. Additionally, the bankfull flow is not the ordinary high flow it is the dominant channel forming flow with a recurrence interval seldom outside the 1 to 2 year range. It is unusual to define high flows without qualifying them. High flows can be any flows above low flow, and low flow is defined as “base flow”, which is groundwater fed flow. However, high flows are generally considered to be those greater than “normal flow” which is what defines the OHWM.

High flow is dependent on the amount of water available in the water shed and is somewhat consistent with the intensity and duration of a storm event (especially storms coinciding with snowmelt). The NOAA generally classifies these storms by frequency of predicted occurrence with 100 year storms being the largest that are typically seen (500 year events are larger, but may occur at more frequent intervals).

If a channel has a levee system, the height of the high flow events will be much higher than in channels without levees because this is the purpose of the levee system. The use of high flow and low flow as a morphologic feature in the Union Slough is somewhat unconventional considering the channel morphology is dependent on all levels of flow, even low flow. Low flow events will have stronger tidal currents that also affect the channel morphology.

The GeoEngineers report states (page 4):

Channel depths range from approximately 12 to 25 feet, from bankfull to maximum depths respectively. The channel gradient is very low, approximately 0.00014 (0.014%) over the length of the project area (HEC-RAS profile output from WEST).

The source of the accurate topographic data, including cross sectional data is not provided in the GeoEngineers report (nor is the source of recent bathymetric data). The accuracy of a model is limited to the accuracy of the data that is entered into the model.

The GeoEngineers report states (page 4):

Observable material along the channel banks consists of well consolidated and cohesive estuarine sediments overlain by more granular overbank deposits, topped by less cohesive levee materials. Where observable, the low flow channel walls are composed of very thin alternating lamina of silt/clay, and silt and fine sand, within the upper two feet of channel banks. This cohesive soil is relatively resistant to erosion. The high flow channel banks are composed of sand and sandy silt overbank type deposits, which are less cohesive and more susceptible to erosion.
The GeoEngineers studies did not include any geologic mapping, any test pits, or drilling activities that incorporated the use of standard penetrometer nor was any laboratory testing conducted on the sediments present on the left bank of the Union Slough or the levees. It is unclear how GeoEngineers determined what materials were “well” consolidated without testing the sediments in some manner (penetrometer or laboratory testing).

The consolidation process is the reduction of bulk soil volume under loading due to the flow of pore water from the pore space. For saturated soils, any increment of loading (called surcharge) will be initially taken up by the pore pressure and result in consolidation until a new equilibrium is reached where the soil solids (or skeleton) takes up the added load.

In other words, the application of stress (such as compaction equipment or a glacial lobe) forces the water out of the pore space reducing the volume of the sediment, making it more consolidated. However, this is not the same as compaction, where sediments are exposed to mechanical stress or have loading (such as the placement of loads or the sediment) where air is removed and the grains are forced closer together.

It should also be noted that the consolidation of the materials is not necessarily a factor of erosion resistance, although cohesion, high shear strength, and the moisture content of the sediment will affect erosion resistance. In the case of the sediments described above, the sediments are layers of sands and silts which means that the bank resistance to erosion is based on the least resistant material that is present. During the February 1, 2013 site visit, SNR observed undercutting all along the left bank of the Union Slough as did GeoEngineers during their site reconnaissance activities.

This undercutting does result in bank collapse as mass wasting deposits and will lead to changes in the channel morphology if the bank is not repaired as part of the levee maintenance. Additionally, it is unclear how estuarine deposits are classified in the channel banks compared to deltaic deposits; how is this distinction made? GeoEngineers uses the term delta and estuary interchangeably; however, these are geologically different features.

The GeoEngineers report states (page 4):

> Under current conditions, most of the erosion along the high flow channel banks likely takes place during very high stage flow events driven by significant storm events, and by localized, small mass-wasting failures. The failures appear to materialize as relatively small soil clumps breaking (calving) or slumping off the bank face. The failure mechanism is typical of many estuarine environments and probably caused by wetting and draining of the bank soils. Evacuation of water from the soils is often accomplished by seepage from pore spaces, and the development of piping vents, either of which can locally affect the integrity of soil structure.

Channels that have levees have faster flows because the water height is confined by the levee and overbanking is prevented. This higher velocity flow creates higher shear stress that results in higher erosion, especially with the sands which typically have lower cohesion than the silts. Additionally, higher velocity flows can result in deeper channel erosion which has exposed peat mats that can become released from the channel bed (these float). The release of peat mats can create “holes” in the channel bed which can affect the channel morphology.

Bank failure is typically caused by undercutting and scour, which is common in channels with levees, especially those that have tidal currents. This can result in large sections of bank failure such as the 75 foot section that is in the process of failing observed during SNR’s site visit on February 1, 2013 (Figure 5-6 – Levee failure approximately 300 feet east of the Tidal Channel A Tide Gate).
This section of the levee had been repaired by the Corps of Engineers approximately 6 months earlier because of heavy scouring and failing banks. The DD5 commissioners (personal communications, 2013) indicate that there is a deep scour hole in the channel bed near the bank, located near this area (believed to be up to 50 feet deep). This is at a point where relatively high hydraulic force can be generated during high flow events and when significant tidal currents enter this section of the Union Slough. The ongoing erosion and bank failures in this area suggest that without ongoing maintenance, the Union Slough would continue to cut into the banks, eventually resulting in levee failure, potentially triggering channel meander to the south.

One of the clear indicators that the Union Slough does meander is the presence of peat mats in the channel bed, because these peat mats were obviously not formed in an active channel. As with all low gradient fluvial features on a delta complex, the channels will meander and blind channels will form and disappear because this is an active sediment transport and sediment depositional system.

This ongoing problem with this section of the levee and the significant erosion along the left bank of the Union Slough observed by SNR on February 1, 2013 suggests that once levee maintenance ceases and the levee is breached, that the channel morphology will change and it is possible that blind Channel A will also begin to change as it has in the past (the DEIS predicts this will happen). These changes will be enhanced by the deposition of sediments in this section of the Union Slough due to a change in the velocity (reduction in flow velocity) of the water because overbanking can resume, allowing flood water to be stored what is currently farmland.

The GeoEngineers report states (page 5):

| Five representative cross sections were selected to evaluate detailed hydraulic output for existing conditions and the two alternative scenarios. The cross sections are located at stations 5977, 8906, 10040, 11761, and 14107 (locations presented in Figure 4 and geometry presented in Figure 5). These cross sections were selected based on their proximity to areas of particular geomorphic interest, including the two levee breach locations, areas sensitive to erosion (e.g., outside of meander bends by Buse Timber Mill), and areas of special concern expressed by the County (e.g., station 10040 located along the vegetated bar not within County ownership). |

It is unclear why only five cross sections were selected to evaluate on an approximately 9,500 foot long section of the Union Slough. Additionally, the model only includes scenarios with intentional breaches and does not factor in the eventual removal of the remaining unmaintained levees due to erosion and potential channel meander. Also, the model does not apparently include the proposed restoration activities described in the DEIS, including the placement of large woody debris and the construction of mounds and other grading activities (including the filing of all existing ditches).

Additionally, because HEC-RAS is a one dimensional model, shear stress is simulated and HEC-RAS has limited capabilities to model shear stress in a tidally influenced channel system. The HEC-RAS model cannot predict changes in sedimentation in the channel which will occur when the flow velocity drops because the historic floodplain will be available for flood storage after the levees are breached.

This means that natural levees will begin to form and as sediments are deposited, sand bars and other features can change the geomorphology of the channel, which can result in a change in the hydrodynamics in the stream flow, which can result in additional changes of the channel morphology in this area.
Additionally, none of the models focused on the blind channel A which can affect the fluvial geomorphology of this area as the morphology and hydrology of this channel changes (the historic maps SNR has provided suggest morphology of all the blind channels in this area have changed since 1869).

![Figure 5-6 - Levee failure approximately 300 feet east of the Tidal Channel A Tide Gate](image)

Additionally, the HEC-RAS model is based on a 15 year storm event; however, the GeoEngineers document states that several 100 year (1%) storm events have been reported at intervals of three to 10 years, which suggests that 1% storm events are more common than 15 year storm events. It is unclear where the data came from for a 15 year storm event on the Union Slough considering there are no stream gages on the Union Slough (or tide gages).
The West Consultants report suggests that the data used in the HEC-RAS model is from a stream gage near the City of Monroe, Washington. This stream gage is located almost 20 miles upstream from the section studied by West Consultants and does not reflect contributions to the Snohomish River flow from downstream streams and rivers (such as the Pilchuck River which is projected to have 1% storm event flows of up to 14,000 cubic feet per second, which is generally equivalent to the maximum flood stage on the Green River).

SNR ran a basic USGS StreamStats model (http://water.usgs.gov/osw/streamstats/) on one segment of the Union Slough (where Tidal Channel A forms a confluence with the Union Slough) and the PK 10 flow suggested by StreamStats is slightly lower than the predicted 15 year event by West Consultants (Figure 5-7 – StreamStats area modeled and Figure 5-8 – StreamStats Analysis); however the predicted 1% event flow is 8.29 cubic feet per second. Because of the complexity of this area and lack of gage data, the StreamStats data has a potential 53% standard error. It is unclear what the potential error is for the West Consultants HEC-RAS model.

![Figure 5-7 - StreamStats area modeled](image1)

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![Figure 5-8 - StreamStats Analysis](image2)
Based on the GeoEngineers report, 1% events occur more often than 15 year events and if the StreamStats data is used for a 1% event (8.29 cubic feet per second), the shear stress would be significant enough to cause erosion and potential channel meander, especially in areas of known high erosion potential.

The GeoEngineers report states (page 7):

Model results were evaluated to assess the potential for in-channel flows to erode cohesive and semi-cohesive channel soils, and to provide a basis for addressing likely responses of the channel to the proposed scenarios. Modeled shear stresses and velocities generated for each cross section were evaluated against published erosion threshold data for a general range of cohesive soil compositions. Erosion thresholds are given in terms of permissible velocities of stable cross sections in cohesive materials (Mirtskhulava, no date available), and in terms of boundary shear stress (Smerdon and Beasley, 1959).

As previously discussed, GeoEngineers did not conduct detailed geologic studies on the Union Slough banks nor were any studies conducted on the deposits in the banks below the water level or the bed of the channel. No samples were collected for testing in a laboratory and therefore the actual characteristics of the left bank and bed deposits are unknown. Published values for erosion have a high potential error factor and cannot be relied on for accuracy. The potential high error factor for erosion potential combined with the potential high error factor for the modeled flows can impact the accuracy of the interpretations significantly.

Studies conducted by Bailey, 2012, suggest that the bank and bed deposits can have relatively high erosion potential; however, Bailey’s studies conducted with a drill rig and the use of a standard penatrometer are limited for this site. Although Bailey’s boring SW-01 was near the Union Slough channel (Figure 5-9 – Test Pit and Boring Locations from Bailey, 2012), which may be somewhat representative.

The standard penatrometer testing for this boring suggest the “estuarine” deposits may have relatively low cohesion and may have relatively low shear strength (with blow counts of 0, 0-1-0, and 0-1-0 at approximately 5 foot intervals). Sands were encountered at 9.5’ below ground surface and these sands to silty sands would also have relatively high erosion potential. Considering these sands extend to the total depth drilled (26.5 feet) and to a depth of 75 feet in boring DW-1 it is possible that the deposits in the bed of the Union Slough are the sands described by Bailey.

GeoEngineers may want to review Bailey’s 2012 report and possibly conduct some additional studies, including conducting some field geology studies that includes borings along the areas of known high erosion. Samples should be collected (including insitu samples in rings or Shelby tubes) for laboratory testing to obtain more accurate values for the characteristics of the bank and bed sediments.

Additionally, actual stage and discharge measurements of the flows in the Union Slough could have been made considering the first studies associated with Smith Island Restoration Project were begun in 2003. The installation of a stream gage that could measure discharge and stage height of the flows in the Union Slough could have been implemented as early as 2007 to obtain accurate data on the Union Slough hydrology.

Additionally, the installation of a tide gage or pressure transducer would have provided valuable information on the actual tidal affects in the Union Slough and if pressure transducers were installed in the blind tidal channels A, B, and C at the same time, it is possible that valuable information on the hydrology in these channels could be identified. Had the pressure transducers been present in the Union Slough and the blind tidal channels A, B, and C; they could have been installed in the wells developed by Bailey in 2012 which would have provided valuable data on the subsurface hydrology and how this subsurface hydrology interacts with the tidal channels and the Union Slough.
The GeoEngineers report states (page 8):

**The apparent lack of dynamic behavior is typical of estuarine environments, where channel forming processes are controlled by low channel gradient, the influence of diurnal tides on base level, and cohesive properties of the bank soils. Key indicators of the long-term stability of the channel include the general absence of alluvial bars, which typically provides the engine for dynamic behavior and lateral migration, and relatively uniform erosion of the high flow channel banks.**

It is unclear why GeoEngineers states that the study area is in the Snohomish River delta and then states that this is an estuarine environment (the GeoEngineers report states that the estuary environment is to the west; page 2 – “Union Slough is a distributary channel of the Snohomish River situated within the Snohomish River delta, which extends into the Puget Sound estuary”).

The lack of typical fluvial geomorphology on a delta (which includes channel meander) is due to the presence of a maintained levee system that has been present at least 100 years. These levees prevent the distributary channels from having overbank flows which causes high channel velocities during high flows, which typically reduces the deposition of sediments that would form sandbars and other depositional features in the channel.

However, once the levees are breached, the high flows in the Union Slough from the south will be able to leave the channel as overbank flows reducing the velocity of the flow, creating ineffective flood storage areas in the proposed Smith Island restoration area. This reduction in water velocity will encourage sediment deposition, which will increase the potential for channel meander. Also, as previously discussed, GeoEngineers has no information on the characteristics of the channel bank or bed deposits. The studies conducted by Bailey, 2012 appear to conflict with GeoEngineers assumptions regarding the characteristics of these sediments.

The GeoEngineers report states (page 9):

**We agree with the conclusions of the report relative to the low potential for channel migration in Union Slough; however, we find the lateral migration rates presented in Table 2 of that report to be out of context with the physical estuary/delta environment. The historical aerial photo record, and our independent analysis, does not support the reported channel migration rates of 5 to 40 feet per year. Based on communication with WEST Consultants, the methods used to geo reference aerial photos, identify bank lines, and define migration rates are likely not consistent with currently acceptable standards, and should be re-evaluated.**

Surprisingly, neither the GeoEngineers report nor the West Consultants report provide any detailed topographic maps of the area based on actual survey data and survey control points. The topography of the area and overall geomorphology is one of the critical components of fluvial geomorphology. Additionally, accurate elevation data and bathymetry are essential for developing any model. There is no discussion in either report regarding elevation data, the accuracy of the data, or the source of the data that was used in the HEC-RAS model.

As previously discussed, historic air photographs of this area are generally meaningless for interpreting the potential for channel migration because the Union Slough has had a maintained levee system for at least 100 years. In addition to the levee system, other manmade features, the topography of the area, and overall geomorphology of the area provide controls for the fluvial geomorphology (along with many other factors) of this area.
Figure 5-9 - Test Pit and Boring Locations from Bailey, 2012

In reality, channel migration across low gradient delta plains is common, hence the name “meandering channels”, which create the dendritic channel patterns as sediments deposited on the delta and tidal currents influence the hydrology and fluvial geomorphology of these channels.

Additionally, it is unclear what independent analysis that GeoEngineers conducted other than two days of field observations. GeoEngineers indicates that it reviewed the 1812 and 1884 Land Office maps (as previously discussed, SNR could not find the 1812 Land Office maps and could only find the Land Office map based on the 1869 survey) and compared the Land Office maps to historic air photographs (GeoEngineers states a 1938 air photograph was compared by the report only includes a 1947 air photograph). SNR’s review of the Land Office map suggests that there have been changes in the Union Slough fluvial geomorphology since 1869; however, GeoEngineers apparently did not compare the Land Office maps to historic USGS topographic maps as SNR has.
Regardless, the GeoEngineers “studies” did not include any geologic field studies, borings or test pits, do not include any analysis of the sediments in the channel banks or bed, and do not including any hydrologic measurements of actual flows in the Union Slough. The model is based on a 15 year event even though the report states that 1% events are more common than 15 year events. The source of the data used in the HEC-RAS model is not provided, nor is the accuracy of the model discussed (what is the anticipated error factor?).

It is presumed that GeoEngineers reviewed the 2007 Battelle (Zhaoqing Yang and Tarang Khangaonkar) report that states:

The Smith Island—Union Slough Restoration Project sites can be successfully restored to tidal wetland by dike removal and breaches along Union Slough. Due to the large restoration area in the Smith Island project and the relatively small river channel cross-section in Union Slough, the Smith Island project along with the Union Slough project result in significant increases in tidal flows in Union Slough. High velocity and bed shear stress distributions are predicted in the Smith Island project site, near the upstream and downstream ends of dike removal.

Yang and Khangaonkar state that a significant increase in tidal flows would occur if the proposed projects were completed and that high velocity and bed shear stress distributions are predicted for the Smith Island project site. Yan and Khangaonkar used a 3 dimensional model that can be more accurate in tidally influenced areas and this type of model can more accurately predict shear stress than the HEC –RAS 1 dimensional model. Based on the sediments identified by Bailey during his 2012 studies, this increase in velocity and shear stress could result in erosion significant enough to change the channel morphology in these areas of high flow and shear stress. It should be noted that Yan and Khangaonkar studies were conducted during base flow conditions.

The GeoEngineers report states (page 9):

The January 2009 flood was calculated to be near a 15-year recurrence interval flood based on data from the gage near Snohomish. Although levees are typically overtopped between the gage and the project site, the model for Union Slough does not simulate the flow volume lost to overtopping.

The West Consultants Memorandum dated May 27, 2011 states:

The model was then calibrated to stage data collected for the Everett Riverfront study on the Snohomish River using water year 2009.

This does not suggest that the data was obtained from the USGS river gage located near Snohomish; additionally, the USGS Snohomish River gage does not provide river flow data and does not have historic information from 2009 (Figure 5-10 – Data Available from the USGS Snohomish River Gage).
USGS 12155500 SNOHOMISH RIVER AT SNOHOMISH, WA

Stream Site

DESCRIPTION:
Latitude 47°54'38", Longitude 122°05'52" NAD27
Snohomish County, Washington, Hydrologic Unit 17110011
Drainage area: 1,714 square miles

AVAILABLE DATA:

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OPERATION:
Record for this site is maintained by the USGS Washington Water Science Center
Email questions about this site to Washington Water Science Center Water Data Inquiries

Figure 5-10 - Data Available from the USGS Snohomish River Gage

Additionally, West Consultants does not provide any information on the stage or discharged data for the Everett Riverfront study, although Figure 1 in the West Consultants memorandum (Figure 5-11 – Figure 1 from the West Consultants May 27, 2011 Memorandum) does show the location of “gage locations” on the Snohomish River (for 2009 gage data, but this does not specify who is operating the gage and if it provides both flow and stage data).

Snohomish County provides the locations of all river gages on the Snohomish River which are shown on Figure 5-12 – River Gage Locations from Snohomish County (http://www.co.snohomish.wa.us/PWApp/SWM/floodwarn/). The gage location shown on the West Consultants Figure 1 is not shown on the Snohomish County gage location map nor does the USGS show a gage location where West Consultants shows the gage locations on Figure 1.

There are no river gages on the Union Slough (there is one on Ebey Slough, but this gage only provides water elevation “stage data”, this gage is operated by Diking District Number 6). It is unclear how the actual discharge volume and stage height can be extrapolated for the Union Slough accurately. The closest USGS gage to the proposed Smith Island Restoration Project that includes discharge volume and gage height for 2009 is near Monroe, Washington (USGS Gage Number 12150800) located approximately 20 miles upstream from the proposed restoration site.

It is also unclear how the data from UNET hydraulic model of the Snohomish River below Monroe for a FEMA Flood Insurance Study in 2001 was incorporated into the model for the Union Slough, specifically for the segment of the Union Slough adjacent to the proposed restoration area.

It should be noted that FEMA flood studies are conducted for the purpose of issuing flood insurance, they are not conducted to determine accurate flood elevations related to levee construction or levee breaching. The FEMA flood insurance rate map (FIRM) map base flood elevations are not necessarily accurate. This is why the FEMA incorporates LOMARs and LOMAs to address potential errors in the FEMA FIRM.
Figure 5-11 - Figure 1 from the West Consultants May 27, 2011 Memorandum

The GeoEngineers report states (page 10):

A comparison of current channel bathymetry with as-buils of the I-5 bridge over Union Slough indicates there has been no observable change in channel floor elevation in more than 40 years.

GeoEngineers did not provide any of the as-buils for the I-5 Bridge in its report for comparison and it is presumed the “recent” bathymetry is from the 2006 Global Remote Sensing studies, which is not very recent considering the GeoEngineers report is dated 2011.

GeoEngineers has repeatedly stated that the Union Slough is entrenched and is incapable of meander, which is true if you consider the reason for the “entrenchment” is the levee system. However, the characteristics of an entrenched channel are, that due to limited to no overbanking potential, the channel continues to incise deeper until the banks become too steep and fail due to undercutting; this results in collapsing banks and channel widening. This process will eventually result in normal channel morphology and in a low gradient river delta system this would be a meandering channel.
Figure 5-12 - River Gage Locations from Snohomish County

However, maintained levee systems prevent channel undercutting through repairs, which means that the channel should theoretically continue to get deeper, especially during major storm events or if channel flow volumes continue to increase, which is known to happen (the channel flows are higher than they were in 1850 because of ongoing clear cut tree harvesting activities, changing forests into farmland, and the development of roads, and cities with impervious surfaces will result in more overland flow) as development continues and more impervious surfaces are added (and more waste water from Publically Owned Treatment Works – POTWs that discharge treated waste water into the river system).

The GeoEngineers report states (page 10):

\[ \text{The range of velocities and shear stresses for both proposed scenarios exceed publish erosion thresholds for cohesive soils, suggesting that channel banks are subject to} \]
As previously discussed, GeoEngineers did not conduct any geologic field activities, including the excavation of test pits and drilling activities to determine the characteristics of the sediments in the channel bank and bed. No samples were collected for laboratory analysis, therefore making GeoEngineers interpretation of the sediments based on assumptions and observations of maintained channel banks associated with the DD5 levee system.

As GeoEngineers states “erosion is clearly taking place in the form of bank undercutting and sloughing, undercutting and block failures of the levee [bank?] materials”; however, GeoEngineers finds that this is inconsistent with air photographs and the “physical geomorphologic conditions observed in the field”. It is unclear why GeoEngineers did not conduct more detailed studies if it has this type of conflict with its interpretations (observed vs. predicted).

As previously discussed, channel migration is prohibited by a maintained levee system and all of the air photographs observed by GeoEngineers were taken after the levee system had been constructed. The only known map of the Union Slough that may predate the levee system is the 1869 Land Office map SNR has included in this letter report (GeoEngineers did not provide copies of the Land Office maps they reference in their report). This 1869 map does suggest that the Union Slough channel morphology was different in 1869 than it is today.

GeoEngineers is correct in stating that erosion is clearly taking place on the Union Slough. SNR observed evidence of significant erosion and bank failure during the February 1, 2013 site visit. This clearly indicates that the Union Slough does have high erosion potential and that this erosion can result in bank failures, which can be a precursor to channel migration.

The GeoEngineers report states (page 11):

Supporting geomorphic indicators observed in this reach include an old breach on Spencer Island, opposite the Smith Island project site. Sometime prior to 1990, a levee breach exposed a section of former estuarine wetland that had been isolated by levee construction. Following the breach, hydraulic changes are likely similar to those expected following the Smith Island project. No evidence of surface scour, side channel formation, or main stem inchannel responses have resulted from that breach over a 20-year aerial photo record review.

It is unclear why portions of Spenser Island were not included in the modeling study to determine how closely this small breach (approximately 35 feet wide – clear breach and 80 feet of debris filled breach) correlates to the proposed breaches on the proposed Smith Island Restoration site. Additionally, it is unclear why West Consultants did not extend any east to west cross sections from the slough through the southern breach to the proposed setback levee. All of the cross sections that extend into the proposed restoration area are north to south cross sections originating at the northern breach location.

Perhaps if studies are conducted on Spenser Island, detailed topographic maps were available, recent bathymetric data was available (2011 data specific to this section of the Union Slough) and the models included the Spenser Island breach, a comparison could be made. However, as previously discussed, it is unclear where any of the data used in the West Consultants HEC-RAS model came from for the 2009 storm event, including accurate elevation data, tide data, and Union Slough stage height and discharge data.
Figure 3 in the GeoEngineers report shows overlays of different years of channel alignments interpreted from historic air photographs. This includes a 1938 air photograph that is omitted from the air photographs provided in Appendix C and does not include the 1947 air photograph included in the Appendix C. The 1965 and 1974 air photographs used in Figure 3 are not included in Appendix C and the air photographs newer than 1998 included in Appendix C are not shown on Figure 3. It is unclear why some air photographs used for comparison in Figure 3 were not included in Appendix C and why newer air photographs in Appendix C were not used for comparison in Figure 3.

The West Consultants Memorandum, page 1 states:

More recently, as part of the Everett Riverfront project for the City of Everett, WEST imported the UNET geometry into HEC-RAS (all but the storage areas), and used 2009 LiDAR and a multi-beam bathymetric survey developed for the Tulalip Tribe to redefine cross sections in the Snohomish River estuary below the Marshlands area.

The bathymetric study conducted for the Tulalip tribe is the bathymetric studies conducted by Global Remote Sensing in October – December 2006, not 2009. The LiDAR imagery for this area is believed to be from the 2005/2006 DNR data set, although data grids were provided to the Puget Sound LiDAR Consortium in 2010 by R. Simmonds. The use of LiDAR elevation data exclusively may be adequate for basic floodplain analysis for base flood elevations used for FEMA Flood Insurance Rate Maps (FIRMs), but would not be considered to be adequate for models developed for detailed hydrologic flow and stress analysis or making determinations for levee design, which require a higher level of accuracy and survey control points.

The West Consultants Memorandum, page 1 states:

The model was then calibrated to stage data collected for the Everett Riverfront study on the Snohomish River using water year 2009. Figure 1 shows the data collection locations and cross section layout. The model results are within approximately 0.3 ft compared to observed data throughout the tidal range (Figure 2). This model was used as the Existing Conditions model and starting basis for project analysis.

SNR cannot find any information on the stage or discharge data collected for the Everett Riverfront study nor is this information provided by West Consultants. Additionally, West Consultants does not discuss the source of the “observed data throughout the tidal range”. SNR could not find any know river gages that recoded data for discharge and stage level on the Snohomish River for 2009 other than the gage near Monroe, Washington. The gage location(s) shown on the West Consultants 1 (Figure 5-11 in this letter report) does not correspond to any published river gage locations. Therefore the data used by West Consultants is unverified. Additionally, because there are no gages on the Union Slough it is unclear how actual discharge and stage heights were established for this distributary channel.

The West Consultants memorandum states (page 1):

In order to examine conditions for the proposed Smith Island Restoration Project, the Existing Conditions model was modified to include the Smith Island project and named “Scenario 1”. In Scenario 1, levees were removed and setback where shown in the Snohomish County Scenario 1 figure (Figure 3). Cross sections were added to convey flow across Smith Island and permit hydraulic storage in the restoration area. Figure 4 shows the cross section placement for Scenario 1.
It is unclear why the HEC-RAS cross sections shown on Figure 4 do not extend across the southern breached section of the levee into the new floodplain that is created by the levee breaches. These cross sections would typically extend to the proposed setback levee perpendicular to the Union Slough channel from the levees on the right bank, through the breach to the new setback levee.

The West Consultants report states (page 21):

*The period for data in Table 2 is from February-July, and represents typical diurnal and spring-neap tidal conditions. Under typical tidal (non-flood) flows, about two thirds of the water entering Union Slough during the flood tide is used to increase tidal elevations in Union Slough.*

Where did the “typical” diurnal and spring-neap tidal conditions data for the Union Slough come from and how were these correlated to the actual flow and stage levels in the Union Slough for the corresponding time frames? SNR is unaware of any tide gages or river gages in the Union Slough.

The GeoEngineers “studies” were conducted to determine how the geomorphology, or more specifically, the fluvial geomorphology, of the Union Slough will respond to the proposed Snohomish County Smith Island Restoration Project. The DEIS suggests that new channel formation and channel meanders are likely, however, the GeoEngineers report (using HEC-RAS model output prepared by West Consultants) suggests that there will be minimal to no channel formation or meander.

However, the GeoEngineers report does not include any actual geologic studies, including subsurface geology and hydrology studies. The GeoEngineers studies were limited to site reconnaissance observations. The sediment erosion susceptibility is based on generalized published data for the types of sediments GeoEngineers believes are present. However, based on the studies conducted by Bailey, 2012 and other subsurface studies conducted in this area (Golder, 2001 and GeoEngineers, 2009) GeoEngineers assumptions regarding the characteristics of these sediments are inconsistent with actual subsurface data collected in this area (Bailey’s studies were conducted in the proposed restoration area).

The Snohomish River is classified as a meandering river and the distributary channels on a river delta also have the characteristics of meandering channels. The term meander means that these channels move in response to changes in the hydrology and sediment transport (and in a delta, tidal currents). Movement can also be caused when moving water encounters more resistant materials (resistant to erosion) including large woody debris moved into the channel or buried debris encountered as the channel meanders.

The presence of peat mats in the Union Slough channel indicates that the channel has meandered because these deposits do not form in active distributary channels. The primary reason the Union Slough has had minimal channel movement since 1911 is because this distributary channel (and the other distributary and mainstem for the Snohomish River) has had a maintained levee system that was clearly present in 1911 based on the USGS topographic map of the Mount Vernon Quadrangle.

The proposed Smith Island Restoration Project will include the breaching of the existing levee system which will change the surface water hydrology and the sediment transport in the Union Slough because the Union Slough will be reconnected with its left bank floodplain. This will result in a change in the fluvial geomorphology of the Union Slough as predicted in the DEIS. Additionally, by reconnecting Tidal Channel A to the tidally influenced Union Slough, this the fluvial geomorphology of this tidal channel will also change.
GeoEngineers relies on assumptions, the review of historic air photographs, and a 1 dimensional HEC-RAS model that uses data from unknown sources to demonstrate that the fundamental concepts of fluvial geomorphology do not and will not occur on the Union Slough.

However, GeoEngineers (and West Consultants) does not have any data that is specific to this section of the Union Slough or the Union Slough in general. There are no stream gages on the Union slough, there are no tide gages or the Union Slough, and there is no recent bathymetric data for the Union Slough (as previously discussed, Globa Remote Sensing, 2007, indicates that the channel morphology will continue to change and actually did change during their bathymetric studies conducted in 2006).

The concepts of fluvial geomorphology on river delta distributary channels are not discussed nor does GeoEngineers explain why normal channel meander and changes to tidal channels will not occur. GeoEngineers focuses on the observations that the Union Slough has had minimal movement since levees were installed and maintained, however this is not representative of what the conditions will be like after the levees are breached. Instead, GeoEngineers could have focused on historic channel meander that occurred before levees were constructed on the distributary channels by focusing on how rivers build deltas.

Regardless, as discussed in this subsection, there are a lot of inconsistencies with the GeoEngineers studies that relied on observations rather than field studies and laboratory and field testing and on unknown sources of data for the HEC-RAS model rather than collecting as much data in the study area as possible as Battelle did (Battelle realized that there was still a lot of data gaps and that it could not predict the response for significant storm events because there is no data on the discharge and stage height for the Union Slough and the only stream gage that monitors both of these parameters and records the data is the stream gage near Monroe, Washington).

Additionally, as will be discussed later, the GeoEngineers report findings appear to be inconsistent with those made by West Consultants, 2007, Channel Migration and Scour Evaluation Everett Delta Natural Gas Pipeline/Smith Island Restoration Snohomish River, Washington report. However, this report also fails to discuss the source of the data used in the HEC-RAS model.

If Snohomish County wants to determine how quickly and how much the Union Slough channel morphology will change if proposed restoration activities are conducted; the geologic, hydrologic, hydrogeologic, and fluvial geomorphologic studies will need to be more comprehensive and the model (if used) will need to use data obtained from the Union Slough in the reach where the proposed breaches will occur. This will also require the collection of recent bathymetric data and accurate survey data to develop accurate, detailed survey maps. Additionally, the studies need to focus on actual fluvial geomorphology, sediment transport, and deposition based on the proposed changes to the existing conditions, including the placement of large woody debris and grading activities proposed to be conducted in the restoration area (e.g. mounds). The studies must also focus on how long it will take for the remaining unmaintained levee system to fail and erode away and how this process will affect the fluvial geomorphology of the Union Slough. None of the models SNR reviewed address changes in the remaining unmaintained levees.

As previously discussed, Snohomish County has been working on the Smith Island Restoration project since 2003; with actual studies being conducted in 2007. Had the County installed a stream gage and pressure transducer (or tide gage) in the Union Slough next to the proposed restoration project, it would have a significant amount of site specific discharge and stage data and tide data, including data on the 2009 and 2012 flood events.

Additionally, if pressure transducers were installed in the tidal channels (in addition to one in the Union Slough), a lot of data on the hydrology of these features could have been obtained and when Bailey conducted his studies, adding pressure transducers to the wells he constructed would have provided lots of valuable data on the ground water – surface water interaction and on the Union Slough base flow.
5.2 Smith Island Levee Analysis for [the] Everett Water Pollution Control Facility and Diking District No. 5, Prepared for the City of Everett, October 2007, prepared by ESA Adolfson

SNR reviewed the 2007 ESA Adolfson report that was also reviewed by a Shannon and Wilson engineer (David Carlton) and Chapter 5 was reviewed by a Shannon & Wilson engineering geologist (Theodor Hopkins). The studies and report primarily focused on surface water hydrology issues associated with the City of Everett Publicly Owned Treatment Works (POTW) located in the southern portion of Smith Island.

The field studies conducted for this “projects” were limited to field observations, no geologic or engineering investigations were conducted (such logging test pits or borings).

The information in this report is of limited usefulness for the proposed Smith Island Restoration project because the studies did not focus on the proposed restoration area and the assumptions regarding the proposed setback levee and restoration area are inaccurate. However, the 1938 air photograph and the LiDAR imagery provided in this report was useful for identifying historic drainage for the blind tidal channels located in northern portion of Smith Island, including Tidal Channels A, B, and C. Additionally, the LiDAR imagery does suggest that the historic breach on Spenser Island has led to sediment accumulation in the Union Slough channel north of this breach (Figure 5-13 – LiDAR Image from Figure 7 in Adolfson 2007 Report).

It is unclear why the breach occurred in the levee protecting Spenser Island; however this breach is located at a bend in the Union Slough approximately 2,500 feet north of the “Buse Cut” a manmade channel that was excavated across Spenser Island to connect the Union Slough to Steamboat Slough. Interestingly, the channel morphology in the Union Slough and the Steamboat Slough occur at almost the same distance north of the Buse Cut and this is where the levee breach occurred on the right bank of the Union Slough.

It is unclear exactly when the Spenser Island levee breach occurred, however, this breach dramatically changed the hydrology on this portion of Spenser Island and apparently led to sediment deposition in the Union Slough channel as water velocities dropped in this bend because water can “overbank” through this breach. However, it is unclear what influence the Buse Cut has had on the fluvial geomorphology and hydrology of the Union Slough and the Steamboat Slough, which is very near the apparently, human modified, connection (the modern day connection is different from the connection shown in the 1869 Land Office Map – Figure 5-2 in this letter report) between the Steamboat Slough and the Ebey Slough (Figure 5-14 – July 2012 Air Photograph of the Buse Cut).

It is unclear how the combined connections between the different distributary channels in this area affect the overall surface water hydrology in this area. However, the surface water hydrology in this area is believed to be very complex. It is also unclear how the Buse Cut has influenced the hydrology of the Union Slough or if this change in the Union Slough hydrology contributed to the levee breach on the right bank of the Union Slough, changing the hydrology of Spenser Island.

The Adolfson 2007 report states (page 11):

We informally compared the results of the Lidar analysis to point information included in various CAD files provided by the City. There is general agreement, but there is enough difference between elevations shown on the Lidar and elevations shown as AutoCad point data to warrant further investigation of actual levee elevations before designing any levee rehabilitation plans.
This suggests that the LiDAR imagery elevation data is not accurate enough to design a levee. This also suggests that this LiDAR elevation data is not accurate enough to use in the HEC-RAS and other models.

Figure 5-13- LiDAR Image from Figure 7 in Adolfson 2007 Report
The Adolfson 2007 report states (page 11):

> The precise delineation of drainage basins is complicated by the lack of topographic variation and degree of disturbance (e.g., roads, agricultural ditches, and other development). Specific survey of several areas and ditch thalwegs would be necessary to refine and verify basin boundaries.

According to Snohomish County, no surveying has been done on the private properties that would be landward of the proposed setback levee and very limited surveying has been conducted in the proposed restoration area. This suggests that more accurate elevation data is required to refine the drainage plans and for the models.

The Adolfson 2007 report states (page 29):

> Underlying these surficial soils, previous borings reveal approximately 22 to 30 feet of deltaic and flood plain deposits consisting of soft, compressible organic silt and sandy silt, including distinct fibrous peat deposits and buried logs and stumps. These upper organic-rich silt deposits are, in turn, underlain by medium dense to dense sand and gravel that extend to considerable depth.

This is generally consistent with the observations made by Bailey, 2012. However, the GeoEngineers, 2011 report conflicts with this Adolfson report and with Bailey. The upper 22 – 30 feet of deltaic and floodplain deposits described here are not highly cohesive nor are they “highly consolidated” (they are listed as compressible).
The Adolfson 2007 report states (page 32):

> Based on our review of quit-claim deeds provided to us by the City, the levees around Smith Island were built by individual land owners to protect agricultural land uses in the 1920s.

Based on SNR’s research the levees on Smith Island have been present at least 100 years. HistoryLink.org suggests that early levees may have been built as early as the late 1860's however, the Land Office 1869 map does not discuss levees in the notes taken by the surveyors, but the map does show an oddly shaped levee in the northwestern portion of Smith Island. The 1911 USGS topographic map of the Mount Vernon Quadrangle shows levees being present on all distributary channels bounding and possibly tidal channels on Smith Island (including the Union Slough).

The Adolfson report included a levee potential overtopping analysis based on LiDAR imagery and predicted 10 year flood event stage heights. However, as previously discussed in this report, there are no stream gages in the Union Slough and it is apparent that all references to flood elevations and discharge rates are based on the USGS stream gage near Monroe, Washington.

Interestingly, a Corps of Engineers determination of non-significance that pertains to flood damaged sections of the Union Slough levee system (damaged in the 2009 storm event) dated September 14, 2012 states:

> While the level of protection can be difficult to determine in tidally influenced areas and previous reports have used various protection levels, the levee did not overtop during the 15-year flood event in 2009, therefore the levee is estimated to offer a 20-year level of protection in its undamaged pre-2009 flood condition.

Regardless, the emergency repairs did require mitigation at a 2:1 ratio for impacts to the unarmored section of levee that was repaired (the section bounding the northern portion of the proposed Smith Island Restoration Area), because this section was armored during the emergency repairs conducted February 21 – 23, 2012; as stated in the Corps of Engineers September 14, 2012 document:

> Site 1 was an armored bank previous to the damage and will be replaced with an armored bank, however a small amount of sedge wetland (0.02 acres) has become established in the footprint and will be impacted by the repair. Repairs to Site 2 will convert approximately 0.7 acres of intertidal wetland and muddy bottom habitat to an armored bank. Compensatory mitigation is proposed at a 2-to-1 ratio to offset the loss of habitat and water quality function. The proposal includes purchase of 1.45 acres of offsite mitigation at the City of Everett advanced mitigation site upstream on Union Slough. The mitigation site is designed to restore intertidal salmon rearing habitat that historically existed along Union Slough. Because the site is on Smith Island and will provide similar habitat characteristics, it is being considered as in-kind mitigation in close proximity to the impacted area.

The Corps apparently had no concerns with levee overtopping; however, scour had caused channel bank erosion and collapse as stated in the Corps of Engineers September 14, 2012 document:

> Flooding occurred on the Snohomish River in January 2009 with a peak stage of 24.12 feet at the Monroe gage (flood stage of 15 feet) resulting in damage to the Union Slough levee system at two sites. River flows damaged the right bank levee (site 1) of the
Note that the Corps of Engineers reference the “Monroe gage” which is also the gage the United States Geological Survey used in its studies of the January 2009 storm event. This is most likely because the Monroe gage is the only recording gage that monitors both discharge and stage height on the Snohomish River. However, there is no stage height or discharge rate for the Union Slough.

SNR’s research did not identify any known DD5 Union Slough levee overtopping events in the last 25 years, however, at least one levee breach has occurred and numerous repairs have been made to the levees due to erosion and failure of the channel banks.

What will be important to understand for the proposed setback levee is what stage height on the Union Slough is representative of an actual 10% event and what an actual 10% event is. Based on the reports reviewed by SNR, Snohomish County suggests that 1% flood events occur at intervals of 3 to 7 years which would mean that this may be the required design parameter if these events consistently occur more often than the predicted 10% events.

As previously discussed, had Snohomish County installed a stream gage in the Union Slough at the proposed restoration area location that records stage height and discharge rates and a pressure transducer or recording tide gage, the data for the different flood events, including the January 2009 flood event. This data could be correlated to the Monroe gage and the appropriate height of the proposed setback levee could be extrapolated much more accurately than predicted flood elevation data will provide.

It should also be noted that the Corps had to perform 2:1 habitat mitigation to conduct simple armoring of the right bank of the Union Slough. Considering the probable effects of the proposed levee breaches will result in higher channel flow velocities downstream of the proposed mitigation area and since the actual scour potential has not been evaluated accurately, it is possible that bank armoring may be required downstream to prevent bank erosion caused by higher velocity flows. This could result in potential mitigation impacts that were not discussed in any of the reports SNR reviewed, including the DEIS (the DEIS only addresses the proposed setback levee).

Additionally, since SNR could not review the design aspects of the proposed setback levee, it is unclear if this design will include armoring on the waterward side of the levee, especially where the proposed setback levee ties into the DD5 levee system.

The Adofson report did not provide meaningful data regarding the potential for DD5 levee overtopping in the proposed Smith Island Restoration area, especially levee overtopping of the proposed setback levee.


The Yang and Khangaonkar report was prepared for the Tulalip tribe for a Snohomish River “estuary” restoration project as part of the feasibility studies. This report is one of the most comprehensive reports SNR reviewed and included 3 Dimensional Modeling. What makes this report somewhat unique is that Yang and Khangaonkar realized that there were data gaps for the models so additional studies were conducted to fill in some of these data gaps. Additionally, the author’s names are (obviously) provided which is customary for scientific reports.
Yang and Khangaonkar used a three-dimensional (3-D) hydrodynamic model for the Snohomish restoration sites choosing the finite-volume unstructured hydrodynamic model (FVCOM). This model uses a combination of tides freshwater discharges, tides, and surface-wind stresses as input to test the hydrodynamic response of the sloughs (distributary channels).

The studies that were conducted to calibrate and validate the Yang and Khangaonkar 3 dimensional modeling were generally conducted over a three week period (October 12 – 27, 2006), such as the Evans-Hamilton tidal and salinity studies and Global Remote Sensing bathymetry studies. This model was used to simulate tidal inundation, tidal currents, and salinity intrusion in the study area for the existing conditions in October, 2006.

In general, Yang and Khangaonkar found that the restoration projects in the lower Snohomish River would result in increased tidal flows towards the river in the main river channel and all distributary channels (sloughs). The model “results” also indicate that when all restoration projects are considered simultaneously, there is a cumulative effect or the river hydrodynamics and the river morphology.

However, the data collected for the model was conducted at a time of low river flow, where ground water base flow was the primary source of water. The Weather Underground indicates that there had only been 2.07 inches of precipitation in the Marysville area from July 1 – October 27, 2006 and the bulk of the Cascade Range snowmelt would be gone by October 12, 2006. This suggests that the salinity and tidal currents observed in the distributary channels and the Snohomish River mainstem may be skewed because these readings were taking at a time of low river flow (base flow conditions).

This may be why Yang and Khangaonkar state the following (page iv):

The model successfully reproduced many important features observed in this unique and complex estuarine system, including wetting and drying processes in the intertidal zone, strong tidal circulation, and salinity intrusion

In reality, the areas modeled are believed to be fluvial deltaic conditions not estuarine conditions. Regardless, when a river is at base flow conditions, the influence of tides (including tidal currents) and “salinity intrusion” will be the highest because the river discharge rates and stage heights are the lowest of the year.

However, it is unclear how Yang and Khangaonkar obtained accurate river discharge and stage heights for the Union Slough or the rest of the channels in the Snohomish River delta considering there are no river gages in these channels. The supporting studies SNR reviewed do not include the collection of this data in the Union Slough from October 12 – 27, 2006. It is also unclear where the elevation data Yang and Khangaonkar used came from (e.g. survey maps).

On page iv., Yang and Khangaonkar state:

Due to the large restoration area in the Smith Island project and the relatively small river channel cross-section in Union Slough, the Smith Island project along with the Union Slough project result in significant increases in tidal flows in Union Slough. High velocity and bed shear stress distributions are predicted in the Smith Island project site, near the upstream and downstream ends of dike removal.
This suggests higher flows occurring because there is more storage generated by the proposed Smith Island restoration project. However, Yang and Khangaonkar focus on erosion (bed shear stress) and not sediment build up, which can eventually lead to increased erosion potential and channel meander. Additionally, although bed shear stress will influence channel depth and undercutting of river banks, the lateral stress in the channel flow can affect bank morphology, including the creation of side channels and other fluvial geomorphologic changes in the channel morphology. Regardless, Yang and Khangaonkar suggest that the hydrologic conditions in the Union Slough will change if the proposed Smith Island restoration project is conducted as planned.

On page v., Yang and Khangaonkar state:

Although the model was calibrated satisfactorily, and it performed well in testing various restoration alternatives, there are still limitations in the model, and further improvement is possible. These model limitations include 1) potential error in specified tide data at the open boundaries, 2) lack of bathymetric LIDAR data near the mouth of the Snohomish River, 3) lack of resolution on the interconnections between the marshlands and sloughs, 4) lack of sediment and bed-form information. Further improvement of model calibration, especially for salinity, can be achieved by overcoming these limitations with additional data and model refinement.

This does not discuss the accuracy of the elevation data used, which was apparently not verified with infield survey data referencing NAVD 88 benchmarks. As the FEMA has found when creating preliminary flood insurance rate maps (PFIRMs) and flood insurance rate maps (FIRMs), topographic elevation control is critical when modeling floodplains and delta complexes (especially delta complexes where topographic gradients are typically low). Also as previously discussed, FEMA FIRMs are not accurate enough to use in levee design or evaluating potential impacts to channel morphology caused by levee breaching (primarily because the elevation data is typically not accurate, but also because FIRMs do not factor in flood control facilities that are not certified by the Corps of Engineers and they are based on predicted flood stage height and discharge rates, which may not be representative of actual flood events).

Page 1-1 of the Yang and Khangaonkar document states:

The lower Snohomish River morphology consists of a number of braided sloughs . . .

Braided river channels are found in an area of fluvial geomorphologic change where topographically higher gradient channels enter an area of lower topographic gradient channels (such as the braided “reach” channels observed at the SR 203 Bridge over the Skykomish River near Monroe, Washington). The channel morphology of the distributary channels in the Snohomish River delta have a meandering channel morphology typical of channels with low topographic gradients.

On page 1-3 and 1-4 Yang and Khangaonkar state:

The effectiveness of each individual restoration project in meeting restoration goals can be evaluated by analyzing the hydrodynamics of the Snohomish River Estuary under current baseline conditions and comparing the findings with proposed restoration alternatives.

The average water depth in the lower Snohomish River and the river delta is about 3 meters relative to mean sea level (MSL). Further out of the river delta, the water depth increases rapidly to deeper than 100 meters.
It appears that the terms estuary and delta are used interchangeably, however, these are two different types of fluvial geomorphic features. Based on the definitions used by Dalrymple and Choi, 2006 (for deltas and estuaries), the areas included in Yang and Khangaonkar modeling activities were on the Snohomish River delta complex, not the estuarine areas.

On page 1-4 Yang and Khangaonkar state:

**Density-induced currents are also important in the Snohomish River estuary because of salinity stratification and a strong freshwater plume produced by Snohomish River flow. The wind effect is also important for the circulation near the mouth and the shallow delta.**

Yang and Khangaonkar consider the salinity stratification (the difference in density between saltwater and fresh water) and the wind as important considerations in the water “circulation” in the river mouth/delta complex. This is an important factor in the hydrology and fluvial geomorphology of this area of the Snohomish River and is not discussed in the other reports provided in Tasks 2-3.

On page 2-1 Yang and Khangaonkar state:

**The data required for the hydrodynamic model setup and calibration include tides, currents, river flow, salinity, temperature, bathymetry, and meteorological information. The required data were obtained from two sources: existing data sources available in the public domain and a field survey specifically designed for this study.**

Any model conducted to simulate river flow and river dynamics must also have very good topographic data, including the heights of the levees and detailed channel cross section data.

On page 2-1 Yang and Khangaonkar state:

**River flow, bathymetry, wind, and some tide data were obtained from open data sources. The Snohomish River flow, which brings freshwater to the bay, was obtained from the U.S. Geological Survey (USGS) gauge at river mile (RM) 25 near the city of Monroe, WA. Wind data were obtained from a NOAA National Weather Service at Paine Field station in Everett, WA. Tides at the open boundaries near the mouths of Possession Sound, Saratoga Passage, and Port Susan Bay were obtained using the XTIDE program based on NOAA’s National Oceanic Service algorithms. Three types of bathymetry data were used. Model bathymetry in most of the open coastal waters (Possession Sound, Saratoga Passage, and Port Susan Bay) was interpolated from the Puget Sound Digital Elevation Model (DEM) from the University of Washington (UW). This data set has a resolution of 30 ft by 1 ft in the horizontal and vertical directions. This resolution is generally sufficient for most coastal waters and bays where water depths are sufficiently deep. However, this resolution is not sufficient for characterizing intertidal channels and the tidal marsh area, which undergoes wetting and drying through secondary channels. To better represent the bathymetry in the shallow area, high-resolution bathymetry light detection and ranging (LIDAR) data were used. The LIDAR data were obtained from the Puget Sound LIDAR Consortium and Snohomish County. A multi-beam riverbed bathymetric survey was also conducted at a resolution of 1 m by 1 m in the river channels as part of the Qwuloolt Marsh restoration project funded by the Tulalip Tribes of Washington. These three sets of data generally provide sufficient information for accurate representation of the bottom topography in the model. Additional river cross-section data upstream of the lower**
Use of the river discharge and stage data from the USGS river gage near Monroe is somewhat problematic unless the gage flow for the Pilchuck River (there is a USGS gage on the Pilchuck River) and in the other tributaries to the Snohomish River downstream of the “Monroe” river gage is factored into the analysis. It is unclear how the actual discharge and stage data was generated for the Union Slough because the hydrogeomorphology in the distributary channel system is complex. All of the distributaries are interconnected and originate from the Snohomish River and “reconnect” in different locations in the delta complex.

It is unclear why the tide data for the Evans and Hamilton, Inc. studies was not used, unless the tidal data used in the model is for different simulations (such as the winter and spring), or why the data originated from the interpreted tide data for the “locations” listed above (as previously discussed, there are no NOAA tide gages in the vicinity of Everett, WA). It should be noted that tides on river deltas and in the delta distributary channels can be very different from those in the open water. The closest NOAA “station” to Port Susan Bay is the Kayak Point location and this is not a gage, it is predicted data.

Using LiDAR imagery for bathymetry determinations can be misleading and is not typically considered to be high resolution data because the water will reflect the light used in the LiDAR (Light Detection and Ranging). The elevations measured in a channel and on a delta plain can vary significantly depending on when the LiDAR survey was conducted (time of day and time of year). However, the Bathymetry data obtained by Global Remote Sensing, LLC will provide more accurate data (conducted on October 18, 2006 and December 22, 2006) for the time frame studied. However, the Snohomish Delta system is dynamic and active; changing with each storm event as suggested in the Global Remote Sensing, LLC report (page 4-1):

It should be noted that riverbed conditions likely changed as a result of the flooding between November 4 and 14, 2006. There were areas surveyed before and after the storm that showed channel changes. GRS hydrographers made every effort to resolve these differences in the channels and to provide the most accurate bathymetric assessment as possible. It should be expected that changes in the channel configuration will occur over time because the river and estuary system is dynamic and active.

It is unclear where the cross sectional data for the Union Slough and Steamboat Slough came from (the only survey data suggested to have been collected for this purpose was obtained by Snohomish County on the Snohomish River mainstem and on Ebey Slough).

On page 2-1 Yang and Khangaonkar state:

Bathymetry data in the main area of the Snohomish basin were obtained from the UW Puget Sound Digital Elevation Model. The data have 30-ft by 30-ft horizontal spatial resolution.

This data source is not listed in the references section of the report and a date is not given. It is unclear how accurate this data is.
On page 2-2 Yang and Khangaonkar state:

The average water depth in the lower Snohomish River and the river delta is about 3 meters.

The Snohomish River is still dredged and historic documentation strongly suggests that the distributary channels were also dredged. This may be why all of the channels are approximately the same depth. However, since the Snohomish River is still dredged, this suggests that the morphology and bed scour interpretations for this river may be influenced by dredging activities.

On page 2-2 Yang and Khangaonkar state:

Scatter-point measurements were conducted by Snohomish County to represent the general marshland elevation for this study. As described above, a significant feature of the Snohomish River is the intertidal mudflat area in the river mouth. The existing LiDAR data did not cover this region. To represent the mudflat elevations accurately in the Snohomish River delta, a separate LiDAR data collection will be required in the future. For this study, the bathymetry in the river delta where LiDAR data were missing was defined by the UW DEM data.

It is unclear if the additional LiDAR imagery and data collection discussed in this report has been collected and the model rerun to determine how large the error factor is.

Figure 2-2 in the Yang and Khangaonkar report suggests that there is a dramatic change in channel depths in all three distributary channels at the same place north of the “Buse cut” the channel elevations in all three (Union Slough, Steamboat Slough, and Ebey Slough) change from approximately 4.5 feet to approximately 8 feet. This is not discussed (why do all of the channels change elevation at approximately the same distance north of the Buse cut?).

On page 2-4 Yang and Khangaonkar state:

The river bathymetry data upstream of the confluence of the Snohomish River and Ebey Slough were not available. River cross-sections measured by Snohomish County were used to set up the model bathymetry for the upstream section of the river. The cross-section locations are plotted in Figure 2-4.

There is no information on how or when this data was obtained (by Snohomish County) for the cross sections. The accuracy of the model is dependent on the accuracy of the data and when it was collected (and the datum used when the data was collected).

On page 2-4 Yang and Khangaonkar state:

The Snohomish River inflow for the study period was obtained from USGS gauge (Station 12150800) near the city of Monroe at RM 25. The river-flow time history during the study period of 2006 is plotted in Figure 2-5. The river flow in October 2006 was generally in the range of 1,700 to 7,000 cfs.

Quilceda Creek is a very small tributary entering the study domain from the high marshland north of the river mouth. The average annual flow of the creek is in the range
of 10 to 12 cfs. Because the stream flow is small and is much further downstream of the study area of interest, a constant river flow of 10 cfs was used in the model setup.

There are other streams and rivers that form confluences with the Snohomish River downstream of the “Monroe” gage. The Pilchuck River forms a confluence with the Snohomish and the flow in this river is much higher than 10 cfs. However, there is no stream discharge and stage data for the Pilchuck prior to 2007. Between October 18 and 27th, 2009 (USGS gage 12155300 – Pilchuck River, near Snohomish) the discharge on the Pilchuck River ranged from approximately 900 cfs to 3,000 cfs, suggesting that the Pilchuck River can contribute a significant amount of flow to the Snohomish River.

If the discharge from all the tributaries downstream of the Monroe gage was not factored in, there could be a significant underestimate of the actual discharge and stage height in the Union Slough and the other distributary channels. However, it is unclear how the Union Slough stage and discharge rate are determined in this complex distributary channel system even if the contributions from rivers and streams downstream from the Monroe stream gage could be factored in to the total flow and stage height of the Snohomish River where the Union Slough, Ebey Slough and Steamboat Slough distributary channels form.

On page 2-4 Yang and Khangaonkar state:

Possession Sound and the Snohomish River Estuary are influenced by tides, predominantly propagating from the entrance of Possession Sound to the north of Saratoga Passage and Port Susan Bay. Tidal elevations along these open boundaries are needed for simulating tidal circulation. Directly measured data near the study area do not exist for the study period. However, predicted tidal elevations at Glendale located near the entrance of Possession Sound, Sand Point in Saratoga Passage, and Kayak Point in Port Susan Bay are available through the NOAA tide-prediction network.

The use of predicted data based on open water measurements for tide gages in Puget Sound cannot simulate the unique geomorphology of the Snohomish River delta or the unique fluvial geomorphology of the distributary channels accurately. This means that error in tidal elevations and timing may not be accurately incorporated into the model for the Union Slough tide elevations. However, tidal currents will also be unknown and the effects of tidal currents are typically greatest when the river is at or close to base flow.

On page 2-9 Yang and Khangaonkar state:

All the salinity profiles were collected during high tides on October 16, indicating the intrusion of high salinity water from Puget Sound.

This would make sense at high tides and channel base flow conditions. However, these studies were conducted when the river flow is the lowest; what happens during the rainy season, especially when there is heavy snowmelt associated with a “pineapple express”?

On page 3-23 Yang and Khangaonkar state:

Union Slough has the least tidal flow and energy. Tidal flows also decrease in the distributary sloughs as tidal waves propagate upstream because part of the tidal flow is diverted into the marshlands between the sloughs.
This is modeling of the channel flow at or near base flow conditions between October 12 and 28, 2006 and factors in numerous levee breaches that allow tidal flows to enter what Yang and Khangaonkar call marshlands on the different “Islands”. However, actual base flow conditions typically only exist from late summer through early fall (depending on the weather patterns for the year). Union slough is often cited as being the narrowest of the distributary channels; this suggests that during high river flow conditions the velocity in this narrower channel would be relatively high compared to the other wider channels.

Because the 3D model was conducted during a period of base flow, river flow was generally not a factor in the modeling of the tidal flow (currents). Typically bed shear stresses are a factor of river flow and tidal currents, however, base flow conditions provide the least river flow stresses, although tidal currents are typically higher during base flow conditions. Additionally, it is unclear what is meant by “tidal waves” unless this is suggesting tidal bore activity was observed in these channels (this was not discussed in the other documents SNR reviewed for Tasks 2 and 3).

On page 4-1 Yang and Khangaonkar state:

> Simulations for the restoration alternatives were conducted for the same period as the calibration conditions from October 12–28, 2006. Model parameters and forcing functions were retained at the same values as those set up during the model calibration.

This indicates that the modeling was conducted using channel base flow conditions which generally only factor in the tidal currents and wind for shear stress. It is unclear why higher river flow conditions were not simulated in the model.

Figure 4-22, page 4-28 of the Yang and Khangaonkar document indicates that the placement of the setback levee is different from the currently proposed location. It is unclear how this change will affect the model because this can only be determined by recalibrating the model to the current proposed location of the setback levee.

On page 4-29 Yang and Khangaonkar state:

> However, tidal flows would increase significantly at Station U1 because of a large increase in the tidal prism and water storage when both Smith Island and Union Slough sites are restored. The percentage increase in tidal flows for the restored conditions would be 91.1% relative to existing conditions (Table 4-3).

A 91.1% increase in tidal flows is significant under base flow conditions; however, it is unclear what will happen during a 1% storm event, which, as previously discussed, can occur more frequently than 15 year events.

On page 4-40 Yang and Khangaonkar state:

> Velocities inside the Smith Island project site are measurable during high tides because of tidal wave propagation through the large area of dike breaches. Velocities in the restored slough in Smith Island are strong, especially during low and ebb tides (Figures C-1 and C-4). Velocities in the Union Slough restoration site are generally small because of shallow water depths and relatively small incoming tidal flows.

This suggests that the conditions for the proposed Smith Island restoration cannot be directly compared to those for the City of Everett Union Slough restoration.

On page 4-40 Yang and Khangaonkar state:
Inside the Smith Island Project site, high bed shear stresses are observed during ebb tides near the entrance of the restored slough channel and the upstream end of the dike breach where Union Slough bends rapidly towards the east (Figure C-6). Potential erosion is likely to occur in these areas because of high velocities and bed shear stresses. Bed shear stresses within the Union Slough project area are generally small, with slightly higher values around the dike breach locations. No major erosion would be expected within Union Slough project site. Changes in river channel morphology would be complicated in Union Slough because of the complex changes in bed shear stress distribution. Potential localized adjustment of channel morphology may occur in Union Slough after the Smith Island and Union Slough restoration projects. Further analysis of geomorphic changes in the river channel may be conducted by morphology experts based on the model results.

Because the Yang and Khangaonkar model only focuses on bed shear stress, it apparently does not consider other fluvial geomorphologic features such as the blind tidal channels and the effects the breaches may have on these channels (the setback levee configuration used by Yang and Khangaonkar be west of Tidal Channel B).

Additionally, the model is still based on existing conditions from October 12–28, 2006, which are believed to be base flow conditions. It is unclear what will happen during a 1% storm event.

On page 5-2 Yang and Khangaonkar state:

The Smith Island - Union Slough projects also show an evident effect on hydrodynamic conditions in other sloughs and the main river channel. Tidal flows would increase by 13.9% in Ebey Slough, 3.2% in Steamboat Slough, and 6.0% in the main river.

This suggests that under what are presumed to be base flow conditions, the proposed Smith Island - Union Slough (this has been implemented) restoration projects would result in a change in the hydrodynamics of all channels in this portion of the Snohomish River delta complex, including the mainstem of the Snohomish River. It is unclear how this change in hydrodynamics will affect the channel morphologies, especially during significant river flow events.

On page 5-2 Yang and Khangaonkar state:

Changes in river channel morphology would be complicated in Union Slough because of the complex changes in bed shear stress distribution. Potential localized adjustment of channel morphology may occur in Union Slough after the Smith Island and Union Slough restoration projects are implemented.

Yang and Khangaonkar focus on the shear stress distribution, however, they do not factor in what happens in areas where the velocity drops, such as the areas between the two breaches for the proposed Smith Island restoration project.

In areas where channel velocity drops, sediment load capacity also drops, which typically results in sediment deposition in these areas. This combined with the higher velocities associated with the predicted higher shear stress by Yang and Khangaonkar would typically suggest that the channel morphology will change to meet the new hydrologic and sedimentary conditions.
Figure C-6, page C-7 in the Yang and Khangaonkar document suggests shear stress greater than 2.0 Pa will occur inside the breach areas of the proposed Smith Island restoration area. Although the setback levee location has changed since this model was conducted, the proposed location of the breaches has apparently not changed (based on SNR’s review of the other documents in Tasks 2 and 3). This suggests that this high shear stress may be located where the setback levee will now be located. It is unclear what the shear stress will be with the current proposed setback levee location or what the shear stress will be during a 1% storm event, however, the West modeling for the Pipeline (April 11, 2007) document prepared for CH2M Hill suggests significant scour will occur (as discussed later in this letter report).

However, even under what are presumed to be base flow conditions, Yang and Khangaonkar found that the potential for a significant increase in localized shear stress exists if the proposed Smith Island restoration project is implemented. Additionally, Yang and Khangaonkar suggest that this increase in shear stress can lead to changes in channel morphology. Oddly, Yang and Khangaonkar did not discuss potential changes in the blind tidal channel morphology even though Figure C-5 (page C-6) shows shear stress in Tidal Channel A greater than 2 Pa during flood tide conditions.

It is unclear why Yang and Khangaonkar did not simulate higher river flow conditions obtain model information on how higher flows will affect the shear stress. However, it appears that they wanted to limit the model to the information they had rather than changing parameters to meet a designed flow event.

Regardless, it is clear (based on the West April 11, 2007 document) that higher channel flow events will increase shear stress significantly enough to result in significant scour (West used finer grain materials in its model) in the sandy bed deposits Yang and Khangaonkar used in their model.

The Yang and Khangaonkar studies did not address the conditions during higher channel flow which is more common than channel base flow conditions (depending on the weather, base flow conditions typically last from August to November). However, even with base flow conditions, Yang and Khangaonkar indicate that there will be a greater than 90% increase in flow during ebb tides if the proposed Smith Island restoration project is implemented.

Yang and Khangaonkar recognized many of the model limitations associated with the lack of accurate data and their studies did include obtaining data for the period studied. However, the proposed setback levee configuration used in the model is not the same as the current configuration and the model is only representative of base flow or near base flow conditions.

Additionally, Yang and Khangaonkar did not consider changes in sediment deposition associated with decreases in the velocity of water downstream of the breaches nor did their model consider the placement of large woody debris or the other modifications proposed in the DEIS as part of the restoration project.

The West Consultants April 7, 2007 report includes modeling for 100 year and 500 year flooding events, which suggest that significant scour can occur during these events. However, neither model focused on what will happen to the remaining unmaintained levees after the proposed breach occurs nor do the models consider eventual levee failures on the remaining unmaintained levee system or the possibility that the remaining levee system will eventually be completely removed.

None of the models, including the Yang and Khangaonkar model used accurate data for the Union Slough because this data is not available. However, all models SNR reviewed indicate that the proposed Smith Island Restoration project will result in changes to the surface water hydrology of the Union Slough.
Additionally, the models and report findings conflict regarding scour and the potential impacts to the Union Slough channel morphology. However, none attempt to predict how the changes suggested by the models will affect the navigability of the Union Slough, how potential channel meander may affect the channel forming process, how the blind tidal channels will change.

As previously discussed, without accurate data for the models (such as actual stage height and discharge rates from base flow to 1% storm events, actual tidal measurements, and more information on the affects of tidal currents), accurate information on the Union Slough bathymetry (recent data), and accurate information on the characteristics of sediments in the Union Slough channel and bed (and the characteristics of the materials in the levees), it is difficult to predict how the fluvial geomorphology of the Union Slough will change if the proposed Smith Island Restoration is conducted.

Additionally, all of the models should have included the proposed use of large woody debris and factored in any other changes to the existing geomorphology of the restoration area or Union Slough banks and channel.

### 5.4 Draft, Snohomish County, Smith Island Estuarine Restoration Union Slough Hydraulic Model Study, November 2012, prepared by TetraTech

The unauthored, draft TetraTech document discusses the previous modeling studies and discusses the 2-dimensional modeling conducted by TetraTech. TetraTech summarizes their report as follows (from page 1):

*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 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.*

This report summarizes the Union Slough Hydraulic Model study for two proposed “restoration projects”, the proposed Snohomish County (and City of Everett) Smith Island restoration project and the Blue Heron restoration project. The purpose of this additional modeling activity was also to address comments pertaining to the draft SEPA Environmental Impact Statement related to potential changes in Union Slough channel morphology and hydrology.

TetraTech lists the goals and objectives of the Hydraulic Model study (page 1) as follows:

*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 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.

This suggests that TetraTech will generate a more accurate model than those previously conducted by Wes Consultants, 2007 and Battelle, 2007. SNR assumes this is because TetraTech believes the use of a 2-dimensional model will provide more accurate results than the 1-dimensional model used by West Consultants and by simulating 100 year event channel flow (however, the TetraTech study actually focused on the 2009 “15 year” flood event), it will provide more accurate information on potential bed shear stress than the Battelle 3-dimensional modeling did (although the West Consultants 2007 study did include simulations for 100 and 500 year events).

On page 3 TetraTech states:

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:

This suggests that the TetraTech 2-Dimensional Model used the same data the models references above used to generate their 2-dimensional model. The two models TetraTech built on were the 3-dimensional model developed by Battelle (Hydrodynamic Modeling Study of the Snohomish River Estuary: Snohomish River Estuary Restoration Feasibility Study, Battelle, 2007) and the 1-dimensional model developed by West Consultants for the GeoEngineers Geomorphic Characterization and Channel Response Assessment for Union Slough (GeoEngineers/West, 2011).

TetraTech did not include the Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared for CH2M Hill, prepared by West Consultants to build their 2-dimensional model.

The TetraTech study was based on three scenarios, existing conditions, conditions with the proposed Smith Island restoration, and conditions with the Smith Island restoration and the Blue Heron restoration. However, it is also based on a different proposed setback levee location than the Battelle studies or the West studies for CH2M Hill. As with the models conducted by Battelle and West, the TetraTech model did not include the proposed large woody debris and the changes to the restoration area geomorphology by proposed grading activities discussed in the DEIS.

It should be noted that because the TetraTech model uses the data from the previous models; therefore, the model is based on incomplete and inaccurate data that is not generated from data collection on the portion of the Union Slough where the proposed restoration activities will be conducted.
On page 4 TetraTech states:

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 than the 3D model (Battelle, 2007), and provides much more information than the 1-D HEC-RAS model.

As with most models, the water surface elevation and channel flow velocities are estimated; this does not suggest a high level of accuracy. Regardless, while RiverFLO-2D may be easier to use and possibly more flexible than the 3-dimensional model used by Battelle, it is unlikely that it provides more detail or more information than a 3-dimensional model. TetraTech should state why it believes this and provide details regarding the advantages of the 2-dimensional model for detail and information generated compared to the Battelle 3-dimensional model.

On page 4 TetraTech states:

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.

The GIS software environment may provide some advantages if additional GIS data were collected by TetraTech for use in the model. It is unclear whether the model used by Yang and Khangaonkar has this capability. However, the most important factor in the accuracy of any model (any type) is the accuracy of the data used in the model. This is why it is important to state the source(s) of the data used in the model and to demonstrate that this data is accurate for the time frame being modeled.

As an example if you are running a model for a 2009 event, the data should be consistent with the time frame you are modeling. This is why all of the Yang and Khangaonkar modeling is based on existing conditions from October 12–28, 2006. Using data for conditions that are different from the time frame modeled can affect the accuracy of the model (e.g. using topographic maps based on the geomorphology of 2012 for a 2009 river flow event, because the 2009 event and subsequent high flow events can change the bathymetry and subsidence and erosion can change the geomorphology of the area being studied over a period of 4 years).

Additionally, it is very important to use accurate discharge and stage data for the area being studied to obtain accurate velocities and stage heights in the model. As discussed for the other Task 2 and 3 reports that include modeling, except for the Battelle model, it is unclear where the discharge and stage data came from for these models, including this TetraTech report (especially for 2009). It is also unclear how any discharge and stage data was obtained for Union Slough since there is no documented gage data for this distributary channel.

On page 4 TetraTech states:

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.

It is unlikely that a 2-dimensional model will produce results that are any more accurate than a 3-dimensional model. The Battelle model focused on the only accurate data they had which was for the period of October 12–28, 2006. However, Battelle was more focused on tidal currents than channel flow from high flow events; possibly because there is no accurate data for high flow events on the Union Slough. The closest river gage that measures stage and discharge for 2006 or 2009 is the USGS gage near Monroe, Washington, located at least 20 miles upstream of the proposed Smith Island restoration project – approximately RM 25. Battelle did focus on base flow (ground water base flow) during two tidal cycles (spring-neap) possibly because they did not have accurate data for high flow events.

On page 4 TetraTech states:

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 Ebeys 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 just downstream of Interstate-5.

TetraTech should explain what the impacts of “boundary conditions” are and why the Snohomish River mainstem was not included in the model considering that Battelle suggested that all channels were affected by the proposed Smith Island restoration project.

On page 5 TetraTech states:

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 extracted at each cross section. 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 systems response to a high flow event, it was based on 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 arbitrarily selected to balance the model run, but still capture the full storm effects.

This suggests the data used in the TetraTech model is the same data West Consultants used for the 2011 GeoEngineers report. Additionally, it is unclear what historical data TetraTech or West Consultants used, unless the data is from the USGS gage near Monroe, Washington, which is the same gage Battelle used.

On page 5 TetraTech states:

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 result in more erosion in the channel.
It is unclear why TetraTech believes a 15 year storm event will have the same shear stress and the same channel velocity (and stage) that a 1% storm event would have and that the same amount of “erosion” will be observed in a 15 year event as will be observed in a 1% event. If this were the case, why did West Consultants model for 100 year and 500 year events in their Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared for CH2M Hill? Why do all of the models SNR reviewed for Tasks 2 and 3 suggest that the greater the storage the higher velocity of the flow in the channel (more tidal storage results in higher velocity flows)?

Additionally, larger flood events would extend further and higher into the proposed restoration area, which would influence Tidal Channel A and would result in higher scour potential, especially during low tide events. These events, especially if wind driven waves (fetches) are generated, will also affect the remaining unmaintained levee system and as these remaining levees fail, the fluvial geomorphology of this portion of the Union Slough will change, but none of the models address this ongoing change in the channel morphology and how this will affect the overall fluvial geomorphology and hydrology of Union Slough.

On page 7 TetraTech states:

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

It is unclear what data TetraTech used in its model that is different from what West Consultants used in their model for the 2011 GeoEngineers report or how this data is different from the model West Consultants used in the model for the report they generated for CH2M Hill on April 11, 2007. It is apparent that TetraTech imported the data from the West Consultants HEC-RAS model for the GeoEngineers report into their RiverFLO-2D model and compared the RiverFLO-2D model output to the West Consultants HEC-RAS model output.

As discussed in this letter report, SNR has concerns with the data used in the West Engineers model prepared for the GeoEngineers 2011 report. If TetraTech used the same data, SNR has the same concerns for the TetraTech model accuracy.

Additionally, if the RiverFLO-2D model is being calibrated to the HEC-RAS elevation data developed by West Consultants for the GeoEngineers 2011 report what is the purpose of conducting the RiverFLO-2D model for obtaining discharge rates (velocity) and stage height?

Although the 2-dimensional model will provide more accurate modeling of the storage it is unclear how it will provide more accurate data for stage height than the 1-dimensional model it was calibrated to especially if the same data used in the HEC-RAS model is used in the RiverFLO-2D model, because the resulting model output will be no more accurate than the HEC-RAS 1-dimensional model if the data used in the HEC-RAS model is not accurate.

On page 10 TetraTech states:

> 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.

The statement that HEC-RAS does not “contain” storage areas is unclear. The unsteady HEC-RAS model will represent overbank flood storage and this is a component of the developing base flood elevation maps for 1% storm events. Additionally, the statement that “tides provide an unlimited volume of water that can fill storage areas and result in higher water surface elevations for a given storm” is somewhat misleading, because although the Puget Sound does have essentially an unlimited amount of water compared to river flood flow, the amount of inundation tides can provide is based on the elevation of the tide, whereas river floodwater can reach much higher elevations based on the geomorphology of the area because the hydraulic head for river flow is much higher than tidal elevations.

As an example, dams provide barriers to river flow which causes the water to rise to whatever level is allowed in the dam because the source of the river hydrology is much higher than the top of the dam. Tides cannot cover areas higher than the highest tide; however, they can inundate large areas that are lower than the highest tide during high tide events. Additionally, tides have bidirectional flow four times a day that can generally be predicted (the timing and approximate height); however, rivers have unidirectional flow, and the discharge rate and stage height are difficult to predict, although during late summer and early fall base flow conditions are somewhat predictable depending on the weather.

If the same data that is used in the HEC-RAS model is used in the RiverFLO-2D model it is not surprising that the surface elevations are similar. However, the accuracy of both models is dependent on the accuracy of the data used in the models.

SNR continues to question the “historical observations” that are mentioned in the reports because SNR is unaware of any river gages on the Snohomish River (or Union Slough) that have historic measurements for discharge and stage height in 2009 other than the USGS gage near Monroe, Washington (approximately river mile 25).

Ebey Slough has a stage gage but the data is not apparently recorded and there is a stage gage near Snohomish, but none of the data is older than 2010 for the Snohomish gage. The gage on the Pilchuck River does have discharge and stage heights and does have data for 2009 (but not 2006); however, this gage does not measure the discharge and stage height of the Snohomish River.

It is unclear where the discharge and stage data used in the West HEC-RAS model came from and where the bathymetry and topographic data came from for the 2001 FEMA study conducted by West Consultants (SNR searched for this document and could not find it).

On page 10 TetraTech states:

The 100-year hydrographs and tidal boundary conditions were extracted from the existing FEMA modeling at the same locations and using the same methodology described above for the January 2009 storm.
This does not provide a date for the existing FEMA modeling. It is presumed that this is the UNET hydraulic model West Consultants conducted for FEMA in 2001 for the Snohomish River below Monroe (FEMA Flood Insurance Study in 2001). As discussed in this letter report, the GeoEngineers 2011 report states: “The Snohomish River and delta have experienced 100-year floods at intervals of three to ten years (Snohomish County, 2005)”. This suggests that either the Hydrographs that were developed for the 100 year events are inaccurate or the 100 year storm event isopluvial maps developed by the NOAA re inaccurate.

Regardless, the accuracy of the 1% hydrographs is dependent on many factors and FEMA maps are known to have inaccuracies, such as the map for the Pilchuck River that “missed” 4,200 feet of levee section (northwest boundary of French Slough, West Consultants, June 29, 2007). Additionally, King County filed challenge studies for most of the FEMA 2005 PFIRMs due to significant inaccuracies on multiple rivers including the Green and the Snoqualmie; the Snoqualmie River is one of the two rivers that form the Snohomish River.

It is unclear where the actual data for river discharge and stage elevations in the Union Slough used in the HEC-RAS or RiverFLO-2D models came from and how accurate this data is.

Figure 11, Page 11 of the TetraTech document indicates much higher flows in Ebey Slough than Union or Steamboat Slough. However, the Battelle report (Page 3-16), which used the 3-dimensional model suggests that the Union Slough has the second highest flows of the channels (second to the Snohomish River mainstem):

> Velocities at Steamboat Slough were smaller than that in the main channel (Figure 3-5) but significantly greater than Ebey Slough and Union Slough (Figure 3-6), indicating that Steamboat Slough is the second largest tributary carrying the Snohomish River flow into Possession Sound.

It is unclear why the TetraTech 2-dimensional model suggests that the flow in Ebey Slough is significantly higher than Steamboat Slough (this should have been discussed).

On page 12, TetraTech states:

> Because our analysis was focused on comparing post-project flood levels to existing conditions, model calibration was not required. Calibration data was not available as there are no high water marks or surveyed water surface elevations on Union Slough for the 100-year flood.

This statement is unclear. Models must be calibrated to determine the potential error the model may generate. The data used for the 1% storm event is not provided and there are no known river gages on the Union Slough. The only known river gage that does have both discharge and stage data on the Snohomish River is the gage near the City of Monroe, Washington (this is the only gage that has any data on the Snohomish River for 2006 and 2009).

This gage does not include the flow from the Pilchuck River or other downstream streams that form confluences with the Snohomish River. Additionally, because there are no gages on the mainstem of the Snohomish (at the mouth) or in the Union Slough or Steamboat slough and only a stage gage on the Ebey Slough, it is unclear how the model was calibrated to the 1% flow and stage of the Union Slough, especially when the statement above states there is no calibration data.

TetraTech should have discussed why calibration data is not necessary and why accurate discharge and stage heights for the Union Slough are not necessary for determining stage height and discharge rates for a 1% storm event.
On page 12, TetraTech states:

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.

This assumes that the FEMA 1% flood elevations (Base Flood Elevations) are accurate. The source of this data, the date this data was generated, and how this information was generated is unclear. The Battelle modeling activities were based on data collection that was conducted for the period of the study wherever possible. However, Battelle knew that the high flow data would have large potential errors because the only gage that provides data on discharge and stage height for the timeframe of the model was the USGS gage near Monroe. This was not a major factor for establishing existing conditions for the period modeled because the Snohomish River and the sloughs were at or close to base flow conditions.

The accuracy of the TetraTech data is unclear, especially when the model output they generate appears to contradict the model output that Battelle generated (for the Steamboat Slough v Ebey Slough).

On page 14, TetraTech states:

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.

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 flow for floodplain management.

It is presumed that TetraTech is referring to the river flow associated with the storm event between January 5 and January 8, 2009. Although the measured rainfall for this storm event was considered to be an approximately a 10% event, the USGS river gages in Western Washington indicated that the river flow and stage heights were equivalent to much larger events as stated by Mastin, M.C., Gendaszek, A.S., and Barnas, C.R., 2010:

The January 2009 flooding was widespread throughout western Washington, setting peaks of record at 21 non-regulated rivers at streamflow-gaging stations operated by the USGS for more than 10 years (fig. 4). Although the 24-hour precipitation totals reflect an event with a return interval of about 10 years (fig. 3), the January 2009 peak flows at many of the streamflow-gaging stations with 50–80 years of record suggest that it was a flooding event with a return interval much greater than 10 years. Factors other than the 24-hour precipitation totals added to the severity of the flooding.

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Regardless, it is unclear how the FEMA developed a 1% discharge rate and stage for the Union Slough and how this factored in the snow melt that can occur (as it did between January 5 and 8, 2009). Even though FEMA FIRMs are used as a basis for issuing flood insurance, the accuracy of these maps for actual modeling purposes is unknown. As previously discussed, the FEMA PFIRM maps for much of the King County river basins were challenged by King County because the PFIRM maps apparently contained significant errors.

Additionally, the Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared for CH2M Hill, prepared by West Consultants did include 100 year and 500 year events in its modeling. It is unclear why TetraTech did not include this study in the studies for this draft document. This West Consultants study suggests that significant scour will occur in the Union Slough during 1% storm events.

On page 14, TetraTech states:

> 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.

This suggests that the TetraTech model is a 2-dimensional “rerun” of the FEMA model, which is apparently based on synthesized tide data, discharge rates, and stage heights for the Union Slough. TetraTech should have analyzed the FEMA data to determine if the use of this data will provide accurate results for the Union Slough as it currently exists and address potential data problems as Battelle did in its studies.

On page 15, TetraTech states:

> 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 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.

As SNR has indicated, it is unclear how GeoEngineers developed bed shear stress thresholds considering it did not conduct any geologic studies (including test pits and borings) to determine what sediments are actually present and the cohesiveness of these sediments (nor was any laboratory testing conducted on the soils or sediments). The October 7, 2007 ESA Adolfson report (page 29), states:

> Underlying these surficial [fill] soils, previous borings reveal approximately 22 to 30 feet of deltaic and flood plain deposits consisting of soft, compressible organic silt and sandy silt, including distinct fibrous peat deposits and buried logs and stumps. These upper organic-rich silt deposits are, in turn, underlain by medium dense to dense sand and gravel that extend to considerable depth.
Additionally, Bailey’s 2012 studies that included the logging of test pits and conducting borings that included the use of a standard penatrometer, suggest that the deposits described in the ESA Adolfson report are also present in the proposed restoration area. These deposits do not exhibit the characteristics that would be expected for highly cohesive materials. Additionally, Bailey indicates that the organic silt and sandy silt (with peat deposits) ranges from 6 feet to approximately 20 feet deep, which suggests that the Union Slough could be intercepting the water bearing sands that are located beneath the organic silts and sandy silts (and peat deposits).

Flow velocity and shear stress are suggested indicators of inducing erosion; however, the deposition of sediments also increases the potential for erosion. If the velocity of water in a channel drops, the sediment load capacity drops and sediments will be deposited. This can result in channel narrowing and an increase in velocity where this channel narrowing occurs. Every model SNR reviewed indicates that if the proposed levee breaches occur, the channel velocity between these two breaches will drop because the Union Slough will be reconnected with its floodplain.

Regardless, it is unclear how GeoEngineers established maximum shear stress values and velocities for the Union Slough without conducting field activities that include test pits and borings (as Bailey did and apparently Golder has in the past) and laboratory data on the characteristics of the sediments and soils along the portion of the Union Slough that will be affected by the proposed Smith Island restoration activities.

On page 18, TetraTech states:

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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.

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 Buse log ramp. This erosion would likely be distributed across the channel and may 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 slightly, this will not inhibit the slough’s sediment transport capacity, particularly given the fine-grained nature of the sediment load through this reach. Based on these results, channel depth in Union Slough will not shallow. Higher shear stresses below the Buse log ramp will prevent sediment deposition and may help flush existing sedimentation at this location.
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The modeling shear stress and velocities was apparently only conducted for the January 2009 event and not the predicted 1% flood event (TetraTech does not discuss what flows they are referencing in the statements above). However, the data in the 2-dimensional model was calibrated to the HEC-RAS 1-dimensional model prepared by West Consultants for the GeoEngineers 2011 report.

The 2011 West Consultants model apparently used the same base data that was used in the Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared by West Consultants.
Since the same data was apparently used in both models, it is unclear why the predicted shear stress and scour would be significantly different in the 2011 GeoEngineers report than the shear stress and scour presented in the model West prepared for the April 11, 2007 report. The 2007 modeling West Consultants conducted for CH2M Hill is not considered by TetraTech or even discussed.

As previously discussed, the GeoEngineers report suggests that 1% storm events occur more often than 15 year events and each 1% event would technically generate similar scour results presented in the April 11, 2007 West Consultants report. Therefore it is unclear what is gained by TetraTech conducting the 2-dimensional modeling, especially when the data used in the model is not validated (as Battelle did). Battelle suggests that the second greatest flows in this portion of the Snohomish River delta is the Steamboat Slough, however, TetraTech suggests that the Ebey Slough has the greatest flows (by far).

High flows on the Snohomish River are apparently not that infrequent. As SNR has indicated the purpose of the levees was to prevent seasonal flooding and to prevent channel migration. Maintained levees will prevent channel migration, however, once the levees are removed, these controlling structures no longer prevent levee migration (meander). Also, the type of sediment load in the Union Slough reach is unknown, SNR has not reviewed any document that includes studies of the sediments in the Union Slough bed or that are being transported by water. Additionally, the higher the velocity of the flow, the coarser the sediment load will be; this is fluvial geomorphology 101.

Any decrease in the channel flow, especially at bends, can result in sediment deposition. In fact the other models do predict sediment deposition, e.g., Battelle (2007) and West Consultants (2007), including sediment deposition in the proposed restoration area.

The Bailey 2012 studies indicate that the water bearing sands are located within 9 feet of the surface near the Union Slough channel. It is feasible that these sands are exposed in the Union Slough bed and this water bearing sand provides base flow for the Union Slough during the late summer and early fall months. High velocity flows can move these sands and redeposit them in areas where the channel velocity drops. SNR has not seen any studies that characterize the sediments in the Union Slough for any reach, based on actual studies that include borings, test pits, sample collection, and laboratory analysis.

Additionally, wind driven waves (fetches), high velocity flow, and the diversion of flood waters inside the remaining unmaintained levee system will cause erosion, underflow, and other conditions that will eventually remove the remaining unmaintained levees. TetraTech does not address this nor do any of the other models SNR reviewed address this (none of the models were conducted with no levee remaining or with failing unmaintained levees). Also, what will happen to the sediments eroded from the remaining levee sections?

TetraTech does not discuss why its modeling results are different from the Battelle studies or from the West Consultants studies conducted for CH2M Hill (2007) or why the TetraTech model provides more accurate model outputs than these other models that were previously conducted, especially when it appears that TetraTech used the West Consultants data in its model. The West Consultants 2007 model for CH2M Hill suggests 10 – 20 feet of scour could result from a 100 and 500 year flood event; TetraTech suggests that erosion will be minor and can be addressed with bank protection.

However, this does not apply to the proposed restoration area where channel migration caused by erosion and the removal of the remaining unmaintained levees by erosion is a concern because none of the models were run with the remaining levees being removed by erosional processes that will be accelerated by having flows on both sides of the levees. Additionally, SNR has not reviewed any document that addresses the potential for the remaining levees to erode after the levees are breached.
5.5 Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared for CH2M Hill, prepared by West Consultants

The West Consultants studies and report were not prepared by licensed engineers, geologists, or specialty geologists nor are there any details on the development of the model, the data sources for the model, or on the limitations of the model. However, the general concepts and interpretations are based on relatively sound fluvial geomorphologic and hydrologic principals, although some of the information is dated, such as the proposed location of the setback levee and a suggestion that the remaining existing levee will be maintained after the breach (this is the only report that discusses this).

However, none of the models or studies SNR has reviewed in Tasks 2 – 3 has evaluated what will happen to the remaining unmaintained levee sections after the levee is breached. This report suggests that the remaining levees will eventually erode away, which is logical considering without maintenance and the modeled scour suggested in this document combined with the observed erosion on the Union Slough banks (and historic bank erosion repairs by the Corps. as recent as February 2012) and levees will continue unchecked which will result in eventual levee failures.

However, after the breach, the levees will be subject to erosion on both sides and cross flow under and possibly, through the remaining levee structure, which will further weaken these structures and the sediments these structures were built on. This will lead to further levee failures which, over time will most likely lead to no remaining levees being present (these studies are apparently the only ones that assumed all the levees would be gone (Figure 11), however, this is not clearly stated in the text).

Additionally, this report is the only report SNR reviewed that relatively accurately depicts the 1869 Land Office survey of this area. It also discusses the changes in the surface water hydrology, such as the filling of the connector channel between the Snohomish River and the Union Slough and actively discusses the blind tidal channels. This report also discussed the issues with decreases in the velocity of the water in the channels which will result in sediment deposition which will lead to bed filling, sand bar formation, and other fluvial geomorphic changes along this segment of the Union Slough (this distributary channel has been “protected” with levees for a long time (at least 100 years based on SNR’s research) and in the other distributary channels (this report indicates that Union Slough and Steamboat slough are expected to have similar fluvial geomorphic changes).

The following are SNR’s comments that pertain to specific statements made in this document.

The West document states (page 2):

Profile plots of the thalweg elevations of the involved channels are shown in Figure 4, Figure 5, Figure 6, and Figure 7. The profile elevation data shown on the figures are taken from the hydraulic model developed for the lower Snohomish River and are mostly based on channel cross section surveys performed by Snohomish County in 1988 (Personal communication with Vaughn Collins, 2003).

The accuracy of the data used to obtain the thalweg elevations is not supported in this document. The datum used was the NGVD 29 which does not directly correlate with the NAVD 88 datum that is generally used in the other documents SNR has reviewed (with exceptions noted in this letter report). Additionally, there is no information on bathymetric data, tide data, or other information that is necessary to generate an accurate model. This report was prepared in 2007, 19 years after the cross section surveys were prepared by Snohomish County and cannot be relied on to be accurate in 2007 (nor can they be relied on in 2013).
The West document states (page 3):

*In general, the proposed and specific restoration measures involve breaching of existing dikes and construction of new dikes to protect adjacent infrastructure. The project is intended to restore natural habitat-forming processes for proper ecosystem function over the long-term. This includes side channel formation, channel migration, and wood recruitment.*

This suggests that side channel formation, channel migration, and wood recruitment (which can induce channel meander) are the goals to restore “natural habitat-forming processes”. These processes will only have one direction to go considering the right bank of the Union Slough will still have levees present. It is also unclear how the proposed breaches will affect the existing breaches on the right bank of the Union Slough.

The West document states (page 3):

*The proposed project consists of construction of new dikes and cross dikes, filling the old borrow ditches adjacent to the existing dike, and breaching the existing dike in three locations. A schematic drawing for the project is shown in Figure 9. As seen on the schematic, the effects of remaining dikes and proposed cross dikes partially protect the pipeline from channel migration. It is noted that none of the proposed breaches are in the vicinity of the pipeline crossing.*

This description is inaccurate based on more recent documents SNR has reviewed that indicate that the proposed setback levee will be in a different location and have a different configuration and that the levees will only be breached in two locations. This also suggests that the “remaining dikes” will partially protect the pipeline from channel migration, however, none of the documents SNR has reviewed document studies that suggest that the remaining levee system will not erode away due to lack of maintenance, erosion on both sides of the levees, and continuing erosion on the waterward side of the levees. Additionally, as previously discussed, Figure 11 in the West document suggests the model was run with no remaining levees bounding the proposed restoration area.

The West document states (page 4):

*As seen from Figure 10 and Table 2, the observed migration distances are relatively minor over the 120 years of record. In general, no significant migration occurred beyond any existing levee. The project area has generally low hydraulic energy gradients that are strongly controlled by tidal base level. The construction and maintenance of the levee system tightly confined the river channels, practically limiting significant movement. It is also recognized that dredging and large woody debris removal have been on-going activities throughout the period of record (Haas and Collins, 2001).*

West recognizes that the levee system, combined with dredging and the removal of “snags” (woody debris) is what has prevented the Union Slough and other channels in this area from meandering. SNR’s historic research (HistoryLink.org) strongly suggests all of the distributary channels have been dredged and have had “snags” removed to allow navigation on these channels. Additionally, deepening the channels made the levees more effective during high flow events because the channels had more capacity for high velocity flow within the levee system. However, dredging also has an effect of “entrenching” the channel in deeper sediments, making channel meander less likely.
Table 2 on page 4 appears to be a reasonable interpretation of channel change in 136 years (1869 – 2007), however all of these changes may not be attributable migration, with much of these changes also occurring because of manmade modifications to the channels, such as the infilling of the channel that connected the Snohomish River to the Union Slough (this led to dramatic changes in the hydrology and morphology of Tidal Channel B); as discussed in the West document: “It is further recognized that differences in measured bank locations are also due to significant human influence.”

The West Document states (page 5):

An existing hydraulic model of the Snohomish River was used to characterize the existing hydraulic conditions of the pipeline alignment. The channel and overbank hydraulic properties needed to perform scour calculations were obtained from a UNET unsteady flow hydraulic model (USCOE 1997) developed for the Snohomish River Flood Insurance Study (WEST 2003). The UNET model represents the Snohomish River, Union Slough, Steamboat Slough, Ebey Slough, and the connector channel that runs between Ebey Slough and Steamboat Slough. The model extends from Possession Sound to well upstream of the area of interest.

Unfortunately, West does not provide much information on the accuracy of the previous models nor does the document discuss the sources of the information used in the models, such as elevation data, bathymetry data, discharge rates in the different distributary channels, stage heights in the different distributary channels, tide elevations correlated to flow events, or other data. The accuracy of this data is integral to the accuracy of the model that already has some inherent accuracy issues (1-dimensional models have limitations).

The West Document states (page 5):

To represent the Smith Island Estuarine Restoration Project, an additional hydraulic model was developed by modifying the geometry of the existing conditions hydraulic model to represent the removal of portions of the levee along Union Slough. Separate models were considered due to the uncertain timing of future restoration efforts. The extent of the assumed levee removal in the future condition hydraulic models is shown in Figure 11. All the hydraulic models for existing and potential future conditions were run with a downstream boundary condition of mean lower low water (-6 ft NGVD).

It is unclear what the “timing issue” is considering West is using data from 1997 and 2003 in the model, unless is referring to the timing of other proposed restoration projects in this area. Additionally, this model is based on a different “geometry” for the proposed Smith Island Restoration area than is currently planned.

The West document states (page 5):

A summary of channel and overbank velocities for the 100- and 500-year floods is shown in Table 3 and Table 4, respectively. As noted in the tables, “Storage Area” is a floodplain area located landward of a levee that has ineffective flow conveyance potential but can store floodwaters when the levee is overtopped. In general, the removal of a portion of levee moderates the velocity of flow in the adjacent channel by allowing flow within former storage areas.
West did run models for 100 and 500 year floods (most of the other studies SNR reviewed, including the GeoEngineers report do not, even though the GeoEngineers report suggests 100 year events occur more frequently than 15 year events. West correctly indicates that by providing flood storage in that proposed restoration area, the water velocity in the channel will be reduced, which means the sediment load capacity of the water will also reduce. As West indicates later (as will be discussed) this leads to sediment buildup in the channel bed and in the new floodplain (the proposed restoration area).

Oddly, Tables 3 and 4 on this page suggest that the overall channel velocity for a 500 year event (5.65 ft/s) event is less than a 100 year event (5.97 ft/s), mainly because the overbank velocity for a 500 year event is shown to be less. West does not discuss this apparent discrepancy.

The West document states (page 6):

> Scour along the channels in the Snohomish River estuary can be caused by floods, local scour around debris, channel migration, tides, or a combination of these factors. Scour potential due to floods can be reasonably estimated based on empirical relations. Local scour due to debris and channel migration are generally unpredictable for a specific location. Similarly, the formation of blind tidal channels may be due to a combination of flood impacts and tidal effects. Consequently, estimates of scour cannot be specific. Use of empirically-based equations that define envelope curves around a range of scour observations for similar conditions, coupled with appropriate margins to account for uncertainty is considered the most reasonable approach to estimating potential scour depths.

The Union Slough is located on the Snohomish River delta that is a prograding delta complex and is not technically an estuary. Scour can occur around more resistant materials such as the buried peat mats in the bed of this distributary channel (this may be one reason the thalweg is described as moving back and forth across the channel in other reports) and wood that may be present in the channel banks (placed during historic deposition in the delta).

Tidal currents, flooding events, and many other factors will affect channel scour, including the type of sediments the channel reach is passing through (bed and bank). However, as West states, although there are many potential reasons scour can occur, there are a limited number of reasons that can be used in a model in an attempt to predict scour.

One of these is the channel flow velocity and stage height during major storm events, ideally synchronizing these flows with actual tidal data, accurate bathymetric data, and accurate cross section data (with accurate elevations). However, there are no river gages on the Union Slough nor are there local tide gages that accurately measure tides, nor is it clear if accurate bathymetric data or topographic data available.

Without Union Slough river gage data the actual channel discharge rate and stage height data is unknown and the contribution to the channel flow from ground water is also unknown (Bailey, 2012, states that the hydraulic head of the ground water is at or above the ground surface on the Hima property which would mean that there is a potential for ground water base flow contributions to the flow in the Union Slough). However, West did model for the 100 year and 500 year flood events which create flow conditions that would provide the highest potential for scour and for potential channel migration.
The West document states (page 6):

Scour depths were calculated for the Snohomish River, and Ebey Slough. Because Union Slough and Steamboat Slough are hydraulically connected at high flows and because the two sloughs are captured by a single cross section in the UNET model, the scour calculations for Union Slough and Steamboat Slough were performed on the cross section that captures both slough channels. In other words, the scour depths are the same for Union Slough and Steamboat Slough. This will yield conservative scour elevations for Union Slough.

Technically, Ebey Slough is hydraulically connected to Steamboat Slough also shown in Figure 5-15 of this report. However, because Union Slough has a narrower channel than Steamboat Slough and Union Slough has tighter bends than Steamboat Slough in the modeled area, it is likely that if the same discharge and stage data were used for both channels, the scour would be greater in Union Slough (however, this would also be dependent on the bathymetry or the two channels which is not discussed). It is presumed that this is what is meant by “this will yield conservative scour elevations for Union Slough”.

However, it would have been preferable for West Consultants to have obtained the information necessary to generate new cross section data across the Union Slough so that the Union Slough could have been modeled independently of the Steamboat Slough. Although, considering that there is no river gage data on the Union Slough or Steam Boat Slough (there is for Ebey Slough, but this is a stage gage only), the model will not accurately depict actual discharge and stage data conditions. Also, because there is no local tide gage coordinating accurate tide data with river stage data is not possible.

SNR has observed the same data issues with all of the other reports we have reviewed, which suggests that none of the models will accurately predict the hydrology and potential changes to the fluvial geomorphology of the Union Slough if the proposed Smith Island Restoration project proceeds as currently planned.

The West document states (page 7):

Based on a geologic profile along the pipeline alignment shown in Figure 12 (Golder 2001), the bed material was assumed to be sandy silt.

Assumptions can lead to model inaccuracies. The studies conducted by Bailey, 2012 on the left bank of the Union Slough (and the proposed restoration area) suggest that the materials can vary, with the sandy silt and peat deposits ranging from 9 – 20 feet deep in the test pits and borings conducted in his studies. These deposits are underlain by sands. This suggests that the bed materials also vary, especially in the confined channel of the Union Slough where water velocity would be higher due to the confinement of the channel by the levee system. This typically leads to channel down cutting and if the deposits observed by Bailey are similar on the right bank of the Union Slough, the bed materials can include sands.

The West document states (page 7):

The calculated estimates of scour depths that are reported are the result of the equation that yielded the greatest scour depth. In general, estimated scour depths are 10 to 20 feet.
It should be noted that the West studies were focused on bed scour, not bank scour and undercutting. The primary reason for these studies was to determine if the pipeline would be exposed by channel bed scour, although potential channel meander is considered for the areas where the pipeline is shallower (the areas behind the existing levees).

These calculated estimated channel bed scour depths are substantial and would be even more substantial if the bed materials are sands. However, according to DD5 there are scour holes that are 50 feet deep near the levee section the Corps of Engineers repaired in the winter of 2012. It is unclear why this deep scour hole is present, but it could be associated with a peat mat that was “released” from the channel bed after it was dislodged during a high flow event. However, it is more likely that the bed sediments in this area are conducive to scour, especially when channel flow encounters strong, extreme high tide current events.

Regardless, it seems that West assumes that a 100 year storm event will only occur every 100 years and therefore there will only be one scour event that will result in 10 – 20 feet of scour. The May 2011 GeoEngineers report (page 2): “The Snohomish River and delta have experienced 100-year floods at intervals of three to ten years (Snohomish County, 2005”). This suggests that there could be five 100 year storm events in 50 years.

Tables 5 and 6 on page 8 suggest that the overbank scour (through the proposed levee breaches) would range between 7.6 feet (100 year event) and 6.9 feet (500 year event). This is substantial erosion in the “overbank area” (the proposed restoration area) which can lead to side channel formation, which is a component of channel meander.

The West document states (page 8):

The results of that analysis defined the minimum burial depth required to avoid potential scour impacts for the existing channel locations. However, it is recognized that the long-term risk of scour affecting the pipeline alignment will be dependent on the potential for the involved channels to migrate during its service life, which is assumed to be 50-years. Scour related impacts to the pipeline could occur if any of the channels were to migrate into the overbank areas where burial depths are significantly shallower. In view of that, an understanding of the migration potential of the involved channels can be used to characterize the potential risk of scour impacts.

In general, channel migration is a natural characteristic of all geologically unconfined watercourses formed in transportable sediments. Typically, the type, magnitude, and rate of channel migration are reflective of a dynamic equilibrium that is characteristic of the involved geomorphic setting and channel type. The magnitude and rate of channel migration reflects changes in hydrology, hydraulics, and sediment transport. Such changes may occur due to both natural and man-made influences. Because the pipeline is installed entirely underground at a depth designed to not be exposed by scour, the pipeline will not affect the hydrology, hydraulics, or sediment transport characteristics of the involved watercourses.

The pipeline segments were shallower because these areas were protected by the existing DD5 levee system; however, if the levees are no longer present to prevent channel meander to the west, which is most likely because the eastern bank (right bank) of the Union Slough is still protected by a levee system. If the Union Slough or side channels to this slough meandered to the west this could present a potential risk that the pipeline could be exposed.

As West points out channel migration is a characteristic of all watercourses formed in transportable sediments, especially in areas where there is a relatively low topographic gradient. This is a component of sinuosity and the fluvial geomorphology of low gradient rivers that fall within the meandering classification. The sinuosity of the distributary channels, Ebey, Steamboat, and Union Sloughs would place them in the meandering fluvial geomorphologic channel classification. Channel meander is channel migration.
The maintained levee system that bounds the banks of the Union Slough has forced a type of equilibrium on the Union Slough fluvial geomorphology. However, when the levees are breached, this equilibrium will change and this distributary channel will no longer be confined in the areas of the proposed breaches, which will lead to changes in the fluvial geomorphology and hydrology of this channel reach. This can lead to channel migration or side channel formation which is a component of channel migration.

Additionally, over time, the remaining unmaintained levee system is expected to eventually be removed by fluvial processes which will increase the likelihood of channel migration. None of the models SNR has reviewed have included modeling on the fate of the remaining levee system after the breaches have been completed and the remaining levee system is no longer maintained. Additionally, none of the models SNR reviewed include scenarios where the existing DD5 levee system is completely removed. Because there are discussions regarding a remaining, maintained DD5 levee after the breaches have been completed, it is unclear if the West modeling described in the 2007 “Pipeline” document was modeled with the levee completely gone as is suggested in Figure 11.

The West Document states (page 9):

Third, the channels have been strongly influenced by the construction and maintenance of an extensive levee system, active management of large woody debris in the channels, and dredging. Last, a number of transportation corridors, bridges, and other developments have been constructed that effectively control the location of the channels.

In general, the pipeline alignment is located in a depositional environment where long-term lateral channel migration would typically be expected. Under natural conditions, overbank sediment deposition would occur during floods and bed load deposition within channels would cause them to shift laterally. However, the existing channels are leveed which artificially increases stage and velocity, confines floods of low return periods, limits the ability for overbank sediment deposition, and generally mutes the potential for dynamic change. It is noted from the channel elevation data presented in Table 1 that significant changes in the minimum elevation of the involved channels do occur. In fact, dredging of the mainstem Snohomish River is conducted for maintenance of a shallow draft navigation channel.

West accurately discusses why the channels have demonstrated significant amounts of channel migration for at least 120 years and does indicate that under natural conditions, overbanking events will eventually lead to channel migration. Additionally, historic dredging of the distributary channels would have reduced the potential for channel migration (and modern day dredging on the Snohomish River).

However, the proposed Smith Island Restoration project will include the breaching of the existing levee system which will change the channel flow and the transport of sediments in the areas where overbanking will occur. This change in the sediment transport and deposition typically leads to changes in channel morphology that can include channel meander (migration).

The West document states (page 9):

A primary reason for the slow rate of channel migration in the project area is believed to be the overfit nature of the river relative to its glacially formed valley.
The Snohomish River is actually an underfit river in a large glacially sculpted Valley. The river valley was not formed by the Snohomish River; it was formed by a combination of tectonic forces, glaciers, and very large glacial outwash rivers called recessional outwash channels. The extremely large meltwater rivers flowed during glacial recessions. The last glacial recession was the Vashon Stade recession that ended near the end of the Pleistocene (approximately 11,500 years before present). This is why the geologic maps of this area suggest that the stratigraphy of the Snohomish River Valley includes recent alluvial surface deposits that are underlain by glacial recessional outwash deposits.

The significant width of a valley that is filled with sediments actually allows the river to meander to a greater extent. A narrower valley would restrict the meander extents. However, the distributary channels are not located in a wide river valley filled with sediments, these channels are located on a prograding delta that is composed of recent alluvial deposits (sediments) that generally range from gravelly sands, sands, silty sands, sandy silts, and silts (clayey silts and silty clays are typically deposited in the distal portions of the delta). The characteristics of the delta deposits changes based on the location of the distributary channels and the locations of overbanking.

Coarser sediments (typically sands and in some cases gravelly sands) are deposited in the proximity of the channels and the finer sediments are deposited further from the channels. As the channels meander, this affects the characteristics of the sediments across the delta creating layers of fine and coarse sediments.

It should be noted that distributary channels on an active delta are not analogous to underfit river channels in a glacially formed river valley. Deltas are dynamic and very active depositional environments which lead to the typical dendritic channel patterns that continuously change. These changes are affected by many factors, including total river flow, total sediment transport, tides, topography (gradient), and the geomorphology of the area.

Deltas have low topographic gradients encouraging channel meander, however, if the topographic gradient were to change, such as may be caused by a seismically induced delta front collapse or delta “settlement”, the distributary channels would “adjust” to the change in the gradient with deeper, straighter channels. This is all part of the dynamics of a fluvial system and the principles of fluvial geomorphology.

The West document states (page 10):

> Another important influence on channel migration potential is the effect of large woody debris. Large wood has been shown to be a dominant influence on the geomorphology of large western Washington Rivers (Collins et al., 2002). Debris jams can create channel avulsions resulting in multiple channels, floodplain sloughs, and distributary channels.

Anything that can resist erosion can influence channel migration potential, including large woody debris that is buried in the channel banks or placed within the channel (such as is done in many river and stream restoration projects). The DEIS indicates that large woody debris will be used in the restoration project and that grading activities will be conducted to change the geomorphology of the farmland. However, none of the models SNR reviewed included the placement of large woody debris or changes in the geomorphology of the farmland (including the creation of mounds). Large woody debris can increase the potential for channel migration as can the creation of mounds and other grading activities.

The West document states (page 11):

> Of greater significance are the entry and exit points to which the sloped portions of the HDD are tied. Both the entry and exit points are located landward of existing levees.
Under existing conditions, it is judged that no significant risk of channel migration affecting the HDD entry and exit points exists since they are protected by levees. If the levee along Union Slough is breached as part of the Smith Island Estuarine Restoration Project, the risk of channel migration would increase, as there would be fewer man-made impediments to channel migration. Also, the blind tidal channels would again be subject to tidal action. However, it should be noted that none of the proposed levee breaches are in the vicinity of the pipeline alignment.

West correctly indicates that the risk of channel migration will increase with any removal of the existing levees as will the risk of changes in the fluvial geomorphology of the blind tidal channel (Tidal Channel A), which appears to have evolved since the 1869 Land Office survey was made. None of the models that were conducted (including the Wes model for the Pipeline) apparently included the tidal channel in the models, possibly because the HEC-RAS mode cannot model blind tidal channels. It should be noted that if the remaining levees are not maintained, it is highly probable that the entire remaining unmaintained levee system will eventually fail and be removed through fluvial erosional processes.

The West document states (page 13):

The reduction in flow will result in a corresponding reduction in sediment transport. As commonly occurring flows would be influenced, it would be expected that on average less sediment would be transported downstream and more sediment would be deposited within the main channel of these watercourses. Over the long-term this will result in bedform formation, reduced flow depth and channel capacity, side channel formation, and increased channel migration.

SNR agrees with this interpretation. The potential for sediment deposition will increase as the unmaintained levees that remain begin to fail and erode, contributing to the sediment deposition in this area. None of the reports SNR reviewed directly address the channel migration potential without any remaining levees on the left bank of the Union Slough bounding the proposed Smith Island Restoration area. Additionally, little is known about the actual construction of the existing levees nor has SNR reviewed any reports that include studies on these levees to determine their resistance to erosion after the proposed breaching of the levee occurs and presumably unmaintained (especially once water will be flowing on both sides of the remaining levees).

The West document states (page 14):

If the levee is breached, but not removed, and maintained, it would be expected that the levee would continue to exert significant lateral migration control on the main Union Slough channel location. The Smith Island Estuarine Restoration Project includes this specific action. In this case, a scour depth based on overbank hydraulic conditions would be considered more appropriate than a scour depth based on channel hydraulics.

If the levees are breached but maintained, the levees may prevent significant channel migration. Scour in areas protected by breached levees would be subject to both floods and tides. Scour due to floods in overbank areas for the 100-and 500-year floods were defined in Table 5 and Table 6 and are expected to range from 6 to 8 feet in depth. Scour action due to tides may form blind tidal channels over time. The depths of remnant blind tidal channels defined from topographic mapping of the area are observed to be less than 5 ft in depth.
These paragraphs suggest that the Smith Island Estuarine Restoration Project includes the specific action of maintaining the remaining levees. However, this document also states that the remaining levee system will be unmaintained. SNR understands that the remaining levees will be unmaintained and that it is assumed that the remaining levees will eventually be removed by erosion, bank failures, slumping and other mechanisms in this tidally influenced fluvial system. The formation of additional blind tidal channels and changes to Tidal Channel A are effectively the same as channel migration.

It is unclear who prepared the West report (there is no stamp or signature), however, fluvial geomorphologic interpretations, interpretations on sedimentology, stratigraphy, surface water hydrology, and ground water hydrology typically require that a licensed geologist, specialty geologist or engineer sign and stamp the report.

None of the Task 2 and Task 3 studies discuss potential impacts to the proposed setback levee or the DD5 levee system downstream from the northern breach where all models suggest the water velocity in the Union Slough will increase. The models do not discuss how to prevent high rates of erosion with the modeled higher velocity flows or how to protect the tidal channel banks from the high potential erosion.

Additionally, none of the models discuss one of the more important aspects of these studies, which is how will the proposed restoration project affect the navigability of the Union Slough. Channel meander can affect the navigability as can the creation of side channels. Additionally, sediment buildup in the channel bed in areas where the flow velocity in the Union Slough decreases can reduce the depth of the water and can impact navigation if sandbars and other depositional features are created.

As discussed in SNR’s comments, there have apparently been no studies on the characteristics of the fill materials in the existing DD5 levee system that bounds the proposed restoration area and therefore nothing is known about the potential rate of erosion that will occur after this section of the DD5 levee system is breached. As more of the remaining levee system fails and erodes, the sediments from the levee will enter the Union Slough channel and the morphology of the left bank of the Union Slough will be in a process of change that has not been predicted by any model (actually none of the models provided any information on potential changes in the Union Slough fluvial geomorphology).

Snohomish County suggested that the County would obtain a dredging permit and that the County will ensure that the Union Slough remains navigable, however, this may not be practical and the various agencies may not issue a dredging permit especially if the dredging will be conducted in an area adjacent to a habitat restoration area. Additionally, it is unclear how dredging will impact the restoration area because none of the models have factored in potential dredging.

SNR recommends that more detailed studies be conducted on this reach of the Union Slough and that a recording stream gage and tide gage (or pressure transducer) be installed in this reach of the Union Slough. Detailed bathymetry studies should be performed and both banks of the Union Slough need to be surveyed to allow accurate cross sections to be created. The sediments in the Union Slough levees and the bed and banks need to be studied and tested (including drilling activities) and the sediment transport characteristics of the Union Slough also need to be studied (for different flow rates).
6 TASK 4 COMMENTS

The subsurface hydrology of the proposed restoration area and vicinity is not well understood. This is why Snohomish County had the Snohomish County department of Public Works hydrogeologist (Bailey) conduct studies in and in the vicinity of the proposed restoration area. However, the focus of these studies were generally limited to the potential saltwater impacts associated with the proposed restoration project and did not include detailed hydrogeologic anc geologic studies.

The purpose of the saltwater intrusion document prepared by TetraTech is unclear. TetraTech did not conduct any additional geologic or hydrogeologic studies and in numerous cases misstated the Bailey, 2012 document. As an example, the TetraTech saltwater suggests that the upper 20 feet of sediment on and in the vicinity of the proposed restoration project are estuary deposits that act as an aquitard. Bailey actually states that these sediments are 9 – 20 feet thick and that these sediments contain numerous sand lenses and peat deposits; it does not state that these sediments are consistently 20 feet thick across the study area.

The Bailey studies and report were conducted to determine what impacts the proposed restoration project would have on ground water quality, or more specifically, how potential saltwater intrusion could impact ground water quality. It is unclear how the unauthored TetraTech document added anything to Bailey’s studies or findings. As discussed above, if anything the TetraTech document should have been a peer review conducted by a licensed hydrogeologist who critiqued the Bailey document (as SNR is now doing).

Additionally, it is unclear why TetraTech had Shannon & Wilson conduct a Modflow model based on the Bailey studies considering the Bailey studies did not include any aquifer testing, including hydraulic conductivity testing of the upper sediments or the sand sediments underlying these upper sediments (or the silts Bailey identified beneath the sands). Without actual data on the aquifer characteristics of the sediments encountered in the borings and test pits, there is no site specific data (e.g., slug test, pump test, or other aquifer testing) to use in the Modflow model.

The determination that the upper sediments have the characteristics of an aquitard suggests that the hydraulic conductivity of these sediments has been measured and that the sediments throughout the study area are consistently the same and have the same hydraulic conductivity throughout the sedimentary layer (the Modflow modeling conducted by Shannon & Wilson used an approximate hydraulic conductivity of 10⁻⁶ cm/sec). It is difficult to understand the rationale for defining the upper 20-feet as an aquitard unit in light of the fact the unit provides virtually no penetration resistance during Standard Penetration Testing (N=0). Additionally, it is unclear how an interpreted hydraulic conductivity of 10⁻⁶ cm/sec was developed for these sediments.

Additionally, the Modflow model was developed for one of the Hima Nursery wells (there are two, although this is not mentioned in any report). The water wells on the Hima Nursery have never had any hydrogeologic studies conducted on them, including slug tests or pump tests. Therefore the hydrogeologic characteristics of these wells are unknown and the data used by Shannon & Wilson in the Modflow model is not based on the actual ground water aquifer these wells are “screened” in.

The Bailey studies did not include the City of Everett POTW 160 acre lagoon (with 5 feet of water present in this lagoon) in his studies nor does Shannon & Wilson state that this lagoon was factored into the Modflow model, however, the Shannon & Wilson Modflow model suggests that the hydraulic head for the ground water aquifer is to the south and that the ground water “flow” is from south to north. The only known source of hydraulic head (ground water recharge) to the south is the City of Everett POTW lagoon.
The primary recharge zone for much of the ground water on the eastern side of the Puget Sound is the Cascade Range to the east (this is where all of snowpack is located). The Puget Sound is the lowest point downgradient from the Cascade Range. This would typically create conditions where the ground water “flow” is from the east to the west. There is no discussion in the Shannon & Wilson report or the TetraTech document that discusses why the ground water flow direction in the Modflow model is inconsistent with typical ground water “flow” in this area nor is there any discussion on the potential influence the 160 acre lagoon could have on the ground water aquifer or the ground water quality. A March 11, 2013 follow-up response to SNR’s request for information from Snohomish County states:

The lagoon was represented as a recharge source in the model, at a recharge rate of five times greater than the surrounding area to reflect the groundwater gradient from the south shown in monitoring well data from the Geologic and Hydrogeologic Field Investigation.

Although not discussed in the Shannon & Wilson report or the TetraTech report, Shannon & Wilson apparently included the lagoon in the Modflow model; however, it is unclear how the potential ground water recharge rate for water in this lagoon was determined or how this recharge is influencing the upper sediments that Shannon & Wilson modeled as an aquitard (10⁻⁶ cm/sec vertical hydraulic transmissivity).

Additionally, considering that the studies conducted by Bailey were primarily focused on saltwater intrusion and included soil and ground water sampling for chlorides and other chemical constituents in the soil and ground water, that a Quality Assurance Project Plan (QAPP) was not developed before these studies were conducted to ensure that the methods used and the quality of data generated met acceptable standards. Considering this study was conducted to address SEPA EIS concerns, it would be customary to develop a QAPP prior to conducting the type of studies Mr. Bailey conducted (a QAPP is required by the USEPA and is typically required by Ecology). Ecology customarily prepares QAPPs for saltwater intrusion studies; however, the studies conducted by Bailey included other sampling and analysis activities that do require strict QA/QC controls and chain of custody documentation.

The following subsections provide specific review comments for each document in Task 4. SNR also provides comments for the Shannon & Wilson document that was not included in the original Task 4 review documents.

6.1 Geologic and Hydrogeologic Field Investigation Report, Smith Island Restoration Project, October 2012, prepared by Snohomish County Department of Public Works, Bailey, K. A.

This report states (page 1) that the purpose of the investigation conducted by Bailey was to “provide geologic and hydrogeologic information specific to Snohomish County Public Works – Surface Water Division’s Smith Island Restoration Project Site and its surrounding properties.” Bailey further states:

“We understand that this information will be utilized by Surface Water and its consultants for the development of the projects permitting, design and construction phase reports, plans and specifications.”

This does not suggest that the focus of the investigation was to study the potential impacts the proposed Smith Island Restoration project would have on saltwater intrusion impacts to the ground water aquifer. It does state that the studies were conducted for permitting, design and construction, plans, and specifications. This suggests that these studies were primarily engineering geology studies associated with the setback levee construction.

Bailey states (page 1):

The excavation of 58 test pits on the Smith Island Restoration Project site.
One gradation from one test pit was performed in the laboratory; almost no lab data for foundation unit/uppermost hydrostratigraphic layer - insufficient data for an engineering feasibility study.

The collection and submittal to the laboratory of 14 soil samples from test borings for soil gradations and hydrometers, as applicable.

There were 58 test pits excavated and logged; 139 soil samples were collected; one gradation was performed on a sample from TP #29. Hydrometer testing for this sample or any of the other soil samples sent to the soil lab is apparently missing. Gradations of 50 to 100 samples for this project would not be unreasonable.

The weekly and/or monthly reading of observation wells at alternating high tide and low tide intervals and the development of hydrographs from the collected data.

Multiple observation well readings covering both high tide and low tide intervals during a one-(1) day period.

It is unclear why pressure transducers such as the Solinst Level or other equipment were not used to monitor water levels in the wells, the tidal channels and the Union Slough. This equipment will provide continuous measurements at the same time at selected intervals (typically 5 – 10 minute readings) that would provide accurate elevation data relative to height of the water in the tidally influenced Union Slough. It would also provide information that can be used to calculate the hydraulic conductivity of the aquifer (if wells or piezometers were installed in the “upper sediments” and this equipment was installed, it would also provide information on the hydraulic conductivity of these materials) especially if aquifer testing, such a slug tests or pump tests were conducted.

The use of a rain gauge with a Solinst RainLogger would also provide information on the potential influence precipitation events have on the tidal channels, ground water, and the Union Slough assuming this equipment was installed as discussed above.

Without using pressure transducers that monitor water levels at the same time and at frequent intervals in a tidally influenced area, the manual readings can have a high level of error. Additionally, without data on the water elevations in the Union Slough and the tidal channels, it is not possible to correctly correlate tidal data to the ground water elevations and other valuable information necessary to accurately model the hydrology is missing.

On page 2, Bailey states:

Acquisition of the project site was completed in the mid-2000’s with the purchase of approximately 386 acres of un-used farmland located north of 12th St NE, east of 1-5 and west and south of Union Slough . . .

"Farmland" implies that the land was used at one time but may presently be idle. It is unclear why this farm land is "unused" or why it is being removed from agricultural production.

The topography is typical of recovered farmland located in the Snohomish River estuary.

It is unclear what Bailey means by “recovered farmland” and why he believes this area is located in the Snohomish River estuary. Bailey should provide some discussion regarding these statements, including the reasons why he determined that this area on the Snohomish River prograding delta is an estuary.
On page 3 Bailey states:

*Ditches and sloughs are mostly dry during summer months and during extended periods of dry weather. During the winter months, when much of the site is under standing water, the ditches and sloughs are full.*

It is unclear where Bailey got this information. DD5 personnel do not suggest that the ditches, tidal channels, and the Union Slough is “mostly” dry during the summer months nor do historic air photographs SNR reviewed from Google Earth suggest that these features are “mostly dry” during the summer months (nor do studies conducted by Battelle). Additionally, it is unclear why Bailey states that much of the “site” is under standing water and the “ditches and sloughs” are full during the winter months. This is an unclear statement (are the sloughs at bankfull flow?) and is inconsistent with the other reports SNR reviewed (such as the drainage reports in Task 1). Bailey should cite the sources he used to make these determinations.

Also, Bailey does not mention the tidal channels unless he is referring to these features as “ditches”.

*The project site is located in the Snohomish River estuary which is an east-west trending topographic depression that was glacially eroded and formed between the Getchell Plateau to the north and the Intercity Plateau to the south.*

Bailey does not discuss why he believes the “project site” is located in an estuary, especially one that extends from the Getchell Plateau to the Intercity Plateau. Based on SNR’s observations and research, the proposed Smith Island Restoration project is located on the Snohomish River prograding river delta.

*The soils in the project area generally consists of interbedded very-soft to soft organic silt, silt and clayey silt with local discontinuous lenses of very-loose to loose fine-grained sand to varying depths up to 20 feet below the ground surface (bgs).*

This description is inconsistent with the GeoEngineers report in Task 2 and 3 and is not a typical description of a potential “aquitard”. GeoEngineers suggests that this material is highly cohesive and highly consolidated material.

*This layer is underlain by near shore marine sediments that are primarily granular soil types (fine-, medium- and coarse-grained sand), generally with densities ranging from loose to medium dense. The near-shore marine sediments are typically underlain at depths greater than 65 feet by alternating zones of very soft to soft, normally consolidated silt and clay, and additional strata of alluvium/near-shore marine sediments. These subsurface conditions reflect the rising sea level during the time of deposition of these sediments.*

It is unclear how Bailey determined that these sands are near shore marine sediments and not fluvially deposited sediments (this should be explained). Additionally, the laboratory results show medium to fine sand. Also, the logs show very little to trace clay and do not show alternating layers of silt and clay.
Additionally, it is unclear why Bailey states that the subsurface conditions reflect rising sea level during the time of deposition. The rate of tectonic uplift in the Puget Lowlands is approximately 1 cm per year (some geologists believe this is isostatic rebound). Assuming at least 10,000 years since the Vashon Stade glacial recession was complete; this suggests that there has been as much as 328 feet of uplift in the last 10,000 years. How is this potential uplift factorec into Bailey’s rising sea level hypothesis?

On page 4, Bailey states:

According to the Natural Resource Conservation Service (formerly the Soil Conservation Service), the mapped surficial soils in the project site consists of four-(4) soil types, the majority of which is the Puget Silty Clay loam, followed by the Snohomish Silt loam, Mukilteo muck and Terris Medisaprist.

NRCS soil classification is not applicable to a geotechnical study; Bailey should have used the USCS classification scheme - this hydrogeologic report is part of a geotechnical investigation to determine the engineering feasibility for constructing the setback levees (as stated in the purpose for these studies).

Additionally, the NRCS soil maps are notoriously incorrect, especially in complex depositional areas such as deltas. What is more important is what was observed in the test pits and borings conducted on the site. However, if Mr. Bailey decided to describe the soils the NRCS suggests are present, he should state whether these soils were observed in the test pits and boring logs.

A staged investigation approach was utilized on this site. A test pit investigation was first performed to delineate the shallow subsurface soil profile across the site. This was followed up with a series of both shallow and deep test borings which were located so as to provide good coverage in the immediate vicinity of the proposed set back dike and cross site coverage for better correlation of existing conditions. Observation wells were installed in each test boring upon completion.

How were test pit and boring locations chosen? How did the test pit studies influence the locations of the borings/wells? How were the borings converted to wells (construction details)? How was riser bypass flow avoided? What research was conducted prior to choosing the boring and test pit locations? Why weren’t pressure transducers used in the monitoring wells? Why weren’t the Hima wells tested? Why wasn’t pump testing or slug testing conducted?

Was this study conducted for ground water studies or for engineering geology studies for the proposed setback levee (the statement above and the purpose stated in this document suggest that these studies were conducted primarily for engineering geology purposes)? This may be why slug testing or pump tests were not conducted and why pressure transducers were not installed in the wells, the Union Slough, and the tidal channels (although Bailey seems to not have noticed the tidal channels based on previous statements).

On page 5, Bailey states:

Soil descriptions were developed in accordance with ASTM D2488 and following the Unified Soil Classification system.

Based on the field classifications of soils using the referenced method, the descriptions are incomplete.
Upon completion of excavation of each test pit bulk soil samples were collected for chemical testing from three-(3) zones: S1 — upper 6" of soil; S2 — above the prevailing ground water table or if a ground water table or ground water seepage was not observed, from the upper 4 ft.; and S3 — below the ground water table or if a ground water table or ground water seepage was not observed, from below 4 ft.

Mr. Bailey does not discuss unsaturated zone flow associated with normal infiltration and potential lateral unsaturated zone flow from surface water features in this area, such as the drainage ditches, the tidal channels, and the Union Slough. What is the difference between the ground water table and ground water seepage? If ground water was observed in the “shallow or upper sediments” why are these sediments considered to be an aquitard, especially when ‘ground water seeps, flows, and a water table were observed in these sediments?’

Also, the field investigation was an opportunity to perform both chemical and physical testing of the site soils especially as it relates to the setback levee alignment foundation conditions. After all, this document states that the primary objective is to obtain data for construction purposes.

Boring depths for the deep test borings ranged between 80 to 85 feet bgs. Primary test boring coverage was in the immediate vicinity of the proposed new set back dike.

It is unclear why these borings were limited to the “immediate vicinity of the proposed ne setback levee” [levee] unless they were conducted for engineering geology purposes. If ground water studies were the primary reason for these borings that were converted to wells, there should have been more and they should have been more widely distributed, especially if the focus was on ground water quality.

Snohomish County has contended that this study was not part of the “design process” however, Bailey states that it is and the placement of the wells suggests that these studies were for design purposes and the ground water analysis was conducted as a secondary task without designing a ground water monitoring program that focused on ground water studies and ground water quality.

What ground water guidance documents were followed to study the ground water characteristics and ground water quality? If the goal was to determine what influence Union Slough has on ground water quality and “recharge” it would have been advisable to install a boring close to the Union Slough and install pressure transducers in the wells constructed in the borings and in the Union Slough to obtain this information. It would have also been advisable to collect water samples from the Union Slough at the same time ground water samples were collected from a well constructed near the Union Slough (the same goes for the mainstem of the Snohomish River).

On page 6, Bailey states:

Soil samples in all test borings were taken in accordance with ASTM D1586-84 standards and specifications. Soil descriptions and classifications were developed in the field by the hydrogeologist in general accordance with ASTM D2488 and following the Unified Soil Classification system. Each test boring was completed with an observation well.

The logs in the Appendices do not reflect ASTM D2488 standards. What standards were used for collecting samples for chemical analysis? This is why a QAPP is required. There is no discussion on how samples were collected, how they were stored, sample labeling, chain of custody, trip blanks, equipment blanks, decontamination procedures, etc.
Additionally, there is no discussion on what analytical parameters were included in the analysis and why and why not metals were excluded from the sample analysis. Additionally, the laboratory methods selected are not discussed including the SW-846 methods used and why these methods were selected (these are different for soil and water samples).

Prior to well development, a downhole geophysical survey was performed at each deep test boring location (DW-01 thru DW-03). Results of the Downhole Geophysical Survey’s are discussed in section 6.2 below. Each observation well, SW-01 thru SW-08 and DW-01 thru DW-03, was developed, purged and ground water samples collected for analysis. A total of 11 water samples were submitted to Edge Analytical Laboratories in Burlington, Washington for analysis.

Conductivity testing and magnetic logs - no lithologic logs - the testing performed could have been combined to include lithologic testing especially in light of the fact that no samples were recovered from the lowermost hydrostratigraphic unit that appears to not have been characterized appropriately.

The downhole geophysical testing could also have been used to provide a preliminary lithologic log for the lowermost hydrostratigraphic unit - no samples, no blow counts - appears to be a fine sand unit (?) based on DW test boring logs for lowermost unit.

What guidance was used for developing and purging the wells? What field monitoring was conducted (e.g., temperature, pH, electrical conductivity, BOD, COD, dissolved oxygen, etc.), especially during well purging prior to collecting ground water samples? How were the ground water samples collected? What type of sample containers were used and how were they obtained? How were ground water samples held until delivery to the laboratory and what preservatives (if any) were used? Is the analytical laboratory approved by Ecology? Was standard Chain of Custody protocols used? What ground water sampling guidance was followed? How were the analytical parameters chosen and why?

Project testing was geared toward delineation of existing salinity and related parameters of soils and ground water on and around the project site.

This is not what is stated in the beginning of the document (as already discussed) nor is it consistent with the boring location selection. As previously stated if the purpose was to study the characteristics of the ground water aquifer(s) and the ground water quality, there would be more wells and they would be distributed throughout the site (this is in an area with a relatively low topographic gradient). Additionally, at a minimum one of the wells on the Hima site would have been sampled.

There are no discussions on saltwater intrusion in this document (or on how to test for ground water quality in general) nor are there references cited regarding the characteristics of saltwater intrusion in unconfined and confined aquifers. It is unclear if the ground water aquifer Bailey studied is a confined aquifer. However at a minimum, Bailey should have discussed the Ghyben-Herzberg relationship.

The thickness of the fresh water wedge for unconfined aquifers is theoretically governed by the Ghyben-Herzberg relationship which establishes a relationship between fresh water head and the location of the salt water-fresh water interface. The relationship states that for every foot of fresh water head above sea level, the depth to the salt water interface is vertically a factor of 40.
Confined aquifers have a somewhat different relationship because of the hydraulic head which typically reduces the potential for on shore saltwater intrusion impacts (the hydraulic head in a confined aquifer typically extends waterward of the shoreline). However, density gradients still form in confined aquifers, with “fresh water” overlying a mixing zone (brackish water) that overlies saltwater.

In general Bailey suggests that ground water aquifer he studied is one big mixing zone at the fresh water saltwater interface that does not conform to the Ghyben-Herzberg relationship or similar saltwater/fresh water relationships. Bailey should have discussed this and he should have discussed the potential water quality impacts (and impacts on the ground water aquifer) from the 160 acre City of Everett POTW lagoon.

The samples were placed in clear plastic bags, sealed, labeled and stored for transportation to the lab for testing. In addition, separate samples were collected from each sample interval for composite testing. A total of 183 soil samples were collected and transported to Soiltest, Inc. in Moses Lake, Washington. Each sample was tested for nitrate nitrogen (N034), ammonium nitrate (NH4-N), ammonia acetate (NH4OAC K), pH, electrical conductivity, sulfur, cations (Ca, Mg, Na) and organic matter (OM).

What Ecology or USEPA guidance was used in collecting the samples? How was equipment decontaminated between each sample collection? What was the purpose of the composite sample for chemical analysis of the soils? How many sample and equipment blank samples were submitted? How were these analytical parameters chosen and which SW 846 methods were used in the analysis? Why weren’t other analysis considered such as phosphorous, MTCA metals, phenols, boron, Phthalates, and PAHs? After all this area is proposed for a salmon habitat restoration area and Union Slough “river water” will be passing through this area after the levee is breached.

Additionally, SNR requested information from the City of Everett POTW for sewer treatment plant sludges that were placed on the farmland that is now proposed to be used for the restoration project. All of the City of Everett sewer treatment plant sludge is used on farmland and other areas as a soil supplement (including the poplar “farms”) and this sewer treatment plant sludge does not contain dangerous wastes, but it does have elevated levels of metals, including zinc, copper, and lead. It also contains elevated levels of sulfur and very high levels of nitrogen (in several forms) and it has elevated levels of phosphorous.

Soil chemistry test results are consistent with soils deposited and found within an estuary/marine environment. A total of 183 soil samples were collected and transported to Soiltest Inc. for testing. For reference purposes, Soil Test Results are contained in Appendix D of this report.

As previously discussed, there was no QAPP prepared for these sampling and analytical activities so it is impossible to determine how the sampling was conducted, where potential error factors are introduced and how the equipment was decontaminated (Ecology has been known to decontaminate with sodium hypochlorite which will impact sodium chloride analysis (chlorides and sodium). It is also unclear why other chemical analysis was not conducted, such as boron, metals (MTCA metals), phosphorous, phenols, PAH’s and other chemicals that may be present on agricultural land.

It is unclear what level of historic research was conducted by Bailey. As previously discussed, the farms that are proposed for restoration activities have had years of sewer treatment plant sludges applied to the land for soil augmentation and for the nitrogen and phosphorous in these sludges.
These sludges are disinfected with chlorine, which may include sodium hypochlorite. It is known that these sludges also have elevated levels of metals such as zinc, copper, and lead. They also have high levels of nitrogen in several forms and have high levels of phosphorous (an example of the analysis of the City of Everett POTW sludge is provided as Figure 6-1 - City of Everett Sludge Analysis from 1/12/94).

The City of Everett POTW sludge analysis does not include analysis for cations such as chlorides and sodium and did not include analysis for sulfur (as sulfate) until later, with a May 2, 2000 sample reporting sulfate levels at 5,700 (solids, units not reported). Although this sludge (the City calls it compost) does not meet any toxic limits for MTCA or the federal hazardous waste levels, it does contain high levels of constituents relative to the federal Clean Water Act (and Safe Drinking Water Act) and they exceed state water quality standards, including those established in Ecology issued general industrial storm water NPDES permits.

Figure 6-1 - City of Everett Sludge Analysis from 1/12/94
On page 7 Bailey states:

In addition, 14 soil samples from the test borings have been submitted to Snohomish County Public Works - Engineering Services Division Soil Laboratory for gradation and/or hydrometer analysis.

SNR did not see hydrometer analysis; this means that the clay content cannot be determined. Which soil method was used (ASTM/USDA)? The storm water management Manual for Western Washington, Ecology, 2005 recommends the USDA method, which can be used to estimate the potential hydraulic conductivity. However, the hydrometer testing must be conducted to obtain better estimates.

Development of the observation wells was a difficult task requiring a special pump and several months time. Upon completion of well development, a round of test sampling was completed. To ensure collection of a representative ground water sample at the time of sampling, each well was pumped for 45 minutes using a Waterra Inertia Pump removing a minimum of 200 gallons of ground water, then an additional minimum 40 gallons of ground water was removed from each well with a down hole Grundfos pump prior to taking the ground water sample. Even though a significant amount of ground water was withdrawn from each well during development and prior to sampling, measured draw down of the ground water surface was minimal. 11 water samples were delivered to Edge Analytical Laboratories in Burlington, Washington. Each sample was tested for turbidity, pH, TSS, TDS, Electrical Conductivity, Alkalinity, Nitrate nitrogen, Chloride, Sodium, Magnesium, Hardness, Calcium and Boron.

How were the wells developed? Why was this a difficult task and was airlift considered at the time the wells were constructed and is so why wasn’t airlift used? Since a QAPP was not developed, what USEPA or Ecology guidance document(s) was used to design the ground water sampling activities, including ground water purging? How was the volume of water purged measured? How was the ground water monitored for pH, temperature, EC, and other parameters so the purging could be conducted until these readings stabilized?

How was the purging pump decontaminated between wells? How was the Grundfos pump decontaminated between wells? Were trip and equipment blanks submitted to the laboratory? How was the ground water sample collected and how was it transferred to the sample containers? How were the samples labeled? How were they stored? Was a Chain of Custody form used? How were the analytical parameters for the samples chosen and why are these different from those chosen for the soils? Why weren’t metals, dissolved oxygen, BOD, COD, and other water quality parameters included in the analysis? What SW 846 methods were requested?

If the purpose of these studies was to conduct saltwater intrusion studies, why didn’t Bailey conduct infield EC measurements as the borings were advanced to determine at what depths to place well screens to study the characteristics of the aquifer for salt water intrusion purposes? The Ghyben-Herzberg relationship should have been considered, especially in this area on the delta of the second largest river in Puget Sound. Bailey’s data is somewhat meaningless because it suggests that the entire aquifer is a mixing zone at the fresh water/saltwater interface.

Why didn’t Bailey design his studies in accordance with accepted methods for identifying areas with potential saltwater intrusion based on actual research and why didn’t he cite the research he conducted prior to conducting these studies? Why didn’t Bailey include discussions on science of saltwater intrusion, and discuss the models, and relationships such as the very fundamental Ghyben-Herzberg relationship?
The results of this investigation show a good correlation with previous but less extensive investigations of the project site and surrounding properties.

Why didn’t Bailey expound on these other investigations and spend some time discussing the purpose of these other studies, how the studies were conducted, and what these studies found?

Based on the results of this investigation and as correlated with previous site investigations reviewed during the preparation of this report (CH2Miliill, 2005), . . .

This reference is not provided in the references section. When and why did CH2M Hill conduct geologic and hydrogeologic studies on this site?

On page 8, Bailey states:

Logged soils consist of interbedded loose to very loose, moist to wet, very fine-grained organic silts, silts, clayey silts and peat with local discontinuous lenses of loose to very loose, moist to saturated, very fine- to fine-grained sands.

The boring logs describe “very fine-grained organic silts, silts and clayey silts”. SNR is unaware of any geologic or engineering method for describing the size of silts and clays. In general silts and clays are too small to describe “grain size” even with a hand lens. However, it is customary to refer to these types of sedimentary materials as simply “fines” (the only way to “accurately” determine if clay is present or the amount of clay that is present is to conduct hydrometer testing). However, it is unclear how this material can be described as an aquitard or how an interpreted vertical hydraulic conductivity value of $10^{-6}$ cm/sec can be applied to these sediments. Additionally, Bailey does not discuss how he determined that the sand lenses are discontinuous.

The observed thickness of the surficial Holocene estuarine sediments was highly variable - ranging from a minimum thickness of approximately nine-(9) feet bgs (TP-20) to a maximum thickness of approximately 21 feet bgs (DW-01, DW-03) at the locations of the site explorations.

It is unclear why Bailey describes these deposits as estuarine sediments without discussing the difference between river deltas and estuaries or how he determined that the study area is located in an estuary. These features are different and he must cite how he is classifying this area as an estuary rather than a prograding river delta with distributary and tidal channels. Also, Bailey states that the thickness of the shallow deposits is highly variable, why does TetraTech state that these deposits are consistently 20 feet thick and are aquitards?

On page 9 Bailey states:

Sloughing of excavated side walls was not observed, even in the deepest test pits, except where ground water seepage was encountered out of discontinuous sand lenses or where peat to peaty soils were encountered.
How does Bailey explain the presence of ground water in the sands and peat but not in the fine materials that were exposed in the test pit? Ground water is at a pressure equal to or greater than atmospheric and is a hydraulic system. Unsaturated zone flow however, is at a pressure less than atmospheric. How does “seep ground water” differ from the “water table”? Why does Bailey believe that the water observed in the sands and in the peat is ground water? How is it possible for ground water to be present only in the sands and peat and not in the fine materials? How long were the test pits left open and was there any evidence that ground water was entering the bottom of the test pits?

On page 9 Bailey states:

They were underlain by very loose, saturated silts to clayey silts to the full depth of our explorations — 80 to 85 ft bgs. Ground water under hydrostatic pressures was encountered within the near shore marine sediments confined by the surficial estuarine sediments on top and the deep alluvium silts and clayey silts at its base.

This “clayey silt” is described as: “75.0 - 85.0' Clayey Silt to Silt; Blue gray, very fine-grained, trace sand, loose, wet (ml, Younger Alluvium - Qyal)” in DW-01; “72.0 - 80.0' Silt; Blue gray, very fine-grained, with occasional lenses of fine-to coarse-grained sand, trace organics” in DW-02; “68.0 - 85.0' Silt to Clayey Silt; Gray brown to blue gray, very fine-to fine-grained, trace to little organics, trace very fine-grained sand, very loose, saturated (ml, Younger Alluvium -Qyal)” in DW-03.

It is unusual to encounter loose wet silt at these depths. It is also unusual to have very low consolidation at the maximum depths drilled (80 to 85 feet bgs). Additionally, it is unclear why Bailey did not collect samples for laboratory analysis from any of these deposits from any boring and how he determined that clays are present without hydrometer testing. It is also unclear why geophysical logs did not include this section of the borings.

Additionally, the “very fine grained” suggest that this is a silty sand or sandy silt and there is no discussion on the sands that are identified in the boring logs.

Without laboratory analysis of the material penetrated (literally, because there were zero blow counts – no penetration resistance) it is unclear what materials were encountered. SNR believes this material has characteristics that are more like, very-fine to fine sand. The descriptions of “loose, saturated with occasional coarse grained sand lenses”; no penetration resistance is very unusual at this depth unless voids are present.

As stated above, a description of very loose to loose silt at this depth is very unusual as is zero blow counts, and no sample recovery. The boring logs for the deep wells have very low credibility with no way of independently determining how this log was created.

None of the test boring logs are logged in conformance with ASTM D 2488-9a as referenced in this report. Had a sample been obtained, and had the sample been tested in the field for dilantancy, the investigator would be able to determine if this material is silt or a fine san. Additionally, it is impossible with the naked eye (even with a hand lens) to log fine to very fine grained silt, either it's clay or it is not, it is silt or it is not, but this can only be determined with laboratory testing (e.g. hydrometer testing, which was not conducted because no samples were collected).

Additionally - this log should have raised a lot of questions for the investigator, but none were raised nor is there any discussions on the characteristics logged for these materials nor is there a discussions on why no sampling or geophysical testing was conducted on these materials that Bailey has decided is an aquitard (he does not discuss what type of ground water aquitard is in what he has identified as a confined aquifer (e.g., leaky aquitard)).
For reference purposes, Soil Gradations of representative soil samples collected from the test borings are contained in Appendix D of this report.

Soil Classifications (USCS) are not shown on the lab sheets.

For reference and correlation purposes boring information from other investigations and/or sources has been included on Geologic Cross Section “B”.

Bailey does not cite references for additional information used in creating Cross Section “B”. Additionally, Bailey did not include a map in Appendix G that shows where these transects are located and orientated. It is customary to provide a map with cross section lines drawn.

On page 10 Bailey states:

Analysis of the soil test results indicates the following generalized site parameters:

The analysis of the soil samples collected by Bailey are suspect because there is no QA/QC data nor are sampling and analytical protocols discussed, mainly because the required QAPP was not prepared and required documentation regarding the QA/QC of the laboratory data is not provided.

As previously discussed, information from the City of Everett POTW received by SNR strongly suggests that sewer treatment plant sludge was applied to this agricultural land the County that is the proposed restoration area. This data does not include pH; however, with the high sulfur content reported, it is possible that this sludge may have a low pH. Regardless, Bailey assumed commercial fertilizers were used on the agricultural land to address the low pH and elevated chloride levels, however, he did not consider that this may be associated with sewer treatment plant sludge that was placed on this agricultural land.

What is unclear is if the residual metals (which Bailey did not conduct laboratory analysis for), phosphorous, nitrogen, and chlorides will affect the water quality of the Union Slough after the levees are breached and the water in the slough crosses this agricultural land that has been apparently treated with sewer treatment plant sludge for years. It is also unclear how this will affect salmonids and other wildlife that will be present in the proposed restoration area.

The results of the soil chemistry testing indicate that the upper site soils were deposited in a marine environment with significant amounts of salts present. Reclamation of the land for farming in the early 1900’s did little to change the soil chemistry.

It is unclear how Bailey can make these statements and conclusions. Had he prepared a QAPP and performed a broader based analysis of the soils, his conclusions may be very different.

On page 11 Bailey states:

Hydrogeologic conditions of the site have been accessed through this investigation during which ground water seepage was observed within the discontinuous sand lenses found in the lower section of the surficial estuarine organic silts, silts and clayey silts and a local aquifer system was delineated within the near shore marine sands to siltly sands in which the site observation wells were screened.
It is presumed that Bailey means “assessed” however, the hydrogeologic investigation for a site that is over 400 acres in size is relatively limited and would not provide information sufficient to identify a “local aquifer system”. It is also unclear why Bailey suggests that the sand lenses are discontinuous but does consider that the upper sediments are continuous throughout this area. It is also unclear why Bailey did not install piezometers in this upper sediment so hydrogeologic testing of these sediments could be conducted (actually, no hydrogeologic testing was conducted, such as slug tests or pump tests in any of the wells).

Additionally, the County has had the opportunity to install pressure transducers in the Union Slough (and a stream gage) and the tidal channels since 2007. This would have provided valuable information and if pressure transducers were then placed in the wells, this would have also provided valuable information that the County does not have and it would have provided more accurate information because all of the pressure transducers would provide information of water elevations and temperature simultaneously in this tidally influenced area. Additionally, LevelLogger manufacturers equipment that also monitors electrical conductivity which would provide valuable information on the salinity of the aquifer, the Union Slough and the tidal channels had this equipment been installed.

Bailey does not discuss the tidal channels in his report (it is presumed he believes these are “ditches”) he also assumed that these are dry during the summer. However, these tidal channels and the borrow ditches are filled with water year-round. Had he investigated this he may have developed different conclusions, especially since it is clear that subsurface flows were observed in most test pits within 4 feet of the surface.

Additionally, the presence of sand lenses and peat that yielded water in every case and the characteristics of the upper sediments (loose to very loose) suggests that these materials may not have the characteristics of an aquitard. Bailey indicates that the ground water in the sand sediments has hydraulic head that is at or above the ground surface, which does suggest that the upper soils provide a confining effect. However, the Figure in Appendix I suggests that the Union Slough is the source of the recharge even though the bed of this distributary channel is topographically lower than the ground water observed in the wells. Additionally, when at base flow conditions, by definition the flow in the Union Slough is ground water flow. The surface water elevation of the water in the Union Slough at base flow is significantly below the ground water elevations Bailey indicates are present.

Bailey does not discuss the 160 acre City of Everett Lagoon that is located upgradient of the proposed restoration site. This lagoon reportedly has 5 feet of water impounded in it and has been present since the early 1960s. It is unclear why Bailey did not consider this a potential ground water recharge source but Shannon & Wilson apparently did in their Modflow model (although this is not discussed, as previously discussed, Snohomish County did confirm that Shannon & Wilson did factor in this lagoon in the Modflow studies).

The studies conducted for the Union Slough levee breach adjacent to the City of Everett POTW and studies conducted by GeoEngineers in 2009\(^6\) for a truck scale that was to be installed suggest that upper sediments at this lagoon are very similar to those Bailey describes for the proposed restoration area.

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\(^6\) Geotechnical Engineering Services Biosolids Program Truck Sale, Everett, WA, 3009, DuRee, Braydan P., and Metcalf, Robert C., GeoEngineers.
The Shannon & Wilson Modflow model shows a strong recharge area to the south where this lagoon is located, which suggests that these upper sediments may have higher hydraulic transmissivity that Bailey has assumed.

Due to the non-uniform nature of the surficial estuarine sediments, ground water flow through this aquitard will be highly variable and complex. During winter months and during extended periods of wet weather when much of the site is covered with several inches to several feet of standing surface water from precipitation, we would expect water to infiltrate downward through the surficial estuarine sediment aquitard resulting in a slow "leakage" of this surface originated ground water into the underlying aquifer over time. During the summer months and during extended periods of dry weather, this flow pattern may reverse itself — with ground water flowing vertically upward towards the ground surface from the underlying confined aquifer (Todd, 1980).

As Bailey indicates, the hydrogeologic characteristics of the upper sediments can be complex, however, because he apparently ignored the tidal channels and the borrow ditch hydrology (year-round) he missed a potential vital clue because the source of this hydrology was never studied. It is also unclear where Bailey obtained information that suuosts that much of the site is covered with several inches to several feet of water during the winter season. This is inconsistent with the agricultural history of the proposed restoration area, with historic air photographs, and with SNR’s discussions with the DDS. Bailey should cite the source of his information regarding the surface water hydrology in the proposed restoration area during the winter and summer months. It is also unclear why Bailey is referencing a ground water text book that is 33 years old. There have been many advancements in ground water hydrology in the last 33 years including extensive work done with unsaturated zone flows.

On page 12 Bailey states:

It should be noted that although the surficial estuarine sediments were described as moist to wet when observed in the test pits and test borings - ground water seepage was not commonly observed within the soils except out of discontinuous sand lenses. The estuarine sediments have a very low effective porosity. Based on gradations (Appendix D) estimated vertical movement of ground water through the aquitard soil is low to very low. Its vertical hydraulic conductivity will range between 8x10-2 and 2 x10-4 ft/day (silt clay) except within the sand lenses, which will have a much higher horizontal hydraulic conductivity (1.0 to 1x10-1 ft/d) and a much higher coefficient of storage (U.S. Bureau of Reclamation, Ground Water Manual, Figure 2.5). This is visually apparent by the relatively rapid ground water seepage that was observed coming out of the sand lenses when they were exposed in the test pit excavations. Observed seepage rates were in general less than 1 gpm and decreased rapidly until the test pits were backfilled.

Horizontal hydraulic conductivity from within the estuarine sediments will be low to very low, in the range of 1x10-2 to 1x10-3 ft/d (U.S. Bureau of Reclamation, Ground Water Manual, Figure 2.5). Hydraulic conductivity of the estuarine sediments should be considered variable based on the interbedded nature of the sediments and how they were observed to change both vertically and laterally across the project site. Flow pathways will reflect the variable nature of the soils both horizontally and vertically.

It is unclear why the US Bureau of Reclamation 1985 ground water manual was used when many more recent references are available. Additionally, it is customary to reference effective permeability rather than effective porosity (gravels have very low porosity but very high effective permeability).
The “gradation” (sieve analysis) did not include hydrometer testing and is limited. It is unclear why Bailey did not conduct any onsite aquifer testing, including testing in the upper sediments (at a minimum, percolation testing could have been conducted). It is apparent that the 160 acre City of Everett lagoon is creating significant ground water recharge per the Shannon & Wilson Modflow model, however, Bailey never conducted testing on the upper sediments which will be integral to the construction of a setback levee and to the subsurface hydrology of this area when the proposed levee breaches are conducted and this farmland is seasonally flooded.

It is unclear how Bailey determined what the hydraulic conductivity of the upper sediments, however, his estimates are extremely low for these sediments that are very loose to loose and have zero field or laboratory testing (permeability) to support these low estimated hydraulic conductivity rates. Additionally, the sands and the peat will have relatively high hydraulic conductivity, however, Bailey does not explain how ground water at a pressure of 1 atmosphere or greater is present in these sediments but is not present in the finer sediments.

On page 13 Bailey states:

**Appendix H of this report. Observation well spacing is not sufficient to generate a ground water contour map across the entire site, but there is adequate spacing in the area of the proposed set back dike to develop this map.**

SNR agrees that there were an insufficient number of wells and that the well spacing was inconsistent with ground water studies. However, SNR disagrees that there is adequate spacing in the area of the proposed setback levee to develop a flownet map.

The Shannon & Wilson Modflow model suggests that there is high hydraulic mounding occurring to the south of the proposed restoration area where the 160 acre lagoon is located and that this is controlling the piezometric surface of the ground water in this area. This is influencing interpretations of the ground water in this area and is why actual hydrogeologic testing should have been conducted, including aquifer testing such as slug tests and/or pumping tests (and all sedimentary units). Additionally, additional wells should have been installed in a manner where an accurate flownet can be developed. These wells, the Union Slough, and the tidal channels should be monitored with continuous reading pressure transducers, preferably the LevelLogger Junior with specific conductance measurement capabilities.

These pressure transducers can be used when aquifer testing is conducted to provide more accurate data on the aquifer characteristics in all sedimentary strata. This pressure transducer monitoring system can also be used to generate actual tidal measurements relative to the tidal influence on the ground water which is a critical component of conducting a salt water intrusion study. It is also important to understand the hydrologic characteristics of the upper sediment because these will be what the proposed setback levee will be built on and based on Bailey’s description of these sediments and the blow counts that were measured in these sediments this information will be important.

1) Piezometric surface of the observation wells was at or above the ground surface during the late winter and early spring months both on the project site and in the wells on adjacent property to the west of the site, This confirms the function of the surficial estuarine sediments acting as an aquitard both on the project site and on the adjacent properties to the west and also indicates that the local marine sediment aquifer is confined across the same area.

2) Each observation well is tidally influenced and responds directly to changes in tide. This indicates a relatively high aquifer diffusivity (ratio of transmissivity to storativity) and a good interface between the near shore marine sand aquifer and the channel beds of the...
Snohomish River to the west — the river is regularly dredged in the vicinity of the project site to maintain marine navigation, and the Union Slough to the north and east. This also helps define the boundaries of the aquifer (see section 8.3 below).

It is unclear what influence the 160 acre lagoon has on the “piezometric surface” elevations observed by Bailey, however, it is clear that hand measured ground water surface elevation data measured in a tidally influenced area is a low level of accuracy. This is why pressure transducers are required to measure the surface elevations accurately.

The influence of the 160 acre lagoon on the ground water hydrology in this area must be studied. This will provide information that will be useful in interpreting what will happen when the proposed levee breaches occur and the area east of the proposed set back levee is inundated during significant flooding events (which occur typically during the rainy season).

SNR is unaware of any dredging in the Union Slough or any of the other distributary channels, Bailey should cite his sources. Tidal influence in ground water aquifers in near shore areas is common and is a component of hydraulic pressure in the aquifer and in the marine water. This response is different in unconfined aquifers and confined aquifers. It is important to conduct the tests necessary to better understand the characteristics of the aquifer in all sedimentary units. Additionally, it is important to identify the source of the hydrology in the tidal channels and in the borrow ditch.

It is unclear how the tidal information or the presence of the distributary channel and the mainstem of the Snohomish River define the “boundaries of the aquifer”. Bailey suggests that there is only one aquifer and this is a confined aquifer with a “potentiometric surface that is at or higher than the ground surface where the wells were installed. However, the elevation data is not provided for any of these wells therefore it is unclear what the elevation of the potentiometric surface is relative to the surface water elevation in the Union Slough or the mainstem of the Snohomish River. Had pressure transducers been installed as discussed above, and the elevations of these transducers surveyed in, this information would be invaluable for actually determining the characteristics of the aquifer and for interpreting the “boundaries”.

How an observation well responds to changes in the ground water gradient caused by tidal flows is complex. Strength of tide, barometric pressures, location of well relative to the river or slough will all affect how an observation well responds at any one time. Individual well readings give a snapshot taken in a specific moment of time indicating the level of response at that location.

SNR agrees and this is why pressure transducers should have been installed as previously discussed. It would also be helpful to provide elevations for the wells or top of well casings on the boring logs. It is impossible to conduct meaningful studies if the ground water elevation and the elevation of the other surface water features are unknown.

On page 14 Bailey states:

The existing ground water table below the project site is defined by the top of the near shore marine sands and silty sands found nine-(9) to 21 feet below the existing ground surface that are confined by the surficial estuarine sediments (negative boundary).

According to Tetra Tech, Layer 1 is about 20 feet thick - where is the maximum thickness and where is the minimum thickness - it would be helpful to have a contour map of the bottom of Layer 1 and geologic contacts of the peat layers. It would also be helpful to have elevation data.
Based on the observed tidal response at the observation well locations, the probable positive (recharge) horizontal boundaries of the aquifer are the Snohomish River to the west and Union Slough to the east and north. The probable southern boundary is unknown at this time. For reference purposes, an **Aquifer Boundary Cross Section** showing probable flow lines is contained in Appendix I of this report.

What about the 160 acre City of Everett lagoon (Shannon – Wilson suggest this is strongly influencing the ground water aquifer, creating a south to north flow direction). It is unclear why the probable recharge boundaries are the Union Slough and Snohomish River without elevation data. What is the elevation of the “piezometric surface” and what is the elevation of the OHWM for the Union Slough and mainstem of the Snohomish River? All seasonal and perennial streams (rivers are big streams) have ground water base flow. This means ground water flows into the channel as part of the flow. Unless the river’s hydraulic head is higher than the ground water, the ground water will be providing base flow to the river. If the hydraulic head is higher than the river surface water elevation, the river can become a ground water recharge source. However, Bailey has not provide the information necessary to make any conclusions.

Also, SNR is not sure if the deeper boundary is completely characterized at this time. From DW-01, -02, and -03, the deeper aquitard can best be described as composed of loose, fine grained soil with a lenses of coarser sand, N=0 (no penetration resistance), and there do not appear to be any soil samples collected for field classification.

Existing ground water conditions were determined through the testing of collected ground water samples for electrical conductivity, pH and chloride levels by Edge Analytical Laboratories, Burlington, Wa. Ground Water Test Results are contained in Appendix F of this report. Existing ground water quality as expressed in Practical Salinity Units (PSU) ranged between approximately 5.0 and 13.8 for the shallow ground water in the vicinity of the proposed set back dike. PSU for ground water out of the deep wells in the vicinity of the proposed set back dike ranged between approximately 13.2 and 18.8. Ground water quality as expressed in PSU for the shallow and deep wells located west of 1-5 (SW-07, DW-03) ranged between 12.2 and 19.9 while the ground water quality as expressed in PSU for the interior shallow well (SW-08) ranged between approximately 13.0 and 17.2.

The PSU for sea salt water is approximately 35 (Hickling Broad, broads-authority.gov.uk).

Water quality for drinking water standards established by the USEPA and Ecology is reported in mg/l or μg/l typically and PSU is not used for ground water quality studies. The measurement is usually correlated to chloride levels in mg/l.

Appendix F should be presented as a table. Also, where is the QA/QC plan (QAPP) for sample collection? or, at a minimum the Sampling Plan for the ground water monitoring?

This is where a detailed discussion on saltwater intrusion science should be discussed including discussions on the density gradients, the fresh water/saltwater interface and the mixing zone that occurs at this interface. As previously discussed, there are zero discussions on unconfined aquifers and confined aquifers and how these are influence by marine saltwater intrusion.

Due to the dynamic characteristics of water composition within estuary and tidal zones, Hem (1982, 1985) found that a ratio between the total dissolved solids and electrical conductivity provided an accurate and predictable value for these variables where KA=S (K is specific conductivity in ohm/cm, S is dissolved solids in mg/l) and A ranges between 0.54 to 0.96 for most settings — the higher values are generally associated with high sulfate or saline waters. The ratio of total dissolved solids to electrical conductivity for...
It is unclear why Bailey did not conduct field measurements for specific conductance, pH, temperature, and other field parameters. It is also unclear why all of Bailey’s references are older references rather than newer references (10 years old or less). There have been major advances in Saltwater Intrusion and ground water studies in general. It is generally more appropriate to use the most recent references possible for scientific studies. Regardless, Bailey should have included field measurements for water quality parameters so that laboratory data can be cross checked. SNR conducted studies in the Black Point area near the Duckabush River where laboratory data was between 10 and 14 times different that field data; where calibrated laboratory grade equipment was used for the field measurements.

Chloride levels in ground water are an indicator of water salinity. Ground water salinity levels were also checked against both laboratory tested electrical conductivity levels and the Geophysical Survey Results (Appendix E). Chloride levels in Puget Sound water range between 14,000 — 19,000 mg/l. Chloride levels within the tested ground water samples from the project site ranged between a low of 3775 mg/l in SW-04 to a high of 12947 mg/l in DW-03.

The City of Everett POTW uses lots of chlorine to disinfect the sewer treatment plant effluent. This effluent goes through a final treatment in a two acre trench. These activities are conducted immediately upgradient of the study area and the Shannon & Wilson Modflow model suggests that the lagoon and other unlined surface water storage and treatment areas are a source of recharge to the ground water aquifer. It is unclear if the chlorides measured are exclusively from saltwater intrusion.

6.2 Draft Snohomish County Smith Island Estuarine Restoration Saltwater Impact Study, November 2012, Prepared for: Snohomish County Public Works Department Surface Water Management Division, Prepared by TetraTech

As previously stated in this letter report, the purpose of this document is unclear nor is the purpose stated in the report. TetraTech did not conduct any additional studies; although it did have Shannon & Wilson prepare a Modflow model based on Bailey’s, 2012 report. The purpose of the Modflow model is also unclear considering that Bailey’s studies did not generate the data necessary to run an accurate Modflow model (as previously discussed in this letter report).

Additionally, as discussed in this subsection, TetraTech has misstated Bailey on several occasions and has added assumptions of their own to Bailey’s findings and conclusions. Additionally, the unauthored draft TetraTech document includes presumptions that are not supported by the data, mostly because much of the data necessary to properly characterize the ground water aquifer and the geology on the agricultural land proposed for use as the Smith Island restoration project was not generated by Bailey during his studies.

SNR could understand TetraTech’s licensed hydrogeologists preparing a supplemental report if TetraTech had conducted the additional studies necessary to develop the data needed to accurately interpret that hydrogeology and geology of the agricultural areas and if these studies did investigate the influence the City of Everett POTW lagoon and ponds have on the ground water aquifer. It would also be understandable if TetraTech conducted more detailed environmental studies that followed customary and often required protocols, such as QAPPs. However, this was not conducted either. Therefore, it is unclear why Snohomish County had TetraTech prepare this report. Regardless, SNR’s comments are presented below:
On page 1 TetraTech states:

The project will restore 400 acres of tidal marshlands that provide critical habitat for endangered Chinook salmon and other salmon species.

This suggests that tidal marshlands were present on the farmland at sometime in the recent past (prior to 1850), however, no supporting documentation has been provided that proves that this site was tidal marshlands prior to 1850. SNR’s review of the history, including information from Snohomish County Public Works, 2009 suggests that much of Smith Island was forested and was cleared prior to Henry Smith purchasing the property to plant “grafted” tree orchards (HistoryLink.org essay 2965), sometime between 1855 and 1870 (this included the an initial attempt to install “dikes” based on the Dutch methods). All historic information SNR reviewed suggests that seasonal flooding was the primary reason the levee system was built, not the periodic tidal inundation.

Additionally, the 1869 Land Office survey notes do not describe tidal marshlands on this portion of Smith Island (T29N, R5E, Sections 4, 9 and 10) although it does describe “tide parries” covered with fine grass (Beach, May 31, 1869). The survey notes also suggest that the vegetation includes spruce, superior quality cedar and fir. These survey notes also states that the "sloughs" are navigable with Ebey and Steamboat sloughs being approximately 12 feet deep. It suggests “other areas” between the sloughs and the river are vegetated with willow, alder, and dogwood.

One of the primary documents SNR has not been provided is the feasibility study that includes studies that demonstrate what conditions were present in this area prior to 1850 and that clearly demonstrate that this farmland was tidal marshland and was a critical habitat for salmon species and that proposed “restoration activities” will actually be a restoration that reestablish a historic habitat that will provide a significant benefit to Chinook salmon and other salmon species (including scientific studies that demonstrate that the resulting “habitat” will achieve the goals of this proposed project).

Public concerns have been raised about whether the estuary water flowing over the site would increase salinity in groundwater and soil on adjacent agricultural lands.

As previously discussed, it is unclear why this portion of the Snohomish River delta continues to be described as an estuary. There have been no geologic studies conducted that demonstrate that the Snohomish River prograding delta is an estuary in the study area. Additionally, the concern that river water from the Union Slough may impact ground water quality has not addressed.

Although saltwater intrusion may be present in the ground water aquifer in this area, the will be a fresh water – saltwater interface that will create a mixing zone. Bailey did not conduct studies to delineate where the fresh water – saltwater interface is located, although geophysical studies suggest that this may be located approximately 20 – 25 feet below the ground surface.

Additionally, Bailey’s studies suggest that the soils in the farmland are impacted with high chloride levels and high levels of nitrogen in at least two forms. Bailey also suggests there are high levels of sulfur in these soils and that these soils have acidic pH levels. It is unclear how the seasonal and tidal inundation of the farmland will affect the fresh water that will be present above fresh water – saltwater interface as this surface water infiltrates through the surface soils that are impacted with “salt”, nitrogen, sulfur, and low pH.
Bailey did not sample for other potential agriculturally related constituents such as metals, PAHs, phenols, pesticides, herbicides, etc. and did not consider the potential use of sewer treatment plant sludge on this farmland (the City of Everett POTW calls this “compost.” SNR’s research strongly suggests that the City of Everett POTW “compost” was placed on this farmland for at least 30 years.

Additionally, there is no discussion on what will happen to the Union Slough water quality as the tidally influenced water, including seasonal flooding, passes over this soils and the water returns to the Union Slough. Finally, there is no discussion on the potential impacts to fish that come in contact with these soils, which are acidic according to Bailey and may have elevated levels of metals and are known to have elevated levels of nitrogen (and very likely, elevated levels of phosphorous).

The study was conducted to address the following specific issues:

- Will the project impact agriculture by increasing salinity levels in soils or in shallow groundwater used by plants?
- Will the project increase salinity levels in water from the well at Hima Farms, which is on property adjacent to the project site?
- Will the project impair Hima Farms’ ability to use groundwater throughout its property?

This is not the stated purpose in the Bailey report. As previously discussed, the state purpose is:

The purpose of these investigations is to provide geologic and hydrogeologic information specific to Snohomish County Public Works – Surface Water Division’s Smith Island Restoration Project Site and its surrounding properties.

We understand that this information will be utilized by Surface Water and its consultants for the development of the projects permitting, design and construction phase reports, plans and specifications.

Based on SNR’s review of the Bailey report, it is apparent that the studies were more focused on engineering geology than ground water hydrology studies (hydrogeologic studies). Interestingly, the Hima wells (there are actually two wells on the Hima property and the well logs for both wells are available in the Washington State Department of Ecology database (http://apps.ecy.wa.gov/welllog/) were not included in the study.

The GeoEngineers studies conducted for the City of Everett POTW (October 23, 2009) and earlier Golder (2001) studies referenced by West Consultants, 2007 (Pipeline Studies) suggest that the upper sedimentary materials beneath the 160 acre lagoon and the other ponds and trenches at this facility are similar to those described by Bailey, 2012 in his studies.

Shannon & Wilson’s, 2012 ground water modeling using Modflow suggest that the 160 acre lagoon does provide significant recharge to the aquifer(s) Bailey studied which suggests that 5 feet of inundation can result in significant infiltration though the upper sediments described as loose, to very loose organic silts, sandy silts, and silts with lenses of sand and pockets of peat. Considering that the elevations in the farmland are up to 5 feet lower than the base of the proposed setback levee, it is possible that at least 5 feet of inundation can be expected during high river flow events. Neither Bailey nor TetraTech discuss how infiltrating water through these upper sediments will affect ground water quality (this ground water is also a source of baseflow in the Union Slough).
Analysis of the top layer of soils at the site indicates poor drainage capabilities and high levels of salinity and minerals which can be problematic for some plants.

Bailey never conducted infield or laboratory testing to determine the hydraulic conductivity of these “upper” sediments and as discussed above, based on the Shannon & Wilson modeling using Modflow (suggesting that the ground water recharge is to the south and that ground water “flow” is to the north; these sediments may have higher permeability and hydraulic conductivity than predicted by Bailey.

Additionally, Bailey’s soil analysis suggests high levels of nitrogen in different forms, high sulfur, low pH, and relatively high salinity. However, Bailey did not include analysis for other constituents that would typically be present on agricultural land, especially if sewer treatment plant sludge were applied to this land as a soil supplement (which is highly likely based on information SNR received from the City of Everett POTW and the close proximity of this farmland to the POTW).

Although the elevated nitrates, sulfur, low pH, and elevated chloride levels in the soil may affect plants, these can also affect ground water and surface water quality. Additionally, if, as SNR suspects, other constituents are present that Bailey did not include in his analysis, such as elevated levels of agricultural chemicals and metals there is a potential to impact the fresh water horizon in the ground water aquifer and the water quality of the river flow in the Union Slough. Additionally, it is unclear how contact with these sediments will affect aquatic organisms, including salmon species.

Groundwater at the site lies in an aquifer composed of sandy soils, from about 20 feet below the ground surface to about 65 feet below ground. Groundwater moves freely within these sands, both horizontally and vertically. However, water movement between the surface and the aquifer is highly restricted by low-permeability organic silt, silt, and clayey silt in the top 20 feet of soils.

This does not accurately reflect what Bailey states in his report. Bailey states that thickness of the upper sediments is highly variable and was observed to range from approximately 9 feet to 20 feet.

Additionally, Bailey never collected samples or had a laboratory analysis of the sediments underlying the sand sedimentary unit. What is curious is that this deeper unit had “zero blow counts” at 70 – 80 feet bgs.

Bailey never conducted any permeability or hydraulic conductivity testing on any of the sediments he encountered during his studies. Therefore the actual permeability and hydraulic conductivity of all sediments described by Bailey remains unknown. It is unclear how TetraTech can state “movement between the surface and the aquifer is highly restricted by low-permeability organic silt, silt, and clayey silt in the top 20 feet of soils” when the actual hydrogeologic characteristics of these sediments is unknown and the Shannon & Wilson Modflow model suggests that the 160 acre lagoon believed to be constructed in similar sediments (Golder, 2001, and GeoEngineers 2009) is apparently providing a major recharge source to the underlying sand aquifer.

Analysis results indicate significant saltwater intrusion throughout the water column in the main aquifer at locations throughout the project site. Groundwater within the main aquifer at the site has salinity approaching that of Puget Sound saltwater and electrical conductivity levels (an indicator of salinity) that far exceed the levels of typical freshwater.
It is unclear how TetraTech can make this statement considering Bailey did not conduct the studies necessary to define the fresh water – saltwater contact (interface) or conduct aquifer testing in any of the sediments. Additionally, as SNR has discussed, the City of Everett POTW uses chlorination in the treatment process which increases the chloride levels in the waste water that is stored in ponds and the 160 acre lagoon. Shannon & Wilson’s Modflow mode suggests that the City of Everett POTW is a significant recharge source for the ground water aquifer in Bailey’s study area.

Neither Bailey nor TetraTech provide any discussions on the characteristics of saltwater intrusion including scientific discussions related to methods used to study saltwater intrusion. There are no discussions on the characteristics of saltwater intrusion in unconfined aquifers, such as the very fundamental Ghyben-Herzberg relationship and confine aquifers or discussions on how saltwater intrusion can migrate through potential aquitards (such as leaky aquitards) via upcoming and other mechanisms.

Bailey’s studies were not conducted as a comprehensive hydrogeologic investigation, these studies were primarily engineering geology studies that included environmental (without any sampling plans or quality assurance plans such as a QAPP) and limited hydrogeologic studies, with no aquifer testing and omitting other study methods that would provide site specific information on the ground water and the ground water aquifers (as previously discussed in this letter report).

The driller’s log for the well on the Hima Farms property indicates that chemical analysis found saltwater with iron. There is no record of pumping from this well since its completion.

As previously discussed the Ecology well log database includes well logs for two wells constructed on the Hima property. SNR did not see any analytical data for either well presented in any of the reports we have reviewed. It is unclear which well TetraTech is referring to; however, Bailey did not conduct any studies on either well.

Monitoring in 2011 of surface waters around Smith Island found highest salinity levels in the Snohomish River main stem on the west side of the island and lowest levels at upstream locations on Union Slough, on the east side. Salinity increases moving downstream on Union Slough, but remains lower than in the Snohomish River main stem. Previous studies reviewed for this analysis also found similar existing salinity levels in surrounding surface waters.

The 2011 monitoring study is not listed in the TetraTech references; therefore it is unclear which study is referenced above. However, it is unclear why the surface water salinity is an issue, because all models SNR reviewed for Tasks 2-3 suggest that the tidal influence will extend further upstream in the Union Slough after the restoration is completed and at this time it is unknown what the salinity in the Union Slough will be, especially since none of the models were based on accurate data, especially discharge and stage heights for the Union Slough tides data in this area of the Union Slough (especially data occurring at the same time).

However, what is more important is the affects Union Slough inundation of the farmland will have on Union Slough water quality and the ground water quality associated with the known and suspected constituents present in the farmland soil that also has low pH and apparently high salinity. As stated above, the Shannon & Wilson Modflow model does strongly suggest that the infiltration does occur when the upper sediments are inundated and it is anticipated that at least 5 feet of inundation can occur to the east of the proposed setback levee if the levees are breached.
However, it remains unclear how the constituents in the soil will affect Union Slough water quality and aquatic organisms that come in contact with the farmland soils after the proposed breach occurs.

On page 2 TetraTech states:

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Groundwater modeling performed for the current saltwater impact study evaluated groundwater flow pathways to the well on the Hima Farms property. The following are key findings:

- For existing conditions, 82 percent of water drawn by the well would come from the Snohomish River main stem and 18 percent would come from Union Slough,

- With the dikes breached the portion of water drawn by the well coming from Union Slough would increase to 28 percent.

Because the dike breaches would increase the portion of groundwater at the Hima well that comes from Union Slough relative to water from the higher-saline Snohomish River, the proposed project is projected to slightly reduce the groundwater salinity at the well location.
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Considering no studies were conducted on either Hima well and no ground water aquifer testing was conducted (not even slug tests) in any of the sedimentary units identified by Bailey (and others), it is unclear how a Modflow model could be calibrated to accurately depict the hydrologic characteristics of the aquifer(s).

This is especially the case when the 160 acre lagoon located upgradient of Bailey’s study area is apparently producing a strong influence on the aquifer.

Considering nothing is known about the aquifer characteristics however (other than hand measured ground water elevations and the analysis of a few ground water samples) it is unclear how Shannon & Wilson can create a Modflow model with this degree of accuracy or how TetraTech can make the statements it has made above with the degree of certainty that is suggested by this statement above.

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Water levels will be above the toe of the proposed new setback dike approximately 60 percent of the time. Without protective measures to prevent seepage through the dike, drainage problems could occur on the landward side of the dike. Engineering design criteria for the setback dike call for an impermeable core and impermeable “key” dug into the underlying substrate to prevent seepage between the dike and underlying ground. The potential for soil damage from dike overtopping will be unchanged from existing conditions, as the proposed levee will be at the same elevation as the existing dike or slightly higher. Only during extreme river floods, when the water is primarily low-salinity flow from the upstream watershed, would water levels approach the top of the levee.
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It is unclear how TetraTech has predicted the height of the water in the Union Slough considering none of the documents SNR has reviewed have provided actual discharge and stage heights for flows in the Union Slough based on measurements made in the Union Slough. This includes tidal interactions with these flows, considering no long term tidal monitoring has been conducted in this area of the Union Slough nor has actual stream gage measurements been made.
SNR is unaware of any material that is impermeable used in levee construction unless the design calls for the use of synthetic materials such as Hypalon liners. However, this does not consider one of the most common reasons for levee breaches, underflow and based on the characteristics of the upper sediments described by Bailey, the likelihood of underseepage is reasonably high (loose to very loose organic silts, sandy silts, and silts with interlayers of permeable sands and pockets of peat.

The upper sediments are described to vary in depth, with Bailey suggesting that these sediments range between 9 – 20 feet deep and are underlain by sands that Bailey suggests have the characteristics of a confined aquifer. It is unclear how any proposed levee design can prevent seepage especially since Tidal Channel B will be locatec landward of the proposed setback levee and this tidal channel is filled with water year-round.

Additionally, Bailey never addressed the tidal channel or the borrow ditch hydrology, both of which have year-round flows. At a minimum, the existing borrow ditch hydrology suggests that underflow occurs beneath the existing levee system and part of the existing levee system will remain with the proposed design.

If an overtopping event does occur, the salinity of the water will be the least concern. Overtopping can lead to levee breaches, but it can also lead to inundation of the area landward of the levee. The existing levee system has an approximately 3,000 foot buffer between the levee bounding the Union Slough and the private properties. This buffer area has a LOT of storage and much of it is topographically lower than the private properties (in some areas 5-7 feet lower).

There is virtually no buffer or storage area landward of the proposed setback levee. If overtopping or an overtopping induced breach occurs serious flooding of the private properties could occur. Additionally, it the water is high enough to overtop the proposed setback levee it will certainly be higher than the water in the 160 acre lagoon and based on the Shannon & Wilson Modflow model, significant ground water recharge may occur and this recharge will pass through soils with elevated nitrogen, high sulfur, low pH, high salinity and potentially other constituents Bailey did not conduct laboratory analysis for. The possibility that these soils could impact ground water quality through infiltration induced by inundation has not been evaluated.

The evaluations conducted for this study found that soils, groundwater and surface waters on and around the Smith Island project site already experience high levels of salinity, due to the estuarine nature of this location. The proposed project, which will allow waters from Union Slough to flow over the land surface of the project site, is not expected to have any negative salinity impact on surrounding properties for the following reasons:

The reason for the elevated chlorides in the soils is unclear because the characteristics of the materials placed on this farmland are also unclear (because the City of Everett POTW does not include chloride testing of their “compost”). The affects the 160 acre lagoon and other ponds and channels on the City of Everett POTW site are also unknown, however, it is known that chlorine is used in the treatment of this water. Shannon & Wilson’s Modflow model strongly suggests that the ponds and lagoon located at this POTW are a ground water recharge source.

As previously discussed there have been no geologic studies SNR has reviewed that indicate that the farmland in the proposed Smith Island Restoration project is located in an estuary. In fact, SNR’s research strongly suggests that this is area is geologically and hydrologically a river delta complex.
Bailey’s studies did not generate the data necessary for TetraTech to develop these conclusions. Additionally, TetraTech is not considering infiltration through the upper sediments where the soils are known to be impacted by historic agricultural activities including elevated chloride levels, that very likely included the application of sewer treatment plant sludge for at least 30 years and possibly the application of other products used in agriculture, including herbicides, pesticides, and fertilizers.

Additionally it is known that cows were raised on this land and that dairy operations were conducted. These types of operations typically have manure ponds which likely existed on this farmland (part of the conditions of the WSDOT taking of land included a cattle crossing culvert under the I-5 freeway (Case Number 74600 State of Washington Superior Court, Snohomish County, October 19, 1962). It is believed that this cattle crossing culvert still exists.

Bailey’s studies did not focus on the fresh water – saltwater interface or discuss the characteristics of the aquifer (including the potential for saltwater intrusion) most likely because he never conducted studies that would provide this information. Bailey did not cite any research he conducted on saltwater intrusion nor did he conduct the level of study typically associated with saltwater intrusion studies. The most likely reason is because his studies were more focused on engineering geology as stated in the purpose of the studies in Bailey’s report. However, even the engineering geology studies did not focus on the engineering characteristics of the upper sediments nor did Bailey discuss the unique characteristics of the deeper sediments at 75 – 80 feet below the ground surface where blow counts continued to be zero.

- The top 20 feet of soils consists of low-permeability organic silt, silt, and clayey silt that greatly restrict water movement between the surface and the underlying aquifer.
- The new setback dike will be designed with an impermeable core to prevent Union Slough water from seeping through the dike to adjoining properties.
- Any water that overtops the new setback dike will have very low salinity because it will consist primarily of runoff floodwaters from upstream in the Snohomish River watershed.
- Inundation of the project area with water from Union Slough is predicted to increase the contribution of Union Slough to withdrawals at the Hima well relative to the contribution from the Snohomish River main stem. This would reduce the salinity of withdrawals from the well because Union Slough water has lower salinity than water in the main stem.

TetraTech neglects to mention the sand lenses and the peat deposits. Additionally, TetraTech does not discuss the fact that no hydrologic testing (there was no field or laboratory testing for the hydrologic characteristics of these sediments) was conducted on these sediments. TetraTech also fails to consider the results of the Shannon & Wilson Modflow model that suggests that there is significant ground water recharge from the City of Everett POTW 160 acre lagoon that based on Golder’s and GeoEngineers studies, is built on the very similar materials to those described by Bailey, 2012. Additionally, Bailey does not state that the upper sediments are uniformly 20 feet thick across the study area. In fact Bailey states that this thickness is highly variable and ranges from 9 – 20 feet thick.

SNR is unaware of any levee building material that is impermeable unless synthetic liners are proposed in the design; however, SNR is unaware of any levees that meet Corps of Engineers specifications that include synthetic liners in the design. However, penetration through levees is much rarer than breaches caused by underflow or overtopping. It is unclear how underflow will be addressed, especially since there is relatively strong evidence that underflow is occurring under the existing levee system and the hydrology for the tidal channels has not been studied or explained.
TetraTech is focusing on the salinity of the Union Slough and how this could potentially impact the water quality of the ground water rather than focusing on the impacts overtopping would have after the setback levee is built. Without an adequate buffer to store overtopping, the area landward of the proposed setback levee could be significantly impacted by inundation.

Additionally, TetraTech assumes that the upper sediments are impervious when it is clear that they are not which means that the elevated chlorides in the soils can be impact the fresh water horizon that should be present as the water generated from inundation infiltrates through the soils. However, TetraTech does not discuss the other constituents that may be present in these soils in addition to elevated nitrogen in at least two forms, sulfur and how the low pH soils will affect the ground water.

Additionally, as previously discussed, Bailey did not conduct the studies necessary to accurately model the hydrologic characteristics of the aquifer(s) in the study area, therefore it is unclear how an accurate Modflow model could be developed that will determine what the Hima well will intercept, especially since nothing is known about the Hima wells than the well logs (SNR is unaware of any hydrologic or laboratory testing of these wells by Bailey).

On page 3 TetraTech states:

This study examines existing conditions related to saltwater influence on properties surrounding the Smith Island Restoration project site and evaluates how the project will affect these conditions. A field investigation and data collection were conducted to characterize existing site conditions, and groundwater modeling was performed to determine how conditions may change following implementation of the Smith Island project. To assess potential impacts to legal water uses in the area from any saltwater issues, a review of documented water rights, water wells, and current water uses was also conducted.

SNR is unaware of any field studies or other hydrogeologic studies conducted by TetraTech. However, the studies conducted by Bailey did not include any field studies that focused on the hydrologic characteristics of the sedimentary units Bailey identified. Additionally, all ground water level measurements were made by hand and did not include measurements in the Union Slough or the tidal channels located in the study area.

However, hand measurements made in a tidally influenced area are inaccurate and are only “snapshots” of actual conditions. It is unclear why pressure transducers were not used at this size (along with a stream gage) in the Union Slough and the tidal channels since the project’s inception and why pressure transducers were not placed in the wells constructed by Bailey.

Additionally, Bailey did not construct enough wells, did not construct wells to characterize the fresh water – salt water interface and did not place wells in a manner that is customary for ground water investigations (more widely disbursed). His placement of the wells was clearly influenced by the desire to collect engineering geology information in the area where the proposed setback levee would be built.

TetraTech’s statement “any saltwater” issues were investigated is unclear considering the soils with high chloride content were not address nor was the upgradient City of Everett POTW that uses significant amounts of chlorine were not considered as potential sources that could impact ground water quality (and Union Slough water quality).

The saltwater impact study was conducted in order to address the following specific issues:
• Will the Smith Island Estuarine Restoration project increase salinity levels in water from the well at Hima Farms, which is on property adjacent to the project site?
• Will the project impair Hima Farms’ ability to use groundwater throughout its property?
• Will the project impact agricultural land use through increasing salinity levels in subsurface water used by deep rooted plants?
• Will the project increase salinity levels in soil on adjacent property, thereby impacting agricultural land use?

This was not the stated purpose of the studies conducted by Bailey, 2012. It is unclear what field studies or other hydrogeologic studies TetraTech conducted for this report. It is clear that TetraTech’s “studies” did not include the City of Everett POTW (lagoon, ponds, and channels).

On page 8 TetraTech states:

Surface water salinity data was collected for this study in the fall of 2011. Salinity profile measurements were made in Union Slough and the Snohomish River during a high tide/low river flow period, when salinity levels are expected to be representative of their upper range. This data informs our understanding about representative maximum salinity levels on the project site following dike removal.

It is unclear why these studies were conducted when the focus was potential impacts to ground water quality. Additionally, these studies were conducted during the fall which is when river flow is typically at its lowest (baseflow conditions are typically present during the fall which means that ground water is the source of the flow) and tidal influences are at their highest.

Presumably, TetraTech was biasing the studies to represent the highest potential salinity in the sloughs and Snohomish River mainstem. However, the value of this information for the stated purpose of the study is unclear. The likelihood that high flow events will occur during the fall is very low which means that significant inundation of the farmland after the proposed breach will be low. The greatest opportunity for infiltration through the soils with known constituents that can affect ground water quality would be during high flow events when inundation will be the greatest.

Additionally, these studies were conducted during existing conditions. Even though the models reviewed in Tasks 2 and 3 lacked the data to provide accurate models, all of these models generally agreed that the tides will extend further up the Union Slough if the levees are breached.

This suggests that the conditions the salinity of the Union Slough in this area may also change. Regardless, it is unclear why the salinity of Union Slough is important to this investigation considering that inundation would typically occur during high flow conditions and under these conditions there would be very little, if any saltwater in the Union Slough.

On page 10 TetraTech states:

The modeled area extends to the Everett Water Pollution Control Facility pond on the south, the Snohomish River on the west, and the Union Slough channel on the east and north. The model grid divides this area into cells as large as 100 feet by 100 feet at the model’s outer boundaries and as small as 20 feet by 20 feet at the Hima Farms well, identified as the closest water well to the project site. The model uses six layers to
Represent subsurface layers (Figure 5): the uppermost layer (Layer 1) represents estuarine sediments (aquitard), and Layers 2 through 6 represent the marine sand aquifer below. The elevation of the bottom of Layer 1 ranges from -5 feet in the northeast to -22.5 feet in the southeast. The model extends down to elevation -75 feet throughout the modeled area.

SNR requested information from Snohomish County regarding the City of Everett POTW lagoon and how the Shannon & Wilson Modflow model addressed this lagoon. The following is the County’s response:

*From Snohomish County:* The lagoon was represented as a recharge source in the model, at a recharge rate of five times greater than the surrounding area to reflect the groundwater gradient from the south shown in monitoring well data from the Geologic and Hydrogeologic Field Investigation.

This suggests that the Shannon & Wilson Modflow model southern boundary extended further to the south than suggested by TetraTech. However, since Bailey did not conduct any hydrogeologic studies in the study area, including studies necessary to develop an accurate Modflow model (e.g., numm tests in each sedimentary unit, slm tests, and the use of pressure transducers in all wells, the Union Slough and the tidal channels, percolation testing, etc.) and no testing was conducted on either of the Hima wells, it is unclear how an accurate Modflow model can be developed.

The Modflow model can simulate groundwater flow based on Bailey’s hand measured elevations, however, these are inaccurate because of the time it takes to obtain hand measured data in a tidally influenced low topographic gradient area and because the model is generally based on assumptions, because no real data was available.

The Modflow model is generally useless unless accurate data is available to use in the model. Additionally, Shannon – Wilson used interpreted hydraulic vertical of 10^-6 cm/sec or less for the upper sedimentary unit, however, there is no data on the hydraulic conductivity of this sedimentary unit that has sand lenses and peat deposits and is loose to very loose material (zero blow counts). It is clear that the Shannon – Wilson Modflow Model is based on assumptions and not actual data.

*Seepage Through New Dike*

Results from the groundwater field investigation and groundwater modeling, along with engineering design criteria for the proposed setback dike were utilized to assess severity of seepage risk.

Through-seepage is not the same as underseepage...none of the data acquired from the groundwater field investigation and modeling can be used to "assess the severity of the risk of "through seepage" risk. Suggest re-title - seepage risk. Additionally, Snohomish County did not allow SNR to ask any questions or provide comments regarding the engineering design criteria because this has not been developed yet. Therefore this statement made by TetraTech is unclear.

On page 12 TetraTech states:

*The Smith Island Restoration Project site consists of approximately 400 acres of land on the northeast portion of Smith Island, within the Snohomish River estuary and near the City of Everett.*
SNR has not seen any geologic studies that suggest that this portion of Smith Island is located on an estuary. This area is on a prograding delta that has distributary and tidal channels and is located next to the Union Slough distributary channel and has three tidal channels located in Bailey’s study area that Bailey never discussed. It is unclear how a hydrogeologic study would not include three surface water features that have surface water present in them year-round.

Drainage ditches and tidal sloughs controlled by tide gates cross the site. Ditches and sloughs are mostly dry during extended periods of dry weather. During winter, when much of the site is under standing water, the ditches and sloughs are full. Vegetation in the project site consists of mostly grass-covered fields and wetlands crossed by tree- and bush-lined drainage ditches and sloughs, along with thicker tree growth locally in the eastern half of the property.

This is inconsistent with SNR’s research and field observations nor is it consistent with DD5 and Hima Nursery’s field observations. SNR’s research and the review of 12 historic air photographs from Google Earth Professional indicate that the tidal channels, the borrow ditch, and the Union Slough (and the other sloughs) are filled with water year-round. Additionally, no wetland studies were provided to SNR nor are any referenced in any document SNR has reviewed therefore the presence of wetlands on this farmland is speculative at best (especially since according to TetraTech the upper sedimentary layer is an aquitard that does not allow near surface ground water to exist on this site and wetland hydrology is ground water hydrology).

On page 13 TetraTech states:

The results of the soil chemistry testing indicate that the upper site soils were deposited in a marine environment with significant amounts of salt present. Reclamation of the land for farming in the early 1900s did little to change the soil chemistry. Predominantly saline acidic soils are prevalent across the site, with significant amounts of organic material below 4 feet bgs.

Soil conditions throughout the project site are consistent with soil types expected in an estuarine environment. Because of their high salt, mineral content and groundwater elevations, the soils may be problematic for some plants.

It is unclear how TetraTech arrived at these conclusions. It is unclear what has influenced the soils on the farmland because Bailey did not conduct actual environmental studies on this site; he conducted general studies with the primary emphasis being engineering geology studies. It is very likely that the farming activities did influence the constituents in the soil, especially the use of sewer treatment plant sludge and other agricultural additives on these soils. The elevated nitrogen, sulfur, low pH and other unusual constituents in the soil should have resulted in more comprehensive studies and research to determine the source and to determine if there are other constituents in the soil that could impact surface water and ground water quality such as metals, PAHs, pesticides, herbicides, etc.

This is a delta complex and it is common to have peat and other organic deposits on a delta complex. It should be noted that the sand lenses and the peat deposits will have relatively high hydraulic conductivity. Additionally, as previously stated, the entire Puget Lowland is in the Cascadia Subduction zone which creates general uplift (along with potential rebound from the Vashon Stade) which means that this area was underwater in the geologic past. Uplift in this area can be as much as 380 feet in the last 10,000 years. This suggests that these sediments may have been in a marine or estuarine environment in the geologic past, but not necessarily in 1850. However, it is just as likely that the biosolids placed on the farmland are contributing to the high chlorides.
On page 15 TetraTech states:

The 2011-2012 geological field investigations identified that groundwater is primarily present in the nearshore marine sediment layer (nearshore marine sands aquifer), the top of which is approximately 20 feet bgs. Above 20 feet bgs, only minor groundwater seepage occurs in the discontinuous sand lenses found in the estuarine surface sediments (estuarine sediment aquitard).

This incorrectly states what Bailey states in his 2012 report. Bailey states that the thickness of the upper sedimentary unit is highly variable, ranging from 9 – 20 feet in the areas he studied. Additionally, as previously discussed, it is unclear how ground water is in the “discontinuous sand lenses” and peat but is not present in the other sedimentary materials in this unit. Had Bailey conducted hydrogeologic studies on this unit this may be explained, however, his hydrogeologic studies were conducted on this or any of the other sedimentary units.

Based on Bailey’s description the sedimentary unit overlying the sand unit is at least semi-pervious to pervious. Until detailed hydrogeologic studies are conducted that include studies on the 160 acre lagoon, ponds, and trenches on the City of Everett POTW site there is no information on the hydrologic or hydrogeologic characteristics of the sediments on the area studied by Bailey nor is there any conclusive information on the characteristics of the ground water. It is unclear why Bailey ignored the obvious hydrology in the tidal channels and the borrow ditch and what hydrology he is describing as ground water seeps in the sand lenses (that may or may not be discontinuous) and in the peat deposits. Additionally, Bailey’s well logs do not suggest that all seepage was minor.

It is believed that the surface estuarine sediments act as an aquitard—a semi-confining bed through which water percolates at a very slow rate:

- Estimated vertical movement of groundwater through these soils is low to very low, ranging from 0.08 to 0.002 feet per day, except in the sand lenses.
- Horizontal hydraulic conductivity in the estuarine sediments also is low to very low, in the range of 0.01 to 0.001 feet per day.

This conclusion is based on the soil types in the surface estuarine sediments and the fact that the piezometric groundwater surface elevation is at or above the existing ground surface during late winter and early spring, both on the project site and on adjacent property to the west. Piezometric groundwater elevation is the potential water surface elevation if there were no restrictions; this is the level to which water will rise in a well drilled into the aquifer. The high piezometric elevation indicates that the groundwater is under pressure due to restriction from the overlying aquitard.

Flow pathways reflect the variable nature of the soils both horizontally and vertically. During extended periods of wet weather, when much of the site is covered with several inches to several feet of standing surface water, water likely flows downward through the surficial estuarine sediments, resulting in a slow leakage toward the underlying aquifer. During extended periods of dry weather, this flow pattern may reverse itself, with groundwater flowing up from the aquifer toward the ground surface.

The estuarine sediment aquitard acts as a significant barrier to surface water infiltrating to the underlying groundwater aquifer. The physical evidence for this is the persistent ponded water on the project site during wet weather. Based on the estimated range of
vertical flow rates provided above, it would take between 250 and 100,000 days for water on the surface to infiltrate to the underlying aquifer.

TetraTech is somehow creating estimates on the hydraulic conductivity of the upper sedimentary unit with no data and is basing these on assumptions. No aquifer testing or other testing on the sedimentary units on this site have been conducted and Bailey’s description of these loose to very loose organic silts, sandy silts, and silts with sand lenses and peat deposits does not suggest that an aquitard is present. Bailey should have conducted additional studies and should have included the lagoon, ponds, and trenches on the City of Everett POTW in these studies to find out why the piezometric surface in the wells is at or above the ground surface.

It would have been extremely helpful to have well elevations and to have piezometers with pressure transducers screened in each sedimentary unit identified by Bailey and to have pressure transducers placed in the Union Slough and the tidal channels (all surveyed to the NAVD 88 datum). Slug testing, pump testing, and the installation of additional wells or piezometers designed for ground water studies would have also been extremely helpful as would hydrogeologic studies on the influence the 160 acre lagoon and other surface water features at the POTW.

Surface water ponding is a component of infiltration related to Horton storage and overland flow. Most sediments will have surface water ponding if runoff is not possible (this is Hortinian storage) because infiltration rates for most sediments are greatly reduced after the wetting front is established. This is a component of the surface tension of water, the air that is present in the pore space, the size of the pores space, and the topographic gradient. It is not “proof” that an aquitard is present. In fact many storm water infiltration facilities pond for significant periods of time during the winter and these facilities are designed to infiltrate surface water.

The well readings also show that water in each well responds rapidly to changes in tide. Both on-site and offsite wells exhibit a rapid response to changing tide levels with little lag time. This indicates that the horizontal hydraulic conductivity of the local aquifer is very high, allowing groundwater levels to rise and fall with the tide in areas that are thousands of feet from a tidal source (Snohomish River and Union Slough). Horizontal conductivity in these layers is estimated to range from 100 to 1,000 feet per day.

As SNR has discussed there are no tide gages or pressure transducers in the Union Slough adjacent to the study area and all water surface elevations in the wells were measured by hand. This does not provide accurate information on the characteristics of the aquifer and needs to be supplemented by the installation of pressure transducers and additional wells in a monitoring system designed to study the ground water and the hydrologic characteristics of each sedimentary unit described by Bailey. Additionally, aquifer testing needs to be conducted, at a minimum slug tests, but preferably pump tests that can provide data on the affects in other wells that are monitored with pressure transducers. It is preferable that the pressure transducers also have the capability of measuring specific conductance in addition to the piezometric or potentiometric surface elevation and temperature, such as the Solinst Junior series with these capabilities.

The 2011-2012 geological field investigations found that the upper level of the groundwater table at the project site is defined by the top of the nearshore marine sands, 9 to 21 feet bgs, confined by the surficial estuarine sediment aquitard. However, the piezometric surface of the groundwater, based on its pressure gradients, is close to or above the ground surface. This is not unusual for a confined aquifer in an estuary environment (Todd, 1987). The lower confining bed of the aquifer is the layer of saturated silts and clays below 60 feet bgs across the site and surrounding properties.
Based on the observed tidal response at the observation well locations, the probable horizontal boundaries of the aquifer are the Snohomish River to the west and Union Slough to the east and north. The probable southern boundary is unknown at this time.

Based on SNR’s review of Bailey’s studies, the ground water “boundaries” cannot be determined at this time. More extensive study will be required as will testing that was never conducted. It is clear that the ground water boundary to the south was never established and that the lagoon and other surface water features on the POTW property are influencing the ground water.

Additionally, as previously stated, the blow counts at 75 – 85 feet in the sediments Bailey assumed constitutes an aquitard were zero, which is unusual. This should have resulted in more study because for some reason Bailey did no collect samples and based on the entire stratigraphic profile logged by Bailey, the sediments described would be highly conducive to liquefaction. The geologic characteristics of the sediments in all of the sedimentary units identified by Bailey are not adequately studied nor are the hydrologic characteristics of these sediments known.

On page 16 TetraTech states:

Results of the field investigations suggest a fairly typical saltwater intrusion water column in the vicinity of Union Slough. The contact becomes mixed and gradational moving away from this boundary toward the center of the site. Moving west from there toward the Snohomish River, the entire water column becomes salt-impacted. In all locations, the tested chloride and electrical conductivity levels within the existing water column are significantly higher than secondary drinking water standards allow, so this groundwater is not economically usable for domestic or commercial applications.

Bailey did not conduct a saltwater intrusion study nor did he provide any discussions on the typical characteristics of saltwater intrusion in a river delta complex. Bailey collected on round of samples in wells that he developed over a period of months and sampled without any QA/QC plan or even a sampling plan. The data is suspect and it is unclear where Bailey places the freshwater – saltwater interface with virtually no data.

In reality the model discussed above would be unusual for the geologic and hydrogeologic setting of Bailey’s study area considering this is where the second largest river in the Puget Sound that is discharging large volumes of fresh water on and through its delta complex into Possession Sound. This near shore area is also where the regional ground water aquifer(s) will be discharging into the Possession Sound.

These regional aquifers have recharge areas in the Cascade Range and have significant hydraulic head. This combined with the characteristics of fresh water – saltwater interfaces suggests that the description provided by TetraTech and Bailey are unusual which is one of the reasons SNR recommends more detailed saltwater intrusion studies be conducted and these studies should be combined with more detailed hydrogeologic studies that include aquifer testing and the use of pressure transducers.

One well exists on the Hima Farms property west of the project site. According to the well log, this 6-inch-diameter well was installed in April 2010. The well was completed at a 74-foot depth, with screens placed in the lower 6 feet. Static water level was recorded at 4 feet below the top of the well. The driller's log listed silt, clay and sand to a 4-foot depth; sand, wood and silt to a 23-foot depth; and sand, wood and water below 23 feet. The log indicates that chemical analysis found saltwater with iron. Snohomish County has not been granted access to the well for sampling, and little information is available regarding
its current and intended use. There is no record of pumping from this well since its completion. The only other wells shown in Ecology’s well database are resource protection (monitoring) wells that are believed to have been decommissioned.

<table>
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<tr>
<td>There are actually two wells on the Hima property and SNR downloaded both of these well logs from Ecology’s well log site (Figures 6-2 and 6-3). Based on the well logs for both wells, neither was “screened”. None of these wells were installed on April 10, 2010 (the shallow well was installed on April 9, 2010). The well log for the well installed on April 9, 2010 does not suggest that 20 feet of organic silt or silt was encountered. The well log suggests that sands were encountered at 4 – 23 feet below the ground surface. The well log indicates that the static water level was 4 feet below the top of casing, which would be close to the ground surface.</td>
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<td>The well log presented as Figure 6-3 suggests different subsurface stratigraphy than Bailey describes and should have been reviewed by Bailey before he conducted his studies. This well was drilled to 112 feet below the ground surface and suggests that the sands were present 93 feet below the ground surface.</td>
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<td>Although there are not many well logs in this area there are boring logs which can be correlated to the stratigraphy identified by Bailey, however, no well or boring logs were presented in any report SNR reviewed, including the October 17, 2011 log prepared by Wolfe Mechanical Services for the well they drilled on the Hima property.</td>
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<tr>
<td>As previously discussed Bailey did not conduct true saltwater intrusion studies nor did he conduct any studies on the characteristics of the ground water aquifer(s). However, the basic science of saltwater intrusion is that fresh water will overly the saltwater at an interface and that a mixing zone will be located at this interface. Confined aquifers that have significant hydraulic head typically have less chance of saltwater intrusion inland of the shoreline than unconfined aquifers, however both aquifers have the potential for a fresh water – saltwater interface if saltwater intrusion is occurring in the near shore area.</td>
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<td>What is unclear is why saltwater intrusion would be present where Bailey suggests it is this far from the marine water in a large fresh water delta complex. Bailey should have conducted additional studies and looked for other sources of chlorides and for potential activities that may be affecting ground water in this area. This includes the lagoons and other surface water features on the City of Everett POTW site.</td>
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<tr>
<td>The studies should also look at other facilities, including historic facilities that could potentially influence the ground water, including ground water quality. It is known that Weyerhaeuser had a pulp mill in this area and that several large detention facilities, a landfill, and other waste facilities were located at this pulp mill and there are other ponds located to the west of the Hima property.</td>
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**WATER WELL REPORT**

**PROPOSED USE:** Domestic □ Indus □ Muni □ Fish □ Other

**TYPE OF WORK:** Owner's type of work (check one only):
- New well □ Reconditioned □ Deepened □ Other □ Drilled □ Installed □ Thru-drilled □ Other

**DIMENSIONS:** Diameter of well: 6 in., Depth: 72 ft., Depth of completion: 72 ft.

**CONSTRUCTION DETAILS:**
- Wellhead: 6 in., Drainage from 72 ft. to 68 ft.
- Installed: Yes
- Installed: From 38 ft. to 39 ft.
- Drilled: From 38 ft. to 39 ft.

**Fertilizers:** Yes □ No □

**Location:**
- N 40° 14′ 12″ Sec 20 T 29 R 45 E
- ENSO 8

**GEOLOGICAL DATA:**
- Material in soil:
- Material:
- Depth:
- Material:

**WELL TESTS:**
- Water test:
- Traffic test:
- Maximum flow:

**CONSTRUCTION OR DECOMMISSION PROCEDURE:**
- Formation: Describe by color, texture, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information (USE ADDITIONAL SHEETS IF NECESSARY).

**MATERIALS:**
- FROM TO
- Brown topsoil
- Brown silt, clay & sand
- Brown sand, Wood & silt
- Gray sand, wood & water

**Chemical analysis:**
- Shows:
- Water with:

**WELL CONSTRUCTION CERTIFICATION:**
- Driller: John Johnson
- Engineer: Terry Smith
- Contractor: Hima Nursery
- Drilling Company: Hima Pump and Drilling
- Address: P.O. Box 124
- City, State, Zip Code: WA, 98252
- Contractor's Registration No.: 06580

**Figure 6-2 - Well Log for April 9, 2010 Well on Hima Property**
Figure 6-3 - Well Log for Well Installed on October 13, 2011 on Hima Property
What is curious is that Bailey indicates that saltwater intrusion is occurring on a site that is almost 3 miles from open marine water. This is somewhat unusual where there are no active ground water withdrawals are taking place and where fresh water in the form of ground water and surface water flow should be sufficient to prevent saltwater intrusion. This is one of the many reasons additional studies that are actually focused on hydrogeologic studies need to be conducted.


Shannon & Wilson used the information from the Bailey, 2012 studies to prepare a Modflow model on the ground water aquifer in Bailey’s study area, however, although not mentioned in the Shannon Wilson, Bailey, or TetraTech report, Shannon Wilson apparently factored in the 160 acre lagoon on the City of Everett POTW site for the model developed for the flow net (ground water flow direction). This is apparently why the ground water flow direction is shown to be from south to north rather than from east to west.

However, the Shannon & Wilson report do not discuss the effects of the hydrologically upgradient City of Everett ponds, trenches, and lagoon on the ground water including what influence this facilities will have on ground water recharge, quality, or the pumping of one of the Hima wells (as with all other reports, the Shannon & Wilson report only discusses one Hima well and the model does not include any information on this well other than the well log).

As previously discussed the Shannon & Wilson Modflow model is generally based on assumptions, because no ground water hydrology data is available from testing the aquifer(s) or the Hima wells. Additionally, Shannon & Wilson apparently assume that the mainstem of the Snohomish River and the Union Slough are a source of ground water recharge all year (this assumes these are "losing streams"), even though there is no evidence that this is the case and Bailey suggests that the hydraulic head for the ground water in the wells he installed is significantly higher than the base flow for either of these surface water features.

Additionally, Modflow cannot factor in unsaturated zone flow, especially when there is no data on the unsaturated zone flow provided in Bailey’s report. The Modflow model was not used to interpret the hydrology of the tidal channels that flow year-round or the borrow ditch that also flows year-round. The Modflow model also assumes that the deeper sedimentary unit described by Bailey as sandy silts and clayey silts is a confining layer and has the characteristics of an aquitard, even though no studies were conducted on this sedimentary unit and no ground water aquifer testing has been conducted.

No laboratory permeability data, no percolation testing, and no aquifer testing such as slug tests and pumping tests were conducted on any of the three sedimentary units described by Bailey. Additionally, there hydrogeologic characteristics of the Union Slough and the mainstem of the Snohomish river are unknown as are the sediments present in the beds of these surface water features or even the banks of these surface water features. Without the required accurate data no model can provide accurate simulations of the existing or other conditions, such as those with the proposed levee breaches and setback levee.

Additionally, there was no testing on either Hima well and without this data or other data on the characteristics of the different aquifer(s) such as pump testing or slug tests, it is virtually impossible to develop an accurate model. Therefore, it is unclear why the Modflow model was conducted at this time. If it is conducted at all it should be conducted when there is sufficient information on the aquifer characteristics of all ground water bearing sedimentary units (aquifers and potential aquifers).
The following are SNR’s comments for the Shannon & Wilson report:

On page 1 Shannon & Wilson state:

Conceptually, the primary impact to groundwater conditions that could potentially result from the restoration would be to groundwater users in the area. At present, no groundwater is currently pumped from wells and only one groundwater supply well is known to exist.

The potential impact is not only to existing ground water users, but also to future ground water users, however, there is also the potential that ground water quality could be impacted by infiltration through soils on sites that have historically been used for agricultural purposes and are believed to have had sewer treatment plant sludge applications placed or these sites. Since ground water provides base flow for all of the distributary channels and the Snohomish River mainstem, this can directly affect the water quality in these surface water features.

Additionally, as previously discussed, there are two wells on the Hima property and neither has had any hydrogeologic studies conducted on them, including water quality and aquifer testing.

Our groundwater impact analysis involved developing a groundwater flow and transport model of the Smith Island area, calibrating the model to existing, pre-restoration hydrologic (baseline) conditions, and simulating the effects of the proposed dike breaching on this baseline to predict changes in groundwater flow and chemistry.

As previously discussed, it is unclear how Shannon & Wilson can calibrate a Modflow model when there is no accurate information available on the aquifer characteristics and limited information on the ground water quality. It is especially difficult to model a well based only on well log data, however, there are two wells on the Hima site and each well suggests different stratigraphy was encountered. Additionally, the well log for the April 2010 Hima well (see Figure 6-2) suggests this well was drilled to a depth of 23 feet below the ground surface. Shannon & Wilson indicate that this well was drilled to 74 feet. This difference is not discussed:

This well, owned by Hima Nursery, was installed in April 2010 to a depth of 74 feet. However, no record of actual pumping exists for this well since its completion.

As previously discussed, the October 2011 well log (Figure 6-3) suggests another well was drilled to 112 feet below the ground surface (suggesting this is the deepest well on the site). The Modflow model would require accurate well construction data and accurate information on the aquifer characteristics.

On page 2 Shannon & Wilson state:

The model domain is bounded by the Everett Water Pollution Control Facility pond in the south, the Snohomish River on the west, and the Union Slough channel on the east and north. The model’s upper surface is based on the 2-foot LIDAR data for the area. The model grid uses computational cells varying in dimension from 100 feet by 100 feet at the model’s outer boundaries to 20 feet by 20 feet at the Hima Nursery Well, “HW-1” (Figure 1). The model uses six discrete layers to represent the subsurface soils.
There is no discussion on the City of Everett POTW lagoon and the other ponds and channels that could influence ground water recharge (Bailey did not include this in his 2012 studies). It is unclear why Shannon & Wilson chose the boundaries they did, considering the western boundary is technically the Possession Sound, the eastern boundary could technically be extended to the regional ground water recharge zone which would typically be the Cascade Range.

It is also unclear what Shannon & Wilson included as the southern boundary, although as previously discussed, Snohomish County indicates that at least for flow net for ground water “flow” direction, Shannon & Wilson factored in the City of Everett POTW 160 acre lagoon (it should be noted that anything larger than 20 acres is not regulated as a pond per the Washington State Shoreline Management Act).

Additionally, it is unclear why Shannon & Wilson used 2’ LiDAR generated elevation data in this 2012 report, when Snohomish County had a survey map generated by Otek (no date). Additionally, Shannon & Wilson assume that the upper sedimentary unit is an aquitard and did not have data on the measured hydraulic conductivity of this unit.

Bailey did not conduct any aquifer testing on this unit, nor were laboratory permeability tests performed or was even basic percolation testing conducted. All “data” used is based on assumptions, because no testing was conducted on any of the sedimentary units. Additionally, as discussed above, it is unclear which well log Shannon & Wilson used for the “Hima Well” because the well log disagrees with Shannon & Wilson’s description of any of the well logs for wells constructed on the Hima Nursery site.

The elevation of the interface between the two hydrogeologic units ranges from -5 feet in the northeast to -22.5 feet in the southeast (Figures 2 and 3). The base of the model is at elevation - 75 feet throughout the domain; no groundwater flow occurs across this lower surface (no flow boundary).

It is unclear how these interfaces were established by Shannon & Wilson and it is unclear which datum is being used for elevations. It is also unclear how the “no flow boundary” was established considering there is no information on the deepest sedimentary unit identified by Bailey, 2012 other than his description in the boring log (this sediment should have been discussed Bailey, because of the zero blow counts at this depth). Additionally the Hima well log for the well installed in October 2011 suggests that the stratigraphy of this well is different from those Bailey constructed, with sands being present to the depth of the well (112 feet BGS).

On page 3 Shannon & Wilson states:

The higher permeability zone lies to the eats f the planned setback dike, and extends to Union Slough in two locations close to the two reaches that are planned to be breached. This higher permeable area would effectively permit more recharge to the underlying aquifer than in the remaining, lower permeable areas.

It is unclear how Shannon & Wilson defined different levels of permeability in the upper sedimentary unit or that they list clay as being one of the sediment types considering no hydrometer testing was conducted. Bailey did not conduct any hydrogeologic testing on this sedimentary unit (not even laboratory permeability testing or percolation testing).

It is known that this area is active farmland and that farm houses existed on this site. Most farm houses would have used onsite septic systems, however, this was not discussed, nor is the source of historic water supplies for this agricultural land (this area has been in agricultural use since at least the 1880s) discussed.
If the upper sediments actually have the characteristics of an aquitard, it is unclear how this area could be farmed or have a septic system. Regardless, it was known that the soils on these agricultural properties have high levels of nitrogen, chloride, sulfur, and very low pH (as previously discussed, it is unclear why Bailey did not include metals and other potential constituents that would be present on farmland).

There is no discussion on the potential impacts to ground water quality from surface water infiltration through these soils when this area is inundated if the proposed levee breaches are conducted (nor is there any discussion on potential impacts to the water quality in the Union Slough if the water comes in contact with these soils after the proposed breaching of the levee).

Neither Bailey nor Shannon & Wilson discuss the unique characteristics of saltwater intrusion in a fresh water ground water system nor have they refined where the actual fresh water/saltwater interface is located. In virtually all ground water systems this far from the marine waters and in a relatively large river delta system there will typically be fresh water overlying any potential saltwater intrusion. It is unclear why this was not discussed and why potential impacts to this fresh water (the Bailey’s studies should have focused on where the fresh water was located or he should have proven than none existed and why) were not discussed.

We estimated the hydraulic conductivity using four different analytical methods (Hazen, 1892; Carman, 1956; Slichter, 1905; Beyer, 1964).

These are all very old references (there are other more recent references such as Fetter, 2001, Fredlund, M. D. et al, 1998, Cronian, A. E, and Gribb, M. M., 2007, etc.). Regardless, the key is that the hydraulic conductivity was estimated on grain size analysis without hydrometer testing. Why didn’t Shannon & Wilson use the methods described in the Storm Water Management Manual for Western Washington, 2005, Ecology for determining interpreted hydraulic conductivity (e.g., Section 3.3.5)?

More accurate data should have been developed by Bailey or other studies should have been conducted on all of the sedimentary units identified by Bailey, 2012.

The analysis produced 27 valid results, which ranged from 0.003 to 183 ft/day, and a mean of 49 ft/day (Figure 6). Six of the sample results are less than 0.1 ft/day, and the remaining 21 sample results are higher than 1 ft/day. We conducted an additional modeling analysis to evaluate the sensitivity of the simulations to a range of aquifer hydraulic conductivity values between 25 and 125 ft/day. This range contains eleven of the valid sample results. Table 1 presents the hydraulic properties assigned to the layers.

It is unclear how these “estimated” resulted in “valid” results. This is a very large range with a lot of potential error. It is also unclear what the 11 “valid sample results” or what “this range contains” means relative to the measured hydraulic conductivity of these sediments since no measurements were made.

On page 3 Shannon & Wilson state:

We used the County’s 11 monitoring wells (8 shallow and 3 deep) as groundwater level calibration points (see Figures 7, 8, and 9). Figure 10 shows the minimum, maximum and mean groundwater levels for these 11 monitoring wells for the period January through July 2012. Figure 11 shows the simulated groundwater levels in the shallow part of the aquifer, for average (January-July 2012), existing conditions. Groundwater in the aquifer generally flows from south to north, discharging to the estuary. The average measured
level between January 17 and July 17, 2012 (21 values per well) were used as the calibration levels. Figure 12 shows the resulting calibrated model groundwater level for the 11 wells with respect to the mean and ±1 standard deviation (SD) from the mean. Overall, the calibrated levels are either similar to or higher than the mean, but less than one SD higher than the mean.

The Bailey hand measured ground water elevation data was used; however, as previously discussed this data should have been obtained with pressure transducers that also measured the elevation of the water in the Union Slough and the elevation of the water in the tidal channels. “Simulated” ground water levels were used in the upper sediments identified by Bailey, 2012.

Shannon & Wilson indicate that ground water flow is from south to north, but do not discuss the inclusion of the City of Everett POTW 160 acre lagoon (it is unclear what surface water elevations were used) as indicated by Snohomish County in this model.

Ground water generally flows from the highest areas, which are generally to the east in the Cascade Range (this is there the Skykomish and Snoqualmie Rivers originate) of recharge to the lowest topographic areas, which in this case is the Puget Sound. In this area of the Puget Sound this typically suggests that ground water will be trend in an east to west direction. This deviation from this typical ground water flow is not discussed by Shannon & Wilson nor is the potential influence of the 160 acre lagoon on their ground water model discussed.

We used the calibrated model to simulate the potential effects of performing the two dike breaches and future groundwater pumping from the Hima Well. For this analysis, two significant conditions were uncertain. These are:

- The pumping rate for the well, and
- The flux of water likely to occur from the breaching.

Based on the data available to Shannon & Wilson for this model, there were many other uncertainties, including data from actual field measurements conducted on the three different sedimentary units and more detailed ground water elevation data gathered by pressure transducer data loggers (such as the Solinst LeveLoggers). What is even more important is that it is unclear what well design Shannon & Wilson used for the Hima well (as previously discussed there are two wells and the April 2010 well log does not match Shannon & Wilson’s description of this well).

Regardless, there has been no testing on either Hima well and none of the surface water models that have been conducted have been accurate enough to provide information on the maximum inundation that would occur from any flood event (as an example, there are no known stream gages on the Union Slough therefore actual discharge rates and stage heights are unknown).

Additionally, all models assume that the remaining unmaintained levee will not begin to fail and erode over time, when these levees begin to fail the surface water hydrology on the proposed restoration site will not be accurately reflected by any model that does not include these changes in the remaining levees (SNR has not seen any studies conducted on the levees, however, as previously discussed, the recently repaired section of the DD5 levee east of Tidal Channel A is continuing to fail as shown in Figure 6-4 below.
On page 4 Shannon & Wilson state:

To account for the unknown pumping rate, we performed several simulations using a range of pumping rates (25, 50, 100, 150, and 200 gallons per minute [gpm]). Assuming an aquifer transmissivity of 3,000 square ft/day (equal to the thickness of 60 feet multiplied by the hydraulic conductivity of 50 ft/day), the specific capacity of the well is likely in the range of 7.5 to 12.5 gpm/ft. Therefore, the well's likely operational drawdown at 200 gpm would range between 13 and 27 feet. It is unlikely that the owner would wish to drawdown the water level in the well by more than 27 feet.

Conceptually, the breached water from the northern and eastern reaches will flow overland across the island and infiltrate through the upper aquitard before recharging the aquifer. The following explains how we derived a flux rate for this.

This is based on assumptions and concepts; it is not based on any hydrologic data or data generated from any hydrogeologic testing of the Hima wells. It is unclear what data Shannon-Wilson is using for the April 2010 Hima well but their description of this well is not the same as the well log filed with the Department of Ecology. It is clear that Shannon & Wilson do not have any data obtained from well testing. Additionally, as stated above there are no accurate models for the inundation that could occur during a major storm event after the levees have been breached or when the remaining levees begin to fail (however, Shannon & Wilson did not use any data from any model SNR reviewed).
The recent groundwater hydrograph for wells SW-01 (located closest to Union Slough) and SW-08 (located in the center of the island) shows an increase of up to 0.6 foot between low and high tides. To determine how much groundwater recharge causes such an increase, we increased the modeled head on Union Slough by between 0.5 and 2.0 feet and observed the change in head at these two wells. The model indicated that a 1-foot rise would reproduce a head increase of between 0.1 and 0.6 foot at these two wells (Figure 13). The resulting increase of flow into the model area ranged between 95 and 150 gpm. Therefore, we increased the recharge to the upper model layer across the area between the planned setback dike and Union Slough from 0.4 inch per year (in/yr) to 6.6 in/yr to represent this additional inflow rate.

Had Snohomish County installed a stream gage and pressure transducer in the Union Slough when the initial studies were being conducted in this area and continued to monitor the Union Slough (and the tidal channels) and had Bailey installed pressure transducers (preferably with specific conductance measurement capabilities for all pressure transducers) actual data would be available that would have a high degree of accuracy. Instead, Shannon & Wilson had to generate hypothetical scenarios (including the assumption that the only sediments present in the Union Slough are the upper sediments identified by Bailey, 2012). The very low infiltration rate of 6.6 inches per year is based on changes in elevation based on assumed tidal influence rather than other potential influences, such as the 160 acre lagoon located hydrologically upgradient of this site, with reported water levels of 5 feet above the bottom of the lagoon (http://www.everettwa.org/default.aspx?ID=99).

It is obvious that the effects of this lagoon were reflected in the Shannon & Wilson ground water “flow” model however, it is curious that Shannon & Wilson did not factor in the lagoon for potential ground water recharge (the lagoon is approximately 2,500 feet topographically upgradient of the Hima wells; the Union Slough is topographically lower and is located approximately 3,700 feet east of the wells; although the mainstem of the Snohomish River is located approximately 1,600 feet west of the Hima Wells, it is also topographically lower).

On page 5 Shannon & Wilson state:

Eleven of the 28 hydraulic conductivity results derived from the grain size analyses fall within the range of 25 to 125 ft/day (see Figure 5). Figure 29 summarizes the results of these cases, and indicates that the range of total particles derived from the two breached areas is between 8 percent (for the 125 ft/day case) and 17 percent (for the 25 ft/day case). Therefore, the relative fraction of recharge water to the Hima well is moderately sensitive to the aquifer hydraulic conductivity pumping rate.

Shannon & Wilson have suggested that the hydraulic conductivity of the upper sedimentary unit is 6 feet per year. It is unclear how this recharge rate was established; however, if this were the case, it is unclear how the assumed hydraulic conductivities of the deeper sand aquifer are related to how the inundation of the proposed restoration area will provide significant amounts of aquifer recharge at an assumed interpreted hydraulic conductivity of 6 feet per year (0.2 feet per day). Regardless, the Modflow model is based on assumptions and is not based on actual data obtained from testing the different sedimentary units and is based on hypothetical scenarios, without including the most likely source of ground water recharge, the 160 acre City of Everett POTW lagoon (and the other ponds and trenches on this site) that is topographically upgradient of the Hima wells and has 5 feet of standing water on the bottom of this lagoon (plus the Shannon & Wilson ground water flow model indicates that this lagoon is controlling ground water “flow” because it is a recharge source.
On page 6 Shannon & Wilson state:

As part of their hydrogeologic field investigation, the County collected groundwater quality data for the 11 monitoring wells.

The fall 2011 water quality monitoring for the Snohomish River and Union Slough indicated the following

Table 2 summarizes the results of water quality mixing analysis, which are summarized as follows:

SNR requested information on the water quality of the waste water in the City of Everett POTW lagoons and in their chlorination trench; however, the POTW staff indicated that there is no information on the water quality in these areas. Additionally, nothing is known about the accumulation of sediments or wastes in the bottom of these surface water features. Therefore the potential impacts these surface water features have on the ground water beneath the Hima site are unknown.

Additionally, it is known that the soils on the agricultural properties Snohomish County is proposing to convert into a restoration area do have constituents present that can impact ground water quality (and the water quality of the Union Slough). However, Bailey did not include analyses for all potential constituents that could be present in these soils, especially if (as is suggested by the City of Everett POTW) sewer treatment plant sludge was placed on these agricultural properties, because these sludges have elevated metals and elevated phosphorous. Additionally, because these were agricultural properties in operation for at least 100 years agricultural chemicals may have been places on these properties and may be present in the soil (such as herbicides, pesticides, PAHs, and other chemicals such as 1,4-dioxane). It should be noted that some agricultural operations also included fueling facilities for agricultural equipment which means that underground storage tanks may have been used to store fuel.

As previously discussed, Bailey’s studies were primarily focused on engineering geology studies, with environmental and ground water studies (including saltwater intrusion studies) being incidental to the engineering geology studies. Although Bailey did not include any discussions on the potential liquefaction potential of the sediments he describes despite the low blow penatrometer blow counts. If a QAPP that included a Sampling and Analysis Plan had been developed perhaps more data would have been obtained on the soils and ground water and the sampling would have been conducted in accordance with USEPA and Ecology protocols (and the data interpretation would also follow these protocols).

Bailey did not conduct a comprehensive saltwater intrusion study and does not discuss where the fresh water/saltwater interface is located on a site with no apparent ground water pumping activities suggested to be present within the boundaries of the study area. The potential impacts from the high chlorides in the soil and the unknown characteristics of the water in the chlorination trench (and elsewhere chlorine disinfection is used) at the City of Everett POTW were not addressed by Bailey or by Shannon & Wilson.

At best the Shannon & Wilson modeling activities can be determined to be inconclusive because there is insufficient data to conduct an accurate model, there is no hydrogeologic information on either Hima well (or any of the wells Bailey constructed), and the source of ground water recharge is unclear (considering the Shannon & Wilson ground water “flow” model suggests that the recharge zone is to the south where the City of Everett POTW’s ponds and lagoon are located. Additionally, the potential impacts the City of Everett POTW surface water facilities may have on ground water quality, including chlorides, is unknown.
The studies conducted by Bailey need to be supplemented with a more comprehensive ground water study that includes aquifer testing on all sedimentary units including testing in additional wells and piezometers that can be used for pump testing and the studies need to include the City of Everett POTW surface water facilities as a source of ground water recharge and as a potential source of chlorides and other constituents. Additionally, actual saltwater intrusion studies need to be conducted using standard protocols for the appropriate aquifer type and data gathering for these types of studies.

Once all of the necessary data has been obtained and this data has been determined to be accurate, including hydrogeologic data on the Hima wells, then Shannon & Wilson can attempt another Modflow model that is based on data, not assumptions.
7 FINDINGS

Although all of SNR’s findings are presented in the previous sections, SNR is providing the following summary of some of the more important findings related to the original goals of the studies summarized in the reports SNR reviewed and how these studies/reports addressed these goals.

It should be noted that SNR’s comments, findings, recommendations are limited to those described in the DD5 contract with SNR and that SNR did not directly comment on design considerations other than those discussed in the DEIS that could affect the fluvial geomorphology, surface water quality, and hydrology of the Union Slough and can affect groundwater quality (e.g., the proposed use of large woody debris, the proposed grading activities in the restoration area etc.).

7.1 Summary of Task 1 Findings

The purpose of the Task 1 studies were to address the changes in drainage that will occur on the private properties located west of the proposed setback dike because the drainage from these private properties currently incorporate Tidal Channel A in their subsurface and surface water drainage system and drainage to Tidal Channel A will be cut off by the proposed setback dike.

The 2011 Cahill report (Snohomish Conservation District), “West Side Drainage”, assumed that the Tidal Channel B 42” culvert under the I-5 freeway would be cleaned by WSDOT and “re-sleeved”; However, the 2012 TetraTech Second Draft “Smith Island Drainage Analysis” assumes that the 42” culvert under the I-5 freeway would be completely blocked and that all drainage on the private properties would need to be rerouted to the Union Slough at a new outfall with a tide gate on the east side of the I-5 freeway.

The studies conducted by Cahill and TetraTech used the Western Washington Hydrology Model (WWHM) provided by the Washington State Department of Ecology (this is based on the USEPA Storm Water Management Model - SWMM model). The WWHM is generally used to model surface water runoff for storm water system design. The TetraTech study also included the use of the USEPA SWMM model.

Cahill used a LiDAR generated topographic map for his studies; however, there has apparently been no surveying conducted on the western private properties. Both studies focus on the use of storm water detention in Tidal Channel B and in a manmade, unlined, “storage area(s).

The TetraTech study included analysis for standby pumps to supplement surface water removal in Tidal Channel B; however, the studies did not focus on the exclusive use of a pumping system to ensure that the surface water elevation in Tidal Channel B did not cover the Hima Nursery drainage pipes (tighlines and culverts) that discharge to Tidal Channel B.

None of the studies evaluated the Tidal Channel drainage capacity west of the I-5 freeway, which is understandable for the TetraTech study that assumed that none of the drainage on the private properties would drain under the I-5 freeway. It should be noted that field studies on the private properties was limited to the observations made by Cahill and there was no analysis made on the WSDOT permitted point source MS4 discharges from the I-5 freeway into the study area, including the direct discharge of WSDOT permitted point source MS4 storm water into Tidal Channel B through a Hima 15” tighline.

Additionally, there was no analysis for the perennial water that flows in the “borrow ditch” that drains to Tidal Channel A nor is there any analysis for a potential landward ditch for the proposed setback dike. Additionally, there were no studies conducted to determine the source of water in the perennially flowing Tidal Channels B and C or analysis regarding the hydraulic connectivity of all the tidal channels.
The following is a summary of the key findings SNR made for Task 1:

1. Both studies are based on the premise that the only potential source of surface water on the private properties will be precipitation and both presume that infiltration to ground water will occur. Additionally both studies presume that the Buse property will not be used agriculturally. However, as discussed in this report, there are other potential sources of surface water hydrology and the Buse property was purchased by Hima Nursery to place in agricultural production. As is the case with the existing Hima operations, subsurface drainage will be used on the former Buse property.

The subsurface drainage system will collect much of the subsurface drainage before it has the opportunity to infiltrate to ground water and therefore needs to be included in the model as an impervious surface. This will include the former Buse property because Hima will install a subsurface drainage system on this property (personal communications with Naeem Iqbal, 2013).

Hima nursery owns the western ditch system that WSDOT currently discharges point source MS4 storm water into. This system uses a sump pump to transfer storm water in the western ditch system to Tidal Channel C 24" culvert drainage area. If a power outage occurs during a significant storm event, it is possible that the western ditch will spill over and enter the Hima central ditch system that discharges directly to Tidal Channel B.

As discussed above, some of the WSDOT water in the western ditch system is already discharged directly into Tidal Channel B via a Hima 15" tightline.

The drainage on the former Buse property and in the northern portion of the borrow ditch that drain to Tidal Channel A are not apparently addressed.

The hydrology source of Tidal Channel B has not been studied nor has the hydraulic conductivity of the tidal channels been studied. If ground water or unsaturated zone flow are the hydrology source, Tidal Channel B may fill with ground water or unsaturated zone flow during a major flooding event; reducing the capacity of Tidal Channel B. Additionally, if Tidal Channel B is hydrologically connected to Tidal Channel A, flooding inundation of Tidal Channel A may affect the water levels in Tidal Channel B.

The proposed use of unlined storm water storage facilities and a unlined ditch system may impacted by rising ground water, increasing unsaturated zone flow, potential underflow beneath the proposed setback dike. This will reduce the capacity of the proposed storage and drainage facilities during major flooding events.

2. The drainage analysis does not factor in potential overtopping or dike breach flows. The existing DD5 levee system has an extensive topographically lower buffer (about 400 acres) that can store significant quantities of floodwater should a levee overtop (overtopping of the existing levee has not been reported within the last 20 years based on SNR’s research) or breach (breaches has occurred and Union Slough bank failures have threatened the levee system, which is why the Corps of Engineers conducted emergency repairs in February 2012). It is unclear how the private properties will be affected by breaches or overtopping of the proposed setback levee compared to impacts from breaches or overtopping with the existing levee system.

3. The DEIS indicates that the tidal channels are considered to be “fish bearing” (page 81 of the DEIS states; “Although they are isolated from Union Slough by dikes and tide gates, the remnant tidal channels and drainage ditches are considered fish-bearing waters.”) regulatory, however, the regulatory issues associated with using these features to store storm water, including the incorporation of these features in a permitted point source MS4 system (WSDOT discharge) has not been addressed.

4. Ground water and potential unsaturated zone flow were not included in the analysis even though the ground
water is known to have a potentiometric surface elevation that is at or above the ground surface on the Hima
property (Bailey, 2012). Unsaturated zone flows are known to occur within 4 feet of the ground surface within sand lenses and in peat deposits. It is possible that the unsaturated zone flow (interpreted by Bailey, 2012 as ground water) observed in the test pits excavated for the Snohomish County saltwater intrusion studies may be linked to the surface water hydrology in the Union Slough. This may explain why the borrow ditch is filled with water year-round, which would suggest there is a potential for under seepage and/or through seepage for the existing levee system and the proposed setback levee.

5. It is unclear why TetraTech did not include an evaluation that only uses pumps (electric pumps with power backup), rather than excavated detention facilities and relocated tide gates, to remove water from Tida Channel B and from the borrow ditch that bounds the landward side of the remaining, maintained DD5 levee.

6. The only topographic maps for the private properties are prepared by Cahill. However, these maps are relatively low resolution maps with LiDAR generated contours without topographic elevation data being provided. Snohomish County did provide SNR with a topographic “survey” map in PDF format; however, this map was difficult to read and does not apparently include survey data for the private properties. Therefore SNR cannot evaluate the accuracy of the elevation data used for the Cahill or TetraTech studies. In areas with relatively low topographic relief, accurate elevation is critical when designing a storm water drainage system.

7.2 Summary of Task 2 and 3 Findings

The review of Task 2 and 3 reports were combined because these studies generally address the same topic, although some reports focused on potential channel migration (meander) and others focused on potential channel bed scour and affects of flooding events the (the Adolson Report focused on potential overtopping of the existing DD5 levee system) studies generally included the use of models, including the 1 dimensional, unsteady HEC-RAS model (2011, West Consultants and 2007, West Consultants). Both of the West Consultants models were based on 2003 modeling West Consultants conducted on the mainstem of the Snohomish River; the 2 dimensional RiverFLO-2D model (TetraTech, 2012) was based on the West Consultants models; and the 3 dimensional FVCOM model (2007 – Battelle) that did not use West Consultants data and included data obtained specifically for the Battelle model.

In general, none of the reports SNR reviewed evaluated overtopping for the proposed setback dike, possibly because the design phase for the proposed setback levee has not been completed and because the location of this dike was still being evaluated when the earlier modes were conducted. Additionally, none of the models evaluated breach potential for the proposed setback levee, most likely for the same reasons the overtopping potential was not evaluated.

SNR noted that all of the Task 2 and 3 reports use the terms estuary and delta interchangeably, however this is geologically incorrect. The subject property is located on the Snohomish River prograding delta complex and is not located on an estuary as stated by Dalrymple and Choi, 2006:

“For example, estuaries, as defined by Dalrymple et al. (1992; see also Boyd et al., 2006; Dalrymple, 2006), form only under transgressive conditions and thus are represented primarily by transgressive successions, whereas deltas are progradational (Dalrymple et al., 2003).”

“Throughout this review, the terms “estuary” and “estuarine” refer only to transgressive coastal areas and not to those areas with brackish-water! Indeed, as will be noted later, brackish-water conditions also occur in deltas and even in some shelf environments, whereas some transgressing coastal areas have either fully fresh or fully marine salinity.”

Also, the geology and history of proposed restoration area seems to be clouded by assumptions rather than facts. SNR has not reviewed any historical document that suggests estuarine tidal marshes were present in the northeastern portion of Smith Island nor does the geology of this area suggest that estuarine tidal marshes were present in this area.
The study area is on an active delta for the second largest river in the Puget Sound and is bounded by a meandering distributary channel and that does produce seasonal flooding events. The study area was subject to tidally influenced water in the Union Slough prior to the construction of levees sometime before 1911. However, it is unclear if the subject property had tidal mudflats present prior to the construction of the levees, however, the 1869 Land Survey survey notes suggest that grasses and forested areas were present (the only levee shown on the 1869 Land Survey map is in the northwestern portion of Smith Island).

The following is a summary of key findings per report:

### 7.2.1 Geomorphic Characterization and Channel Response Assessment for Union Slough, 2011, GeoEngineers/West Consultants

1. The GeoEngineers report suggests that data on the local geology was collected, however, the report does not discuss any geologic or hydrogeologist studies that were conducted. Based on SNR’s review of the GeoEngineers report, no test pits, drilling activities, and sample collection activities were conducted. No sediment testing was conducted by GeoEngineers to determine the characteristics of the bank or bed materials in Union Slough, including consolidation and cohesiveness.

2. It is unclear why GeoEngineers used historic air photographs that date from 1947 (a 1938 air photograph is referenced but not included in the report) to demonstrate that the Union Slough has not meandered significantly even though the 1911 USGS topographic map of the Mount Vernon Quadrangle indicates that all of the distributary channels in this area, including the Union Slough were protected by maintained levees. It is known that the Union Slough has meandered historically because peat mats that do now form in active channels are present in the bed of this channel.

3. It is unclear why GeoEngineers believes that once the levees are breached that the Union Slough will not meander, especially when the remaining, unmaintained DD5 levees are gone due to erosion caused by high water flow, wind driven waves, changes in sediment deposition, and changes in the water dynamics as water flows in the southern breach and out the northern breach (the levees will have water on both sides). It is also unclear why none of the modeling includes scenarios where the existing levees are completely gone, which is what the eventual fluvial geomorphology of this area will reflect if the proposed mitigation project proceeds and the levee is breached as planned (none of the reports SNR was given to review addresses this).

4. The GeoEngineers report (page 2) states:

   The Snohomish River and delta have experienced 100-year floods at intervals of three to ten years (Snohomish County, 2005). The largest floods are typically caused by rain-on-snow events (FEMA, 2005).

   If 100 year (1%) floods are occurring at intervals of every three to ten years why did West Consultants limit the model to what has been determined to be a “predicted” 15 year flood event?

5. As with all of the studies that included modeling, none of the models used actual tidal data obtained in the Union Slough nor did any of the models use data from a recording stream gage in the Union Slough. It is unclear where the stream gage data for the West Consultants model came (it is suggested to come from the Monroe gage but West Consultants also references other sources) from and it is unclear where the elevation data came from for the cross sections. Additionally, the only known bathymetry data for the Union Slough was from a study conducted by Global Remote Sensing in 2006. The Global Remote Sensing report indicates that the channel bathymetry changed after its studies were conducted and indicated that this bathymetry will continue to change because the Union Slough is “dynamic and active.”
6. The GeoEngineers document states (page 3):

The cohesive, estuarine sediments deposited comprising the Union and Steamboat Slough channels are more resistant to lateral erosion and, as a result, these channels are entrenched.

GeoEngineers did not conduct any studies on the sediments in the stream channels, including test pits and borings nor was any analysis performed on any of the sediments. The 2012 studies conducted by Bailey suggest that these sediments, at best, have “normal consolidation” and have low compressive strength based on standard penetrometer blow counts. Additionally, these deposits have the characteristics of overbank deposits that are layers of sands and silts which is not necessarily an indicator of high erosion resistance. Additionally, the use of the term “entrenched” is unclear because these channels are artificially constrained by the levees (not entrenched).

7. It is unclear why only five cross sections were selected to evaluate on an approximately 9,500 foot long section of the Union Slough. Additionally, the model only includes scenarios with intentional breaches and does not factor in the eventual removal of the remaining unmaintained levees due to erosion and potential channel meander. Also, the model does not apparently include the proposed restoration activities described in the DEIS, including the placement of large woody debris and the construction of mounds and other grading activities (including the filling of all existing ditches).

8. The West Consultants report suggests that the data used in the HEC-RAS model is from a stream gage near the City of Monroe, Washington. This stream gage is located almost 20 miles upstream from the section studied by West Consultants and does not reflect contributions to the Snohomish River flow from downstream streams and rivers (such as the Pilchuck River which is projected to have 1% storm event flows of up to 14,000 cubic feet per second, which is generally equivalent to the maximum flood stage on the Green River).

9. The GeoEngineers report states (page 9):

The January 2009 flood was calculated to be near a 15-year recurrence interval flood based on data from the gage near Snohomish. Although levees are typically overtopped between the gage and the project site, the model for Union Slough does not simulate the flow volume lost to overtopping.

The West Consultants Memorandum dated May 27, 2011 states:

The model was then calibrated to stage data collected for the Everett Riverfront study on the Snohomish River using water year 2009.

This does not suggest that the data was obtained from the USGS river gage located near Snohomish; additionally, the USGS Snohomish River gage does not provide river flow data and does not have historic information from 2009 (Figure 5-10 – Data Available from the USGS Snohomish River Gage).

10. It is unclear why the HEC-RAS cross sections shown on Figure 4 do not extend across the southern breached section of the levee into the new floodplain that is created by the levee breaches. These cross sections would typically extend to the proposed setback levee perpendicular to the Union Slough channel from the levees on the right bank, through the breach to the new setback levee.

11. The GeoEngineers “studies” were conducted to determine how the geomorphology, or more specifically, the fluvial geomorphology, of the Union Slough will respond to the proposed Snohomish County Smith Island
Restoration Project. The DEIS suggests that new channel formation and channel meander are likely, however, the GeoEngineers report (using HEC-RAS model output prepared by West Consultants) suggests that there will be minimal to no channel formation or meander.

12. The GeoEngineers report does not include any actual geologic studies, including subsurface geology and hydrology studies. The GeoEngineers studies were limited to site reconnaissance observations. The sediment erosion susceptibility is based on generalized published data for the types of sediments GeoEngineers believes are present. However, based on the studies conducted by Bailey, 2012 and other subsurface studies conducted in this area (Golder, 2001 and GeoEngineers, 2009) GeoEngineers assumptions regarding the characteristics of these sediments are inconsistent with actual subsurface data collected in this area (Bailey's studies were conducted in the proposed restoration area).

13. The Snohomish River is classified as a meandering river and the distributary channels on a river delta also have the characteristics of meandering channels. The term meander means that these channels move in response to changes in the hydrology and sediment transport (and in a delta, tidal currents). Movement can also be caused when moving water encounters more resistant materials (resistant to erosion) including large woody debris moved into the channel or buried debris encountered as the channel meanders.

14. The presence of peat mats in the Union Slough channel indicates that the channel has meandered because these deposits do not form in active distributary channels. The primary reason the Union Slough has had minimal channel movement since 1911 is because this distributary channel (and the other distributary and mainstem for the Snohomish River) has had a maintained levee system that was clearly present in 1911 based on the USGS topographic map of the Mount Vernon Quadrangle.

15. The proposed Smith Island Restoration Project will include the breaching of the existing levee system which will change the surface water hydrology and the sediment transport in the Union Slough because the Union Slough will be reconnected with its left bank floodplain. This will result in a change in the fluvial geomorphology of the Union Slough as predicted in the DEIS. Additionally, by reconnecting Tidal Channel A to the tidally influenced Union Slough, this the fluvial geomorphology of this tidal channel will also change.

16. GeoEngineers relies on assumptions, the review of historic air photographs, and a 1 dimensional HEC-RAS model that uses data from unknown sources to demonstrate that the fundamental concepts of fluvial geomorphology do not and will not occur on the Union Slough.

17. However, GeoEngineers (and West Consultants) does not have any data that is specific to this section of the Union Slough or the Union Slough in general. There are no stream gages on the Union slough, there are no tide gages on the Union Slough, and there is no recent bathymetric data for the Union Slough (as previously discussed, Global Remote Sensing, 2007, indicates that the channel morphology will continue to change and actually did change during their bathymetric studies conducted in 2006).

18. The concepts of fluvial geomorphology on river delta distributary channels are not discussed nor does GeoEngineers explain why normal channel meander and changes to tidal channels will not occur. GeoEngineers focuses on the observations that the Union Slough has had minimal movement since levees were installed and maintained, however, this is not representative of what the conditions will be like after the levees are breached. Instead, GeoEngineers could have focused on historic channel meander that occurred before levees were constructed on these distributary channels by focusing on how rivers build deltas.

19. The GeoEngineers report findings appear to be inconsistent with those made by West Consultants, 2007, Channel Migration and Scour Evaluation Everett Delta Natural Gas Pipeline/Smith Island Restoration Snohomish River, Washington report. However, this report also fails to discuss the source of the data used in the HEC-RAS model.
7.2.2 Smith Island Levee Analysis for [the] Everett Water Pollution Control Facility and Diking District No. 5, 2007, ESA Adolfson

The field studies conducted for this “projects” were limited to field observations, no geologic or engineering investigations were conducted (such logging test pits or borings).

The information in this report is of limited usefulness for the proposed Smith Island Restoration project because the studies did not focus on the proposed restoration area and the assumptions regarding the proposed setback levee and restoration area are inaccurate. However, the 1938 air photograph and the LiDAR imagery provided in this report was useful for identifying historic drainage for the blind tidal channels located in northern portion of Smith Island, including Tidal Channels A, B, and C. Additionally, the LiDAR imagery does suggest that the historic breach on Spenser Island has led to sediment accumulation in the Union Slough channel north of this breach.

The Adolfson description of the upper sediments is generally consistent with the observations made by Bailey, 2012. However, the GeoEngineers, 2011 report conflicts with the Adolfson report and with Bailey. The upper 22 – 30 feet of deltaic and floodplain deposits described here are not highly cohesive nor are they “highly consolidated” (they are listed as compressible). Bailey suggests the upper “organic rich” deposits are 9 – 20 feet thick.

Adolfson suggests that the levees were built in the 1920s by individual landowners; however, as previously discussed the 1911 USGS topographic map of the Mount Vernon Quadrangle suggests that levees were in place by 1911. It is unclear if these levees were built by individual landowners or by Diking and Drainage Improvement Districts, however, this is irrelevant. What is more important is that the USGS topographic map suggests that these flood control features were present at least as early as 1911.

Adolfson suggests that the upper sediments include logs and stumps. This suggests that this sediment sequence may be more recent and may be associated with higher flows combined with erosion created by logging activities to the east. Regardless, when stream flow encounters more resistant materials in the channel bed or banks, the channel morphology can change. This change can include channel meander.


The Yang and Khangaonkar report was prepared for the Tulalip tribe for a Snohomish River “estuary” restoration project as part of the feasibility studies. This report is one of the most comprehensive reports SNR reviewed and included 3 Dimensional Modeling. What makes this report somewhat unique is that Yang and Khangaonkar realized that there were data gaps for the models so additional studies were conducted to fill in some of these data gaps. Additionally, the author’s names are (obviously) provided which is customary for scientific reports.

Yang and Khangaonkar used a three-dimensional (3-D) hydrodynamic model for the Snohomish restoration sites; choosing the finite-volume unstructured hydrodynamic model (FVCOM). This model uses a combination of tides, freshwater discharges, tides, and surface-wind stresses as input to test the hydrodynamic response of the sloughs (distributary channels).

The studies that were conducted to calibrate and validate the Yang and Khangaonkar 3 dimensional modeling were generally conducted over a three week period (October 12 – 27, 2006), such as the Evans-Hamilton tidal and salinity studies and Global Remote Sensing bathymetry studies. This model was used to simulate tidal inundation, tidal currents, and salinity intrusion in the study area for the existing conditions in October, 2006.
In general, Yang and Khangaonkar found that the restoration projects in the lower Snohomish River would result in increased tidal flows towards the river in the main river channel and all distributary channels (sloughs). The model results also indicate that when all restoration projects are considered simultaneously, there is a cumulative effect on the river hydrodynamics and the river morphology.

However, the data collected for the model was conducted at a time of low river flow, where ground water base flow was the primary source of water. The Weather Underground indicates that there had only been 2.07 inches of precipitation in the Marysville area from July 1 – October 27, 2006 and the bulk of the Cascade Range snowmelt would be gone by October 12, 2006. This suggests that the salinity and tidal currents observed in the distributary channels and the Snohomish River mainstem may be skewed because these readings were taking at a time of low river flow (base flow conditions).

Yang and Khangaonkar focus on erosion (bed shear stress) and not sediment build up, which can eventually lead to increased erosion potential and channel meander. Additionally, although bed shear stress will influence channel depth and undercutting of river banks, the lateral stress in the channel flow can affect bank morphology, including the creation of side channels and other fluvial geomorphic changes in the channel morphology. Regardless, Yang and Khangaonkar suggest that the hydrologic conditions in the Union Slough will change if the proposed Smith Island restoration project is conducted as planned.

As with other reports SNR reviewed, Yang and Khangaonkar suggest that the study area is located in an estuary however, as previously discussed, this area is not geologically an estuary, it is a prograding river delta with meandering distributary channels and a mainstem channel that form the typical dendritic delta channel morphology. SNR is unaware of any geologic studies that have been conducted in this area that would suggest that an estuary is present this far inland on relatively large prograding delta complex.

On page 2-4 Yang and Khangaonkar state:

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**The Snohomish River inflow for the study period was obtained from USGS gauge (Station 12150800) near the city of Monroe at RM 25. The river-flow time history during the study period of 2006 is plotted in Figure 2-5. The river flow in October 2006 was generally in the range of 1,700 to 7,000 cfs.**

**Quilceda Creek is a very small tributary entering the study domain from the high marshland north of the river mouth. The average annual flow of the creek is in the range of 10 to 12 cfs. Because the stream flow is small and is much further downstream of the study area of interest, a constant river flow of 10 cfs was used in the model setup.**

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There are other streams and rivers that form confluences with the Snohomish River downstream of the “Monroe” gage. The Pilchuck River forms a confluence with the Snohomish and the flow in this river is much higher than 10 cfs. However, there is no stream discharge and stage data for the Pilchuck prior to 2007. Between October 18 and 27th, 2009 (USGS gage 12155300 – Pilchuck River, near Snohomish) the discharge on the Pilchuck River ranged from approximately 900 cfs to 3,000 cfs, suggesting that the Pilchuck River can contribute a significant amount of flow to the Snohomish River.

It is unclear why Quilceda Creek with an annual flow range of 10 to 12 cfs was included in the model, but the flow in the Pilchuck River the forms a confluence with the Snohomish River near Snohomish, Washington was not used in the model setup.
As with all the other models, measured tidal data for the Union Slough does not exist and the models apparently relied on predicted tides in open water conditions, such as the predicted tides for Kayak Point. This can create error in the model, especially for tidal current predictions. The Yang and Khangaonkar model was calibrated to base flow or near base flow conditions and this is typically when tides and tidal currents have the most influence on the channel hydrology.

As with the other “older” reports SNR reviewed, Figure 4-22, page 4-28 of the Yang and Khangaonkar document indicates that the placement of the setback levee is different from the currently proposed location. It is unclear how this change will affect the model because this can only be determined by recalibrating the model to the current proposed location of the setback levee.

On page 4-29 Yang and Khangaonkar state:

> However, tidal flows would increase significantly at Station U1 because of a large increase in the tidal prism and water storage when both Smith Island and Union Slough sites are restored. The percentage increase in tidal flows for the restored conditions would be 91.1% relative to existing conditions (Table 4-3).

A 91.1% increase in tidal flows is significant under base flow conditions; however, it is unclear what will happen during a 1% storm event, which, as previously discussed, can occur more frequently than 15 year events.

On page 4-40 Yang and Khangaonkar state:

> Velocities inside the Smith Island project site are measurable during high tides because of tidal wave propagation through the large area of dike breaches. Velocities in the restored slough in Smith Island are strong, especially during low and ebb tides (Figures C-1 and C-4). Velocities in the Union Slough restoration site are generally small because of shallow water depths and relatively small incoming tidal flows.

This suggests that the conditions for the proposed Smith Island restoration cannot be directly compared to those for the City of Everett Union Slough restoration.

On page 4-40 Yang and Khangaonkar state:

> Inside the Smith Island Project site, high bed shear stresses are observed during ebb tides near the entrance of the restored slough channel and the upstream end of the dike breach where Union Slough bends rapidly towards the east (Figure C-6). Potential erosion is likely to occur in these areas because of high velocities and bed shear stresses. Bed shear stresses within the Union Slough project area are generally small, with slightly higher values around the dike breach locations. No major erosion would be expected within Union Slough project site. Changes in river channel morphology would be complicated in Union Slough because of the complex changes in bed shear stress distribution. Potential localized adjustment of channel morphology may occur in Union Slough after the Smith Island and Union Slough restoration projects. Further analysis of geomorphic changes in the river channel may be conducted by morphology experts based on the model results.

Because the Yang and Khangaonkar model only focuses on bed shear stress, it apparently does not consider other fluvial geomorphologic features such as the blind tidal channels and the effects the breaches may have on these channels (the setback levee configuration used by Yang and Khangaonkar is west of Tidal Channel B).
Additionally, the model is still based on existing conditions from October 12–28, 2006, which are believed to be base flow conditions. It is unclear what will happen during a 1% storm event.

On page 5-2 Yang and Khangaonkar state:

Changes in river channel morphology would be complicated in Union Slough because of the complex changes in bed shear stress distribution. Potential localized adjustment of channel morphology may occur in Union Slough after the Smith Island and Union Slough restoration projects are implemented.

Yang and Khangaonkar focus on the shear stress distribution, however, they do not factor in what happens in areas where the velocity drops, such as the areas between the two breaches for the proposed Smith Island restoration project.

In areas where channel velocity drops, sediment load capacity also drops, which typically results in sediment deposition in these areas. This combined with the higher velocities associated with the predicted higher shear stress by Yang and Khangaonkar would typically suggest that the channel morphology will change to meet the new hydrologic and sedimentary conditions.

However, Yang and Khangaonkar do suggest that the Union Slough channel morphology will change if the proposed restoration projects are implemented. This is suggested because of the complex changes in bed shear stress distribution. However, as with all the other models the Yang and Khangaonkar modes does not address the proposed placement of large woody debris and grading activities that the DEIS suggests will be conducted as part of the restoration activities nor does it address failures in the remaining unmaintained levee system.

Although the setback levee location has changed since this model was conducted, the proposed location of the breaches has apparently not changed (based on SNR’s review of the other documents in Tasks 2 and 3). This suggests that this high shear stress may be located where the setback levee will now be located. It is unclear what the shear stress will be with the current proposed setback levee location or what the shear stress will be during a 1% storm event, however, the West modeling for the Pipeline (April 11, 2007) document prepared for CH2M Hill suggests significant scour will occur.

However, even under what are presumed to be base flow conditions, Yang and Khangaonkar found that the potential for a significant increase in localized shear stress exists if the proposed Smith Island restoration project is implemented. Additionally, Yang and Khangaonkar suggest that this increase in shear stress can lead to changes in channel morphology. Oddly, Yang and Khangaonkar did not discuss potential changes in the blind tidal channel morphology even though Figure C-5 (page C-6) shows shear stress in Tidal Channel A greater than 2 Pa during flood tide conditions.

It is unclear why Yang and Khangaonkar did not simulate higher river flow conditions obtain model information on how higher flows will affect the shear stress. However, it appears that they wanted to limit the model to the information they had rather than changing parameters to meet a designed flow event.

Regardless, it is clear (based on the West April 11, 2007 document) that higher channel flow events will increase shear stress significantly enough to result in significant scour (West used finer grain materials in its model) in the sandy bed deposits Yang and Khangaonkar used in their model.
The Yang and Khangaonkar studies did not address the conditions during higher channel flow which is more common than channel base flow conditions (depending on the weather, base flow conditions typically last from August to November). However, even with base flow conditions, Yang and Khangaonkar indicate that there will be a greater than 90% increase in flow during ebb tides if the proposed Smith Island restoration project is implemented.

Yang and Khangaonkar recognized many of the model limitations associated with the lack of accurate data and their studies did include obtaining data for the period studied. However, the proposed setback levee configuration used in the model is not the same as the current configuration and the model is only representative of base flow or near base flow conditions.

Additionally, Yang and Khangaonkar did not consider changes in sediment deposition associated with decreases in the velocity of water downstream of the breaches nor did their model consider the placement of large woody debris or the other modifications proposed in the DEIS as part of the restoration project.

The West Consultants April 7, 2007 report includes modeling for 100 year and 500 year flooding events, which suggests that significant scour can occur during these events. However, neither model focused on what will happen to the remaining unmaintained levees after the proposed breach occurs nor do the models consider eventual levee failures on the remaining unmaintained levee system or the possibility that the remaining levee system will eventually be completely removed.

None of the models, including the Yang and Khangaonkar model used accurate data for the Union Slough because this data is not available. However, all models SNR reviewed indicate that the proposed Smith Island Restoration project will result in changes to the surface water hydrology of the Union Slough.

Additionally, the models and report findings conflict regarding scour and the potential impacts to the Union Slough channel morphology. However, none attempt to predict how the changes suggested by the models will affect the navigability of the Union Slough, how potential channel meander may affect the channel forming process, how the blind tidal channels will change.

As previously discussed, without accurate data for the models (such as actual stage height and discharge rates from base flow to 1% storm events, actual tidal measurements, and more information on the affects of tidal currents), accurate information on the Union Slough bathymetry (recent data), and accurate information on the characteristics of sediments in the Union Slough channel and bed (and the characteristics of the materials in the levees), it is difficult to predict how the fluvial geomorphology of the Union Slough will change if the proposed Smith Island Restoration is conducted.

**7.2.4 Draft, Snohomish County, Smith Island Estuarine Restoration Union Slough Hydraulic Model Study, November 2012, prepared by TetraTech**

As with all the draft TetraTech documents SNR reviewed, the reports do not include the names of the authors, which is somewhat unusual (this report is draft and the names of the authors is included) for technical reports, especially those that include geologic and engineering studies.

Although it is understandable the additional modeling would be required considering the configuration of the proposed setback levee had changed since the Yang and Khangaonkar modeling was conducted, however, it is unclear why Snohomish County did not have Yang and Khangaonkar simply rerun their model with the new setback levee configuration after studies had been conducted to address the data needs Yang and Khangaonkar identified in their report.
Models are only as accurate as the data that is used in them and even with accurate data; models do not always predict changes accurately, especially in complex hydrologic systems such as the Snohomish River delta. However, in complex systems where tidal influence (including tidal currents) increased the complexity it is often best to use the more complex models such as 3-dimensional models to predict the potential changes that can occur when the Union Slough channel morphology is changed with the proposed restoration project. It is also important to include all of the proposed changes associated with the proposed restoration in the model, such as the placement of large woody debris and grading activities that will change the geomorphology of the existing farmland.

TetraTech suggests that it will generate a more accurate model than those previously conducted by West Consultants, 2007 and Battelle, 2007. SNR assumes this is because TetraTech believes the use of a 2-dimensional model will provide more accurate results than the 1-dimensional model used by West Consultants and by simulating 100 year event channel flow (however, the TetraTech study actually focused on the 2009 “15 year” flood event), it will provide more accurate information on potential bed shear stress than the Battelle 3-dimensional modeling did (although the West Consultants 2007 study did include simulations for 100 and 500 year events as West Consultants did). However, TetraTech did not discuss how a 2-dimensional model will produce more accurate predictions than a 3-dimensional model will. Additionally, TetraTech did not discuss the quality of the data used in their model as Battelle did. In fact, TetraTech suggests that the data they used is exactly the same as West used for the GeoEngineers geomorphologic studies.

The two models TetraTech built its model on were the 3-dimensional model developed by Battelle (Hydrodynamic Modeling Study of the Snohomish River Estuary: Snohomish River Estuary Restoration Feasibility Study, Battelle, 2007) and the 1-dimensional model developed by West Consultants for the GeoEngineers Geomorphic Characterization and Channel Response Assessment for Union Slough (GeoEngineers/West, 2011).

It is unclear why TetraTech did not include the Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared for CH2M Hill, prepared by West Consultants to build their 2-dimensional model.

It is also unclear why new; site specific data was not generated for the TetraTech 2-dimensional model. There are obvious problems with the data used in the previous modeling studies reviewed by SNR (Battelle even identified some of these inaccuracies). There are many significant data gaps which means assumptions were used in the model data, which impacts the accuracy of the model. Additionally, as with all of the other Task 2 and 3 reports reviewed by SNR, the TetraTech model does not consider changes in the remaining unmaintained levee system nor does the model reflect the completed proposed restoration project with the placement of large woody debris and modifications to the geomorphology of the farmland in the proposed restoration area.

On page 5 TetraTech states:

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 result in more erosion in the channel.
It is unclear why TetraTech believes a 15 year storm event will have the same shear stress and the same channel velocity (and stage) that a 1% storm event would have and that the same amount of “erosion” will be observed in a 15 year event as will be observed in a 1% event. If this were the case, why did West Consultants model for 100 year and 500 year events in their Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared for CH2M Hill? Why do all of the models SNR reviewed for Tasks 2 and 3 suggest that the greater the storage the higher velocity of the flow in the channel (more tidal storage results in higher velocity flows)?

Additionally, larger flood events would extend further and higher into the proposed restoration area, which would influence Tidal Channel A and would result in higher scour potential, especially during low tide events. These events, especially if wind driven waves (fetches) are generated, will also affect the remaining unmaintained levee system and as these remaining levees fail, the fluvial geomorphology of this portion of the Union Slough will change, but none of the models address this ongoing change in the channel morphology and how this will affect the overall fluvial geomorphology and hydrology of Union Slough.

On page 7 TetraTech states:

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

It is unclear what data TetraTech used in its model that is different from what West Consultants used in their model for the 2011 GeoEngineers report or how this data is different from the model West Consultants used in the model for the report they generated for CH2M Hill on April 11, 2007. It is apparent that TetraTech imported the data from the West Consultants HEC-RAS model for the GeoEngineers report into their RiverFLO-2D model and compared the RiverFLO-2D model output to the West Consultants HEC-RAS model output.

As discussed in this letter report, SNR has concerns with the data used in the West Engineers model prepared for the GeoEngineers 2011 report. If TetraTech used the same data, SNR has the same concerns for the TetraTech model accuracy.

Additionally, if the RiverFLO-2D model is being calibrated to the HEC-RAS elevation data developed by West Consultants for the GeoEngineers 2011 report what is the purpose of conducting the RiverFLO-2D model for obtaining discharge rates (velocity) and stage height?

Although the 2-dimensional model will provide more accurate modeling of the storage it is unclear how it will provide more accurate data for stage height than the 1-dimensional model it was calibrated to especially if the same data used in the HEC-RAS model is used in the RiverFLO-2D model, because the resulting model output will be no more accurate than the HEC-RAS 1-dimensional model if the data used in the HEC-RAS model is not accurate.

On page 10 TetraTech states:

The 100-year hydrographs and tidal boundary conditions were extracted from the existing FEMA modeling at the same locations and using the same methodology described above for the January 2009 storm.
This does not provide a date for the existing FEMA modeling. It is presumed that this is the UNET hydraulic model West Consultants conducted for FEMA in 2001 for the Snohomish River below Monroe (FEMA Flood Insurance Study in 2001). As discussed in this letter report, the GeoEngineers 2011 report states: “The Snohomish River and delta have experienced 100-year floods at intervals of three to ten years (Snohomish County, 2005).” This suggests that either the Hydrographs that were developed for the 100 year events are inaccurate or the 100 year storm event isopluvial maps developed by the NOAA re inaccurate.

Regardless, the accuracy of the 1% hydrographs is dependent on many factors and FEMA maps are known to have inaccuracies, such as the map for the Pilchuck River that “missed” 4,200 feet of levee section (northwest boundary of French Slough, West Consultants, June 29, 2007). Additionally, King County filed challenge studies for most of the FEMA 2005 PFIRMs due to significant inaccuracies on multiple rivers including the Green and the Snoqualmie; the Snoqualmie River is one of the two rivers that form the Snohomish River.

It is unclear where the actual data for river discharge and stage elevations in the Union Slough used in the HEC-RAS or RiverFLO-2D models came from and how accurate this data is.

Figure 11, Page 11 of the TetraTech document indicates much higher flows in Ebey Slough than Union or Steamboat Slough. However, the Battelle report (Page 3-16), which used the 3-dimensional model suggests that the Union Slough has the second highest flows of the channels (second to the Snohomish River mainstem):

Velocities at Steamboat Slough were smaller than that in the main channel (Figure 3-5) but significantly greater than Ebey Slough and Union Slough (Figure 3-6), indicating that Steamboat Slough is the second largest tributary carrying the Snohomish River flow into Possession Sound.

It is unclear why the TetraTech 2-dimensional model suggests that the flow in Ebey Slough is significantly higher than Steamboat Slough (this should have been discussed).

On page 12, TetraTech states:

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.

This assumes that the FEMA 1% flood elevations (Base Flood Elevations) are accurate. The source of this data, the date this data was generated, and how this information was generated is unclear. The Battelle modeling activities we based on data collection that was conducted for the period of the study wherever possible. However, Battelle knew that the high flow data would have large potential errors because the only gage that provides data on discharge and stage height for the timeframe of the model was the USGS gage near Monroe. This was not a major factor for establishing existing conditions for the period modeled because the Snohomish River and the sloughs were at or close to base flow conditions.

The accuracy of the TetraTech data is unclear, especially when the model output they generate appears to contradict the model output that Battelle generated (for the Steamboat Slough v Ebey Slough).

On page 15, TetraTech states:

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
FINDINGS

As SNR has indicated, it is unclear how GeoEngineers developed bed shear stress thresholds considering it did not conduct any geologic studies (including test pits and borings) to determine what sediments are actually present and the cohesiveness of these sediments (nor was any laboratory testing conducted on the soils or sediments). The October 7, 2007 ESA Adolfsen report (page 29), states:

Underlying these surficial [fill] soils, previous borings reveal approximately 22 to 30 feet of deltaic and floodplain deposits consisting of soft, compressible organic silt and sandy silt, including distinct fibrous peat deposits and buried logs and stumps. These upper organic-rich silt deposits are, in turn, underlain by medium dense to dense sand and gravel that extend to considerable depth.

Additionally, Bailey’s 2012 studies that included the logging of test pits and conducting borings that included the use of a standard penetrometer, suggest that the deposits described in the ESA Adolfsen report are also present in the proposed restoration area. These deposits do not exhibit the characteristics that would be expected for highly cohesive materials. Additionally, Bailey indicates that the organic silt and sandy silt (with peat deposits) ranges from 9 feet to approximately 20 feet deep, which suggests that the Union Slough could be intercepting the water bearing sands that are located beneath the organic silts and sandy silts (and peat deposits).

Flow velocity and shear stress are suggested indicators of inducing erosion; however, the deposition of sediments also increases the potential for erosion. If the velocity of water in a channel drops, the sediment load capacity drops and sediments will be deposited. This can result in channel narrowing and an increase in velocity where this channel narrowing occurs. Every model SNR reviewed indicates that if the proposed levee breaches occur, the channel velocity between these two breaches will drop because the Union Slough will be reconnected with its floodplain.

Regardless, it is unclear how GeoEngineers established maximum shear stress values and velocities for the Union Slough without conducting field activities that include test pits and borings (as Bailey did and apparently Golder has in the past) and laboratory data on the characteristics of the sediments and soils along the portion of the Union Slough that will be affected by the proposed Smith Island restoration activities.

The modeling shear stress and velocities was apparently only conducted for the January 2009 event and not the predicted 1% flood event (TetraTech does not discuss what flows they are referencing in the statements above). However, the data in the 2-dimensional model was calibrated to the HEC-RAS 1-dimensional model prepared by West Consultants for the GeoEngineers 2011 report.

The 2011 West Consultants model apparently used the same base data that was used in the Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared by West Consultants.

Since the same data was apparently used in both models, it is unclear why the predicted shear stress and scour would be significantly different in the 2011 GeoEngineers report than the shear stress and scour presented in the model West prepared for the April 11, 2007 report. The 2007 modeling West Consultants conducted for CH2M Hill is not considered by TetraTech or even discussed.
As previously discussed, the GeoEngineers report suggests that 1% storm events occur more often than 15 year events and each 1% event would technically generate similar scour results presented in the April 11, 2007 West Consultants report. Therefore it is unclear what is gained by TetraTech conducting the 2-dimensional modeling, especially when the data used in the model is not validated (as Battelle did). Battelle suggests that the second greatest flows in this portion of the Snohomish River delta is the Steamboat Slough, however, TetraTech suggests that the Ebey Slough has the greatest flows (by far).

High flows on the Snohomish River are apparently not that infrequent. As SNR has indicated the purpose of the levees was to prevent seasonal flooding and to prevent channel migration. Maintained levees will prevent channel migration, however, once the levees are removed, these controlling structures no longer prevent levee migration (meander). Also, the type of sediment load in the Union Slough reach is unknown, SNR has not reviewed any document that includes studies of the sediments in the Union Slough bed or that are being transported by water. Additionally, the higher the velocity of the flow, the coarser the sediment load will be; this is fluvial geomorphology 101.

Any decrease in the channel flow, especially at bends, can result in sediment deposition. In fact the other models do predict sediment deposition, e.g., Battelle (2007) and West Consultants (2007), including sediment deposition in the proposed restoration area.

The Bailey 2012 studies indicate that the water bearing sands are located within 9 feet of the surface near the Union Slough channel. It is feasible that these sands are exposed in the Union Slough bed and this water bearing sand provides base flow for the Union Slough during the late summer and early fall months. High velocity flows can move these sands and redeposit them in areas where the channel velocity drops. SNR has not seen any studies that characterize the sediments in the Union Slough for any reach, based on actual studies that include borings, test pits, sample collection, and laboratory analysis.

Additionally, wind driven waves (fetches), high velocity flow, and the diversion of flood waters inside the remaining unmaintained levee system will cause erosion, underflow, and other conditions that will eventually remove the remaining unmaintained levees. TetraTech does not address this nor do any of the other models SNR reviewed address this (none of the models were conducted with no levees remaining or with failing unmaintained levees). Also, what will happen to the sediments eroded from the remaining levee sections?

TetraTech does not discuss why its modeling results are different from the Battelle studies or from the West Consultants studies conducted for CH2M Hill (2007) or why the TetraTech model provides more accurate model outputs than these other models that were previously conducted, especially when it appears that TetraTech used the West Consultants data in its model. The West Consultants 2007 model for CH2M Hill suggests 10 – 20 feet of scour could result from a 100 and 500 year flood event; TetraTech suggests that erosion will be minor and can be addressed with bank protection.

However, this does not apply to the proposed restoration area where channel migration caused by erosion and the removal of the remaining unmaintained levees by erosion is a concern because none of the models were run with the remaining levees being removed by erosional processes that will be accelerated by having flows on both sides of the levees. Additionally, SNR has not reviewed any document that addresses the potential for the remaining levees to erode after the levees are breached.
7.2.5 Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, West Consultants

The general concepts and interpretations in this report are based on relatively sound fluvial geomorphologic and hydrologic principals, although some of the information is dated, such as the proposed location of the setback levee and a suggestion that the remaining existing levee will be maintained after the breach (this is the only report that discusses this).

As with all of the reports SNR reviewed for Tasks 2 and 3, the West Consultants studies did not factor in the complete proposed mitigation as described in the DEIS nor did the model factor in failing unmaintained levees that will remain after the breaches have been conducted. The addition of large woody debris and the proposed grading activities that will change the existing farmland geomorphology are not factored into the model.

This report is the only report SNR reviewed that relatively accurately depicts the 1869 Land Office survey of this area. It also discusses the changes in the surface water hydrology, such as the filling of the connector channel between the Snohomish River and the Union Slough and actively discusses the blind tidal channels. This report also discussed the issues with decreases in the velocity of the water in the channels which will result in sediment deposition which will lead to bed filling, sand bar formation, and other fluvial geomorphologic changes along this segment of the Union Slough (this distributary channel has been “protected” with levees for a long time (at least 100 years based on SNR’s research) and in the other distributary channels (this report indicates that Union Slough and Steamboat slough are expected to have similar fluvial geomorphologic changes).

The West document states (page 3):

In general, the proposed and specific restoration measures involve breaching of existing dikes and construction of new dikes to protect adjacent infrastructure. The project is intended to restore natural habitat-forming processes for proper ecosystem function over the long-term. This includes side channel formation, channel migration, and wood recruitment.

This suggests that side channel formation, channel migration, and wood recruitment (which can induce channel meander) are the goals to restore “natural habitat-forming processes”. These processes will only have one direction to go considering the right bank of the Union Slough will still have levees present. It is also unclear how the proposed breaches will affect the existing breaches on the right bank of the Union Slough.

The West document states (page 4):

As seen from Figure 10 and Table 2, the observed migration distances are relatively minor over the 120 years of record. In general, no significant migration occurred beyond any existing levee. The project area has generally low hydraulic energy gradients that are strongly controlled by tidal base level. The construction and maintenance of the levee system tightly confined the river channels, practically limiting significant movement. It is also recognized that dredging and large woody debris removal have been on-going activities throughout the period of record (Haas and Collins, 2001).
West recognizes that the levee system, combined with dredging and the removal of “snags” (woody debris) is what has prevented the Union Slough and other channels in this area from meandering. SNR’s historic research (HistoryLink.org) strongly suggests all of the distributary channels have been dredged and have had “snags” removed to allow navigation on these channels. Additionally, deepening the channels made the levees more effective during high flow events because the channels had more capacity for high velocity flow within the levee system. However, dredging also has an effect of “entrenching” the channel in deeper sediments, making channel meander less likely.

The West Document states (page 5):

An existing hydraulic model of the Snohomish River was used to characterize the existing hydraulic conditions of the pipeline alignment. The channel and overbank hydraulic properties needed to perform scour calculations were obtained from a UNET unsteady flow hydraulic model (USCOE 1997) developed for the Snohomish River Flood Insurance Study (WEST 2003). The UNET model represents the Snohomish River, Union Slough, Steamboat Slough, Ebey Slough, and the connector channel that runs between Ebey Slough and Steamboat Slough. The model extends from Possession Sound to well upstream of the area of interest.

Unfortunately, West does not provide much information on the accuracy of the previous models nor does the document discuss the sources of the information used in the models, such as elevation data, bathymetry data, discharge rates in the different distributary channels, stage heights in the different distributary channels, tide elevations correlated to flow events, or other data. The accuracy of this data is integral to the accuracy of the model that already has some inherent accuracy issues (1-dimensional models have limitations).

However, the West Consultants model in the GeoEngineers geomorphology study apparently uses the same data and the TetraTech model is calibrated to the West Consultants HEC-RAS model used in the GeoEngineers study. What is unclear is why the West model for CH2M Hill for the pipeline study is different from the model prepared for GeoEngineers. It is also unclear why the same data was used for each model West Consultants prepared rather than conducting the studies necessary to obtain site specific stream gage data, accurate topographic data, and accurate cross sectional data (and accurate bathymetry. It is also unclear why accurate tide data was not obtained in this area of the Snohomish River delta.

The West document states (page 6):

Scour along the channels in the Snohomish River estuary can be caused by floods, local scour around debris, channel migration, tides, or a combination of these factors. Scour potential due to floods can be reasonably estimated based on empirical relations. Local scour due to debris and channel migration are generally unpredictable for a specific location. Similarly, the formation of blind tidal channels may be due to a combination of flood impacts and tidal effects. Consequently, estimates of scour cannot be specific. Use of empirically-based equations that define envelope curves around a range of scour observations for similar conditions, coupled with appropriate margins to account for uncertainty is considered the most reasonable approach to estimating potential scour depths.

As previously stated, models cannot accurately predict channel migration nor can the accurately predict scour. The models can estimate scour based on the parameters entered into the model. However, as with any fluvial system, especially in a delta, there are countless variables that cannot be predicted and therefore models only provide generalized trends, such as drop in channel discharge rates where the proposed breaches are made.
The model will also predict an increase in discharge rates downstream of the northern breach because tide and flood storage is now available in the floodplain exposed by the levee breaches. This storage must drain through the same channel downstream which means that stage height will be higher and the discharge rate will also be higher. It does not require a model to make this prediction because this is a fundamental principal of fluvial geomorphology.

The West document states (page 7):

*The calculated estimates of scour depths that are reported are the result of the equation that yielded the greatest scour depth. In general, estimated scour depths are 10 to 20 feet.*

It should be noted that the West studies were focused on bed scour, not bank scour and undercutting. The primary reason for these studies was to determine if the pipeline would be exposed by channel bed scour, although potential channel meander is considered for the areas where the pipeline is shallower (the areas behind the existing levees).

It is unclear why TetraTech did not discuss this model in their November 2012 report and why TetraTech does no discuss why they predict very little scour and West Consultants who apparently used the same model data (hydrology, bathymetry, topography, etc.) predict significant channel bed scour. Interestingly, although Yang and Khangaonkar did not model for 100 and 500 year events, their model also predicted high scour potential in the Union Slough.

The West document states (page 8):

*In general, channel migration is a natural characteristic of all geologically unconfined watercourses formed in transportable sediments. Typically, the type, magnitude, and rate of channel migration are reflective of a dynamic equilibrium that is characteristic of the involved geomorphic setting and channel type. The magnitude and rate of channel migration reflects changes in hydrology, hydraulics, and sediment transport. Such changes may occur due to both natural and man-made influences. Because the pipeline is installed entirely underground at a depth designed to not be exposed by scour, the pipeline will not affect the hydrology, hydraulics, or sediment transport characteristics of the involved watercourses.*

As West points out channel migration is a characteristic of all watercourses formed in transportable sediments, especially in areas where there is a relatively low topographic gradient. This is a component of sinuosity and the fluvial geomorphology of low gradient rivers that fall within the meandering classification. The sinuosity of the distributary channels, Ebey, Steamboat, and Union Sloughs would place them in the meandering fluvial geomorphologic channel classification. Channel meander is channel migration.

It is unclear why GeoEngineers and TetraTech disagree with this fundamental principle of fluvial geomorphology and why they believe that a meandering distributary channel such as the Union Slough would not resume meandering once the channel is no long constrained by a maintained levee system.

The West Document states (page 9):

*Under natural conditions, overbank sediment deposition would occur during floods and bed load deposition within channels would cause them to shift laterally. However, the existing channels are leved which artificially increases stage and velocity, confines floods of low return periods, limits the ability for overbank sediment deposition, and generally mutes the potential for dynamic change. It is noted from the channel elevation*
data presented in Table 1 that significant changes in the minimum elevation of the involved channels do occur. In fact, dredging of the mainstem Snohomish River is conducted for maintenance of a shallow draft navigation channel.

Again West is citing fundamental fluvial geomorphic principals however, neither GeoEngineers or TetraTech discuss fluvial geomorphology or why a meandering distributary channel will not resume meandering when it is no longer constrained by a levee system. Once the channel has access to its floodplain there will be a change in the fluvial dynamics that will result in sediment deposition, the ongoing failures of the remaining unmaintained levee system and eventually, resumed channel meander. However, what is more important is how these changes will affect the navigability of the Union Slough and none of the models address this.

The West document states (page 10):

Another important influence on channel migration potential is the effect of large woody debris. Large wood has been shown to be a dominant influence on the geomorphology of large western Washington Rivers (Collins et al., 2002). Debris jams can create channel avulsions resulting in multiple channels, floodplain sloughs, and distributary channels.

This is the only report that discusses the impacts that large woody debris can have on channel morphology. However, the West model did not include modeling for large woody debris proposed to be placed in the restoration area in the DEIS most likely because this aspect of the proposed restoration was not available at the time the model was conducted.

The West document states (page 11):

If the levee along Union Slough is breached as part of the Smith Island Estuarine Restoration Project, the risk of channel migration would increase, as there would be fewer man-made impediments to channel migration. Also, the blind tidal channels would again be subject to tidal action. However, it should be noted that none of the proposed levee breaches are in the vicinity of the pipeline alignment.

Neither GeoEngineers nor TetraTech discuss this in their reports, nor do they apparently include the tidal channels in the models. Again this is fundamental fluvial geomorphology and West Consultants has accurately interpreted the probable results of the proposed levee breaches.

The West document states (page 13):

The reduction in flow will result in a corresponding reduction in sediment transport. As commonly occurring flows would be influenced, it would be expected that on average less sediment would be transported downstream and more sediment would be deposited within the main channel of these watercourses. Over the long-term this will result in bedform formation, reduced flow depth and channel capacity, side channel formation, and increased channel migration.
SNR agrees with this interpretation. The potential for sediment deposition will increase as the unmaintained levees that remain begin to fail and erode, contributing to the sediment deposition in this area. None of the reports SNR reviewed directly address the channel migration potential without any remaining levees on the left bank of the Union Slough bounding the proposed Smith Island Restoration area. Additionally, little is known about the actual construction of the existing levees nor has SNR reviewed any reports that include studies on these levees to determine their resistance to erosion after the proposed breaching of the levee occurs and presumably unmaintained (especially once water will be flowing on both sides of the remaining levees).

It is unclear why GeoEngineers and TetraTech do not make the same conclusions that West Consultants makes especially since West Consultants produced the model that GeoEngineers interpreted for its geomorphology studies and the West data was used in the TetraTech model.

None of the Task 2 and Task 3 studies discuss potential impacts to the proposed setback levee or the DD5 levee system downstream from the northern breach where all models suggest the water velocity in the Union Slough will increase. The models do not discuss how to prevent high rates of erosion with the modeled higher velocity flows or how to protect the tidal channel banks from the high potential erosion.

Additionally, none of the models discuss one of the more important aspects of these studies, which is how will the proposed restoration project affect the navigability of the Union Slough. Channel meander can affect the navigability as can the creation of side channels. Additionally, sediment buildup in the channel bed in areas where the flow velocity in the Union Slough decreases can reduce the depth of the water and can impact navigation if sandbars and other depositional features are created.

As discussed in SNR’s comments, there have apparently been no studies on the characteristics of the fill materials in the existing DD5 levee system that bounds the proposed restoration area and therefore nothing is known about the potential rate of erosion that will occur after this section of the DD5 levee system is breached. As more of the remaining levee system fails and erodes, the sediments from the levee will enter the Union Slough channel and the morphology of the left bank of the Union Slough will be in a process of change that has not been predicted by any model (actually none of the models provided any information on potential changes in the Union Slough fluvial geomorphology).

Snohomish County suggested that the County would obtain a dredging permit and that the County will ensure that the Union Slough remains navigable, however, this may not be practical and the various agencies may not issue a dredging permit especially if the dredging will be conducted in an area adjacent to a habitat restoration area. Additionally, it is unclear how dredging will impact the restoration area because none of the models have factored in potential dredging.

7.3 Summary of Task 4 Findings

The summary of SNR’s findings for Task 4 only addressed the studies and report prepared by Bailey, 2012 and the report prepared by Shannon and Wilson, 2012 (Modflow modeling). The unauthored 2012 TetraTech report is reviewed and SNR’s findings for this report are included in the previous section. However, the TetraTech report does not add anything to the Bailey or Shannon Wilson studies and reports.

As discussed in SNR’s review of this report, the purpose stated in the Bailey report does not mention saltwater intrusion studies and focuses more on engineering geology than it does on saltwater intrusion. Oddly, Bailey does not consider the potential impacts the City of Everett POTW will have on the ground water hydrology of the proposed restoration area that is located immediately down gradient of this facility that operates an 160 acre lagoon with 5 feet of standing water in it (it is also downgradient of the 2 acre final chlorination trench).
Although Bailey did log a significant number of test pits that were excavated on the farmland that is proposed to become the Smith Island Restoration area, none of these were conducted on the private properties. However, the number of borings and wells for a 440 acre area (not including the private properties which were actually the focus of the study because it is these properties that would be impacted by potential saltwater intrusion) was limited and most of the borings were focused in the area of the proposed setback levee for engineering purposes rather than a hydrogeologic investigation.

It is unclear what level of research Bailey conducted in his studies, including research on the City of Everett POTW that is located immediately upgradient of his study area and research on the history of this area, including how farmers historically obtained water for the agricultural operations on this site, how sewage was handled on this site, how farm equipment was fueled, and what type of soil amendments, fertilizers, herbicides, and pesticides were used on this site. It is clear that cattle operations, most likely dairy operations, were conducted on the farmland considering that WSDOT was required to include a cattle crossing under the I-5 when it was built. It is unclear if manure ponds were used on this site; however, this is a consideration if the investigation will include environmental studies such as those Bailey conducted (soil sampling and analysis and ground water sampling and analysis).

It is unclear why Bailey’s studies focused on the engineering geology of the proposed restoration area or why Bailey chose to conduct environmental studies, when the focus was apparently on what impacts they proposed restoration project would have on the potential for saltwater intrusion into the ground water aquifer being used by Hima Nursery. However, since Bailey chose to conduct environmental studies, it is unclear why these studies did not focus on the most likely source of potential environmental impacts on the soils in the restoration area and the ground water, the City of Everett POTW that is located immediately upgradient of his study area.

The DEIS states that biosolids from the City of Everett POTW were used in the proposed restoration area additionally, the 160 acre lagoon and other ponds and trenches manage sanitary sewage including sewage from commercial and industrial facilities. Additionally sewer treatment plants use a lot of chlorine in the treatment process and this chlorine is “neutralized” with sulfur compounds including sulfur dioxide gas and sodium metabisulfite (and other sulfur compounds). The chlorine is converted to chloride in the chlorine “neutralization” process and the sulfur compounds can contribute sodium to this chloride (such as sodium metabisulfite). This effective creates saltwater which can potentially impact the ground water beneath the City of Everett POTW.

Additionally, biosolids are treated with high levels of chlorine and then the chlorine is “neutralized” with the sulfur compounds. These biosolids also have high levels of phosphorous, nitrogen in various forms, high conductivity from the chlorides from the chlorine treatment process (and high sodium from chlorine “neutralization” if sulfur salts are used, such as sodium metabisulfite). These biosolids also have high sulfur content naturally and added sulfur from the chlorine “neutralization”. Biosolids also contain elevated levels of metals such as copper, zinc, lead, iron, and other metals and they can contain other organic compounds such as Polybrominated Diphenyl Ethers (PBDEs); however, Bailey did not conduct analysis for other constituents of biosolids that were known to have been placed in the restoration area, but he did for sulfur, nitrogen, phosphorous, chloride, and pH.

The high sulfur content in the biosolids can be converted to sulfurous and sulfuric acid in the environment, especially a wet oxidizing environment. This will reduce the pH which has been problematic in the surface water discharges from the farmland. The biosolids will have high chloride levels and most likely high levels of sodium chloride if sulfur salts were used to “neutralize” the chlorine. This suggests that the somewhat unusual analysis Bailey obtained for the soils he sent for laboratory testing can be attributed to the placement of biosolids in the restoration area this can be problematic for the proposed use of this farmland as a restoration area that will include breaching the dikes and flooding this area with water from Union Slough.
Additionally, the Shannon and Wilson Modflow model for the ground water “flow” based on Bailey’s well elevator measurements indicates that the recharge area for the ground water is not to the east as is typical for this area, it is from the south which is where the 160 acre lagoon and other ponds and trenches that manage the sewer treatment plant water are located. Considering this water is treated with chlorine and neutralized with sulfur compounds, it is very possible that this facility is an artificial source of salt water intrusion and it is possible that the 5 feet of standing water in the 160 acre lagoon may explain why the ground water in the wells constructed by Bailey was at or above the ground surface.

It is also possible that the 160 acre lagoon and other surface water features at the City of Everett POTW are creating unsaturated zone flows that are a source of the perennial flows in the tidal channels located in the restoration area and west of the proposed setback levee. However, Bailey did not study the hydrology of the tidal channels, most likely because the state purpose of the study was to obtain engineering geology information.

Regardless, as is discussed in the next section of this report, Snohomish County will need to conduct much more detailed hydrogeologic and environmental studies to determine how the City of Everett POTW is influencing the subsurface hydrology and how the placement of biosolids on the farmland proposed to be used in the restoration project will affect the water quality of the Union Slough and how the soils that these biosolids were placed on will impact the aquatic organisms that will be using this proposed habitat.

Additionally, these studies should include actual saltwater intrusion studies that also consider other potential sources of saltwater such as the City of Everett POTW. As discussed in SNR’s comments for the Bailey report, Bailey does not discuss why there is no clear fresh water contact observed as is typically associated Ghyben-Herzberg relationship nor does Bailey discuss why he believes the aquifer is a confined aquifer other than the observed high piezometric surface (at or above the ground surface) without determining the recharge source for this, considering the Union Slough is located to the east and would not provide the hydraulic head Bailey was observing under normal flow conditions. Additionally, Bailey did not try to correlate what he observed with fundamental concepts of saltwater intrusion in a confined aquifer, nor did he try to evaluate potential pathways for saltwater from the Possession Sound being this far inland in the delta of the second largest river in the Puget Sound area.

SNR generated a lot of comments for the Bailey studies and to a lesser extent, the Shannon and Wilson modeling because these studies were not focused and included a lot of areas of study but none of these studies led to any viable conclusion and actually the findings pointed to the need of much more detailed studies that follow correct hydrogeologic and environmental studies protocols, including the preparation of a Quality Assurance Project Plan for all environmental studies that include sampling and field and/or laboratory analysis. Additionally, the studies should have and now, must include an analysis of the impacts the City of Everett POTW has on the subsurface hydrology. These studies must also focus on the characteristics of the soils that received biosolids from the City of Everett POTW if this area will proceed to be converted to a salmon habitat restoration area that will be flooded by the Union Slough.
8 Recommendations

The following is a summary of recommendations SNR has prepared based on our review of the documents provided by Snohomish County.

8.1 Task 1 Recommendations

In summary, SNR believes that additional studies (including subsurface, hydrogeologic studies) need to be conducted and all potential surface water sources need to be addressed, including permitted point source MS4 storm water from WSDOT. Accurate topographic data is required for the area landward of the proposed setback levee (this should also include the area the setback levee will be built on) and this data should include accurate elevation data for tidally influenced flows in the Union Slough based recent measurements in Union Slough to the nearest 1/100th of a foot.

The drainage in drainage basin B2 and the northwestern portion of drainage basin A2 should also be characterized, including flows in the borrow ditch for the remaining DD5 levee section bounding the northern portion inside of the proposed setback levee area.

The potential impacts that subsurface hydrology will have on the surface water drainage needs to be evaluated, as well as the inundation of the proposed restoration area, especially in Tidal Channel B and any drainage system associated with the setback levee. It is known that the borrow ditch drainage system landward of the existing levee system has water in it year around, and run-on controls may be required landward of the proposed setback levee. This needs to be studied and addressed in the drainage plan.

There are potential regulatory issues that may need to be addressed. Tidal Channel B is considered to be “fish bearing waters” which suggests that federal and state codes that regulate these types of water bodies would need to be evaluated, especially since permitted MS4 point source water from I-5 is directly discharged into Tidal Channel B, which is proposed to be used for storage (and it is unclear how this will affect the regulatory status of the proposed 5 acre storm water detention facility).

Apparently, TetraTech did not conduct any field studies on the surface water hydrology of the private properties or the restoration area, nor were subsurface studies conducted to characterize the subsurface hydrology, including the hydrology of the tidal channels. The only field studies that were conducted were conducted by Steven Cahill, PE and these studies were limited in scope and did not include subsurface investigations or those that that include subsurface hydrologic studies. This may be why Mr. Cahill describes Tidal Channel B as “Drain Ditch B” on the Project Site Map drawings (tidal channels are natural features).

Additionally, the WWHM and SWMM models may not be the most appropriate models to use for surface water drainage analysis for the existing conditions and the proposed conditions if the setback levee is constructed. These models are specifically designed for storm water system design and do not factor in subsurface drainage systems, tidal channels being used as storm water conveyances, nor will these programs include potential hydrologic issues with near surface ground water, unsaturated zone flow and hydrology potentially affected by levees.

TetraTech should conduct actual surface water hydrology studies on the private properties, including subsurface studies that include testing of the surface sediments for hydrologic properties. Detailed surveying should be conducted to insure that accurate elevations are used in any design and modeling. TetraTech should also look at models that may be more appropriate for the studies that need to be conducted, including those listed by the United States Geologic Survey at: http://water.usgs.gov/software/lists/surface_water.
All of the private property that will be located landward of the proposed setback levee is agricultural land where stormwater standards associated with development are not required. TetraTech should consider the option of using pumps exclusively and where necessary, adding drainage ditches and pumps, such as the area north of Tidal Channel B.

The Drainage Plan must also include all other sources of water, such as the water that is present year-round in the “borrow ditch” and may be present in any drainage system associated with the proposed setback dike.

8.2 Tasks 2 and 3 Recommendations

If modeling is going to be used to determine if channel migration will occur, or more importantly to determine if the navigability of the Union Slough will be affected by the proposed restoration project, very accurate survey data and cross sections are required. This means that both banks of the Union Slough must be surveyed to an accuracy of 0.01 feet including the bathymetry which must be recently acquired (because the bathymetry will continue to change).

Additionally, the channel bed and bank sediments must be mapped and the engineering characteristics of these sediments must be determined, including grain size analysis, cohesiveness, consolidation, and shear strength. A recording stream gage that measures discharge velocity in cubic feet per second and stage height in feet needs to be installed in the Union Slough in the vicinity of the propose southern breach and a recording tide gage or pressure transducer that also measures electrical conductivity should be installed in the same location as the stream gage. Additionally, an analysis of the sediments being transported by the Union Slough at different flow rates should be conducted.

The fill materials in the existing DD5 levee need to be sampled and the engineering characteristics of these fill materials need to be tested to provide information necessary to predict how quickly the levees will fail and erode after maintenance has stopped and the flow from the Union Slough breaches begins to erode the landward side of the remaining unmaintained levees.

All data gaps need to be filled with, accurate, site specific data and the appropriate model needs to be chosen that will be accurately calibrated, preferably a 3-dimensional model. The model must be accurately calibrated to the existing conditions based on the data collected and then must be calibrated to the conditions that will be present as proposed in the DEIS. The model should also be calibrated to model conditions with failing unmaintained levee sections and for conditions with no remaining unmaintained levees.

The model should be run for all scenarios listed above at different flood stages, including 100 and 500 year flood stages. The sediment transport and deposition must be modeled as should the formation of depositional features in the Union Slough such as sand bars. Changes in the fluvial geomorphology of the Union Slough need to be analyzed, including the potential for the development of side channels. Additionally, changes in the fluvial geomorphologic characteristics of Tidal Channel A need to be analyzed. The effects of the placement of large woody debris, the creation of mounds and other grading activities must also be modeled.

The modeling should also determine the maximum stage height for the Union Slough for each flood event (e.g. 15 year, 50 year, 100 year, and 500 year) and each modeled scenario to insure that the proposed setback levee will not be overtopped.

The modeling should not only focus on potential channel meander and bank and bed scour, it should also focus on the potential impacts to the navigability of the Union Slough and the other sloughs that are used by Buse lumber to deliver logs to this facility. The modeling should also focus more closely to the potential impacts to the downstream DD5 levee system and if there is a potential for greater bank instability or levee failure, the armoring of those portions of the DD5 levee system that will be impacted.
The modeling needs to include the final restoration described in the DEIS which includes the placement of large woody debris and any changes in the geomorphology of the existing farmland due to grade and fill activities. Additionally, the erosion potential in the proposed mitigation area must be determined and the potential changes in the Tidal A channel fluvial geomorphology should also be modeled.

The studies must also focus on how long it will take for the remaining unmaintained levee system to fail and erode away and how this process will affect the fluvial geomorphology of the Union Slough. None of the models SNR reviewed address changes in the remaining unmaintained levees.

As previously discussed, Snohomish County has been working on the Smith Island Restoration project since 2003; with actual studies being conducted in 2007. Had the County installed a stream gage and pressure transducer (or tide gage) in the Union Slough next to the proposed restoration project, it would have a significant amount of site specific discharge and stage data and tide data, including data on the 2009 and 2012 flood events.

Additionally, if pressure transducers were installed in the tidal channels (in addition to one in the Union Slough), a lot of data on the hydrology of these features could have been obtained and when Bailey conducted his studies, adding pressure transducers to the wells he constructed would have provided lots of valuable data on the ground water – surface water interaction and on the Union Slough base flow.

To address potential overtopping of the proposed setback levee, it is important to know what stage height on the Union Slough is representative of an actual 10% flood event and what constitutes an actual 10% flood event. Based on the reports reviewed by SNR (GeoEngineers), Snohomish County suggests that 1% flood events occur at intervals of 3 to 7 years which would mean that this may be the required design parameter if these events consistently occur more often than the predicted 10% events.

The discrepancies between the various models SNR reviewed need to be addressed. In general the Yang and Khangaonkar study and the West Consultants study prepared for CH2M Hill are the most comprehensive and actually incorporate fluvial geomorphologic principals. These studies also predict that significant scour and channel migration will occur if the proposed breaching of the DD5 levees occurs.

It is unclear why the model West prepared by GeoEngineers provided different results than their model did for CH2M Hill considering that it appears that the same basic model data was used. It is also unclear why TetraTech studies were conducted and why the 2-dimensional model was run using the same data that West used in the GeoEngineers report. Regardless, none of the models used site specific data (although Battelle did obtain some site specific data and conducted their studies during base flow or near base flow conditions and conducted the model for the time frame that the collected data covered). Much of the data used in the models is based on assumptions and predictions for an area that has complex hydrology and fluvial geomorphology.

It is apparent that none of the models addressed the real question, which is how will the proposed Smith Island Restoration Project impact the Union Slough and the navigability of the Union Slough and to provide a prediction of stage heights and discharge rates for the design of the proposed setback levee. However, what is also important is how will the proposed restoration project impact water quality and the fish this restoration area is being designed to protect.
As discussed in the Task 4 findings and recommendations, the studies conducted by Bailey suggest that the soils in the farmland proposed to be used for this restoration project are apparently impacted by the placement of "biosolids" from the City of Everett POTW located immediately south of the proposed restoration project. The soil analysis conducted by Bailey suggests that high levels of nitrogen in various forms, sulfur, low pH and high salinity are present in these soils and sediments. It is unclear how the transport of these sediments into the Union Slough will impact the water quality of the Union Slough and how contact with these soils and sediments will impact aquatic organisms including fish.

Bailey’s analysis of the soils and sediments did not include other known constituents known to be present in the City of Everett POTW biosolids and those that are known to be present in virtually all biosolids. These soils and sediments need to be resampled and analyzed for all potential constituents found in biosolids that can impact the water quality of the Union Slough and can impact the health of aquatic organisms that come in contact with the soils and sediments. The new models Snohomish County has conducted should also include an erosion analysis of the remaining levees (which should also be tested for potential constituents that can impact water quality and aquatic organisms) and the soils inside the completed restoration area to determine how an increase in sediment loads will impact the turbidity and phosphorous loads in the Union Slough.

8.3 Task 4 Recommendations

Much more extensive hydrogeologic and environmental studies must be conducted to identify the potential impacts the City of Everett POTW has on the subsurface hydrology and ground water quality. Additionally, actual saltwater intrusion studies need to be conducted using pressure transducers with specific conductance measurement capabilities in all existing and new wells that need to be placed and constructed to properly model the aquifer and to characterize the characteristics of the aquifer including water quality. These new wells must be constructed so that the potential impacts from the City of Everett POTW can be modeled and identified through ground water sampling.

The source of the water in the tidal channels needs to be identified as does the source of the water in the “borrow ditch” system. Pressure transducers should be placed in the tidal channels and in the Union Slough (these should also have specific conductance measurement capability) so that the hydrology of surface water features and ground water can be monitored at exactly the same intervals.

All environmental studies must be conducted in accordance with a SWPPP that is prepared and this SWPPP must include a sampling and analysis plan, this includes soil sampling activities and laboratory analysis for soils. The laboratory analysis parameters must be expanded to those constituents that are known to be present in biosolids and are generated at sewer treatment facilities and would be present in the lagoon, ponds, and trenches at the City of Everett POTW.

SNR requested information from the City of Everett POTW on ground water monitoring, the chemical characteristics of the water in the ponds and other surface water features, and on the biosolids. SNR also requested information on the monitoring of the lagoon and ponds. The only information the City of Everett POTW provided SNR with was limited analysis of the biosolids and a GeoEngineers geotechnical report dated 2009 related to geotechnical engineer studies associated with a truck scale being built for the biosolids program. The City of Everett POTW states that they have none of the other information requested by SNR.

Bailey should have included the City of Everett POTW in his ground water studies considering it is obvious that this is a significant recharge source that is located immediately upgradient of his study area. Additionally, the only potential recharge source that would provide the piezometric surface readings Bailey observed would be the 160 acre lagoon and the other surface water features this POTW facility.
This is further supported by the Shannon and Wilson Modflow model that indicates that ground water is flowing from south to north rather than from east to west. The only potential source of recharge to the south is the City of Everett POTW lagoon, ponds, and trenches. Additionally, considering the potential ground water quality impacts from the City of Everett POTW based on Bailey’s studies, it is possible that the ground water is being impacted by more than salt and it is possible that this is also the source of the hydrology in Tidal Channel A (and the other Tidal Channels) which could impact water quality in the proposed Smith Island Restoration Area.

It is clear that Bailey’s studies were inconclusive regarding saltwater intrusion associated with the proposed restoration project. However, it is unclear why Bailey did not address the high salt content of the soils on the farmland that is proposed to be used for this proposed restoration project or the other constituents that are present in the soils and sediments that can impact water quality. Considering that if the levee system is breached the Union Slough will flow into the farmland and during high tides and storm events a significant amount of surface water will be present and this surface water will infiltrate through the soils and sediments in the restoration area, which can lead to potential impacts to water quality.

The additional ground water studies that need to be conducted must address how the infiltration through the soils with the low pH, high nitrogen compounds, high sulfur and high salts (which need to be characterized for other potential constituents present in biosolids) will impact ground water quality and how this will impact the water quality of the Union Slough and impact aquatic organisms that come in contact with these soils.

This report has been prepared by the SNR staff listed below. If you have any questions or require more information please contact us at 425-788-3015.

Sincerely,

SNR COMPANY

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MEETING SUMMARY
Smith Island Restoration Project
DID5 Independent Review for County Technical Studies

April 18, 2013, 8:00 – 11:00 am
Snohomish County Department of Public Works, Surface Water Management Administration West Building, 3rd Floor, Willis Tucker Conference Room
3000 Rockefeller Avenue, Everett

Note: Discussion summary is shown in italics under each agenda item below.

Meeting Purpose: Discuss findings from DID#5 technical review of County impact studies; Identify significant issues that require action; Determine next steps

Attendees:
Naeem Iqbal (Hima Farms)
Asif Iqbal (Hima Farms)
Mark Hecker (Buse Timber Co.)
Will Miller (Buse Timber Co.)
Vic Loehrer (Dagmars Marina)
Peter Ojala (DID#5 legal representative)
Steve Neugebauer (SNR Company)
Steve Dickson (Snohomish County)
Bob Aldrich (Snohomish County)
Kirk Bailey (Snohomish County)
Cynthia Carlstad (Tetra Tech)
Stephen Thomas (Shannon & Wilson)
Dave Cline (Shannon & Wilson)
Greg Laird (Otak)
Steve Thomsen (Snohomish County)
Debbie Terwilleger (Snohomish County)
Mark Sadler (City of Everett)
Heather Griffin (City of Everett)

Agenda Items:

- Introductions
  
  *Steve Dickson chaired the meeting.*

- Meeting format and approach to working through review comments
  
  *Vic Loehrer commented that the Everett wastewater treatment plant seemed like the most significant issue raised, and adequate time should be allocated to discuss.*

- Topics of concern
  
  1. Drainage for Hima Farms property
     1. I-5 runoff
     2. Subsurface and groundwater contribution (quantity and quality)
     3. Seepage through and under the dike (existing and new dikes)
     4. WSDOT culvert
     5. Use of pump-only scenario with no storage needed
6. Runoff from former Buse property
7. Power outages
8. Storage pond lining

First issue raised was the concern that biosolids were applied to the area and that the project and inundation of the area may affect water quality with respect to fish habitat. Likely there were only a couple of applications of biosolids on the order of 125 c.y per application. SNR indicated that biosolids applications in marine environment could cause low pH, high sulphur and high zinc concentrations, and that a systematic study had not been performed. The EIS and design team responded that the historic applications have likely degraded and have run off the site into ditches and the slough, and that no difference has been observed in groundwater quality between the wells in the Harnden area compared with the rest of the site. SNR indicated that this may be a NPDES permit issue, to which the design team felt that farm runoff would not be regulated under an NPDES permit.

Drainage analysis did not include I-5 runoff, which includes the east ½ of I-5 and flows from the WSDOT outfall into a pipe running to Tidal Channel “C”.

Modeled soil parameters used farm land cover and soil types, but considering they are likely fully saturated should have been modeled to cause no infiltration, and thus no subsurface/groundwater storage.

The EIS drainage study did not include through or under seepage for the existing and proposed levees. Subsurface and groundwater contribution were also not specifically included, nor was a study of the potential connectivity of Tidal Channels A and B.

SNR indicated that proposed drainage storage could be affected by groundwater if not lined.

Drainage systems will require maintenance.

Hydraulic head could possibly be supplied by the County’s inundated project site and from the City of Everett WPCF ponds. The ponds could be leaking and affecting local groundwater quality. How are the City ponds affecting groundwater flow and water quality entering the Tidal B drainage channel, and how will water quality of pump discharge be addressed if a future issue?

Runoff from former Buse property east of I5 was included.

Drainage design criteria is to keep storage below drain tile of -0.6ft (NAVD88). Asif (Hima Farms) indicated that the drain tile elevation may be located at 1.46ft (the survey datum was not referenced in this comment).

A pump-only scenario was evaluated, using an 8 cfs pump and is included in the drainage report. This capacity was determined to be excessive under most conditions.

The drainage analysis assumed that the WSDOT 42-inch culvert that links east/west Tidal Channel B under I-5 conveys no water as a conservative assumption. DID#5 and/or Hima Farms had previous discussions with WSDOT about maintenance of the culvert in the past. There is currently no active engagement with WSDOT on the topic. Steve N. commented that the culvert was installed for fish passage rather than drainage and this purpose could obligate WSDOT to more actively maintain it.

Power outages may affect ability to use existing pump in Tidal Channel C.
Regarding classification of Tidal Channel B – it is classified as a Managed Watercourse Without Headwaters under DMD#5’s draft Drainage Maintenance Plan, and as such, is not considered a fish-bearing water.

The design team provided discussion that levee through and underseepage and groundwater contributions to the Tidal Channel B drainage system were being evaluated in the current phase of design. New geotechnical borings along the new levee alignment have shown the presence of a limited sand lens between Tidal Channel A and Tidal Channel B. It is unknown whether the lens is fully continuous between the tidal channels. The design is looking at conservative (high) seepage rate contributions to the drainage system as they relate to possible sand lens connections, and assuming that sand lens connections exist along the entire length of Tidal Channel B.

Regarding possible groundwater contribution to Tidal Channel B – although the Geologic and Hydrogeologic Field Investigation concluded that the surficial geologic layer acts as primarily an aquitard (does not yield groundwater in usable quantity), it is possible that some limited upward groundwater movement exists from the underlying aquifer. Current design phase studies are evaluating the lateral flow connection between Tidal Channel A and B along sand layers within the upper soil unit, and will address the potential for limited vertical flow upward from the underlying aquifer.

Follow-up:

1. Field-confirm contributing drainage area and survey features that County has not had access to on Hima Farms property (County and Hima Farms to work together on scope, access, and drainage mapping)
2. Review WSDOT’s NPDES Phase 1 Stormwater permit to determine nature of permitted outfall. Take action as needed based on results.
3. Progress with drainage design for landward side of levee. This will include capacity for any new drainage area identified from #1, estimated seepage through existing Union Slough levee, estimated seepage through new setback levee, groundwater contribution, and conservative estimate for possible subsurface hydraulic continuity between Tidal Channel A and Tidal Channel B. Evaluate whether a storage facility should be lined to be considered by the design team based on available data. Evaluate whether adding Channel C basin drainage significantly adds to storage volume.
4. Add and classify drainage facilities (channels, storage pond, pump facilities) to be built as part of the Smith Island Project to the District’s Drainage Maintenance Plan.
5. Determine how pump discharge quality can be addressed as part of permitting.

2. Navigability of Union Slough

1. Erosion of remnant dikes
2. Sediment deposition in Union Slough
3. Erosion of downstream dikes

There is concern about ability to deliver logs to Buse via Union Slough after the project is implemented. Tug boat operators may rely on the existing dike for orientation and channel locating. Problem areas include the sharp corner immediately downstream from the Buse cut (connecting channel between Union and Steamboat Sloughs). The possibility of installing way-finding markers or providing updated channel bathymetry to aid GPS navigation was discussed. If way finding markers are preferred, poles for osprey nests and as markers for location of old dike could be considered where the breaches have been made. Recommended to coordinate with the tug boat operators to discuss navigation options.
Remnant dikes are to remain as upland-edge habitat restoration element of the project and to aid in channel retention and will not be left to erode away. Recent projects such as Spencer Island (which is over 20 years old) have not resulted in significant erosion of the remnant dikes. Who will maintain the remnant dikes, and what does maintenance include are outstanding questions?

Modeling and geomorphic studies do not indicate that sediment accumulation will be a problem in downstream areas of Union Slough. There was a concern about sediment deposition in Union Slough affecting log-barge operation. The County and the models don’t indicate this is a problem. Cynthia described changes in Union Slough hydraulic conditions including increases and decreases in localized velocities and shear stresses in Union Slough. She indicated that there is low potential for Union Slough sedimentation due to the proposed condition velocities and fine sediment sizes within the Union Slough system that will remain mobile.

County is prepared to monitor sediment deposition through periodic bathymetric surveys, and to seek authorization and remove accumulated sediment or debris if it were to occur and cause problems for navigation as a contingency and adaptive management action.

Use of the remnant dikes, in particular edge habitat, for District mitigation purposes was also discussed in concept. This opportunity will be explored further; those in attendance did not have conclusive knowledge or information to evaluate viability of various approaches. This could potentially be an element of a District Nationwide 31 permit.

Model studies indicate increased erosive pressure downstream during the combined condition of a river flood and ebb tide. This condition is predicted for the reach downstream from the project site (downstream from I-5 bridge to below the Buse log ramp). Modeling predicts this potential impact to be concentrated in the center of the channel, rather than on the margins. This could also affect the existing downstream levees. Discussion centered on whether it would be prudent to strengthen the downstream levees with bioengineered measures in advance of project implementation or monitor with the County commitment to repair and strengthen any areas that experience impacts post-project. The District stated that the latter approach is most important and this approach is also preferred by the County. There is no indication that these levees are in poor condition and would suffer from post-project conditions. The District’s participation in the PL84-99 program provides access to rapid Corps flood-fighting response and repairs should the need arise. The use of bioengineering measures needs to also be considered in the context of participation in the Corps PL84-99 program and acceptability within the program.

Follow-up:

1. Arrange meeting with Buse tug boat operator (Jack Sanford – Dunlap) to learn what needs/constraints they envision with delivering logs through Union Slough now and post-project implementation. Follow up as needed.
2. Obtain updated Union Slough bathymetry and document edge habitat as baseline for future mitigation.
3. Survey and document existing condition of downstream levees.
4. Pursue viable alternatives to preserve ability for Buse to deliver logs, including:
• Initiate permitting for potential post-project sediment removal from Union Slough

• Consider other options for delivering logs to Base; evaluate cost and preference aspects for use in the event that Union Slough became impassible due to an event such as a fallen tree.

3. Project design based on adequate data
   1. Subsurface hydraulic connection between Tidal Channel A and B
   2. Seepage - through and under dike
   3. Topographic data for Hima Farms land
   4. Flood levels and design dike height
   5. Modeling for interior project elements
   6. Everett WWTP influence

Most topics under this heading were discussed above as follows:
• Project design assumes that some subsurface connection exists between Tidal Channel A and B. Landward drainage facilities will be sized to accommodate a conservative estimate of possible flow contribution. More borings have occurred for the design phase.
• Seepage through the new levee is being estimated and accommodated in design for landward drainage facilities.
• New topographic data will be acquired by County surveyors, working with Hima Farms to gain access and locate pertinent features
• Possible groundwater influence from Everett WWTP will be accommodated in design of landward drainage facilities.

New levee design height has been set at 15' NAVD88 based on the following:
• FEMA base flood elevation
• Historical high tide observations
• Consistency with City of Everett levees that provide protection to the WPCF. This is corroborated by observed flood levels by City staff during historical floods.
• Levee will be eligible for participation in the PL84-99 Rehabilitation and Inspection Program.
• Levee will not be eligible for levee certification per the Corps design guidelines and FEMA accreditation as providing 100-year flood protection (does not have 3-feet of freeboard above base flood level).

• Next steps

Steve Dickson laid out the following next steps:
  1. County to work with Hima Farms on scope for survey; complete survey
  2. County to meet with Dunlap Towing to learn more about possible Union Slough navigability issues.
  3. County will deploy water level and salinity data loggers in Union Slough, tidal channels, and monitoring wells.
  4. District will finalize SNR consultant review report.
  5. County will finalize technical impact studies
  6. County will issue Final EIS for Smith Island Project in May 2013.
  7. County will apply for Shoreline permit at about the time the FEIS issued. Appeal period for the FEIS and Shoreline Permit will run concurrently.
8. County will work with District to schedule project design-related topics for each upcoming District meeting as a means for continuing the information exchange and discussion about project design elements.

9. County will progress with project design, with the goal of completing the 60% design level by the end of May, 2013.
### Snohomish County's Response to Smith Island Restoration Project; Tasks 1-4 Report Review; Comments, Findings and Recommendations Report that was prepared by SNR Company April 2013

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<th>ITEM</th>
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<td>1</td>
<td>Both studies are based on the premise that the only potential source of surface water on the private properties will be precipitation and both presume that infiltration to ground water will occur. Additionally both studies presume that the Buse property will not be used agriculturally. However, as discussed in this report, there are other potential sources of surface water hydrology and the Buse property was purchased by Hima Nursery to place in agricultural production. As is the case with the existing Hima operations, subsurface drainage will be used on the former Buse property.</td>
<td>The analysis and design of drainage facilities interior to the proposed dike have progressed since the work cited in the Tetra Tech report. The Smith Island Interior Drainage Report (Otak, 2013) includes subsurface seepage from the existing and setback dikes based on the Shannon and Wilson detailed groundwater analysis, as well as conservative measures by assuming that nearly all interior areas will drain to the interior drainage system due to agricultural drain tiles, as well as saturated soil conditions that assume high levels of runoff from precipitation. The study also models rainfall events in excess of a 1-Percent Annual Chance (100-year) event with seven days of flood conditions on Union Slough, which would prevent gravity drainage, and finds the drainage system provides storage capacity with freeboard under the modeled conditions. The volume of water from agricultural operations is insignificant relative to the volume of water modeled in these events, and irrigation from the agricultural operation is unlikely during large scale flood events.</td>
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<td>The drainage analysis does not factor in potential overtopping or dike breach flows. The existing DD5 levee system has an extensive topographically lower buffer (about 400 acres) that can store significant quantities of floodwater should a levee overttop (overtopping of the existing levee has not been reported within the last 20 years based on SNR’s research) or breach (breaches has occurred and Union Slough bank failures have threatened the levee system, which is why the Corps of Engineers conducted emergency repairs in February 2012). It is unclear how the private properties will be affected by breaches or overtopping of the proposed setback levee compared to impacts from breaches or overtopping with the existing levee system.</td>
<td>The existing dike system has a minimum elevation of approximately 12 and the existing dike was not overtopped during recent floods when other dikes in the valley upstream and downstream of the project site were overtopped. The setback dike will be constructed to a top elevation of 15 feet NAVD88 and has been designed to standards exceeding those of USACE, which provides a level of flood protection higher than the existing dikes for the property owners interior of the dike. A comparison of overtopping rates of the existing and proposed setback dike with the area of storage behind the respective dikes shows that the higher elevation of the setback dike will provide more time before the interior is inundated and that the property owners will be inundated faster with the existing dike due to the lower top elevation, even with the area between the existing dike and the landowners.</td>
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<td>The DEIS indicates that the tidal channels are considered to be “fish bearing” (page 81 of the DEIS states; “Although they are isolated from Union Slough by dikes and tide gates, the remnant tidal channels and drainage ditches are considered fish-bearing waters.”) regulatory, however, the regulatory issues associated with using these features to store storm water, including the incorporation of these features in a permitted point source MS4 system (WSDOT discharge) has not been addressed.</td>
<td>There is some question as to whether or not the channel in question are fish bearing, and if so, fish bearing with not headwaters. This is a permitting question, and not necessarily a design question Washington State Department of Fish and Wildlife is currently reviewing jurisdictional authority for the drainage features on the project site.</td>
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<td>Ground water and potential unsaturated zone flow were not included in the analysis even though the ground water is known to have a potentiometric surface elevation that is at or above the ground surface on the Hima property (Bailey, 2012). Unsaturated zone flows are known to occur within 4 feet of the ground surface within sand lenses and peat deposits. It is possible that the unsaturated zone flow (interpreted by Bailey, 2012 as ground water) observed in the test pits excavated for the Snohomish County saltwater intrusion studies may be linked to the surface water hydrology in the Union Slough. This may explain why the borrow ditch is filled with water year-round, which would suggest there is a potential for under seepage and/or through seepage for the existing levee system and the proposed setback levee.</td>
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<td>Topic being addressed under current engineering studies. Initial through and levee underseepage estimates developed in the design phase of work used seepage rate estimates assuming a sand lens connected directly between the East and West Tidal Channels (or otherwise referred to as tidal channels A&amp;B), which is conservative and likely overpredicts the amount of seepage. This information was used for developing storage pond volumes, interior drainage conveyance structures and tidewater conveyance structures. The interior drainage design was demonstrated to accommodate these conservative seepage rates. Subsequent to this initial design analysis an update was performed to the groundwater MODFLOW model that more accurately represented site topography, bathymetry, soil layers, sand lenses, drain tiles and drainage structures. The updated model was used to finalize the interior drainage design plans using updated seepage rates. Groundwater flow was analyzed as part of the County's assessment. The report includes hydrographs and interpreted piezometric head contour maps based on data the County collected during 2012. We would not characterize unsaturated zone flow as occurring - rather, the descriptions from the test pit logs are typically seeps, which individually are unmeasureable. These seeps occur in fine-grained sand lenses that are mostly found in the lower part (below 10 feet) of the younger alluvium unit, and rarely as shallow as 4 feet. The S&amp;W SWI model is being updated to more accurately represent the hydraulic properties of this unit as part of the current 2013 engineering design work. The relationship between flow/seepage in the shallow aquitard unit and the underlying sand aquifer is being explored as part of the engineering design. This includes measuring groundwater levels in three of the County's shallow observation wells, and water levels in Union Slough and two tidal channels using transducers and dataloggers.</td>
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<td>It is unclear why Tetra Tech did not include an evaluation that only uses pumps (electric pumps with power backup), rather than excavated detention facilities and relocated tide gates, to remove water from Tidal Channel B and from the borrow ditch that bounds the landward side of the remaining, maintained DD5 levee.</td>
<td>The existing drainage system includes storage of surface water within remnant tidal channels that is discharged through tide gates. The system designed provides a significantly improved storage to land area ratio. Operation and maintenance costs are minimized with a system that only requires pumping during significant storm events. The Tetratech study evaluates gravity drainage as well as a pumping system. The gravity drainage system (or excavated detention facilities) is designed for County land, and provides benefit to adjacent property owners by improving drainage conditions and reducing the cost of pump operation. Additionally, the design alternatives of one gravity outlet, two gravity outlets, as well as two gravity outlets with a pump station with 2 or 4 cfs outflow are evaluated in the Otak 2013 drainage analysis.</td>
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<td>6</td>
<td>The only topographic maps for the private properties are prepared by Cahill. However, these maps are relatively low resolution maps with LiDAR generated contours without topographic elevation data being provided. Snohomish County did provide SNR with a topographic “survey” map in PDF format; however, this map was difficult to read and does not apparently include survey data for the private properties. Therefore, SNR cannot evaluate the accuracy of the elevation data used for the Cahill or TetraTech studies. In areas with relatively low topographic relief, accurate elevation is critical when designing a storm water drainage system.</td>
<td>Survey data of key drainage features was available for the preliminary analysis prepared by Cahill and TetraTech. Access has now been provided to private land previously not accessible. Extensive surveys have been conducted since this comment was made, and subsequently incorporated into detailed drainage design for the project.</td>
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<td>The GeoEngineers report suggests that data on the local geology was collected, however, the report does not discuss any geologic or hydrogeologist studies that were conducted. Based on SNR’s review of the GeoEngineers report, no test pits, drilling activities, and sample collection activities were conducted. No sediment testing was conducted by GeoEngineers to determine the characteristics of the bank or bed materials in Union Slough, including consolidation and cohesiveness.</td>
<td>A significant amount of historical geotechnical field explorations have been performed for the Smith Island Estuary Restoration project, Union Slough Estuary Restoration project and the City of Everett wastewater treatment pond, to which the GeoEngineers report is referring. Snohomish County Public Works and Shannon &amp; Wilson have also performed additional subsurface explorations since the publication of the GeoEngineers report. Shannon &amp; Wilson recently produced a Draft Geotechnical Report that summarizes much of the available data. A figure in the report shows recent and historical test pits, borings, and cone penetration tests exploration locations performed at the site. In general, the surficial layer in the proposed marsh and levee setback area was characterized as estuary deposits comprised of soft, organic silt and clayey silt with abundant organics, scattered peat layers and sand lenses, and local wood fragments and logs. Below was another estuary deposit consisting of very soft, slightly clayey to clayey silt and organic silt with scattered to abundant sand lenses, seams, and layers. Scattered to locally abundant organics and wood fragments were also present in the lower estuary deposit. Underlying the estuary deposits is an alluvial deposit consisting of very loose to dense, trace of silt to silty sand. Scattered shells, wood fragments and fine organics were observed in the alluvial deposit.</td>
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<td>It is unclear why GeoEngineers used historic air photographs that date from 1947 (a 1938 air photograph is referenced but not included in the report) to demonstrate that the Union Slough has not meandered significantly even though the 1911 USGS topographic map of the Mount Vernon Quadrangle indicates that all of the distributory channels in this area, including the Union Slough were protected by maintained levees. It is known that the Union Slough has meandered historically because peat mats that do now form in active channels are present in the bed of this channel.</td>
<td>GeoEngineers reviewed the historical land survey maps (1884 prior to levee and dike construction) and aerial photographs from 1938 through 2007. The 1884 land map generally shows the river meanders and tidal channel meanders have changed very little since 1884, with the exception of man-made navigation and flood control dredging, excavations and levee building. An aerial photograph from 1938 can be found in the ESA-Adolfson “Smith Island Levee Analysis Report”, 2007.</td>
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<td>3</td>
<td>It is unclear why GeoEngineers believes that once the levees are breached that the Union Slough will not meander, especially when the remaining, unmaintained DDS levees are gone due to erosion caused by high water flow, wind driven waves, changes in sediment deposition, and changes in the water dynamics as water flows in the southern breach and out the northern breach (the levees will have water on both sides). It is also unclear why none of the modeling includes scenarios where the existing levees are completely gone, which is what the eventual fluvial geomorphology of this area will reflect if the proposed mitigation project proceeds.</td>
<td>The GeoEngineers report bases this interpretation on the hydraulic modeling results, observations about existing channel conditions, and observations about channel response to the previous levee breach on Spencer Island. They reported that no evidence of surface scour, bank erosion adjacent to the breach, expansion of the breach, or any main stem channel responses was detected following the Spencer Island breach. Regarding current channel conditions, their geomorphologist interpreted the existing channel is entrenched within the cohesive sediments of the delta. In this situation, the channel is more likely to down cut then move laterally. They notes some areas of bank erosion, such as where the current levee repair is taking place, but interpreted the slumping occurring elsewhere along the levee to be associated with slope failure fueled by repeated wet-dry cycles, rather than fluvial erosion from lateral migration energy. Remnant levees are considered a valuable asset for long term success of the restoration project, (complex edge habitat, wave attenuation, etc.) Water flow is not as simplistic as &quot;water flows in and water flows out&quot; out, as demonstrated by the extensive hydraulic modelling efforts that have accompanied design work. Because of the value of the remnant dikes to the restoration effort, it is not a valid assumption that they will be &quot;completely gone&quot;.</td>
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The GeoEngineers report (page 2) states: the GeoEngineers report states that the model was developed to confine flows between levees to simulate flow volumes typical of 15 to 25-year events, and evaluate the primary hydraulic parameters (boundary shear stress and velocity) for channel forming events. The report may be indicating that existing levees are overtopped every few years in the reference to 100-year events from the 2005 Snohomish County NHMP (which was updated in 2010).

The WEST study uses data collected near the project site on the Snohomish River, which included the 15-year event. The 15-year event used by the WEST study is appropriate for determining boundary shear stress for channel-forming events because the 15-year occurs more frequently than a 100-year event (by definition) but is also a conservative estimate of the amount shear stress since an approximately 2-year event is generally the “channel-forming” discharge. In addition, the 100-year event was modeled by Tetratech (May 2013).

Stage data is being collected on Union Slough as of 2013, and studies up to this point have used stage data collected from the Snohomish River for the Everett Riverfront Study, as cited by WEST Consultants, which is the closest location to the project site. In a comparison of tidal gauge records in the Everett vicinity and including a gauge from Seattle, the Snohomish River gauge data was consistent with these other gauges and provided the level of detail best suited for the hydraulic analysis. The stage data from the Snohomish River is representative of stage levels on Union Slough due to the upstream and downstream connections with the Snohomish which control tide levels on Union Slough, and the Snohomish stage attributed to river flow provides a conservative estimate on the amount of stage within Union Slough from river flow.

The bathymetry of Union Slough may change locally for short periods in response to the variability and interaction of stream flow and tides. The County will establish a baseline of the bathymetry prior to construction of the project and monitor it to assess if sediment deposition increases post-construction.

GeoEngineers did not conduct any studies on the sediments in the stream channels, including test pits and borings nor was any analysis performed on any of the sediments.

It is correct that GeoEngineers did not conduct sediment sampling as part of their analysis. These statements were based on field observations and their professional knowledge about geomorphology, especially the interpretation of dominant channel-forming processes based on physical evidence. They reported observing the upper portion of the low-flow channel walls being composed of very thin alternating lamina of silt/clay, silt and fine sand within the upper two feet of the channel banks. Nearly vertical channel sides, such as exist in the Union Slough low-flow channel, can only be maintained in solid rock or cohesive sediments. Non-cohesive material will not sustain a nearly-vertical channel wall.

Five surveyed cross sections were determined to be sufficient for calibration because of the homogeneity of the Union Slough channel, (as additional cross sections are generated within the model, if necessary. Remant levees are considered a valuable asset for long term success of the restoration project, (complex edge habitat, wave attenuation, etc.). Because of the value of the remnant dikes to the restoration effort, it is not a valid assumption that they will be "completely gone". There is no plan to create mounds or other such structures, the planned wood structures will most likely not be "visible" within the resolution of the models used.

The cohesive, estuarine sediments deposited comprising the Union and Steamboat Slough channels are more resistant to lateral erosion and, as a result, these channels are entrenched.

It is unclear why only five cross sections were selected to evaluate on an approximately 9,500 foot long section of the Union Slough. Additionally, the model only includes scenarios with intentional breaches and does not factor in the eventual removal of the remaining unmaintained levees due to erosion and potential channel meander. Also, the model does not apparently include the proposed restoration activities described in the DEIS, including the placement of large woody debris and the construction of mounds and other grading activities (including the filling of all existing ditches).

Remant levees are considered a valuable asset for long term success of the restoration project, (complex edge habitat, wave attenuation, etc.). Because of the value of the remnant dikes to the restoration effort, it is not a valid assumption that they will be "completely gone". There is no plan to create mounds or other such structures, the planned wood structures will most likely not be "visible" within the resolution of the models used.

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<td>The West Consultants report suggests that the data used in the HEC-RAS model is from a stream gage near the City of Monroe, Washington. This stream gage is located almost 20 miles upstream from the section studied by West Consultants and does not reflect contributions to the Snohomish River flow from downstream streams and rivers (such as the Pilchuck River which is projected to have 1% storm event flows of up to 14,000 cubic feet per second, which is generally equivalent to the maximum flood stage on the Green River).</td>
<td>The WEST report states that the stage data is from the Everett Riverfront Project, and shows on Figure 1 in Appendix A that the location is downstream of the Pilchuck River and approximately 2 miles upstream of the split between the Snohomish River and Union Slough.</td>
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<td>9</td>
<td>The GeoEngineers report states (page 9): The January 2009 flood was calculated to be near a 15-year recurrence interval flood based on data from the gage near Snohomish. Although levees are typically overtopped between the gage and the project site, the model for Union Slough does not simulate the flow volume lost to overtopping.</td>
<td>The GeoEngineers report states that the January 2009 flood is estimated as a 15-year recurrence interval storm. As SNR shows in Figure 5-10, the USGS station has historical peak discharges (about 24 years on record), which is the data used for frequency analyses. The length of record of the historical peak discharges from this gage is sufficient for determining a 15-year recurrence interval.</td>
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<td>It is unclear why the HEC-RAS cross sections shown on Figure 4 do not extend across the southern breached section of the levee into the new floodplain that is created by the levee breaches. These cross sections would typically extend to the proposed setback levee perpendicular to the Union Slough channel from the levees on the right bank, through the breach to the new setback levee.</td>
<td>The HEC-RAS cross sections shown in Figure 4 are used to determine shear, stream power, and velocity for Union Slough in the study. If the cross sections shown in Figure 4 extended across Smith Island, the results would not provide accurate results for velocities within the Union Slough main channel.</td>
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<td>11</td>
<td>The GeoEngineers “studies” were conducted to determine how the geomorphology, or more specifically, the fluvial geomorphology, of the Union Slough will respond to the proposed Snohomish County Smith Island Restoration Project. The DEIS suggests that new channel formation and channel meander are likely, however, the GeoEngineers report (using HEC-RAS model output prepared by West Consultants) suggests that there will be minimal to no channel formation or meander.</td>
<td>The GeoEngineers report is commenting on the proposed project to increase meandering and erosion of Union Slough. The DEIS is commenting on formation and erosion of channels in the restored marsh, which will have restored tidal and flood flows to the marsh, hence the potential for tidal channel development and erosion.</td>
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<td>12</td>
<td>The GeoEngineers report does not include any actual geologic studies, including subsurface geology and hydrology studies. The GeoEngineers studies were limited to site reconnaissance observations. The sediment erosion susceptibility is based on generalized published data for the types of sediments GeoEngineers believes are present. However, based on the studies conducted by Bailey, 2012 and other subsurface studies conducted in this area (Golder, 2001 and GeoEngineers, 2009) GeoEngineers assumptions regarding the characteristics of these sediments are inconsistent with actual subsurface data collected in this area (Bailey’s studies were conducted in the proposed restoration area).</td>
<td>GeoEngineers reports surficial geology...“mapped in the project area is composed of the younger alluvium and estuarine sediments. The younger alluvium consists of floodplain deposits, up to 20 meters thick, composed primarily of cohesive and compact silty sand, interbedded with occasional sand or gravel lenses. The younger alluvium is interfingered with the estuarine sediment and composed primarily of silt and clay with organic matter.” This is consistent with geologic and soil studies performed by Shannon &amp; Wilson, 2013 for the levee setback geotechnical design, Snohomish County 2012 for the groundwater and saltwater intrusion studies, and Golder 2001 for the Williams Pipeline crossing.</td>
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<td>The Snohomish River is classified as a meandering river and the distributary channels on a river delta also have the characteristics of meandering channels. The term meander means that these channels move in response to changes in the hydrology and sediment transport (and in a delta, tidal currents). Movement can also be caused when moving water encounters more resistant materials (resistant to erosion) including large woody debris moved into the channel or buried debris encountered as the channel meanders.</td>
<td>Comment noted. The Snohomish River is a meandering channel.</td>
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<td>14</td>
<td>The presence of peat mats in the Union Slough channel indicates that the channel has meandered because these deposits do not form in active distributary channels. The primary reason the Union Slough has had minimal channel movement since 1911 is because this distributary channel (and the other distributary and mainstream for the Snohomish River) has had a maintained levee system that was clearly present in 1911 based on the USGS topographic map of the Mount Vernon Quadrangle.</td>
<td>The Union Slough channel and Snohomish River delta channels have migrated across the delta over very long periods of time. The West, GeoEngineers and Battelle reports address the potential for Union Slough channel erosion and migration and indicate that the potential resulting from the project is low. The levee setback design is considered erosion and migration potential along the length of the setback and has included erosion and scour protection measures along the new structure.</td>
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<td>15</td>
<td>The proposed Smith Island Restoration Project will include the breaching of the existing levee system which will change the surface water hydrology and the sediment transport in the Union Slough because the Union Slough will be reconnected with its left bank floodplain. This will result in a change in the fluvial geomorphology of the Union Slough as predicted in the DEIS. Additionally, by reconnecting Tidal Channel A to the tidally influenced Union Slough, this the fluvial geomorphology of this tidal channel will also change.</td>
<td>The DEIS and hydrodynamic and geomorphologic supporting studies have evaluated these changes and presented information regarding how much change is expected. The primary area expecting to have change is along Tidal Channel A in the marsh restoration area that will have new / restored tidal and flood flows. The hydrodynamic and sediment changes the Union Slough channel are much more subtle and typically have slightly lower flow velocities and slightly lower sediment transport capacity, which is not expected to significantly change Union Slough channel morphology. The County has adopted a channel survey, monitoring and adaptive management plan for addressing changes in the Union Slough channel.</td>
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<td>16</td>
<td>GeoEngineers relies on assumptions, the review of historic air photographs, and a 1 dimensional HEC-RAS model that uses data from unknown sources to demonstrate that the fundamental concepts of fluvial geomorphology do not and will not occur on the Union Slough.</td>
<td>The GeoEngineers and WEST report states the source of the data used for modeling in Appendix A, including the Everett Riverfront Study for stage data, and topographic data generated from 2009 LiDAR and a bathymetric survey. The report states the objective of the study was to assess potential channel responses for the proposed condition, and the evaluation includes a comparison of modeled velocities and shear stresses to erosion thresholds based on soil type.</td>
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<td>17</td>
<td>However, GeoEngineers (and West Consultants) does not have any data that is specific to this section of the Union Slough or the Union Slough in general. There are no stream gages on the Union slough, there are no tide gages on the Union Slough, and there is no recent bathymetric data for the Union Slough (as previously discussed, Global Remote Sensing, 2007, indicates that the channel morphology will continue to change and actually did change during their bathymetric studies conducted in 2006).</td>
<td>Please refer to the response to the previous “comment”. The GeoEngineers work examined as-built drawings for the I-5 bridge, comparing the bathymetry at that site to the most recent survey, some 40 years later. No observable change in channel floor elevation was present. The bathymetry of Union Slough may change locally for short periods in response to the variability and interaction of stream flow and tides. The County will establish a baseline of the bathymetry prior to construction of the project and monitor it to assess if sediment deposition increases post-construction. The stage data collected on the Snohomish River is representative for Union Slough because the upstream and downstream connections between the Snohomish and Union Slough that control tide stages and the river flow included in the stage from the Snohomish provides a conservative estimate for Union Slough.</td>
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<td>The concepts of fluvial geomorphology on river delta distributary channels are not discussed nor does GeoEngineers explain why normal channel meander and changes to tidal channels will not occur. GeoEngineers focuses on the observations that the Union Slough has had minimal movement since levees were installed and maintained, however, this is not representative of what the conditions will be like after the levees are breached. Instead, GeoEngineers could have focused on historic channel meander that occurred before levees were constructed on these distributary channels by focusing on how rivers build deltas.</td>
<td>The GeoEngineers report does discuss the fluvial geomorphology and erosion processes of a river delta distributary channel in an estuarine (tidal) setting on Page 8 of their report. They present information discussing the low potential for erosion based in indicators affecting channel migration, such as the absence of alluvial bars which drive channel erosion and meandering, and the observation of current instability related to geotechnical wetting / drying of the river and levee banks and subsequent slumping, which typically does not cause wide-spread channel erosion and migration. GeoEngineers then assesses the likely changes by reviewing changes in hydrodynamic model for the proposed conditions, as well as making observations at other levee breach and restoration projects near the site at Spencer Island. Their analysis indicates that proposed hydraulic conditions will have lower velocity and sediment transport capacity in most of the Union Slough channel, indicating less energy for bank erosion. Observations of Spencer Island restoration indicate that no major changes have occurred on Union Slough as a result of the restoration project that is now more than 10 years old. The GeoEngineers report indicates that the potential erosion from channel migration is low.</td>
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<td>19</td>
<td>The GeoEngineers report findings appear to be inconsistent with those made by West Consultants, 2007, Channel Migration and Scour Evaluation Everett Delta Natural Gas Pipeline/Smith Island Restoration Snohomish River, Washington report. However, this report also fails to discuss the source of the data used in the HEC-RAS model.</td>
<td>The West report describes the long term potential for increases in channel migration resulting from lower sediment transport capacity along Union Slough. They do not speculate or calculate changes in rates of channel migration or erosion, but merely state there is a change. They also state that the potential for Union Slough migration is significantly constrained if the existing levee is breached and maintained to limit channel erosion and migration, which is the current plan, as reviewed by GeoEngineers. The County plan for breaching and vegetation planting on the existing levee is similar to what West described as &quot;maintaining&quot; the levee by keeping an erosion resistance land feature in place to limit meandering. Both the West and GeoEngineer reports indicate that channel migration resulting from increased bank erosion is low, especially if the project &quot;breaches&quot; the levees and does not wholly remove the levees.</td>
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**Smith Island Levee Analysis for [the] Everett Water Pollution Control Facility and Diking District No. 5, 2007, ESA Adolfson**

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<td>The field studies conducted for this “projects” were limited to field observations, no geologic or engineering investigations were conducted (such logging test pits or borings).</td>
<td>Comment noted.</td>
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<td>However, the data collected for the model was conducted at a time of low river flow, where ground water base flow was the primary source of water. The Weather Underground indicates that there had only been 2.07 inches of precipitation in the Marysville area from July 1 – October 27, 2006 and the bulk of the Cascade Range snowmelt would be gone by October 12, 2006. This suggests that the salinity and tidal currents observed in the distributary channels and the Snohomish River mainstream may be skewed because these readings were taking at a time of low river flow (base flow conditions).</td>
<td>The Battelle report states that the modeling was used to simulate tidal inundation, tidal currents, and salinity intrusion, and the period of data collected is sufficient for the intended analysis. Periods of higher river flow will have lower salinity due to freshwater inflow, and less influence from the higher salinity coastal waters and groundwater.</td>
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<td>Yang and Khangaonkar focus on erosion (bed shear stress) and not sediment build up, which can eventually lead to increased erosion potential and channel meander. Additionally, although bed shear stress will influence channel depth and undercutting of river banks, the lateral stress in the channel flow can affect bank morphology, including the creation of side channels and other fluvial geomorphologic changes in the channel morphology. Regardless, Yang and Khangaonkar suggest that the hydrologic conditions in the Union Slough will change if the proposed Smith Island restoration project is conducted as planned.</td>
<td>The Battelle modeling results and findings indicate that changes in Union Slough are most likely to occur in high velocity and high shear stress areas, which are predicted in and around the upstream and downstream breach areas, and that scour and erosion should be anticipated in those areas. The Battelle report indicates that changes in river channel (Union Slough channel) morphology are complex and that localized adjustments may occur. The Battelle report specifically states &quot;Based on predicted bed shear stresses, significant sediment erosion or deposition in the main river channel and distributary sloughs would likely not occur as a result of restoration projects. However, small scale, localized changes in river morphology may occur near dike breach areas.&quot;.</td>
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<td>As with other reports SNR reviewed, Yang and Khangaonkar suggest that the study area is located in an estuary however, as previously discussed, this area is not geologically an estuary, it is a prograding river delta with meandering distributary channels and a mainstream channel that form the typical dendritic delta channel morphology. SNR is unaware of any geologic studies that have been conducted in this area that would suggest that an estuary is present this far inland on relatively large prograding delta complex.</td>
<td>Pritchard in his 1967 report &quot;What is an estuary; physical viewpoint. Pp 3-5, G.H. Lauf (end), Estuaries&quot;, defines an estuary as &quot;An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage.&quot; In this case is the estuary influence of sea-water, brackish water and tidal effects are found along the distributary channels of the Snohomish River, including Union Slough and the adjacent marshes in the River Delta, all of which have open connections with the Puget Sound, and all of which have measurably diluted water (brackish) resulting from river flows. Shipman (2008 - Geomorphic Classification of Puget Sound Near shore Landforms) describes this overlapping as estuarine &quot;river&quot; deltas in which marine influences (salinity and tides) extend significant distances upstream (into the river delta).</td>
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On page 2-4 Yang and Khangaonkar state:

The Snohomish River inflow for the study period was obtained from USGS gauge (Station 12150800) near the city of Monroe at RM 25. The river-flow time history during the study period of 2006 is plotted in Figure 2-5. The river flow in October 2006 was generally in the range of 1,700 to 7,000 cfs. Quilceda Creek is a very small tributary entering the study domain from the high marshland north of the river mouth. The average annual flow of the creek is in the range of 10 to 12 cfs. Because the stream flow is small and is much further downstream of the study area of interest, a constant river flow of 10 cfs was used in the model setup.

There are other streams and rivers that form confluences with the Snohomish River downstream of the “Monroe” gage. The Pilchuck River forms a confluence with the Snohomish and the flow in this river is much higher than 10 cfs. However, there is no stream discharge and stage data for the Pilchuck prior to 2007. Between October 18 and 27th, 2009 (USGS gage 12155300 – Pilchuck River, near Snohomish) the discharge on the Pilchuck River ranged from approximately 900 cfs to 3,000 cfs, suggesting that the Pilchuck River can contribute a significant amount of flow to the Snohomish River.

On page 4-28 of the Battelle report states that the modeled increase in tidal flows are due to the large restoration area relative to the small river cross section of Union Slough. The approximately 340-acre restoration area allows for additional storage capacity for tidal fluctuations and floodplain attenuation during high river flows.

On page 4-29 Yang and Khangaonkar state:

However, tidal flows would increase significantly at Station U1 because of a large increase in the tidal prism and water storage when both Smith Island and Union Slough sites are restored. The percentage increase in tidal flows for the restored conditions would be 91.1% relative to existing conditions (Table 4-3).

A 91.1% increase in tidal flows is significant under base flow conditions; however, it is unclear what will happen during a 1% storm event, which, as previously discussed, can occur more frequently than 15 year events.

The Battelle report states on page 1-4 that the objective of their study is to develop a 3D hydrodynamic model covering the entire Snohomish River Estuary and Possession Sound using a finite-volume, unstructured coastal-circulation model. Not having worked for Battelle, I can only assume that the influence of Quilceda Creek may be more significant in their circulation model configuration, than the addition of the Pilchuck River (and other tributaries) to the flows of Snohomish River.

Regardless, the USGS data for the Snohomish River and Pilchuck River from October 2007 (the first year available after 2006) shows that the flow volumes contributed by the Pilchuck River for the month of October are approximately 4% of the flow in the Snohomish River and are insignificant relative to the scale of the study area in the Battelle study, which is also evaluating tidal flows and focusing on a time period when tidal flows are dominant. Detailed analysis of river flows has been provided in other reports such as the Tetratech Union Slough Hydraulic study (2013) and the GeoEngineers/WEST 2011 study.

The 2007 Battelle report states that tide stages were used from NOAA’s National Oceanic Service for three locations (Glendale, Sand Point, and Kayak Point) at open boundaries as required for simulating tidal circulations. As described in the Battelle report, field measurements of stage were collected at mooring stations and used to calibrate modeled water surface elevations, which provided an accurate representation of field measurements as shown in Figure 3-4 and Table 3-1 in the Battelle Report.

Additional measured stage data is being collected for Union Slough as of 2013.

The location of the updated Smith Island setback dike alignment is approximately 900 feet from the location shown in the Battelle report at the farthest point. The distance is relatively insignificant compared to the Puget Sound region modeled in the Battelle 2007 study. Additional detailed studies have used the updated proposed setback dike alignment since the Battelle report, such as the Tetra Tech Union Slough Hydraulic Study.
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<td>9</td>
<td>On page 4-40 Yang and Khangaonkar state: Velocities inside the Smith Island project site are measurable during high tides because of tidal wave propagation through the large area of dike breaches. Velocities in the restored slough in Smith Island are strong, especially during low and ebb tides (Figures C-1 and C-4). Velocities in the Union Slough restoration site are generally small because of shallow water depths and relatively small incoming tidal flows. This suggests that the conditions for the proposed Smith Island restoration cannot be directly compared to those for the City of Everett Union Slough restoration.</td>
<td>The Smith Island Estuary Restoration and the Union Slough Restoration site differ in regards to factors such as the size of the projects and the interaction of Union Slough with the respective restoration areas. The two projects are similar in regards to their geographic locations and the flow characteristics of Union Slough.</td>
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<td>10</td>
<td>On page 4-40 Yang and Khangaonkar state: Inside the Smith Island Project site, high bed shear stresses are observed during ebb tides near the entrance of the restored slough channel and the upstream end of the dike breach where Union Slough bends rapidly towards the east (Figure C-6). Potential erosion is likely to occur in these areas because of high velocities and bed shear stresses. Bed shear stresses within the Union Slough project area are generally small, with slightly higher values around the dike breach locations. No major erosion would be expected within Union Slough project site. Changes in river channel morphology would be complicated in Union Slough because of the complex changes in bed shear stress distribution. Potential localized adjustment of channel morphology may occur in Union Slough after the Smith Island and Union Slough restoration projects. Further analysis of geomorphologic changes in the river channel may be conducted by morphology experts based on the model results. Because the Yang and Khangaonkar model only focuses on bed shear stress, it apparently does not consider other fluvial geomorphologic features such as the blind tidal channels and the effects the breaches may have on these channels (the setback levee configuration used by Yang and Khangaonkar is west of Tidal Channel B).</td>
<td>The Battelle - Puget Sound hydrodynamic 3D model was used to identify areas where higher shear stresses may occur resulting from the levee setback project(s), for which the comment refers to the high bed shear stresses near the levee breaches. The model does have information on tidal channels, as there are several historical tidal channels in the marsh restoration area that were included in the model. The modeling results indicate that there are not significantly high shear stresses occurring away from the breach areas, which indicates that significant erosion will not occur in these existing channels. It is anticipated that additional channels will develop and reestablish in the marsh restoration area. These channels were not explicitly modeled primarily because they will be smaller channels and are smaller than the resolution of the hydrodynamic modeling grid. The volume of water in these channels (i.e. the energy for erosion) is small compared to the overall marsh restoration area and volume of the tidal prism flowing to the restoration area.</td>
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<td>11</td>
<td>Additionally, the model is still based on existing conditions from October 12–28, 2006, which are believed to be base flow conditions. It is unclear what will happen during a 1% storm event.</td>
<td>The stated objectives from the Battelle report is to model the propagation of tidal waves and circulation for the existing and proposed restoration alternatives. The Tetra Tech Union Slough Hydraulic Model Study modeled large flood events for the restoration conditions. The existing levees are below the Base Flood Elevation (1% Annual Chance) and the setback dike will be built to a higher level of protection (the Base Flood Elevation).</td>
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On page 5-2 Yang and Khangaonkar state:

Changes in river channel morphology would be complicated in Union Slough because of the complex changes in bed shear stress distribution. Potential localized adjustment of channel morphology may occur in Union Slough after the Smith Island and Union Slough restoration projects are implemented. Yang and Khangaonkar focus on the shear stress distribution, however, they do not factor in what happens in areas where the velocity drops, such as the areas between the two breaches for the proposed Smith Island restoration project.

The Battelle report does address the potential changes in shear stress distribution between the breaches and states that changes in river channel (Union Slough channel) morphology are "complex" and that localized adjustments may occur. The Battelle report specifically states "Based on predicted bed shear stresses, significant sediment erosion or deposition in the main river channel and distributary sloughs would likely not occur as a result of restoration projects. However, small scale, localized changes in river morphology may occur near dike breach areas." The County has planned to monitor the Union Slough channel between the breaches including bathymetric survey to document changes in channel conditions, and possibly dredging if future impacts are observed.

In areas where channel velocity drops, sediment load capacity also drops, which typically results in sediment deposition in these areas. This combined with the higher velocities associated with the predicted higher shear stress by Yang and Khangaonkar would typically suggest that the channel morphology will change to meet the new hydrologic and sedimentary conditions.

The County has performed additional hydrodynamic modeling subsequent to the Battelle hydrodynamic model to evaluate localized flow patterns from large wood debris placement and tidal channel excavation and blockages planned at the restoration site. This modeling shows that these features affect localize flow patterns in the marsh restoration area and do not affect large-scale hydrodynamic flow patterns, velocities and shear stresses in Union Slough and other areas.

Although the setback levee location has changed since this model was conducted, the proposed location of the breaches has apparently not changed (based on SNR’s review of the other documents in Tasks 2 and 3). This suggests that this high shear stress may be located where the setback levee will now be located. It is unclear what the shear stress will be with the current proposed setback levee location or what the shear stress will be during a 1% storm event, however, the West modeling for the Pipeline (April 11, 2007) document prepared for CH2M Hill suggests significant scour will occur.

The County has performed additional hydrodynamic modeling to evaluate the revised levee setback alignment and restoration plans. The revised model shows (similarly to the original models) that the areas of highest shear stress and potential for erosion occur at or near the levee breach locations.

It is unclear why Yang and Khangaonkar did not simulate higher river flow conditions obtain model information on how higher flows will affect the shear stress. However, it appears that they wanted to limit the model to the information they had rather than changing parameters to meet a designed flow event.

The purpose of the Battelle study was to develop the hydrodynamic model for tidal circulation based on the collected data. The Tetra Tech Union Slough Hydraulic Study presents additional detail of the hydraulics during a large flood event for the Smith Island project.

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<td>On page 5-2 Yang and Khangaonkar state: Changes in river channel morphology would be complicated in Union Slough because of the complex changes in bed shear stress distribution. Potential localized adjustment of channel morphology may occur in Union Slough after the Smith Island and Union Slough restoration projects are implemented. Yang and Khangaonkar focus on the shear stress distribution, however, they do not factor in what happens in areas where the velocity drops, such as the areas between the two breaches for the proposed Smith Island restoration project.</td>
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<td>13</td>
<td>In areas where channel velocity drops, sediment load capacity also drops, which typically results in sediment deposition in these areas. This combined with the higher velocities associated with the predicted higher shear stress by Yang and Khangaonkar would typically suggest that the channel morphology will change to meet the new hydrologic and sedimentary conditions.</td>
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<td>14</td>
<td>However, Yang and Khangaonkar do suggest that the Union Slough channel morphology will change if the proposed restoration projects are implemented. This is suggested because of the complex changes in bed shear stress distribution. However, as with all the other models the Yang and Khangaonkar modes does not address the proposed placement of large woody debris and grading activities that the DEIS suggests will be conducted as part of the restoration activities nor does it address failures in the remaining unmaintained levee system.</td>
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<td>15</td>
<td>Although the setback levee location has changed since this model was conducted, the proposed location of the breaches has apparently not changed (based on SNR’s review of the other documents in Tasks 2 and 3). This suggests that this high shear stress may be located where the setback levee will now be located. It is unclear what the shear stress will be with the current proposed setback levee location or what the shear stress will be during a 1% storm event, however, the West modeling for the Pipeline (April 11, 2007) document prepared for CH2M Hill suggests significant scour will occur.</td>
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<td>16</td>
<td>However, even under what are presumed to be base flow conditions, Yang and Khangaonkar found that the potential for a significant increase in localized shear stress exists if the proposed Smith Island restoration project is implemented. Additionally, Yang and Khangaonkar suggest that this increase in shear stress can lead to changes in channel morphology. Oddly, Yang and Khangaonkar did not discuss potential changes in the blind tidal channel morphology even though Figure C-5 (page C-6) shows shear stress in Tidal Channel A greater than 2 Pa during flood tide conditions.</td>
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<td>17</td>
<td>It is unclear why Yang and Khangaonkar did not simulate higher river flow conditions obtain model information on how higher flows will affect the shear stress. However, it appears that they wanted to limit the model to the information they had rather than changing parameters to meet a designed flow event.</td>
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<td>The Battelle report does address the potential changes in shear stress distribution between the breaches and states that changes in river channel (Union Slough channel) morphology are &quot;complex&quot; and that localized adjustments may occur. The Battelle report specifically states &quot;Based on predicted bed shear stresses, significant sediment erosion or deposition in the main river channel and distributary sloughs would likely not occur as a result of restoration projects. However, small scale, localized changes in river morphology may occur near dike breach areas.&quot; The County has planned to monitor the Union Slough channel between the breaches including bathymetric survey to document changes in channel conditions, and possibly dredging if future impacts are observed.</td>
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<td>See previous comments 2 and 13 for discussion about how much change is likely to occur.</td>
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<td>The County has performed additional hydrodynamic modeling subsequent to the Battelle hydrodynamic model to evaluate localized flow patterns from large wood debris placement and tidal channel excavation and blockages planned at the restoration site. This modeling shows that these features affect localize flow patterns in the marsh restoration area and do not affect large-scale hydrodynamic flow patterns, velocities and shear stresses in Union Slough and other areas.</td>
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<td>The County has performed additional hydrodynamic modeling to evaluate the revised levee setback alignment and restoration plans. The revised model shows (similarly to the original models) that the areas of highest shear stress and potential for erosion occur at or near the levee breach locations.</td>
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<td>The Battelle hydrodynamic model, and other later hydrodynamic models do indicate higher shear stresses and erosion potential in Tidal Channel A areas, which are being accounted for in the EIS and project design plans.</td>
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<td>The purpose of the Battelle study was to develop the hydrodynamic model for tidal circulation based on the collected data. The Tetra Tech Union Slough Hydraulic Study presents additional detail of the hydraulics during a large flood event for the Smith Island project.</td>
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| 10   | On page 7 TetraTech states:  
For this study, initial model results were compared to results of the unsteady HEC-RAS model (GeoEngineers/WEST Consultants, 2011), as shown in Figures 6 to 10.  
It is unclear what data TetraTech used in its model that is different from what West Consultants used in their model for the 2011 GeoEngineers report or how this data is different from the model West Consultants used in the model for the report they generated for CH2M Hill on April 11, 2007. It is apparent that TetraTech imported the data from the West Consultants HEC-RAS model for the GeoEngineers report into their RiverFLO-2D model and compared the RiverFLO-2D model output to the West Consultants HEC-RAS model output.  
Hydraulic boundary conditions were taken from the West model:  
Incoming flows to each slough (Ebeys, Union, Steamboat)  
Downstream water surface elevations (tide levels) for each slough  
The base surface was developed from bathymetry data and LiDAR topographic data with spot survey provided by Snohomish County.  
The data used by Tetra Tech is primarily the same data used in the GeoEngineers/West study. The LiDAR base map may include more spot survey data.  
The West 2007 work used older topographic and cross section data; West updated the model with 2009 LiDAR and multi-beam bathymetric survey data for modeling work conducted for the City of Everett for the Everett Riverfront project. |  |
| 11   | As discussed in this letter report, SNR has concerns with the data used in the West Engineers model prepared for the GeoEngineers 2011 report. If TetraTech used the same data, SNR has the same concerns for the TetraTech model accuracy. | Please see response to comment #10 above. And #5, #16 under the Geomorphic Characterization and Channel Response Assessment for Union Slough, 2011, GeoEngineers/West Consultants section above. |
| 12   | Additionally, if the RiverFLO-2D model is being calibrated to the HEC-RAS elevation data developed by West Consultants for the GeoEngineers 2011 report. What is the purpose of conducting the RiverFLO-2D model for obtaining discharge rates (velocity) and stage height ? | The River FLO-2D model predicts velocities and stage heights that incorporate the two-dimensional flow attributes, which provides more information, and is more reflective of the actual flow conditions at the project site. |
| 13   | Although the 2-dimensional model will provide more accurate modeling of the storage it is unclear how it will provide more accurate data for stage height than the 1 –dimensional model it was calibrated to especially if the same data used in the HEC-RAS model is used in the RiverFLO-2D model, because the resulting model output will be no more accurate than the HEC-RAS 1-dimensional model if the data used in the HEC-RAS model is not accurate. | See above response. The two models use different approaches to calculating the velocities and stage heights. The 2D model will better represent the complex flow patterns present in the project vicinity. |
| 14   | On page 10 TetraTech states:  
The 100-year hydrographs and tidal boundary conditions were extracted from the existing FEMA modeling at the same locations and using the same methodology described above for the January 2009 storm.  
This does not provide a date for the existing FEMA modeling. It is presumed that this is the UNET hydraulic model West Consultants conducted for FEMA in 2001 for the Snohomish River below Monroe (FEMA Flood Insurance Study in 2001). As discussed in this letter report, the GeoEngineers 2011 report states: “The Snohomish River and delta have experienced 100-year floods at intervals of three to ten years (Snohomish County, 2005)”. This suggests that either the Hydrographs that were developed for the 100 year events are inaccurate or the 100 year storm event isopluvial maps developed by the NOAA are inaccurate. | The model date was 2007, as described in a memo from Ray Walton, West Consultants to Vaughn Collins, Snohomish County, dated June 29, 2007.  
Comment noted on the recent frequency of 100 year events. |
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<td>Regardless, the accuracy of the 1% hydrographs is dependent on many factors and FEMA maps are known to have inaccuracies, such as the map for the Pilchuck River that “missed” 4,200 feet of levee section (northwest boundary of French Slough, West Consultants, June 29, 2007). Additionally, King County filed challenge studies for most of the FEMA 2005 PFIRMs due to significant inaccuracies on multiple rivers including the Green and the Snoqualmie; the Snoqualmie River is one of the two rivers that form the Snohomish River.</td>
<td>Comment noted. Potential issues with FEMA maps were beyond the scope of questions addressed by the Tetra Tech modeling work.</td>
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<td>16</td>
<td>It is unclear where the actual data for river discharge and stage elevations in the Union Slough used in the HEC-RAS or RiverFLO-2D models came from and how accurate this data is.</td>
<td>The County has the LiDAR and bathymetric data. The City of Everett owns the stage elevations. Flow data is housed with the USGS.</td>
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<td>17</td>
<td>Figure 11, Page 11 of the TetraTech document indicates much higher flows in Ebey Slough than Union or Steamboat Slough. However, the Battelle report (Page 3-16), which used the 3-dimensional model suggests that the Union Slough has the second highest flows of the channels (second to the Snohomish River mainstream). Velocities at Steamboat Slough were smaller than that in the main channel (Figure 3-5) but significantly greater than Ebey Slough and Union Slough (Figure 3-6), indicating that Steamboat Slough is the second largest tributary carrying the Snohomish River flow into Possession Sound. It is unclear why the TetraTech 2-dimensional model suggests that the flow in Ebey Slough is significantly higher than Steamboat Slough (this should have been discussed).</td>
<td>Figure 11 in the Tetra Tech report displays flows (vol/time) at the upper boundary of the model whereas the Battelle report discusses velocities on p. 3-16. The hydrograph in Figure 11 is taken from the effective FEMA model. It is not known why the Battelle report makes the statement “indicating that Steamboat Slough is the second largest tributary” in the context of discussing relative velocities between the sloughs.</td>
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<td>18</td>
<td>On page 12, TetraTech states: 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. This assumes that the FEMA 1% flood elevations (Base Flood Elevations) are accurate. The source of this data, the date this data was generated, and how this information was generated is unclear. The Battelle modeling activities we based on data collection that was conducted for the period of the study wherever possible. However, Battelle knew that the high flow data would have large potential errors because the only gage that provides data on discharge and stage height for the timeframe of the model was the USGS gage near Monroe. This was not a major factor for establishing existing conditions for the period modeled because the Snohomish River and the sloughs were at or close to base flow conditions.</td>
<td>The effective FEMA model establishes floodplain regulation for flood insurance and building code purposes. It is the only recognized flood level prediction for the 100-year flood (FEMA base flood) that we know of. Since calibration data is not available for the 100-year flood, Tetra Tech determined that this was the appropriate comparison to make.</td>
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<td>19</td>
<td>The accuracy of the TetraTech data is unclear, especially when the model output they generate appears to contradict the model output that Battelle generated (for the Steamboat Slough v Ebey Slough).</td>
<td>See Item 17 above.</td>
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<td>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 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. As SNR has indicated, it is unclear how GeoEngineers developed bed shear stress thresholds considering it did not conduct any geologic studies (including test pits and borings) to determine what sediments are actually present and the cohesiveness of these sediments (nor was any laboratory testing conducted on the soils or sediments). The October 7, 2007 ESA Adolfson report (page 29), states: Underlying these surficial [fill] soils, previous borings reveal approximately 22 to 30 feet of deltaic and flood plain deposits consisting of soft, compressible organic silt and sandy silt, including distinct fibrous peat deposits and buried logs and stumps. These upper organic-rich silt deposits are, in turn, underlain by medium dense to dense sand and gravel that extend to considerable depth. The GeoEngineers/West report also notes that a comparison on I-5 bridge as-built with the 2009 channel bathymetry indicates no observable change in channel floor elevation in more than 40 years. The Tetra Tech model study did not include a separate geomorphic assessment, and utilized the geomorphic interpretations made by GeoEngineers in the 2011 study.</td>
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<td>Additionally, Bailey’s 2012 studies that included the logging of test pits and conducting borings that included the use of a standard penetrometer, suggest that the deposits described in the ESA Adolfson report are also present in the proposed restoration area. These deposits do not exhibit the characteristics that would be expected for highly cohesive materials. Additionally, Bailey indicates that the organic silt and sandy silt (with peat deposits) ranges from 9 feet to approximately 20 feet deep, which suggests that the Union Slough could be intercepting the water bearing sands that are located beneath the organic silts and sandy silts (and peat deposits). As discussed in Item 20, erosion thresholds recommended by GeoEngineers (2011) were represented in model output figures. These corroborate with observed areas of erosion under existing conditions. Lower threshold values could be used if a more conservative approach is desired.</td>
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<td>Flow velocity and shear stress are suggested indicators of inducing erosion; however, the deposition of sediments also increases the potential for erosion. If the velocity of water in a channel drops, the sediment load capacity drops and sediments will be deposited. This can result in channel narrowing and an increase in velocity where this channel narrowing occurs. Every model SNR reviewed indicates that if the proposed levee breaches occur, the channel velocity between these two breaches will drop because the Union Slough will be reconnected with its floodplain. Comment noted. However, if deposition results in a narrower channel, and then the narrower channel causes higher velocities (during high flow periods), then during higher velocity periods, the deposited sediment will erode (at least partially). This is how a stream is constantly working toward its equilibrium.</td>
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<td>Regardless, it is unclear how GeoEngineers established maximum shear stress values and velocities for the Union Slough without conducting field activities that include test pits and borings (as Bailey did and apparently Golder has in the past) and laboratory data on the characteristics of the sediments and soils along the portion of the Union Slough that will be affected by the proposed Smith Island restoration activities.</td>
<td>See Item 20 above.</td>
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<td>24</td>
<td>The modeling shear stress and velocities was apparently only conducted for the January 2009 event and not the predicted 1% flood event (TetraTech does not discuss what flows they are referencing in the statements above). However, the data in the 2-dimensional model was calibrated to the HEC-RAS 1-dimensional model prepared by West Consultants for the GeoEngineers 2011 report.</td>
<td>It is correct that the shear stress and velocities were presented only for the January 2009 (approximately 15-year flow). These parameters are available for the 1% flood event, and could be presented if desired. However the model is not calibrated for the 1% event, which is why shear stress and velocities were not reported in the document. The 2D model was not calibrated to the 1D model; rather the 1D model was compared to the 2D model as part of the model validation.</td>
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<td>The 2011 West Consultants model apparently used the same base data that was used in the Channel Migration and Scour Evaluation, Everett Delta Natural Gas Pipeline/Smith Island Restoration, Snohomish River, Washington, April 11, 2007, prepared by West Consultants.</td>
<td>The West 2007 work used older topographic and cross section data; for the 2011 work, West updated the model with 2009 LiDAR and multi-beam bathymetric survey data for modeling work conducted for the City of Everett for the Everett Riverfront project. (See GeoEngineers/West, 2011, Appendix A, p. 1) The more recent work also utilizes the 2009 flow series, based on monitoring data for the Everett Riverfront project.</td>
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<td>Since the same data was apparently used in both models, it is unclear why the predicted shear stress and scour would be significantly different in the 2011 GeoEngineers report than the shear stress and scour presented in the model West prepared for the April 11, 2007 report. The 2007 modeling West Consultants conducted for CH2M Hill is not considered by TetraTech or even discussed.</td>
<td>See item 25 for differences in data used for model. Regarding differences in reported shear stress and scour: No scour analysis was done for the 2011 GeoEngineers/West study or for the 2013 Tetra Tech study so a comparison can not be made with the 2007 West study. Shear stress results were not compared between the three studies, but are not dissimilar - the 2007 West report states a shear stress of 0.2 lb/sq. ft for Ebey slough for the 100 year flood. The shear stresses modeled in the 2013 Tetra Tech work range from nearly 0 to 2.1 lbs./sq. ft, depending on location within the channel, for the 15-year flood.</td>
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<td>As previously discussed, the GeoEngineers report suggests that 1% storm events occur more often than 15 year events and each 1% event would technically generate similar scour results presented in the April 11, 2007 West Consultants report. Therefore it is unclear what is gained by TetraTech conducting the 2-dimensional modeling, especially when the data used in the model is not validated (as Battelle did). Battelle suggests that the second greatest flows in this portion of the Snohomish River delta is the Steamboat Slough, however, TetraTech suggests that the Ebey Slough has the greatest flows (by far).</td>
<td>See above responses for comment about use of validated data. See item 17 for response to comment regarding discrepancy between Tetra Tech and Battelle portrayal of relative size of Ebey versus Steamboat Slough.</td>
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<td>High flows on the Snohomish River are apparently not that infrequent. As SNR has indicated the purpose of the levees was to prevent seasonal flooding and to prevent channel migration. Maintained levees will prevent channel migration, however, once the levees are removed, these controlling structures no longer prevent levee migration (meander). Also, the type of sediment load in the Union Slough reach is unknown, SNR has not reviewed any document that includes studies of the sediments in the Union Slough bed or that are being transported by water. Additionally, the higher the velocity of the flow, the coarser the sediment load will be; this is fluvial geomorphology 101.</td>
<td>The coarseness of the sediment load is determined by the grain size of particles delivered to the channel, although it is true that higher flow velocities will have the ability (competence) to transport larger particles if they exist. Comment noted that sediment sampling has not been done in Union Slough. Based on dredging done by the Corps of Engineers in the lower Snohomish mainstream, it is expected that this reach is transporting mainly fine to medium sand as a maximum bed load grain size.</td>
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<td>29</td>
<td>Any decrease in the channel flow, especially at bends, can result in sediment deposition. In fact the other models do predict sediment deposition, e.g., Battelle (2007) and West Consultants (2007), including sediment deposition in the proposed restoration area.</td>
<td>The 2013 Tetra Tech study also predicts some sediment deposition.</td>
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<td>30</td>
<td>The Bailey 2012 studies indicate that the water bearing sands are located within 9 feet of the surface near the Union Slough channel. It is feasible that these sands are exposed in the Union Slough bed and this water bearing sand provides base flow for the Union Slough during the late summer and early fall months. High velocity flows can move these sands and redeposit them in areas where the channel velocity drops. SNR has not seen any studies that characterize the sediments in the Union Slough for any reach, based on actual studies that include borings, test pits, sample collection, and laboratory analysis.</td>
<td>If the water bearing sand layer described in Bailey 2012 is connected to Union Slough, this condition would not be changed by implementing the restoration project.</td>
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<td>31</td>
<td>Additionally, wind driven waves (fetches), high velocity flow, and the diversion of flood waters inside the remaining unmaintained levee system will cause erosion, underflow, and other conditions that will eventually remove the remaining unmaintained levees. TetraTech does not address this nor do any of the other models SNR reviewed address this (none of the models were conducted with no levees remaining or with failing unmaintained levees). Also, what will happen to the sediments eroded from the remaining levee sections?</td>
<td>The fate of the remnant levee sections was not evaluated in the Tetra Tech 2013 model study. Subsequent project design work indicates that the remnant levee sections will be stabilized as upland habitat features. If the remnant levees (or sections of them) do erode, the eroded sediment would likely redeposit adjacent to the remnant levee, in a quiet water portion of Union Slough, or be flushed out of the slough, depending upon the hydraulic setting and location.</td>
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<td>32</td>
<td>TetraTech does not discuss why its modeling results are different from the Battelle studies or from the West Consultants studies conducted for CH2M Hill (2007) or why the TetraTech model provides more accurate model outputs than these other models that were previously conducted, especially when it appears that TetraTech used the West Consultants data in its model. The West Consultants 2007 model for CH2M Hill suggests 10 – 20 feet of scour could result from a 100 and 500 year flood event; TetraTech suggests that erosion will be minor and can be addressed with bank protection.</td>
<td>The model results from the three studies are consistent. As discussed above, the Battelle model evaluated different flow conditions (low versus high), and focused on tidal prism effects (it is an ocean model). The West modeling work utilized HEC-RAS, a 1-D river model. The Tetra Tech work utilized a 2D model to generate more detailed results that accounted for the complex flow patterns at the project site and nearby areas. Scour was not evaluated in the Tetra Tech or GeoEngineers/West 2011 study.</td>
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<td>However, this does not apply to the proposed restoration area where channel migration caused by erosion and the removal of the remaining unmaintained levees by erosion is a concern because none of the models were run with the remaining levees being removed by erosional processes that will be accelerated by having flows on both sides of the levees. Additionally, SNR has not reviewed any document that addresses the potential for the remaining levees to erode after the levees are breached.</td>
<td>The fate of the remnant levee sections was not evaluated in the Tetra Tech 2013 model study. Subsequent project design work indicates that the remnant levee sections will be stabilized as upland habitat features. If the remnant levees actively erode, the eroded sediment would likely redeposit adjacent to the remnant levee, in a quiet water portion of Union Slough, or be flushed out of the slough, depending upon the hydraulic setting and location.</td>
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<td>The general concepts and interpretations in this report are based on relatively sound fluvial geomorphologic and hydrologic principals, although some of the information is dated, such as the proposed location of the setback levee and a suggestion that the remaining existing levee will be maintained after the breach (this is the only report that discusses this).</td>
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<td>As with all of the reports SNR reviewed for Tasks 2 and 3, the West Consultants studies did not factor in the completed proposed mitigation as described in the DEIS nor did the model factor in failing unmaintained levees that will remain after the breaches have been conducted. The addition of large woody debris and the proposed grading activities that will change the existing farmland geomorphology are not factored into the model. All levees designed to protect adjacent property will continue to be maintained after construction. The remnant dike within the restoration area between breach areas does not protect adjacent properties and is located on the inside of a bend where channel velocities are lower. The referenced study indicates lower Union Slough channel velocities due to the Smith Island project in the reach adjacent to the project site and the condition of the remnant dike is relatively insignificant, as are the large woody debris structures to hydraulic models covering the 340-acre restoration area.</td>
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<td>This report is the only report SNR reviewed that relatively accurately depicts the 1869 Land Office survey of this area. It also discusses the changes in the surface water hydrology, such as the filling of the connector channel between the Snohomish River and the Union Slough and actively discusses the blind tidal channels. This report also discussed the issues with decreases in the velocity of the water in the channels which will result in sediment deposition which will lead to bed filling, sand bar formation, and other fluvial geomorphic changes along this segment of the Union Slough (this distributary channel has been “protected” with levees for a long time (at least 100 years based on SNR’s research) and in the other distributary channels (this report indicates that Union Slough and Steamboat slough are expected to have similar fluvial geomorphic changes). We agree that the National Geodetic Survey Map with the 1869 Survey is useful information. The WEST 2007 Study describes the limitations of this data and the channel migration analysis including any inaccuracies in the 1869 survey and mapping, human influence (i.e. fill placement) on the river banks during the 150 years, and the alignment of aerial images. We also agree that the Smith Island project will result in reduced channel velocities and overbank storage in this reach of Union Slough, including the deposition of overbank sediment, which are natural floodplain functions. As noted in the WEST 2007, the breaching of levees will increase overbank sediment deposition.</td>
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<td>The West document states (page 3): In general, the proposed and specific restoration measures involve breaching of existing dikes and construction of new dikes to protect adjacent infrastructure. The project is intended to restore natural habitat-forming processes for proper ecosystem function over the long-term. This includes side channel formation, channel migration, and wood recruitment. This suggests that side channel formation, channel migration, and wood recruitment (which can induce channel meander) are the goals to restore “natural habitat-forming processes”. These processes will only have one direction to go considering the right bank of the Union Slough will still have levees present. It is also unclear how the proposed breaches will affect the existing breaches on the right bank of the Union Slough. The processes described are generally for the responses and processes anticipated in the marsh restoration area (such as tidal channel erosion and migration and wood recruitment in the marsh). Currently, Spencer Island, east of the south end of the Smith Island site, has been breached and is directly east of the project site. The Southern Tip of the Biringer Farm / Blue Heron area east and north of the Smith Island site has existing levee breaches and the remainder of the site is planned for breaching and restoration in the next few years. Channel migration and erosion soil channel response will be varied. It is noted that Spencer Island and the south area of Blue Heron have been breached for some time now, and there there is little (or no) evidence of major channel erosion and migration resulting from these breaches.</td>
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<td>The West document states (page 4): As seen from Figure 10 and Table 2, the observed migration distances are relatively minor over the 120 years of record. In general, no significant migration occurred beyond any existing levee. The project area has generally low hydraulic energy gradients that are strongly controlled by tidal base level. The construction and maintenance of the levee system tightly confined the river channels, practically limiting significant movement. It is also recognized that dredging and large woody debris removal have been on-going activities throughout the period of record (Haas and Collins, 2001). West recognizes that the levee system, combined with dredging and the removal of “snags” (woody debris) is what has prevented the Union Slough and other channels in this area from meandering. SNR’s historic research (HistoryLink.org) strongly suggests all of the distributary channels have been dredged and have had “snags” removed to allow navigation on these channels. Additionally, deepening the channels made the levees more effective during high flow events because the channels had more capacity for high velocity flow within the levee system. However, dredging also has an effect of “entrenching” the channel in deeper sediments, making channel meander less likely. Evidence prior to levee construction (i.e. the 1884 T-sheet survey map) tends to indicate that channel erosion and migration rates were low as Tidal Channels A and B are in a similar condition to that when the dikes were constructed. Typically, tidal channel migration is a slow process due to the gradual deposition of fine sediment layers, low energy and low channel velocities. Major large wood debris blockages can cause avulsions and major channel migration. Union Slough however is currently maintained for navigation for Buse Timber access, and large wood debris blockages will continue to be managed and removed.</td>
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<td>The West Document states (page 5): An existing hydraulic model of the Snohomish River was used to characterize the existing hydraulic conditions of the pipeline alignment. The channel and overbank hydraulic properties needed to perform scour calculations were obtained from a UNET unsteady flow hydraulic model (USCOE 1997) developed for the Snohomish River Flood Insurance Study (WEST 2003). The UNET model represents the Snohomish River, Union Slough, Steamboat Slough, Ebey Slough, and the connector channel that runs between Ebey Slough and Steamboat Slough. The model extends from Possession Sound to well upstream of the area of interest. Unfortunately, West does not provide much information on the accuracy of the previous models nor does the document discuss the sources of the information used in the models, such as elevation data, bathymetry data, discharge rates in the different distributary channels, stage heights in the different distributary channels, tide elevations correlated to flow events, or other data. The accuracy of this data is integral to the accuracy of the model that already has some inherent accuracy issues (1-dimensional models have limitations). The WEST 2003 model was a FEMA Flood Insurance Study, and Flood Insurance Studies have a minimum accuracy equivalent to 2-foot contours, or a minimum vertical accuracy of 1.2 feet at the 95% confidence level. One-dimensional models are appropriate for riverine flow such as Union Slough and the use of a one-dimensional model does not cast doubt on the results or imply a lack of accuracy.</td>
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However, the West Consultants model in the GeoEngineers geomorphology study apparently uses the same data and the Tetra Tech model is calibrated to the West Consultants HEC-RAS model used in the GeoEngineers study. What is unclear is why the West model for CH2M Hill for the pipeline study is different from the model prepared for GeoEngineers. It is also unclear why the same data was used for each model West Consultants prepared rather than conducting the studies necessary to obtain site specific stream gage data, accurate topographic data, and accurate cross sectional data (and accurate bathymetry. It is also unclear why accurate tide data was not obtained in this area of the Snohomish River delta.

As stated in the GeoEngineers/WEST 2011 Study, the WEST UNET model was updated with 2009 topographic LiDAR and bathymetric data, and converted to HEC-RAS. Tide data was collected from the nearby Everett Riverfront Project in 2009. Updated data was used in the GeoEngineers/WEST 2011 model, and the two studies have different stated objectives (Impacts of Scour depth near the Gas Pipeline in the WEST 2007 report, versus shear stress and stream power for Union Slough in the GeoEngineers/WEST 2011 report).

The West document states (page 6):

Scour along the channels in the Snohomish River estuary can be caused by floods, local scour around debris, channel migration, tides, or a combination of these factors. Scour potential due to floods can be reasonably estimated based on empirical relations. Local scour due to debris and channel migration are generally unpredictable for a specific location. Similarly, the formation of blind tidal channels may be due to a combination of flood impacts and tidal effects. Consequently, estimates of scour cannot be specific. Use of empirically-based equations that define envelope curves around a range of scour observations for similar conditions, coupled with appropriate margins to account for uncertainty is considered the most reasonable approach to estimating potential scour depths.

As previously stated, models cannot accurately predict channel migration nor can the accurately predict scour. The models can estimate scour based on the parameters entered into the model. However, as with any fluvial system, especially in a delta, there are countless variables that cannot be predicted and therefore models only provide generalized trends, such as drop in channel discharge rates where the proposed breaches are made.

Scour analysis does have a level of uncertainty, however there are tools available to the designers for evaluating scour in and around the pipeline crossing the project. First, there are multi-dimensional hydrodynamic models that have been evaluated for the project that can be used to estimate scour from shallow marsh flows and flows in tidal channels and tidal channel elongation in and around the pipe. These flow conditions have much lower energy potential for scouring around the pipeline. Estimates for these type of scour are being evaluated. Second, the project design has the ability to limit scour by thoughtful design of the breach, the tidal channels and the pipeline protection measures. To date the following types of scour protection measures are under development in the project design: 1) limit the eastern breach such that scour occurs primarily at the breach and not in tidal channels near the pipeline 2) fill and block ditches that might elongate towards the pipeline 3) build protective measurements such as buried rock windrows that would cutoff tidal channel elongations along the entire length of the shallow pipeline at the site, 4) consider filling and grading above the pipeline to promote drainage away from the pipeline to designated tidal channel drainage areas. These design concepts are presented in further detail in a Design Letter Report: Setback Levee Erosion Protection Recommendations Rev. Oct. 2013.

We agree that the Smith Island project will provide additional floodplain storage, which provides the benefit of attenuating flood peaks. The Battelle report indicates increased discharge rates downstream of the project due to tidal momentum, but reports do not support the comment regarding increased stage height downstream of the Smith Island project. This comment does not provide any specific reason for predicting tidal stage to be higher within the channel. In addition, the Tetra Tech Union Slough Hydraulic Study (May 2013) finds potentially erosive velocities similar to existing conditions downstream of the project site but that flood levels are lowered by 1 to 2 feet in Union Slough near the I-5 bridge after construction of the Smith Island project due to flood peak attenuation. The constriction downstream of the project site where erosion may occur will be monitored and maintained as necessary to protect the existing levee.
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| 10   | The West document states (page 7):  
The calculated estimates of scour depths that are reported are the result of the equation that yielded the greatest scour depth. In general, estimated scour depths are 10 to 20 feet.  
It should be noted that the West studies were focused on bed scour, not bank scour and undercutting. The primary reason for these studies was to determine if the pipeline would be exposed by channel bed scour, although potential channel meander is considered for the areas where the pipeline is shallower (the areas behind the existing levees). | Comment noted. The comment does not identify a specific issue as it relates to the Environmental Impact Statement. |
| 11   | It is unclear why Tetra Tech did not discuss this model in their November 2012 report and why Tetra Tech does not discuss why they predict very little scour and West Consultants who apparently used the same model data (hydrology, bathymetry, topography, etc.) predict significant channel bed scour. Interestingly, although Yang and Khangaonkar did not model for 100 and 500 year events, their model also predicted high scour potential in the Union Slough. | The WEST 2007 report uses conservative scour equations to estimate scour depths for the peak of the 100-year and 500-year flood event within Union Slough to determine any potential impacts to the pipeline, and finds essentially no change from existing conditions for the Smith Island project (page 8). The Tetratech report evaluates spatially-distributed erosion potential along Union Slough using bed shear stress criteria from the GeoEngineers/WEST 2011 study. The Tetratech 2012 and GeoEngineers/WEST 2011 reports find that both the existing condition and the Smith Island project condition velocities indicate potential for erosion along Union Slough, with a localized increase in velocities of a few feet per second possible at a location downstream of the site. The Battelle (Yang and Khangaonkar) 2007 study presents velocities and bed shear stress and indicates that localized adjustment of channel morphology may occur near Smith Island, but the study did not predict scour depths and does not support the statement made about high scour potential. The studies generally found localized increases in velocities of several feet per second during ebb tides immediately downstream of the project and at breach entrances, and found lower velocities and bed shear stresses at other locations along Union Slough near the Smith Island project area. |
| 12   | The West document states (page 8):  
In general, channel migration is a natural characteristic of all geologically unconfined watercourses formed in transportable sediments. Typically, the type, magnitude, and rate of channel migration are reflective of a dynamic equilibrium that is characteristic of the involved geomorphic setting and channel type. The magnitude and rate of channel migration reflects changes in hydrology, hydraulics, and sediment transport. Such changes may occur due to both natural and man-made influences. Because the pipeline is installed entirely underground at a depth designed to not be exposed by scour, the pipeline will not affect the hydrology, hydraulics, or sediment transport characteristics of the involved watercourses.  
As West points out channel migration is a characteristic of all watercourses formed in transportable sediments, especially in areas where there is a relatively low topographic gradient. This is a component of sinuosity and the fluvial geomorphology of low gradient rivers that fall within the meandering classification. The sinuosity of the distributary channels, Ebey, Steamboat, and Union Sloughs would place them in the meandering fluvial geomorphologic channel classification. Channel meander is channel migration. | Comment noted. The comment does not identify a specific issue as it relates to the Environmental Impact Statement. |
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<td>It is unclear why GeoEngineers and TetraTech disagree with this fundamental principal of fluvial geomorphology and why they believe that a meandering distributary channel such as the Union Slough would not resume meandering once the channel is no long constrained by a maintained levee system.</td>
<td>The morphology of the area indicates that it is primarily a tidal channel morphology versus a river meander morphology. Historical maps, pre-dike construction, show a similar channel pattern as today. None of the work states that no migration is expected, but rather that major channel pattern changes are not expected.</td>
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<td>14</td>
<td>The West Document states (page 9): Under natural conditions, overbank sediment deposition would occur during floods and bed load deposition within channels would cause them to shift laterally. However, the existing channels are leveed which artificially increases stage and velocity, confines floods of low return periods, limits the ability for overbank sediment deposition, and generally mutes the potential for dynamic change. It is noted from the channel elevation data presented in Table 1 that significant changes in the minimum elevation of the involved channels do occur. In fact, dredging of the mainstream Snohomish River is conducted for maintenance of a shallow draft navigation channel. Again West is citing fundamental fluvial geomorphologic principals however, neither GeoEngineers or Tetra Tech discuss fluvial geomorphology or why a meandering distributary channel will not resume meandering when it is no longer constrained by a levee system. Once the channel has access to its floodplain there will be a change in the fluvial dynamics that will result in sediment deposition, the ongoing failures of the remaining unmaintained levee system and eventually, resumed channel meander. However, what is more important is how these changes will affect the navigability of the Union Slough and none of the models address this.</td>
<td>The Tetra Tech report does discuss the potential effects of sedimentation and erosion (Appendix I of the FEIS) and their analysis reflects that of Battelle's analysis that localized sedimentation and erosion is expected, but not to the degree to significantly impact navigation operations, or to cause significant scour or channel migration of the Union Slough channel. The County has also made commitments to Buse to perform bathymetric surveys and pursue dredging if necessary resulting from adverse sedimentation in the portions of Union Slough Buse uses for log transport navigation.</td>
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<td>15</td>
<td>The West document states (page 10): Another important influence on channel migration potential is the effect of large woody debris. Large wood has been shown to be a dominant influence on the geomorphology of large western Washington Rivers (Collins et al., 2002). Debris jams can create channel avulsions resulting in multiple channels, floodplain sloughs, and distributary channels. This is the only report that discusses the impacts that large woody debris can have on channel morphology. However, the West model did not include modeling for large woody debris proposed to be placed in the restoration area in the DEIS most likely because this aspect of the proposed restoration was not available at the time the model was conducted.</td>
<td>The Collins et al, 2002, reference discusses massive wood jams on western rivers, not the single or multiple pieces envisioned for any restoration project in the Snohomish River. In this case, it is a matter of scale. Wood might have an influence on river morphology when the mass reaches channel spanning dimensions, in this instance, the wood that created such jams in the past simply doesn't exist any longer.</td>
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| 16   | The West document states (page 11):  
If the levee along Union Slough is breached as part of the Smith Island Estuarine Restoration Project, the risk of channel migration would increase, as there would be fewer man-made impediments to channel migration. Also, the blind tidal channels would again be subject to tidal action. However, it should be noted that none of the proposed levee breaches are in the vicinity of the pipeline alignment.  
Neither GeoEngineers nor Tetra Tech discuss this in their reports, nor do they apparently include the tidal channels in the models. Again this is fundamental fluvial geomorphology and West Consultants has accurately interpreted the probable results of the proposed levee breaches. | The next two sentences in the WEST 2007 report after the quoted text state "Additionally, it should be recognized that the same geomorphic setting would still control the Union Slough channel. The extremely low gradient of the valley and tidal control on the hydraulics of flow would still strongly control the potential for dynamic channel movement." The report subsequently describes that breaching the levee will likely cause overbank sediment deposition and riparian vegetation establishment, and generally increase resistance to bank erosion and channel migration. This finding is consistent with the GeoEngineers/WEST 2011 report, and the Tetra Tech report was not a geomorphic study.  
Both the GeoEngineers and Tetra Tech studies used topographic data covering Smith Island, including the tidal channels, in their respective models. |
| 17   | The West document states (page 13):  
The reduction in flow will result in a corresponding reduction in sediment transport. As commonly occurring flows would be influenced, it would be expected that on average less sediment would be transported downstream and more sediment would be deposited within the main channel of these watercourses. Over the long-term this will result in bed form formation, reduced flow depth and channel capacity, side channel formation, and increased channel migration.  
SNR agrees with this interpretation. The potential for sediment deposition will increase as the unmaintained levees that remain begin to fail and erode, contributing to the sediment deposition in this area. None of the reports SNR reviewed directly address the channel migration potential without any remaining levees on the left bank of the Union Slough bounding the proposed Smith Island Restoration area. Additionally, little is known about the actual construction of the existing levees nor has SNR reviewed any reports that include studies on these levees to determine their resistance to erosion after the proposed breaching of the levee occurs and presumably unmaintained (especially once water will be flowing on both sides of the remaining levees). | The Tetra Tech - Snohomish County, Smith Island Estuarine Restoration Union Slough Hydraulic Model Study (May 2013) and the Battelle - Hydrodynamic Modeling Study of the Snohomish River Estuary: Snohomish River Estuary Restoration Feasibility Study (Oct. 2007) reports both address sedimentation, scour, erosion and channel migration and have indicated that localized sedimentation and bank erosion is anticipated and that significant sediment deposition and channel migration are not likely. |
<p>| 18   | It is unclear why GeoEngineers and TetraTech do not make the same conclusions that West Consultants makes, especially since West Consultants produced the model that GeoEngineers interpreted for its geomorphology studies and the West data was used in the TetraTech model. | This comment is addressed above. Conclusions are consistent between the three modeling studies. |
| 19   | None of the Task 2 and Task 3 studies discuss potential impacts to the proposed setback levee or the DD5 levee system downstream from the northern breach where all models suggest the water velocity in the Union Slough will increase. The models do not discuss how to prevent high rates of erosion with the modeled higher velocity flows or how to protect the tidal channel banks from the high potential erosion. | Tetra Tech Union Slough report addresses this issue. Moderate velocity and shear stress increases are predicted downstream from the I-5 bridge during high river flows and ebb tides. These increases are primarily located mid-channel, rather than adjacent to the existing levees. |</p>
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<td>Additionally, none of the models discuss one of the more important aspects of these studies, which is how will the proposed restoration project affect the navigability of the Union Slough. Channel meander can affect the navigability as can the creation of side channels. Additionally, sediment buildup in the channel bed in areas where the flow velocity in the Union Slough decreases can reduce the depth of the water and can impact navigation if sandbars and other depositional features are created.</td>
<td>Model results, both 1-D and 2-D indicate that sediment aggradation in the vicinity of Union Slough will be negligible. Minor sediment deposition may occur within Union Slough between the two breaches due to flow velocity decrease in this segment. Localized deposition may also occur in back-eddy areas adjacent to tidal channel connections to Union Slough.</td>
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<td>As discussed in SNR’s comments, there have apparently been no studies on the characteristics of the fill materials in the existing DD5 levee system that bounds the proposed restoration area and therefore nothing is known about the potential rate of erosion that will occur after this section of the DD5 levee system is breached. As more of the remaining levee system fails and erodes, the sediments from the levee will enter the Union Slough channel and the morphology of the left bank of the Union Slough will be in a process of change that has not been predicted by any model (actually none of the models provided any information on potential changes in the Union Slough fluvial geomorphology).</td>
<td>Remnant levees are considered a valuable asset for long term success of the restoration project, (complex edge habitat, wave attenuation, etc.) Water flow is not as simplistic as “water flows in and water flows” out, as demonstrated by the extensive hydraulic modelling efforts that have accompanied design work. Because of the value of the remnant dikes to the restoration effort, it is not a valid assumption that they will be “completely gone”. The project design includes plantings and addition of wood features along the edges of the remaining levees to encourage stability and create habitat.</td>
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<td>Snohomish County suggested that the County would obtain a dredging permit and that the County will ensure that the Union Slough remains navigable, however, this may not be practical and the various agencies may not issue a dredging permit especially if the dredging will be conducted in an area adjacent to a habitat restoration area. Additionally, it is unclear how dredging will impact the restoration area because none of the models have factored in potential dredging.</td>
<td>Comment noted. Snohomish County has discussed application for a dredging permit with the Corp of Engineers and Washington Department of Fish and Wildlife, and it was agreed the agencies could support a permit for the purpose of mitigation of the restoration project and that the County would apply for an individual permit at the same time as it applies for project permits.</td>
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<td><strong>SUMMARY OF FINDINGS</strong></td>
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<td>The summary of SNR’s findings for Task 4 only addressed the studies and report prepared by Bailey, 2012 and the report prepared by Shannon and Wilson, 2012 (modflow modeling). The unauthored 2012 TetraTech report is reviewed and SNR’s findings for this report are included in the previous section. However, the TetraTech report does not add anything to the Bailey or Shannon Wilson studies and reports.</td>
<td>Comment noted.</td>
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<td>As discussed in SNR’s review of this report, the purpose stated in the Bailey report does not mention saltwater intrusion studies and focuses more on engineering geology than it does on saltwater intrusion. Oddly, Bailey does not consider the potential impacts the City of Everett POTW will have on the ground water hydrology of the proposed restoration area that is located immediately down gradient of this facility that operates an 160 acre lagoon with 5 feet of standing water in it (it is also down gradient of the 2 acre final chlorination trench).</td>
<td>Minimal information currently exists for the depth, hydro stratigraphic conditions and groundwater flow associated with the POTW pond. As part of S&amp;W’s seawater intrusion analysis, the numerical flow/transport model assumed that pond provides additional recharge (over and above natural, precipitation-derived recharge) to the shallow unit. This simulated recharge results in the groundwater flow in the main aquifer having a north and westerly component. The final chlorination trench is up gradient from the project area, and is therefore an existing condition feature. The County has no control over discharge to this unlined trench. The project is not expected to increase discharge from this trench to the groundwater.</td>
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<td>Although Bailey did log a significant number of test pits that were excavated on the farmland that is proposed to become the Smith Island Restoration area, none of these were conducted on the private properties. However, the number of borings and wells for a 440 acre area (not including the private properties which were actually the focus of the study because it is these properties that would be impacted by potential saltwater intrusion) was limited and most of the borings were focused in the area of the proposed setback levee for engineering purposes rather than a hydro geologic investigation.</td>
<td>Access into adjacent properties for initial geologic and hydro geologic investigations was requested by the County and was denied by adjacent property owners including Hima Farms, limited access was granted by Dagmar Marine to one location on their property. Test pits were utilized to delineate shallow surficial soil and shallow ground water properties across the County Property. Test borings and observation wells were placed adjacent to the property boundary with Hima Farms, across I-5 on Dagmar Marine Property, and interior on County Property. These were used to delineate deeper soil and ground water properties throughout the area. These combined subsurface investigations indicated a uniform depositional history of soils across the project site and onto the Dagmar Property across I-5 to the west – and consistent ground water aquifer properties throughout the same area, which would include the Hima Farms property and the southern portions of the Dagmar Marine property. Soil and ground water properties of include studies on these levees to determine their resistance to erosion after the proposed breaching of levees.</td>
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<td>It is unclear what level of research Bailey conducted in his studies, including research on the City of Everett POTW that is located immediately up gradient of his study area and research on the history of this area, including how farmers historically obtained water for the agricultural operations on this site, how sewage was handled on this site, how farm equipment was fueled, and what type of soil amendments, fertilizers, herbicides, and pesticides were used on this site. It is clear that cattle operations, most likely dairy operations, were conducted on the farmland considering that WSDOT was required to include a cattle crossing under the I-5 when it was built. It is unclear if manure ponds were used on this site; however, this is a consideration if the investigation will include environmental studies such as those Bailey conducted (soil sampling and analysis and ground water sampling and analysis).</td>
<td>Environmental studies of the County property and the now Hima Farms property were performed by AGI, Inc. (now CDM Smith) during the property acquisition phase of the project. These investigations were detailed (full Phase I and Phase II Environmental Site Investigations) and included the sampling and testing of shallow surficial soils at specific locations on the property that were determined to be potentially impacted by historic property uses such as farming, agricultural operations, nursery operations, pesticide use, and associated mechanic work. The results of these studies were taken into account during all phases of the work performed for the Geologic and Hydro geologic Field Investigation Report.</td>
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<td>It is unclear why Bailey’s studies focused on the engineering geology of the proposed restoration area or why Bailey chose to conduct environmental studies, when the focus was apparent on what impacts they proposed restoration project would have on the potential for saltwater intrusion into the ground water aquifer being used by Hima Nursery. However, since Bailey chose to conduct environmental studies, it is unclear why these studies did not focus on the most likely source of potential environmental impacts on the soils in the restoration area and the ground water, the City of Everett POTW that is located immediately up gradient of his study area.</td>
<td>Our analysis of the profusion of soil chemistry data concluded that the reclamation of the land for farming in the early 1900’s seems to have done little to change the overall soil chemistry across the site. The use of fertilizers and biosolids from the City of Everett Waste Water Treatment Facility appears to have done little to alter the overall soil chemistry in the project site when tested parameters are compared between historically farmed areas of the site and nursery leases with those areas that have not been farmed or utilized for nursery purposes. Predominantly saline acidic soils are prevalent across the site. The presence of the City of Everett Waste Water Treatment Facility does not affect the data collected or the conclusions drawn based on the collected data. Based on conversations with City of Everett Waste Water Treatment Facility staff, there is no documented interaction between their ponds and the confined aquifer below Smith Island. Design level study and analysis will determine what influence the City of Everett Waste Water Treatment Facility ponds may or may not have on the ground water quality within the confined aquifer below the project site and whether or not there is a potential impact to the project site. Based on the data collected during the course of this site investigation and interviews with the Waste Water Treatment staff – the impact from the ponds and applied biosolids, if any, to both shallow soil and ground water appears minimal or non-existent at this time. As part of S&amp;W’s seawater intrusion analysis, the numerical flow/transport model assumed that pond provides additional recharge (over and above natural, precipitation-derived recharge) to the shallow unit. This simulated recharge results in the groundwater flow in the main aquifer having a north and westerly component. Following project implementation, the modeling indicated that the flow component estimated from the treatment pond will be reduced at the project site.</td>
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<td>The DEIS states that biosolids from the City of Everett POTW were used in the proposed restoration area additionally, the 160 acre lagoon and other ponds and trenches manage sanitary sewage including sewage from commercial and industrial facilities. Additionally sewer treatment plants use a lot of chlorine in the treatment process and this chlorine is “neutralized” with sulfur compounds including sulfur dioxide gas and sodium metabisulfite (and other sulfur compounds). The chlorine is converted to chloride in the chlorine “neutralization” process and the sulfur compounds can contribute sodium to this chloride (such as sodium metabisulfite). This effective creates saltwater which can potentially impact the ground water beneath the City of Everett POTW.</td>
<td>While the WPCF uses sodium hypochlorite to disinfect the wastewater, the concentration of any chloride potentially created by the neutralization of the chlorine compound is likely very low compared to what is present in the surrounding environment. The dosage applied to the wastewater is typically well under 1.0 parts per million and following disinfection the amount neutralized is typically in the 0.1 to 0.2 part per million range. Any chloride created is a very small amount when compared to chloride concentrations in the Snohomish River and Union Slough, which has salinity of 0.1 to 5.7 parts per thousand (100 to 5700 parts per million) per pg. 85 of the Draft Smith Island Drainage Analysis.</td>
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<td>Additionally, biosolids are treated with high levels of chlorine and then the chlorine is “neutralized” with the sulfur compounds. These biosolids also have high levels of phosphorous, nitrogen in various forms, high conductivity from the chlorides from the chlorine treatment process (and high sodium from chlorine “neutralization” if sulfur salts are used, such as sodium metabisulfite). These biosolids also have high sulfur content naturally and added sulfur from the chlorine “neutralization”. biosolids also contain elevated levels of metals such as copper, zinc, lead, iron, and other metals and they can contain other organic compounds such as Polybrominated Diphenyl Ethers (PBDEs); however, Bailey did not conduct analysis for other constituents of biosolids that were known to have been placed in the restoration area, but he did for sulfur, nitrogen, phosphorous, chloride, and pH.</td>
<td>The WPCF’s biosolids are not treated with chlorine or “neutralized” with sulfur compounds. biosolids do contain phosphorous, nitrogen and other macro and micro nutrients and organic matter essential for soil fertility and plant growth. Everett’s biosolids are not chlorinated or have added sulfur, so “high levels” of sulfur or “high conductivity from the chlorine treatment process” would not be present. biosolids do contain copper zinc, iron and lead in very low amounts. These compounds and biosolids reuse are strictly regulated and acceptable levels of various compounds are established in Federal and State biosolids regulations. Levels of all regulated compounds in Everett’s biosolids are consistently below the ceiling limits established in Federal and State biosolids regulations.</td>
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<td>The high sulfur content in the biosolids can be converted to sulfurous and sulfuric acid in the environment, especially a wet oxidizing environment. This will reduce the pH which has been problematic in the surface water discharges from the farmland. The biosolids will have high chloride levels and most likely high levels of sodium chloride if sulfur salts were used to “neutralize” the chlorine. This suggests that the somewhat unusual analysis Bailey obtained for the soils he sent for laboratory testing can be attributed to the placement of biosolids in the restoration area this can be problematic for the proposed use of this farmland as a restoration area that will include breaching the dikes and flooding this area with water from Union Slough.</td>
<td>The WPCF’s biosolids are not treated with chlorine or “neutralized” with sulfur compounds. biosolids do contain phosphorus, nitrogen and other macro and micro nutrients and organic matter essential for soil fertility and plant growth. Everett’s biosolids are not chlorinated or have added sulfur, so “high levels” of sulfur or “high conductivity from the chlorine treatment process” would not be present. Biosolids do contain copper, zinc, iron and lead in very low amounts. These compounds and biosolids reuse are strictly regulated and acceptable levels of various compounds are established in Federal and State biosolids regulations. Levels of all regulated compounds in Everett’s biosolids are consistently below the ceiling limits established in Federal and State biosolids regulations.</td>
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<td>Additionally, the Shannon and Wilson Modflow model for the ground water “flow” based on Bailey’s well elevation measurements indicates that the recharge area for the ground water is not to the east as is typical for this area, it is from the south which is where the 160 acre lagoon and other ponds and trenches that manage the sewer treatment plant water are located. Considering this water is treated with chlorine and neutralized with sulfur compounds, it is very possible that this facility is an artificial source of salt water intrusion and it is possible that the 5 feet of standing water in the 160 acre lagoon may explain why the ground water in the wells constructed by Bailey was at or above the ground surface.</td>
<td>The distance between the northern edge of the POTW pond and the nearest County well (SW-06 - highest recorded head of +5.5 feet) is approximately 2,000 feet. Although the recharge flux provided by the ponds is uncertain, it is unlikely that the POTW Pond is the primary cause of artesian heads this far away in what is a relatively highly transmissive aquifer. More likely, the elevated piezometric levels in the County wells are more strongly influenced by tidal levels as was indicated in the County's hydrogeologic assessment. This relationship between tides in Union Slough, Snohomish River and groundwater levels is being explored as part of the 2013 engineering design work.</td>
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<td>It is also possible that the 160 acre lagoon and other surface water features at the City of Everett POTW are creating unsaturated zone flows that are a source of the perennial flows in the tidal channels located in the restoration area and west of the proposed setback levee. However, Bailey did not study the hydrology of the tidal channels, most likely because the state purpose of the study was to obtain engineering geology information.</td>
<td>The current hydrogeologic characterization and groundwater modeling study findings indicate that the Snohomish River and Union Slough are the primary sources of aquifer recharge at the site, with the Everett POTW being a smaller recharge component. Recent data collection and expanded modeling has been performed further evaluating the relationship between the shallow soil unit (estuarine deposits) and the underlying sand aquifer (alluvial deposits) and the tidal channels. Piezometric levels in the sand aquifer are strongly controlled by the tidal fluctuations in Union Slough. The recent modeling studies support the EIS and technical studies that minor amounts of seepage will flow into the tidal channels. Estimated seepage rates to the adjacent property and farm area are small with average flow rates less than 0.2 cfs (90 gpm) total from the shallow soils to the channels and a smaller component of flow the underlying aquifer in the tidal channels. Finally, the changes that will occur as a result of the project indicated that the current south-north groundwater gradient will shift to east-west which would reduce flows and seepage from the south (the POTW area).</td>
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<td>Regardless, as is discussed in the next section of this report, Snohomish County will need to conduct much more detailed hydrogeologic and environmental studies to determine how the City of Everett POTW is influencing the subsurface hydrology and how the placement of biosolids on the farmland proposed to be used in the restoration project will affect the water quality of the Union Slough and how the soils that these biosolids were placed on will impact the aquatic organisms that will be using this proposed habitat.</td>
<td>For clarification, the City of Everett POTW is an existing condition at the project site and not a proposed condition. Also, the Smith Island estuary restoration project does not involve placement of biosolids in the project. Additional hydrogeologic studies are being performed to evaluate the effects of seepage and salinity impacts on the adjacent properties. The City of Everett will be providing more information regarding the historic placement of biosolids in the proposed restoration area.</td>
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Additionally, these studies should include actual saltwater intrusion studies that also consider other potential sources of saltwater such as the City of Everett POTW. As discussed in SNR’s comments for the Bailey report, Bailey does not discuss why there is no clear fresh water contact observed as is typically associated Ghyben-Herzberg relationship nor does Bailey discuss why he believes the aquifer is a confined aquifer other than the observed high piezometric surface (at or above the ground surface) without determining the recharge source for this, considering the Union Slough is located to the east and would not provide the hydraulic head Bailey was observing under normal flow conditions. Additionally, Bailey did not try to correlate what he observed with fundamental concepts of saltwater intrusion in a confined aquifer, nor did he try to evaluate potential pathways for saltwater from the Possession Sound being this far inland in the delta of the second largest river in the Puget Sound area.

SNR generated a lot of comments for the Bailey studies and to a lesser extent, the Shannon and Wilson modeling because these studies were not focused and included a lot of areas of study but none of these studies led to any viable conclusion and actually the findings pointed to the need of much more detailed studies that follow correct hydrogeologic and environmental studies protocols, including the preparation of a Quality Assurance Project Plan for all environmental studies that include sampling and field and/or laboratory analysis. Additionally, the studies should have and now, must include an analysis of the impacts the City of Everett POTW has on the subsurface hydrology. These studies must also focus on the characteristics of the soils that received biosolids from the City of Everett POTW if this area will proceed to be converted to a salmon habitat restoration area that will be flooded by the Union Slough.

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<td>The surface and groundwater data collected from the County’s observation wells indicate that the groundwater in the underlying sand aquifer (from 20 to 70 feet below surface) is brackish-saline (on the order of 15 to 25 ppt). Three deeper County wells (screened 55-65 feet bgs) have higher salinity/TDS than in the shallow wells (screened 20-30 feet bgs) which supports the assertion that the groundwater aquifer is brackish to saline and heavily influenced by the Sound and tidal flows in the distrubary channels. Relatively low salinity (mildly brackish water) has been measured in Tidal Channel A and Tidal Channel B. The source of this water is rainfall runoff (fresh) of the interior area of the levees and farms, and seepage flows from the upper estuarine deposit soil layer and minor seepage from the underlying alluvial soil layer (both brackish). A Ghyben-Herzberg relationship will not occur if the existing aquifer is brackish. Technically, freshwater has not been observed at the site, nor in adjacent tidal channels or Sloughs (less than 0.1ppt for drinking water and 0.5ppt for agricultural water). Without fresh water, a Ghyben-Herzberg salinity layer cannot by definition be observed.</td>
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<td>SNR generated a lot of comments for the Bailey studies and to a lesser extent, the Shannon and Wilson modeling because these studies were not focused and included a lot of areas of study but none of these studies led to any viable conclusion and actually the findings pointed to the need of much more detailed studies that follow correct hydrogeologic and environmental studies protocols, including the preparation of a Quality Assurance Project Plan for all environmental studies that include sampling and field and/or laboratory analysis. Additionally, the studies should have and now, must include an analysis of the impacts the City of Everett POTW has on the subsurface hydrology. These studies must also focus on the characteristics of the soils that received biosolids from the City of Everett POTW if this area will proceed to be converted to a salmon habitat restoration area that will be flooded by the Union Slough.</td>
<td>The saltwater intrusion analysis was indeed highly focused on quantitatively evaluating the potential effects of the proposed project on salinity concentrations to groundwater users in the area. The evaluation used available information and site-specific data (such as aquifer and aquitard geometry, recorded groundwater elevations, river salinity). The analysis accounted for the likely hydrologic effects of the POTW pond at the southern end of the study area. Although no formal QAPP was prepared for the geologic/hydrogeologic exploration field work/laboratory testing, the County followed its own internal protocols in performing the work. A QAPP has been developed for current and future ground and surface water modeling studies for the project.</td>
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### RECOMMENDATIONS

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<td>In summary, SNR believes that additional studies (including subsurface, hydrogeologic studies) need to be conducted and all potential surface water sources need to be addressed, including permitted point source MS4 storm water from WSDOT. Accurate topographic data is required for the area landward of the proposed setback levee (this should also include the area the setback levee will be built on) and this data should include accurate elevation data for tidally influenced flows in the Union Slough based recent measurements in Union Slough to the nearest 1/100th of a foot. Monitoring, modeling, and detailed design work have been completed to address this issue. For modelling, design, and construction purposes, accuracies greater than 1/10 of a foot are sufficient. Other technical publications and analyses, completed as a result of design work, are referenced elsewhere in this matrix.</td>
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<td>The drainage in drainage basin B2 and the northwestern portion of drainage basin A2 should also be characterized, including flows in the borrow ditch for the remaining DDS levee section bounding the northern portion inside of the proposed setback levee area. These drainage areas are characterized in the subsequent Otak Interior Drainage Analysis (October 2013). Seepage flows from the existing levee including flow into the toe ditch are evaluated in the Shannon and Wilson Geotechnical Report (2013) in Appendix F.</td>
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<td>The potential impacts that subsurface hydrology will have on the surface water drainage needs to be evaluated, as well as the inundation of the proposed restoration area, especially in Tidal Channel B and any drainage system associated with the setback levee. It is known that the borrow ditch drainage system landward of the existing levee system has water in it year around, and run-on controls may be required landward of the proposed setback levee. This needs to be studied and addressed in the drainage plan. The surface water drainage and subsurface hydrology have been studied in detail in the Otak Interior Drainage Design (October 2013) and the Shannon and Wilson Groundwater (2013) engineering reports respectively. The design of the setback dike and drainage system significantly increases storage capacity and improves drainage conditions for surface and subsurface water.</td>
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<td>There are potential regulatory issues that may need to be addressed. Tidal Channel B is considered to be “fish bearing waters” which suggests that federal and state codes that regulate these types of water bodies would need to be evaluated, especially since permitted MS4 point source water from I-5 is directly discharged into Tidal Channel B, which is proposed to be used for storage (and it is unclear how this will affect the regulatory status of the proposed 5 acre storm water detention facility). See Response from #3 “Drainage” above.</td>
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<td>Apparently, Tetra Tech did not conduct any field studies on the surface water hydrology of the private properties or the restoration area, nor were subsurface studies conducted to characterize the subsurface hydrology, including the hydrology of the tidal channels. The only field studies that were conducted were conducted by Steven Cahill, PE and these studies were limited in scope and did not include subsurface investigations or those that include subsurface hydrologic studies. This may be why Mr. Cahill describes Tidal Channel B as “Drain Ditch B” on the Project Site Map drawings (tidal channels are natural features). The field studies and surveys were conducted for the restoration area and the area interior to the setback dike, including the drainage system of the private property, as described in the Shannon and Wilson Geotechnical Report (2013), the Otak Interior Drainage Design Report (2013), and the Shannon and Wilson Groundwater Report (2013), in addition to earlier studies such as the Snohomish County Geologic and Hydrogeologic Field Investigation Report (2012). Access to the private property was not available at the time of the Tetra Tech study.</td>
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<td>Additionally, the WWHM and SWMM models may not be the most appropriate models to use for surface water drainage analysis for the existing conditions and the proposed conditions if the setback levee is constructed. These models are specifically designed for storm water system design and do not factor in subsurface drainage systems, tidal channels being used as storm water conveyances, nor will these programs include potential hydrologic issues with near surface ground water, unsaturated zone flow and hydrology potentially affected by levees. Subsurface hydrology is studied in detail in the Shannon and Wilson Groundwater Report (2013). WWHM and SWMM are stormwater models and are used for surface water routing, storage, and discharge calculations. Soil conditions are assumed to be saturated in the stormwater models for Smith Island, and subsurface flows from the Groundwater study that affect surface features are included as inflows into the stormwater models. The issues described in this comment do not apply to WWHM and SWMM stormwater modeling.</td>
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<td>Tetra Tech should conduct actual surface water hydrology studies on the private properties, including subsurface studies that include testing of the surface sediments for hydrologic properties. Detailed surveying should be conducted to insure that accurate elevations are used in any design and modeling. Tetra Tech should also look at models that may be more appropriate for the studies that need to be conducted, including those listed by the United States Geologic Survey at: <a href="http://water.usgs.gov/software/lists/surface_water">http://water.usgs.gov/software/lists/surface_water</a>.</td>
<td>Access to the private property was not allowed at the time of the Tetra Tech study. Detailed surveying on the private property, including ditches and tidal channels, has been conducted by Snohomish County. Soil conditions for the stormwater modeling are assumed to be at or near saturation for surface water models, and subsurface conditions are studied in the Shannon and Wilson Geotechnical and Groundwater Reports. The Washington Department of Ecology's WWHM and the EPA's SWMM models used by Tetra Tech are standard engineering practice for continuous simulations within Snohomish County, and WWHM is an interface based on the HSPF model found on the USGS site referenced by this comment.</td>
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<td>All of the private property that will be located landward of the proposed setback levee is agricultural land where storm water standards associated with development are not required. Tetra Tech should consider the option of using pumps exclusively and where necessary, adding drainage ditches and pumps, such as the area north of Tidal Channel B.</td>
<td>The use of a stormwater pump has been included for evaluation in the design of the setback dike drainage system since initial concept design. Interior drainage analyses have evaluated the alternatives of gravity pipe systems with or without a pump station as a contingency measure to inform the final design of the setback dike drainage system.</td>
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<td>The Drainage Plan must also include all other sources of water, such as the water that is present year-round in the &quot;borrow ditch&quot; and may be present in any drainage system associated with the proposed setback dike.</td>
<td>The water that is present year-round in the existing ditches are due to seepage from Union Slough and groundwater sources since it is present year-round. The Groundwater studies determine seepage flow rates for these features Interior Drainage Analyses use flow rates.</td>
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<td>If modeling is going to be used to determine if channel migration will occur, or more importantly to determine if the navigability of the Union Slough will be affected by the proposed restoration project, very accurate survey data and cross sections are required. This means that both banks of the Union Slough must be surveyed to an accuracy of 0.01 feet including the bathymetry which must be recently acquired (because the bathymetry will continue to change).</td>
<td>Survey and bathymetric work has been completed.</td>
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<td>Additionally, the channel bed and bank sediments must be mapped and the engineering characteristics of these sediments must be determined, including grain size analysis, cohesiveness, consolidation, and shear strength. A recording stream gage that measures discharge velocity in cubic feet per second and stage height in feet needs to be installed in the Union Slough in the vicinity of the propose southern breach and a recording tide gage or pressure transducer that also measures electrical conductivity should be installed in the same location as the stream gage. Additionally, an analysis of the sediments being transported by the Union Slough at different flow rates should be conducted.</td>
<td>This question has been addressed in several statements in this review. Please refer to Item 1, 3, 4, 5, &amp; 6, in “Geomorphic Characterization and Channel Response Assessment for Union Slough, 2011”.</td>
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<td>The fill materials in the existing DD5 levee need to be sampled and the engineering characteristics of these fill materials need to be tested to provide information necessary to predict how quickly the levees will fail and erode after maintenance has stopped and the flow from the Union Slough breaches begins to erode the landward side of the remaining unmaintained levees.</td>
<td>Remant levees are considered a valuable asset for long term success of the restoration project, (complex edge habitat, wave attenuation, etc.) Water flow is not as simplistic as &quot;water flows in and water flows&quot; out, as demonstrated by the extensive hydraulic modelling efforts that have accompanied design work. Because of the value of the remnant dikes to the restoration effort, it is not a valid assumption that they will be completely gone.</td>
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<td>All data gaps need to be filled with accurate, site specific data and the appropriate model needs to be chosen that will be accurately calibrated, preferably a 3-dimensional model. The model must be accurately calibrated to the existing conditions based on the data collected and then must be calibrated to the conditions that will be present as proposed in the DEIS. The model should also be calibrated to model conditions with failing unmaintained levee sections and for conditions with no remaining unmaintained levees.</td>
<td>This comment does not specifically describe the data that the author thinks is required other than what has been addressed in response to the previous comments. There is no indication in this comment about what a 3-Dimensional model would be used for. If the intended purpose is a hydraulic model, there is no basis or justification for use of a 3-Dimensional model, as one-dimensional models are often appropriate for riverine hydraulics and two-dimensional models are necessary for distributary flow applications. The added complexity of a 3-Dimensional model is unnecessary and not preferable for most applications, except for cases such as modeling of salinity transport and hydrodynamic response across the Puget Sound region as in the Battelle 2007 Study. Data has been collected at the site and used for calibration of subsurface hydrology models as described in the Shannon and Wilson Groundwater Report (2013). In addition, many of the hydraulic studies such as the Tetra Tech Union Slough Hydraulic Study, the GeoEngineers/WEST 2011 model, and the Battelle 2007 model, and the WEST 2007 Report describe their respective calibration processes.</td>
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<td>The model should be run for all scenarios listed above at different flood stages, including 100 and 500 year flood stages. The sediment transport and deposition must be modeled as should the formation of depositional features in the Union Slough such as sand bars. Changes in the fluvial geomorphology of the Union Slough need to be analyzed, including the potential for the development of side channels. Additionally, changes in the fluvial geomorphologic characteristics of Tidal Channel A need to be analyzed. The effects of the placement of large woody debris, the creation of mounds and other grading activities must also be modeled.</td>
<td>The model should also determine the maximum stage height for the Union Slough for each flood event (e.g. 15 year, 50 year, 100 year, and 500 year) and each modeled scenario to insure that the proposed setback levee will not be overtopped. The setback dike will be constructed to an elevation of 15.0 feet NAVD88, which is higher than existing dikes, and constructed to significantly higher standards than existing dikes on the island. The maximum stage height has been determined in for the events modeled in hydraulic studies such as the Tetra Tech 2013 and West 2007 Reports, such as the 100-year, 500-year, and the January 2009 corresponding to an approximately 15-year event. The existing dikes on the island are overtopped at a stage of approximately 12 feet NAVD88, and will be overtopped before stages reach the top elevation of 15 feet NAVD88 of the setback dike, which corresponds to a 100-year flood level.</td>
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<td>The modeling should not only focus on potential channel meander and bank and bed scour, it should also focus on the potential impacts to the navigability of the Union Slough and the other sloughs that are used by Buse lumber to deliver logs to this facility. The modeling should also focus more closely to the potential impacts to the downstream DD5 levee system and if there is a potential for greater bank instability or levee failure, the armor of those portions of the DD5 levee system that will be impacted.</td>
<td>The modeling needs to include the final restoration described in the DEIS which includes the placement of large woody debris and any changes in the geomorphology of the existing farmland due to grade and fill activities. Additionally, the erosion potential in the proposed mitigation area must be determined and the potential changes in the Tidal A channel fluvial geomorphology should also be modeled. A new low flow tidal model has been developed by Snohomish County and Northwest Hydraulic Consultants using River FLO-2D. This model, similar to previous models, shows areas of high bed shear stresses near the breaches, and provides improved estimates of tidal channel flow conditions along Tidal Channel A and the smaller tidal channels in the marsh restoration area. The modeling output is being used to refine the restoration design plans. The revised and updated modeling has not identified significant changes in hydrodynamic conditions of the marsh as compared with the original hydrodynamic modeling and information from Batelle, Tetra Tech, and West that are presented in the FEIS.</td>
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<td>The studies must also focus on how long it will take for the remaining unmaintained levee system to fail and erode away and how this process will affect the fluvial geomorphology of the Union Slough. None of the models SNR reviewed address changes in the remaining unmaintained levees.</td>
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<td>As previously discussed, Snohomish County has been working on the Smith Island Restoration project since 2003; with actual studies being conducted in 2007. Had the County installed a stream gage and pressure transducer (or tide gage) in the Union Slough next to the proposed restoration project, it would have a significant amount of site specific discharge and stage data and tide data, including data on the 2009 and 2012 flood events.</td>
<td>Comment noted. The County has recently installed data logger transducers in Union Slough, Tidal Channels A &amp; B as well as in groundwater observation wells across the project site. This information is being used to confirm hydrogeologic interpretations, confirm soil layer permeability and conductivities, document the connectivity between Union Slough the tidal channels the aquitard and underlying sand aquifer, and further calibrating and refining the MODFLOW model.</td>
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<td>Additionally, if pressure transducers were installed in the tidal channels (in addition to one in the Union Slough), a lot of data on the hydrology of these features could have been obtained and when Bailey conducted his studies, adding pressure transducers to the wells he constructed would have provided lots of valuable data on the ground water – surface water interaction and on the Union Slough base flow.</td>
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<td>To address potential overtopping of the proposed setback levee, it is important to know what stage height on the Union Slough is representative of an actual 10% flood event and what constitutes an actual 10% flood event. Based on the reports reviewed by SNR (GeoEngineers), Snohomish County suggests that 1% flood events occur at intervals of 3 to 7 years which would mean that this may be the required design parameter if these events consistently occur more often than the predicted 10% events.</td>
<td>The setback dike will be constructed to an elevation of 15.0 feet NAVD88, which corresponds to a 1% Annual Chance (100-year) flood event. This exceeds the elevation of existing dikes on the island (typically 12-13 feet elevation), and the setback dike will be constructed to a significantly higher standard than existing dikes. The 10% Annual Chance event (10-year) flood event is documented by FEMA as approximately 11.5 feet for Smith Island, which means the setback dike will have about 3.5 feet of freeboard during a 10% annual chance flood event. The GeoEngineers' report references a Snohomish County report (March 2005 Natural Hazards Mitigation Plan, Chapter 14: Flood). That report could not be located to identify the misstatement. The 100-year event would not be the 100-year event if it occurred at intervals of three to ten years.</td>
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<td>The discrepancies between the various models SNR reviewed need to be addressed. In general the Yang and Khangaonkar study and the West Consultants study prepared for CH2M Hill are the most comprehensive and actually incorporate fluvial geomorphic principals. These studies also predict that significant scour and channel migration will occur if the proposed breaching of the DDS levees occurs.</td>
<td>This comment does not provide any specifics on what discrepancies need to be addressed. The WEST 2007 report referenced by this comment found a low risk of channel migration due to the Smith Island project. which is consistent with the GeoEngineers/WEST 2011 Geomorphic Characterization Report. The Battelle 2007 study presents velocities and bed shear stress (as GeoEngineers/WEST 2011 did) and indicates that localized adjustment of channel morphology may occur near Smith Island, but does not support the statement made in this comment that significant scour and channel migration will occur. The studies generally found localized increases in velocities of several feet per second during ebb tides immediately downstream of the project, but found lower velocities and bed shear stresses within Union Slough for the reach near the Smith Island project area.</td>
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<td>It is unclear why the model West prepared by GeoEngineers provided different results than their model did for CH2M Hill considering that it appears that the same basic model data was used. It is also unclear why Tetra Tech studies were conducted and why the 2-dimensional model was run using the same data that West used in the GeoEngineers report. Regardless, none of the models used site specific data (although Battelle did obtain some site specific data and conducted their studies during base flow or near base flow conditions and conducted the model for the time frame that the collected data covered). Much of the data used in the models is based on assumptions and predictions for an area that has complex hydrology and fluvial geomorphology.</td>
<td>This comment does not indicate the results that the author expects to be the same. The two WEST studies evaluated different criteria (impacts of Scour depth near the Gas Pipeline in the WEST 2007 report, versus shear stress and stream power for Union Slough in the GeoEngineers/WEST 2011 report). In addition, the GeoEngineers/WEST 2011 Study used updated data, including 2009 topographic LiDAR and bathymetric data, and tide data was collected from the nearby Everett Riverfront Project in 2009. The WEST 2007 and GeoEngineers/WEST 2011 studies are consistent in that they conclude that there is a low potential for channel migration in Union Slough. The draft Tetratech 2012 Hydraulic study states that it was conducted to analyze flow patterns and areas of erosion and sedimentation, as well as provide details to address comments from the June 2011 Draft EIS. As discussed above, the studies used topographic and bathymetric data collected for the site, and best available tidal data from the nearby Everett project. Additional data has been collected on Union Slough as of 2013.</td>
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<td>It is apparent that none of the models addressed the real question, which is how will the proposed Smith Island Restoration Project impact the Union Slough and the navigability of the Union Slough and to provide a prediction of stage heights and discharge rates for the design of the proposed setback levee. However, what is also important is how will the proposed restoration project impact water quality and the fish this restoration area is being designed to protect.</td>
<td>The FEIS has a revised and clarified section addressing impacts to Union Slough sedimentation and navigability. The hydrodynamic modeling from Tetra Tech and Battelle both indicate the potential for minor sedimentation and localized bank erosion, and unlikely major channel migration nor impacts to navigation. Also, the County has committed to bathymetric surveys of Union Slough and dredging if the project impacts navigability in the future.</td>
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<td>As discussed in the Task 4 findings and recommendations, the studies conducted by Bailey suggest that the soils in the farmland proposed to be used for this restoration project are apparently impacted by the placement of “biosolids” from the City of Everett POTW located immediately south of the proposed restoration project. The soil analysis conducted by Bailey suggests that high levels of nitrogen in various forms, sulfur, low pH and high salinity are present in these soils and sediments. It is unclear how the transport of these sediments into the Union Slough will impact the water quality of the Union Slough and how contact with these soils and sediments will impact aquatic organisms, including fish.</td>
<td>The WPCF’s biosolids are not treated with chlorine or “neutralized” with sulfur compounds. Biosolids do contain phosphorous, nitrogen and other macro and micro nutrients and organic matter essential for soil fertility and plant growth. Everett’s biosolids are not chlorinated or have added sulfur, so “high levels” of sulfur or “high conductivity from the chlorine treatment process” would not be present. Biosolids do contain copper, zinc, iron and lead in very low amounts. These compounds and biosolids reuse are strictly regulated and acceptable levels of various compounds are established in Federal and State biosolids regulations. Levels of all regulated compounds in Everett’s biosolids are consistently below the ceiling limits established in Federal and State biosolids regulations.</td>
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<td>Bailey’s analysis of the soils and sediments did not include other known constituents known to be present in the City of Everett POTW biosolids and those that are known to be present in virtually all biosolids. These soils and sediments need to be resampled and analyzed for all potential constituents found in biosolids that can impact the water quality of the Union Slough and can impact the health of aquatic organisms that come in contact with the soils and sediments. The new models Snohomish County has conducted should also include an erosion analysis of the remaining levees (which should also be tested for potential constituents that can impact water quality and aquatic organisms) and the soils inside the completed restoration area to determine how an increase in sediment loads will impact the turbidity and phosphorous loads in the Union Slough.</td>
<td>Our analysis of the profusion of soil chemistry data concluded that the reclamation of the land for farming in the early 1900’s seems to have done little to change the overall soil chemistry across the site. The use of fertilizers and biosolids from the City of Everett Waste Water Treatment Facility appears to have done little to alter the overall soil chemistry in the project site when tested parameters are compared between historically farmed areas of the site and nursery leases with those areas that have not been farmed or utilized for nursery purposes. Predominantly saline acidic soils are prevalent across the site. The presence of the City of Everett Waste Water Treatment Facility does not affect the data collected or the conclusions drawn based on the collected data. Based on conversations with City of Everett Waste Water Treatment Facility staff, there is no documented interaction between their ponds and the confined aquifer below Smith Island. Design level study and analysis will determine what influence the City of Everett Waste Water Treatment Facility ponds may or may not have on the ground water quality within the confined aquifer below the project site and whether or not there is a potential impact to the project site. Based on the data collected during the course of this site investigation and interviews with the Waste Water Treatment staff – the impact from the ponds and applied biosolids, if any, to both shallow soil and ground water appears minimal or non-existent at this time. As part of S&amp;W’s seawater intrusion analysis, the numerical flow/transport model assumed that pond provides additional recharge (over and above natural, precipitation-derived recharge) to the shallow unit. This simulated recharge results in the groundwater flow in the main aquifer having a north and westly component. Following project implementation, the modeling indicated that the flow component estimated from the treatment pond will be reduced at the project site.</td>
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<td>Much more extensive hydrogeologic and environmental studies must be conducted to identify the potential impacts the City of Everett POTW has on the subsurface hydrology and ground water quality. Additionally, actual saltwater intrusion studies need to be conducted using pressure transducers with specific conductance measurement capabilities in all existing and new wells that need to be placed and constructed to properly model the aquifer and to characterize the characteristics of the aquifer including water quality. These new wells must be constructed so that the potential impacts from the City of Everett POTW can be modeled and identified through ground water sampling.</td>
<td>The 2013 engineering design investigation includes additional data collection, aquifer characterization and modeling studies. These studies provide refinement on estimates provided in the EIS groundwater, hydrogeologic characterization and salt-water intrusion modeling studies. Specific information includes additional observations of groundwater conductance/salinity data and piezometric levels in the shallow aquitard and sand aquifer which are used for further calibration of the MODFLOW model, and using the model to further quantify (refine) the potential effects of the project in support of design. To date, the monitoring, calibration and additional modeling indicate that the information presented in the EIS was reasonable and that the effects identified can be mitigated with design. With respect to the City of Everett POTW, the EIS assessment indicate that this is an existing condition that is included in the hydrogeologic characterization and groundwater modeling studies. The EIS groundwater modeling and the revised groundwater modeling both agree and demonstrate that the proposed groundwater conditions will shift the groundwater gradients from existing south-north (POTW pond recharge influenced) to more east-west (with a Union Slough influence), thereby reducing the potential effects of the POTW on the adjacent properties.</td>
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<td>The source of the water in the tidal channels needs to be identified as does the source of the water in the “borrow ditch” system. Pressure transducers should be placed in the tidal channels and in the Union Slough (these should also have specific conductance measurement capability) so that the hydrology of surface water features and ground water can be monitored at exactly the same intervals.</td>
<td>The primary source of water to the channels is precipitation runoff of interior drainage areas, with minor seepage inflows from the upper estuarine deposit soil layers and the underlying alluvial sand aquifer layer. Salinity in the tidal channels has been measured to be less than 5ppt, which is less brackish than the surrounding Sloughs, and salinities in adjacent soils and underlying aquifer. The current engineering design work includes installation of pressure transducers (for piezometric level, temperature and conductance) in the tidal channel, Union Slough, three County shallow groundwater wells (20-30 feet) and two new shallow (10 foot) piezometers. The study findings are being used to provide revised estimates of the source(s) and flux of seepage into the channels, and the hydraulic relationship between the aquitard and sand aquifer. Additionally, surface water runoff modeling and analyses are being performed and information regarding the amount of surface water drainage and flow to the tidal channels will be provided in an updated interior drainage report as part of the design documents.</td>
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<td>All environmental studies must be conducted in accordance with a SWPPP that is prepared and this SWPPP must include a sampling and analysis plan, this includes soil sampling activities and laboratory analysis for soils. The laboratory analysis parameters must be expanded to those constituents that are known to be present in biosolids and are generated at sewer treatment facilities and would be present in the lagoon, ponds, and trenches at the City of Everett POTW.</td>
<td>Comment noted.</td>
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<td>SNR requested information from the City of Everett POTW on ground water monitoring, the chemical characteristics of the water in the ponds and other surface water features, and on the biosolids. SNR also requested information on the monitoring of the lagoon and ponds. The only information the City of Everett POTW provided SNR with was limited analysis of the biosolids and a GeoEngineers geotechnical report dated 2009 related to geotechnical engineering studies associated with a truck scale being built for the biosolids program. The City of Everett POTW states that they have none of the other information requested by SNR.</td>
<td>SNR submitted a request for information to Everett Public Works regarding effluent and biosolids quality. Everett Environmental Laboratory provided lagoon system effluent data for metals, pH, ammonia, nitrate+nitrite and biosolids quality data to SNR. Everett provided all the information SNR requested and would respond to any appropriate Freedom of Information Act request.</td>
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<td>Bailey should have included the City of Everett POTW in his ground water studies considering it is obvious that this is a significant recharge source that is located immediately upgradient of his study area. Additionally, the only potential recharge source that would provide the piezometric surface readings Bailey observed would be the 160 acre lagoon and the other surface water features this POTW facility.</td>
<td>The POTW is a potential source of groundwater seepage, but not likely significant as the reviewer describes, due to the soil type and low permeability of the upper soil layers along the POTW and the project site, as well as the drainage infrastructure surrounding the pond that directs flows away from the pond to the east, south and west of the POTW, and not to the north where the proposed project lies. The S&amp;W SWI modeling accounted for additional recharge from the pond to the sand aquifer. We believe that the primary cause of the elevated piezometric levels in the County's shallow groundwater observation wells is the tidal range in Union Slough and the Snohomish River, with the POTW being minor in comparison.</td>
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<td>This is further supported by the Shannon and Wilson Modflow model that indicates that ground water is flowing from south to north rather than from east to west. The only potential source of recharge to the south is the City of Everett POTW lagoon, ponds, and trenches. Additionally, considering the potential ground water quality impacts from the City of Everett POTW based on Bailey’s studies, it is possible that the ground water is being impacted by more than salt and it is possible that this is also the source of the hydrology in Tidal Channel A (and the other Tidal Channels) which could impact water quality in the proposed Smith Island Restoration Area.</td>
<td>Other, larger sources of groundwater exist from the south and west, namely the Snohomish River, and adjacent marshes such as Union Slough marsh restoration areas. Also, the comment describes an existing condition, whereby the proposed project will limit/reduce these effects by shifting the groundwater gradient from south-north (Snohomish River and POTW influence) to east-west (Union Slough influence), hence limiting the influence of the POTW plant.</td>
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<td>It is clear that Bailey’s studies were inconclusive regarding saltwater intrusion associated with the proposed restoration project. However, it is unclear why Bailey did not address the high salt content of the soils on the farmland that is proposed to be used for this proposed restoration project or the other constituents that are present in the soils and sediments that can impact water quality. Considering that if the levee system is breached the Union Slough will flow into the farmland and during high tides and storm events a significant amount of surface water will be present and this surface water will infiltrate through the soils and sediments in the restoration area, which can lead to potential impacts to water quality.</td>
<td>The County’s groundwater quality monitoring program (eleven observation wells) indicates that poor quality groundwater already exists throughout the project area in the sand aquifer. The total dissolved solids in the either shallow wells (screened in the upper 20 feet of the sand aquifer)’s range from 7,250 to 20,700 mg/L. The TDS levels in the three deeper wells are greater than 20,000 mg/L. This is considered brackish groundwater. Chloride levels are consistently high in these wells. Recent additional groundwater flow and salinity modeling of the project area (as part of the 2013 engineering design work) under existing and future conditions indicates that no significant impairment to the sand aquifer groundwater quality will occur under high tides.</td>
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<td>The additional ground water studies that need to be conducted must address how the infiltration through the soils with the low pH, high nitrogen compounds, high sulfur and high salts (which need to be characterized for other potential constituents present in biosolids) will impact ground water quality and how this will impact the water quality of the Union Slough and impact aquatic organisms that come in contact with these soils.</td>
<td>The 2013 engineering design investigation will include two shallow piezometers that will be instrumented to provide information concerning the shallow groundwater chemistry, and to evaluate infiltration rates. The data from these piezoemeters will also be used to determine the hydraulic relationship between the shallow alluvium and sand aquifer, and quantify the source of seepage into the tidal channels.</td>
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