Fir Island Farm Estuary Restoration Project
Interior Drainage Engineering Report
Skagit County, Washington

November 7, 2014

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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1.0 INTRODUCTION

This report presents the results of the interior drainage engineering analyses and design recommendations for the proposed Fir Island Farm restoration project in Skagit County, Washington. The purpose of this report is to evaluate the potential project effects on local agricultural drainage systems and farming activities that may result from the setback of the sea dike for the Washington State Department of Fish and Wildlife (WDFW) Fir Island Farm – Estuary Restoration Project. Effects that may occur include changes in tidal tailwater conditions on the tidegates and the drainage system interior to the dike system, increases in ground and surface water elevations, and increases in salinity on crops and in crop root zone areas. This report presents study methods and results of groundwater seepage and interior drainage surface water modeling studies, and recommendations for final design.

This report supersedes a previous report provided in February 26, 2014. The new information in this report includes evaluation of alternatives that were in response to recommendations made in the February 26, 2014, report. These additional alternatives are described as “Response Study” throughout this report. The term “Response Study” is related to specific language used in the project grants. Also, changes and revisions were made to the February 26, 2014, report based on an Independent Technical Review (ITR) by a third-party consultant team to the project. ITR comments and tracking of the responses and changes made to this report are presented toward the end of this report.

Our services were conducted in accordance with the contract and scope of services stated in the WDFW Contract No. 10-1431, Amendment 7, dated May 1, 2013. The scope of services is summarized as follows:

- Install, reinstall, and collect and analyze ground and surface water data for the project to measure and collect data to document the existing conditions baseline, and establish a monitoring network for long-term observations, including:
  - Install three pairs of dual-depth groundwater monitoring wells and associated pressure transducer equipment.
  - Perform slug tests in each of the groundwater observation wells.

   - Reinstall up to six surface water data loggers.
- Use data and observations to calibrate models for baseline conditions, and evaluate proposed project effects on groundwater seepage, mounding, saltwater intrusion, and surface water drainage, and evaluate the impacts on adjacent farms, specifically:
   - Potential changes of interior drainage surface water elevations and groundwater elevations in the spring and early summer growing season.
   - Likely changes of salinity conditions in the spring and early summer growing seasons, and fall/winter flood seasons.
   - Seepage into the interior drainage stormwater ponds and channels in the spring and early summer growing seasons and the fall/winter flood seasons.
- Perform sensitivity analyses on select aspects of surface and groundwater conditions including:
   - Tailwater conditions such as hydrodynamic effects of the proposed project, Erosion, Sedimentation, and Vegetation.
   - Upstream headwater factors such as storage pond vegetation growth and effects on limiting storage and conveyance for the proposed project (SPC).
   - Sea Level Rise on "Without Project" and proposed "Project".
- Perform a response study based on the recommendations of the February 26, 2014, report.
- Update and resubmit this report.

2.0 PREVIOUS REPORTS AND STUDIES

Shannon & Wilson, Inc. (S&W) prepared the following reports related to interior drainage as part of the 2011 project feasibility study:

- Technical Memorandum 1.2.1, Hydrologic Monitoring and Modeling of Interior Drainage Baseline Conditions, May 27, 2011.
- Technical Memorandum 1.2.1b, Data Logger Redeployment, October 19, 2011.
- Technical Memorandum 3.3, Interior Drainage Hydrologic and Hydraulic Assessment of Alt. 2A, November 4, 2011.
- Fir Island Snow Goose Reserve, Restoration Feasibility Study, 2011.

The hydrologic monitoring and modeling technical feasibility study reports developed in 2011 provide an overview of the baseline conditions and analysis of the preferred restoration alternative for the project. These reports provide information on site and basin characteristics, modeling, calibration, and alternatives analyses. In summary, conclusions in these previous reports include:

- The proposed setback dike has the potential to impact interior drainage areas with increased flood water surface elevations. The feasibility study demonstrated flood effects could be mitigated by constructing a larger storage pond immediately north of the setback dike project.
- Seepage through the dike into the interior drainage system would likely be slow and not directly impact the drainage system.
- Localized groundwater effects could occur, including minor increases in ditch surface water elevations and groundwater elevations along the setback dike. These effects could be mitigated using gravity drainage (tidegates). If needed, a pump station may be necessary to mitigate these effects and would be evaluated as a project response study if needed.

This report presents new analyses regarding the potential effects identified in the feasibility study. It uses new data and boundary condition information available from recent coastal hydrodynamic modeling, coastal engineering studies, geotechnical data collection, and expanded seepage analyses.

3.0 DRAINAGE BASIN AND SITE CHARACTERIZATION SUMMARY

The Fir Island Farm restoration project is located on the WDFW Snow Goose Reserve at Fir Island, as shown in Figure 1. The project site is located south of Fir Island Road, approximately 3.1 miles west of Conway, Washington. The WDFW Snow Goose Reserve property is comprised of 245 acres that are currently farmed, with special farming provisions and lease agreements with the neighboring property, to meet the reserve's Snow Goose management objectives. Natural tidal exchange to the site has been eliminated from the historic construction of dikes along Skagit Bay. One-way tidegates in the existing dike provide interior farm drainage and block inflow of tidal flow to the "interior" farm areas. The proposed restoration involves a 5,700-foot-long setback dike and approximately 127 acres of tidal marsh restoration.

The Fir Island Farm Snow Goose Reserve site has three major interior drainage areas, namely Brown and Rawlins Road Sloughs, Claude O. Davis and No Name Sloughs, and Dry and MacDonald Sloughs (Figure 2). Nearly all land within the 3,456-acre (5.4-square-mile) drainage basin is rural farm land, with sparse rural residential properties supporting farming. Roads and associated infrastructure make up but a small fraction of the drainage basin.

Brown Slough and Rawlins Road Sloughs (Brown Slough) have a combined drainage area of 629 acres. Brown Slough drains through a set of two 48-inch, top-hinge flapgates and one 48-inch screwgate at the Brown Slough tidegate complex just west of the (WDFW) Fir Island Farm parking area.

No Name and Claude O. Davis Sloughs (No Name Slough) have a combined drainage area of 1,007 acres draining through a set of two 48-inch, top-hinge flapgates near the center of the existing dike to be removed at the project site. One of the pipes is currently plugged due to pipe damage and leakage.

Dry Slough and MacDonald Slough (Dry Slough) have a combined drainage area of 1,720 acres. MacDonald Slough drains areas east of Dry Slough and meets with Dry Slough just upstream from the dike drainage outlet. Dry Slough drains through the dike through two 48-inch, top-hinge flapgates.

Surficial soils in the basin are generally dominated by Skagit silt loam with varying degrees of Sumas silt loam, Sedro Woolley silt loam, Mount Vernon very fine sandy loam, and Briscot fine sandy loam (Natural Resources Conservation Service [NRCS], 2012). Nearly all surficial soils in the basin are characterized as hydrologic group D, with high potential for runoff when soils are saturated (NRCS, 2012).

We note that the NRCS soil data and classification of hydrologic group D indicates high clay contents, or high water table (NRCS, 2012). S&W's soil classification testing indicates the near-surface soils are classified as slightly clayey SILT and sandy SILT that overlie a layer of slightly silty SAND. It is likely that the hydrologic group D classification exists due to shallow depth to groundwater (i.e., small volumes of soil storage) in the area (NRCS, 2007). This would imply that the soils have increased soil-water storage, if well drained, and actually have low storage potential due to high groundwater table.

The use of groundwater in the area appears to be minimal, likely due to the fairly shallow saline groundwater. A review of Washington State Department of Ecology (Ecology) website available well records (Ecology, 2014) indicates Maynard Axelson owns the nearest "domestic" well, which is located approximately 2,300 feet north of the project, on the north side of Fir Island Road. The well is 80 feet deep. The driller's log indicates that salt water exists between 50 and 80 feet. The well record has a note indicating the well was planned to supply water for "rare bird ponds." The Ecology database shows several groundwater observation wells in the Wiley Slough and Fir Island Farm project areas.

We reviewed the Washington State Department of Health (WDOH) online database to identify wellhead protection areas for non-exempt potable supply wells (WDOH, 2014). The database did not indicate wellhead protection areas in the project area. Instead, the primary water supply for the residents of Fir Island is provided by an existing water supply line.

4.0 HYDROLOGIC MONITORING

S&W and WDFW installed the groundwater and surface water, hydrologic monitoring network shown in Figure 1. The purposes of these installations are to: (a) document existing baseline conditions for use in engineering design and modeling calibrations, and (b) monitor and track post-project effects and use the data for future adaptive management decision making.

For this project phase, S&W installed seven surface water data loggers, three pairs of groundwater data loggers (six data loggers total), and one barometric data logger at the site in June 2013 through September 2014. Locations of installations are shown in Figure 1, and installation information listed in Table A-1.

A detailed discussion of data logger installations and monitoring results is provided in Appendix A (Hydrologic Monitoring). The project survey datum and elevations presented in this report are North American Vertical Datum of 1988. The following section describes in general ground and surface water elevations, salinity and temperature conditions for the June 2013 through September 2014 monitoring period.

Groundwater levels are on average 2.1 feet, 3.6 feet, and 3.3 feet and below the ground surface, for the South Hayton field (B-9w-13), Hayton North field (B-7w-13) and WDFW North field (B-5w-13) respectively. On average, the measured groundwater elevations were within the 2 foot root zone 19 percent, 6 percent and 13 percent of the time for the South Hayton field, Hayton North field and WDFW North field respectively. During the wet season, these values increased to 38 percent, 32 percent and 14 percent of the time respectively. During the spring/summer season these values decreased to 6 percent, 3 percent and 3 percent of the time respectively. Groundwater elevations will be important parameters to continue monitoring into the future to document post-project conditions.

No Name Slough had salinity levels exceeding the agricultural crop irrigation water quality criteria for salinity which is typically one to two parts per thousand (nearly equal to practical salinity units) (Mass, 1990). Dry Slough similarly had salinity levels exceeding crop water quality criteria for salinity along DS-1.1 near the Hayton South field. Notably, DS-1.3 had much lower salinity levels near the Hayton North field area.

Surface water data loggers (DS-1.0-LTC, NNS-2.0-LTC, and BS-2.0-LTC) installed in the Skagit Bay front area collected tidal water elevations measurements. The tidal data collected exhibited mixed tides (indicating typical two highs and two lows per tidal cycle) with a truncated low tide. The truncated low tide elevation is similar to tidal flow conditions observed along the Skagit River delta. Skagit River flows, groundwater conditions, and delta marsh geomorphology do not allow for full drainage down to the Puget Sound low tide elevations. This truncated low tide condition is termed river “surge”.

The salinity in No Name Slough (NNS-2.1) ranged from 2.5 to 10.2 psu, which is considered brackish. Salinity in Dry Slough (SW-DS-1.1) ranged from 5 to 8 psu which is considered brackish. Further upstream, salinity in Dry Slough (DS-1.3) ranged from 0.1 to 2.0 psu, which is considered slightly brackish. Both of these ditches are situated immediately along existing farm operations.

Surface water salinity measurements in the Skagit Bay data loggers (DS-1.0-LTC, NNS-2.0-LTC, and BS-2.0-LTC) ranged from 0.1 to 29.0 psu, which range from freshwater, to brackish, to salt water salinity levels. The lowest periods of salinity for the data loggers located in the Skagit Bay occurred from May through August in 2014. Observed salinity levels differ between Dry Slough, No Name Slough and Brown Slough.

Surface water data loggers installed in the Skagit Bay area collected tidal water temperature measurements. Temperatures ranged from 10 to 30 degrees Celsius, which periodically is significantly above the 16 degree Celsius water quality standard. Peak water temperature measurements occurred in late June 2013. Diurnal temperature changes range on the order of 6 degrees Celsius, while seasonal temperatures ranged by 20 degrees Celsius.

5.0 FARM CROP AND ROOT ZONE INFORMATION

Root zone criteria were analyzed for the project to evaluate how often groundwaterlevels extend into the critical root zone area.

Critical root zone depths depend upon crop type, soil type, drainage, and groundwater conditions. Crops grown on the adjacent Hayton Farm include strawberries, raspberries, blackberries, blueberries, and other berry crops such as marionberries and loganberries. Crops grown on the WDFW Snow Goose Reserve property are subject to snow goose foraging winter crop rotations. Crops typically include spring-planted vegetable seed crops such as spinach, red beets, and radish, and annual summer crops such as potatoes and broccoli. Root zone depths for the crops listed above range from 6 to 18 inches (NRCS, 2005). We selected a critical root zone depth of 24 inches to conservatively estimate potential groundwater effects on adjacent farm properties and crops.

The root zone criteria evaluated for the project were based on the amount of time water elevations exceed the critical root zone elevations. The critical root zone "inundation" criterion used for the project is a 10 percent increase in the time pond elevations exceed the critical root zone elevation. We used the modeled storage pond elevations to calculate how often the critical root zones are inundated. The hydrologic monitoring data show that the ditch water elevations are typically higher than adjacent groundwater elevations. Therefore, using ditch (and pond) surface water elevations will provide a conservative estimate of the time groundwater elevations exceed the critical root zones.

The 10 percent increase compares how often the proposed "Project" conditions increase above the "Without Project" conditions. For years where there is little root zone inundation, one week for example, the 10 percent criterion translates into a 0.7-day increase in critical root zone inundation. For years where there was longer critical root zone inundation period for existing conditions, three weeks for example, the 10 percent criterion translates into a 2.1-day increase in critical root zone inundation. Using a hydraulic conductivity value of 1.5 feet per day for the upper soil unit, the 2.1-day rise in surface water level at the interior drainage storage pond would have 3.1 feet of migration from the pond edge into the field, which would be a minor change in groundwater migration into the farm areas. This result indicates that the 10 percent increase criterion is a conservative criterion for evaluating crop root zone impacts.

We note the potential areas of impact extend beyond the project site and could affect low elevation farm fields beyond the project area. Inundation root zones in adjacent and upstream farm areas are variable due to the topography of the farm fields. Figure 3 shows the farm elevations upstream of the project site along the No Name Slough basin. The root zone effects analysis uses groundwater and surface water modeling, with the 10 percent criterion, and accounts for the variability in basin topography. More detail regarding the analysis approach is described below and in the accompanying appendices.

6.0 SEEPAGE ANALYSIS

We performed seepage analyses to evaluate the potential for seepage-related impacts to the interior drainage storage pond, upstream drainage channels, and adjacent farm areas. A detailed discussion of the seepage analyses is provided in Appendix B.

To summarize, the seepage analysis involved the following tasks:

- Analyze in situ field slug test data to calculate hydraulic conductivity for the deeper sandy soil unit.
- Perform grain-size analyses and use the results to calculate hydraulic conductivity.
- Estimate seepage rates to the interior drainage storage pond using hydrologic surface water level measurements.
- Develop and use a SEEPW numerical flow model to predict seepage rates to the interior drainage storage pond.

The hydraulic conductivity estimates and seepage analysis modeling results were used to calculate seepage inflows to the HEC-RAS surface water (model (Figure 4). The following is a summary of the field testing, seepage analysis and modeling methods, and recommendations for seepage inflows to the interior drainage surface water system.

S&W performed single-well slug tests to support the seepage analysis. We analyzed the test data to derive hydraulic conductivities for the project site using the solutions of Bouwer (1989) and Butler (1999). Although both methods are applicable for slug tests in the wells, our opinion is the the Bouwer and Rice solution provides a better match and results. These soil properties were used in the SEEP/W model soil unit layers to estimate seepage inflows through and underneath the dike to the interior drainage system. The range of hydraulic conductivities for the slug tests in the Ha sand unit using the Bouwer and Rice method are 57 to 283 feet/day (ft/day) (0.02 to 0.11 centimeters per second [cm/sec]), and the overall geomean is 132 ft/day (0.05 cm/sec).

We analyze 45 soil samples collected from test pits and soil borings at the site, and calculated hydraulic conductivity using six separate empirical equations. Average hydraulic conductivity values calculated for each sample are based only on the valid results. The calculated geomean hydraulic conductivities based on soil properiteis for the upper soil unit (Hm), the middle unit (Ha) and the lower unit (He) are 0.04, 31.4, and 0.09 feet per day, respectively.

Details regarding the SEEP-W model, land surface, soil layering and properties, and surface and groundwater boundary conditions, are described in Appendix B. Steady-state seepage analyses were performed for three representative sections along the existing dike, the northern section of the setback dike, and the eastern section of the setback dike. The SEEP/W model results for the "Without Project" steady state seepage range from 270 to 700 gallons per minute (gpm) along the 3,300-foot length of the existing dike. The SEEP/W model results for the proposed "Project" dike length of 5,300 feet range from 60 to 120 gpm (combined for the north and east zones).

Hydrologic monitoring data were used to estimate existing condition seepage inflow to the No Name Slough drainage system. The estimate was performed by calculating the change in interior drainage channel storage volume while the tidegates are closed on each cycle. Seepage inflows include existing dike through and underseepage, and upgradient groundwater baseflow inflows. Using the hydrologic surface water monitoring data for the site, total seepage inflows to the storage pond are estimated at 1 cubic foot per second (cfs) (450 gpm). Appendix C provides details regarding the surface water monitoring seepage rate calculations used as input to the HEC-RAS pond model.

We used seepage rates calculated observed surface and groundwater monitoring data to model seepage effects to the No Name Slough interior drainage pond. The calculated seepage rate averages 1.0 cfs (450 gpm). This seepage rate reflects the fact that the length of the dike along the pond for the Project condition will be similar to the length of existing dike along the borrow ditch.

For Dry Slough, we used the seepage inflow rate of 1.0 cfs (450 gpm) plus 0.2 cfs (100 gpm). The additional 0.2 cfs (100 gpm) is based on the SEEP-W calculated seepage rates for the new 3,000 feet of dike along Dry Slough. In our opinion, these values are conservative, because the SEEP/W model indicates that seepage rates to the interior drainage storage pond and Dry Slough should be less for Project conditions versus Without Project conditions. Also, the Project condition project has reduced interior drainage channel lengths and drainage areas compared to Without Project conditions; therefore, less upgradient groundwater baseflow inflow should occur to the system.

One cfs seepage flow represents the total inflow from both upstream drainage basin from surface water flow in the No Name Slough system, as well as through and under seepage at the existing dike system. Of this 1.0 cfs the SEEP-W modeling results indicate through and underseepage rates are on the order of 0.13 and 0.33 cfs. For tidal conditions, dike through and underseepage represents 13 to 33 percent of flow in the No Name Slough drainage channels. For a two-year flood event, the dike through and underseepage represents between 1 and 3 percent of the flow in the channel, and for the 100-year flood event, the dike through and underseepage represent less than 1 percent of the flow in the channel.

We performed a sensitivity analysis for SEEP/W seepage modeling to evaluate the effects of a worst case scenarios where the entire upper silt soil layer was a coarse sand layer allowing for increased seepage (Appendix B). We calculated seepage rates assuming a sand layer would be present in place of the upper farm silt layer. The SEEP/W model sensitivity analysis evaluated a sand layer running the entire length of the setback dike. The modeling results indicate that the full sand layer seepage rate was on the order of the 1.0 cfs,and similar to the 1.0 cfsused for daily seepage inflow rates in the surface water, interior storage pond model. Also, the seepage sensitivity results indicate that seepage is a lesser factor affecting pond and groundwater elevations compared to the project tailwater effects or Sea Level Rise effects. Therefore, seepage was not evaluated as a “key” sensitivity factor discussed further in Appendix D.

7.0 SURFACE WATER MODELING

Surface water modeling for the project involves hydrologic runoff modeling combined with hydraulic open channel flow modeling (Figure 4). These models were used to calculate interior drainage and interior drainage storage pond water surface elevations that occur upstream from the Project drainage tidegates. Existing “Without Project” and proposed “Project” conditions modeling were performed to compare average pond elevations and salinity conditions during key farm planting and growing seasons. The modeling analyses evaluated levee performance using a 50-year hydrologic runoff, tide and Sea Level Rise scenarios. . We ran the Western Washington Hydrologic Model that uses 50-year rainfall records from 1948 to 1958, to model precipitation and runoff for a known 50-year period. Sea Level Rise was considered for both “Without Project” and “Project” conditions.

The key concern of the adjacent property owners and farmers is that the project will raise water surface elevations in the drainage ditches, thereby impacting farming on adjacent property. This study evaluated interior storage pond elevations during April planting periods. April was selected as the key month as this is when observed groundwater tables, and surface water modeling results have the highest average surface elevations, and that local farmers are starting spring planting operations for summer crops. In our opinion April is representative of when key high groundwater and surface water conditions occur, and when the farmers need access to their fields, and should be used to evaluate farm drainage impacts.

We calculated surface water inflows from the upstream basins using the Western Washington Hydrology Model (WWHM, 2012). Seepage inflows and groundwater base flows presented in the previous section were added to the surface water runoff modeling flows from the WWHM model. Downstream tidal boundary conditions were applied at the pond tidegate outlet. The boundary conditions were modified based on the key sensitivity factors over the 50-year modeling period. Details of the hydrologic runoff modeling and boundary conditions are provided in Appendix C.

An unsteady-state HEC-RAS (U.S. Army Corps of Engineers, 2010) model was created for the No Name Slough and Dry Slough interior drainage systems. The hydraulic model was used to evaluate the effects of the setback dike on potential increases in spring season and flood water surface elevations of the "Project" interior drainage storage pond. The original model setup and calibration was developed as part of the S&W Fir Island Farm Feasibility Study (S&W, 2011). The model was modified using new seepage and surface water inflows and boundary conditions for this phase of study. Both the "Without Project" and "Project" conditions were modeled over a 50-year time period. Details of the hydraulic modeling and boundary conditions are provided in Appendix C.

We performed sensitivity analyses for Sea Level Rise and marsh Erosion-Sedimentation-Vegetation effects on drainage tailwater conditions. Possible changes to interior drainage pond vegetation and roughness conditions that may affect Storage Pond Capacity over time, with varying degrees of drainage maintenance, were analyzed. More detailed information for the sensitivity analysis is included in Appendix D.

The hydraulic modeling results for Sea Level Rise scenarios and effects in No Name Slough are summarized in Appendix C, Tables C-4 and C-5. The project effects are limited primarily to No Name Slough, as this is the location subject to the tidal hydrodynamic effect and the sensitivity parameters discussed in Appendix D. Dry Slough will not likely have the same tidal hydrodynamic or sensitivity factor effects because it is mostly isolated from the tailwater effects that occur along the setback dike. Our seepage analyses show that it should have only minor increases in seepage. The anticipated minor increases in seepage for Dry Slough can be accommodated by an additional 48-inch tidegate to the existing drainage system.

The hydraulic modeling results for No Name Slough and the interior drainage storage pond indicate that "Project" water surface elevations in the storage pond likely will increase during the key early growing season (April). The effects include increases in tailwater elevations that reduce drainage functions of the tidegates, and could increase groundwater elevations into root zones at the adjacent WDFW farm field to the north, and other adjacent and upstream farm properties within the No Name Slough Basin.

The initial results showed that Sea Level Rise will affect farm properties in the No Name Slough Basin for “Without Project” and “Project” conditions. Compared to “Without Project” the combined effects for the “Project” Sea Level Rise with the hydrodynamic tailwater effects would have additional impacts on 106 acres immediately after project implementation and up to an additional 319 acres at the end of the 50-year modeling period in the No Name Slough basin and on the WDFW field. These acreages are “Project” increases above the “Without Project” condition account for 11 to 32 percent of the farm properties located in the No Name Slough drainage basin. These effects do not include the uncertainty of the key sensitivity factors discussed further in Appendix D. The planned drainage improvements, such as additional tidegates and pump stations that will mitigate these effects are discussed further in later sections of the report.

A mass balance model was used to estimate salinity effects on the “Project” interior drainage storage pond. The parameters included seepage inflow rates along the length of the “Without Project” and “Project” dike sections, base flow groundwater inflows to the interior drainage storage pond, and average Skagit Bay and No Name Slough salinity concentrations recorded during the 2013 data-collection period. The calculations indicate that salinities in the pond will be equal or lower for the “Project” condition (Appendix C, Table C-6).

8.0 SENSITIVITY ANALYSIS

A sensitivity analysis was performed to evaluate the effects of coastal hydrodynamics, marsh Erosion-Sedimentation-Vegetation and interior storage pond vegetation and maintenance conditions on the performance of the interior drainage system. The sensitivity analysis considers how changes in these conditions may occur over a design life period of 50 years. The study uses a Monte Carlo analysis to perform the sensitivity analysis. Details of the sensitivity analysis are provided in Appendix D.

The Monte Carlo method is a statistical technique used to model the range of expected sensitivity factors (inputs) to characterize the uncertainty of the pond water surface elevation (output). For the Fir Island project, we identified three key sensitivity factors, including:

- Sea Level Rise– This is a model downstream tidal boundary condition.

- Erosion-Sedimentation-Vegetation conditions in the restored marsh that can affect interior drainage system tailwater conditions – This is a model downstream tidal boundary condition.
- Storage Pond Capacity represents the effects vegetation and maintenance conditions may have on the interior storage pond capacity.

The recommendations for Sea Level Rise and Erosion-Sedimentation-Vegetation sensitivity factors and input parameters were presented in S&W Coastal Engineering Recommendations Report (S&W, 2014). These factors and the Storage Pond Capacity sensitivity factors, the input/output relationships and probability distributions applied in the Monte Carlo analysis are described in Appendix D.

The "Without Project" Sea Level Rise Only and "Project" Sea Level Rise + Hydrodynamic (tailwater), Erosion-Sedimentation-Vegetation, and Storage Pond Capacity combined effects probability distributions were randomly sampled and analyzed using a Monte Carlo simulation. The resulting range of probable storage pond water surface elevation outputs and statistics are shown as cumulative distribution functions (Appendix D, Tables D-6 and D-7, and Figures D-12 through D-14). The sensitivity analysis results are summarized as follows:

- Assuming the project was built in 2013 (i.e., when the analysis started), the expected range (10 to 90 percent cumulative probability) of average April interior drainage storage pond water surface elevations is:
- – 3.3 to 3.6 feet for the "Without Project." 100 percent of the effect is Sea Level Rise
- – 4.1 to 4.4 feet for the "Project." 98 percent of the effect is related to Sea Level Rise plus the "Project" hydrodynamic (tailwater) effect
- For 2033, the expected range (10 to 90 percent cumulative probability) of average April pond water surface elevations is:
- – 3.4 to 3.8 feet for the "Without Project." 100 percent of the effect is Sea Level Rise
- – 4.1 to 4.9 feet for the "Project." 88 percent of the effect is related to Sea Level Rise plus the "Project" hydrodynamic (tailwater) effect
- For 2063, the expected range (10 to 90 percent cumulative probability) of average April pond water surface elevations is:
- – 3.7 to 5.1 feet for the "Without Project." 100 percent of the effect is Sea Level Rise
- – 4.4 to 6.2 feet for the "Project." 88 percent of the effect is related to Sea Level Rise plus the "Project" hydrodynamic (tailwater) effect

For reference, the farms in the basin are typically between 6 and 8 feet elevation, with the critical root zones extending 2 feet below existing grade. The farm areas less than 7 feet in elevation are those most exposed to risks from groundwater effects.

The results of the modeling and sensitivity analysis indicate that the "Project" is expected to have an effect on the interior drainage system and adjacent farm properties. The effects could include higher surface and groundwater elevations effects on hundreds of acres of farm property upstream from the Project along the WDFW field and the No Name Slough drainage basin. The predominant factor driving these effects is the hydrodynamic tailwater effect resulting from the setback dike. Sea Level Rise effects are equal for the "Without Project" and "Project" alternatives, and the Erosion-Sedimentation-Vegetation and Storage Pond Capacity factors for the "Project" alternative are of lesser concern.

Additional sensitivity analysis could be performed on the hydrodynamic tailwater effect by rerunning the coastal hydrodynamic model, calibrated to more recent hydrologic low tide data, and by varying the model loss (vegetation and channel roughness) coefficients over a range of vegetation and channel roughness conditions. That said, the predicted hydrodynamic tailwater effect seems logical, as it will take a longer for a larger volume of tidal water to drain from the restored marsh area. The low-tide period is somewhat fixed and does not allow for full drainage of an increased volume of water. Additional modeling may add certainty and reduce predictions of the size of the hydrodynamic tailwater effect (i.e., 0.50 foot instead of 0.75 foot), but impacts to upstream farm areas are likely to occur regardless of the certainty of the tailwater effects. Instead, we recommended in the February 2014 report evaluating mitigation alternatives as part of the response study. Section 9.0 and 10.0 discuss these mitigation alternatives, and Section 11.0 presents our final recommendations and recommended Project drainage mitigation measures.

9.0 ORIGINAL RECOMMENDATIONS PROVIDED IN FEBRUARY 2014 REPORT

The results of the Draft February 2014 report indicated that the Project was expected to have an effect on adjacent farm fields, using the original "Project" design configuration. The information contained in the Draft February 2014 report was presented to Consolidated Diking District 22 (CDD22) as preliminary findings at a series of CDD22 meetings in late 2013 and early 2014. S&W and WDFW made a preliminary recommendation to evaluate a pump station as part of the project design as a project response study to mitigate for possible project effects on interior drainage conditions.

CDD22 indicated that their preference is to evaluate gravity drainage options by connecting the storage pond to Dry Slough through a set of tidegates on the east side of the pond for gravity drainage, as a first option. Then, evaluate a pump station to provide backup drainage pumping in the interior drainage storage pond. We noted that the project study had to date, attempted to isolate No Name Slough from Dry Slough to limit the potential effects on the Hayton Farm. Shunting drainage flows from No Name Slough to the east into Dry Slough could have additional effects on the Hayton Farm property. The Hayton South Fields have low field elevations that could be affected by these types of operations.

CDD22 also commented that the “Project” interior drainage storage pond was likely too wide to accommodate maintenance dredging with a clamshell. CDD22 inquired if a narrower and longer pond configuration could be considered. We modified the design pond width in later phases of study, and incorporated a narrower width in the design plans.

CDD22 questioned the seepage rates estimates provided in the study in the late 2013 early 2014 meetings. Their comments were based on CDD22 experience with dewatering pumping operations being overwhelmed by seepage in other areas along Fir Island. The seepage rates used in the study were based on soil properties and observed monitoring data. We ultimately used the hydrologic monitoring surface water data in the interior drainage ditch system to estimate seepage inflows into the channels. CDD22 also expressed concern that a seepage cutoff structure may still be needed. To address these questions, additional seepage analyses and cutoff studies were included in the response study discussed below.

To mitigate for the project effects and address CDD22 concerns, the following response study recommendations were made with the February 2014 report:

- Assess tide gates connecting the No Name Slough storage pond to Dry Slough.
- Assess a pump station in the No Name Slough storage pond.
- Assess a third tidegate connecting Dry Slough to the Skagit Bay to accommodate additional inflows from the interior drainage storage pond and minor increases in seepage, and shunting of flows from No Name to Dry Slough.
- Assess the combined operations of these features.
- Further evaluate and reduce uncertainty of seepage estimates and evaluate the need and costs of a seepage cutoff system.
- Consider a narrower and longer interior drainage storage pond.

10.0 RESPONSE STUDY ALTERNATIVES

The response study was performed to analyze alternatives for mitigating project effects on neighboring farm properties. The response study analysis included the following tasks:

- Evaluate an interior drainage storage pond that would have a maximum width of 150 feet to allow for drag line dredging. We designed a interior drainage storage pond that will be 135 feet wide to balance land uses across the site. We confirmed that the modified pond plan and volume provides adequate storage (Appendix C).
- Evaluate the effectiveness and cost of a seepage cutoff wall (barrier) along the setback dike (Appendix B).
- Evaluate gravity drainage tidegate option by adding a third tidegate at the downstream end of Dry Slough to accommodate additional seepage from dike setback (Appendix C).
- Evaluate gravity drainage tidegate options between the interior storage pond and Dry Slough to reduce pond water surface elevations (Appendix C).
- Evaluate a pump station option in the interior storage pond to reduce pond water surface elevations. The pump station would discharge through a pipe leading to the new marsh area (Appendix C).

The details of the response study technical analyses are included in Appendices B and C, and summarized below.

The revised “Project” interior drainage storage pond configuration will have a pond width of 135 feet and length of 2,200 feet. The revised pond dimensions provide adequate flood storage volume as compared to the original design interior drainage storage pond volume (Appendix C).

Installation of a seepage cutoff wall (barrier) along the setback dike would reduce seepage to the interior drainage system. Depending on the depth of cutoff and assumed soil hydraulic conductivity, seepage from the Skagit Bay side could be reduced by up to 90 percent, or up to 1.1 cfs (500 gpm). In order to be effective, a cutoff wall would need to be at least 20 feet deep so it would and penetrate into the underlying sand (Ha) layer. The cost is estimated at more than $1 million for this type of installation along the entire length of the dike setback. The addition of two 48-inch tidegates from the Project interior drainage storage pond to Dry Slough was requested as an alternative by CDD22. Without a pump station, this alternative would incrementally reduce storage pond water elevations, but not enough to mitigate for the hydrodynamic tailwater effects on the interior drainage storage pond (Appendix C, Figure C-5). The additional tidegates cannot drain water below the elevated tailwater condition on the pond.

However, the addition of the two 48-inch tidegates in combination with the pump station would improve gravity drainage to the east. The tidegates reduce the amount of operating time for the pump station discussed below.

The addition of a pump station to the interior drainage storage pond has the ability to lower the pond elevations and match existing conditions water surface elevations in the pond (Appendix C, Figure C-5). Two 3,000-gpm pumps would be needed to accommodate the anticipated inflows and seepage rates into the pond. A third pump is recommended for maintenance and emergency flood pumping operations. The pump station will have electrical power supply run from Fir Island Road, with a diesel power backup electrical port. The power backup will allow connection of a diesel generator to the pump station if there is an electrical power outage during flood pumping conditions.

We recommend the pump begin operating at elevation 3.5 feet and drawing down to a shutdown elevation of 3.0 feet during the Spring and Summer periods (March through October), with an operation elevation of 4.5 feet drawing down to elevation of 4.0 feet (November through February). These values are based on data from existing conditions baseline monitoring of the No Name Slough, Dry Slough and groundwater along the adjacent farm fields. Every 1 foot of pumping draw of freshwater in the surface water ditches and groundwater, down has approximately 40 feet upward salt water intrusion. The project analysis shows no effect on maximum flood elevations and groundwater elevations during fall/winter periods, so pump operations during those periods are not required as a result of the "Project."

11.0 FINAL RECOMMENDATIONS

Based on the outcomes from the response study alternatives analysis, we recommend including a third tidegate in Dry Slough at the Skagit Bay (downstream) tidegate outlet, adding two 48-inch tidegates at the east end of the interior storage pond into to Dry Slough, and adding a pump station located at the eastern third of the interior storage pond with three, 3,000-gpm pumps discharging through the dike into the Project marsh restoration area. This proposal was accepted by WDFW, CDD22 the Steering Committee, project partners, funding and granting agencies in the summer of 2014. The pump station design has been included in the 90 percent design plans.

With respect to a seepage cutoff, the "Project" and tidegate alternatives described below should adequately discharge the additional seepage into the interior drainage pond and Dry Slough and are much less costly. Therefore, in our opinon, a cutoff wall system is not necessary (Appendix C, Figure C-4).

12.0 INDEPENDENT TECHNICAL REVIEW (ITR)

An ITR of this study and report was performed by Moffatt & Nichol, and Golder Associates. A copy of the ITR comments and responses is included in Appendix E.

13.0 LIMITATIONS

This report was prepared for the exclusive use of WDFW and other members of the Design Team for specific application to the design of the Fir Island Farm Restoration Project. Within the limitations of the scope, schedule, and budget, the analyses, conclusions and recommendations presented in this report were prepared in accordance with generally accepted professional engineering principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied. The findings of this report in no way guarantee that any agency or its staff will reach the same conclusions as S&W. Refer to Appendix F for Important Information About Your Geotechnical/Environmental Report.

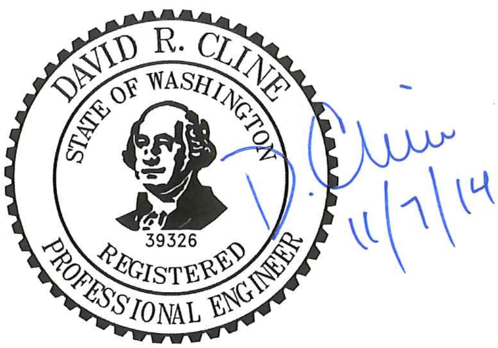
The analyses, conclusions, and recommendations contained in this report are based on site conditions as they presently exist, and further assume that the explorations and soil properties assumed herein are representative of the subsurface conditions throughout the Fir Island Farm project site; that is, the subsurface conditions throughout the project and affected areas are not significantly different from those disclosed by the explorations. Unanticipated soil conditions are commonly encountered and cannot fully be determined merely by taking soil samples from a limited number of soil borings. Such unexpected conditions frequently require that additional expenditures be made to attain properly constructed projects. Therefore, some contingency fund is recommended to accommodate such potential extra costs. Our conclusions and recommendations are based on our understanding of the project as described in this report and the site conditions as interpreted from the explorations.

If, during final design and construction, subsurface conditions different from those encountered in the field explorations are observed or appear to be present, we should be advised at once so that we could review these conditions and reconsider our recommendations where necessary. If there is substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed because of natural forces or construction operations at or adjacent to the site, we recommend that this report be reviewed to determine the applicability of the conclusions and recommendations concerning the changed conditions or the time lapse.

Facts and conditions referenced in this report may change over time. Facts and conditions set forth here are applicable as described only at the time this report was written. We believe that the conclusions stated here are factual, but no guarantee is made or implied.

The data contained in this report are based in part upon specialized hydrodynamic modeling prepared by others (i.e., Battelle) in support of the project. We assume that the data and modeling output provided by others has been accurately developed and calibrated and that it comprises reliable information to perform related analyses. S&W cannot make claims regarding the correctness or accuracy of these models and data provided by Battelle, as it is a proprietary model.

SHANNON & WILSON, INC.



David R. Cline, P.E., C.F.M.
Senior Associate

DRC:CMH:SDT:CAR/drc

14.0 REFERENCES

Bouwer, H., 1989, The Bouwer and Rice slug test – an update: Ground Water, v. 27, no. 3, p. 304-309.

Butler, J.J., Jr., 1999, The design, performance, and analysis of slug tests: Lewis Publishers, CRC Press, Boca Raton, Florida.

Maas, E.V., 1990, Crop salt tolerance, in: Tanji, K.K. (Ed.), Agricultural Salinity Assessment and Management, ASCE Manuals and Reports on Engineering No. 71, ASCE, New York, p. 262-304.

Natural Resources Conservation Service, 2005, National Engineering Handbook, Part 632 Irrigation Guide, Chapter 8, Project and Farm Water Irrigation Requirements.

Natural Resources Conservation Service, 2007, National Engineering Handbook, Part 630 Hydrology, Chapter 7, Hydrologic Soil Groups.

Natural Resources Conservation Service, 2012, Soil Survey Geographic (SSURGO) database for Skagit County, Washington: Available: http://soildatamart.nrcs.usda.gov/, accessed October 2013.

Shannon & Wilson, Inc. (S&W), 2011, Fir Island Snow Goose Reserve, restoration feasibility study, Washington Department of Fish and Wildlife, Fir Island Washington: Report prepared by Shannon & Wilson. Inc, Seattle, Wash., 21-1-12318-003, for Washington Department of Fish and Wildlife, Olympia, Wash., December.

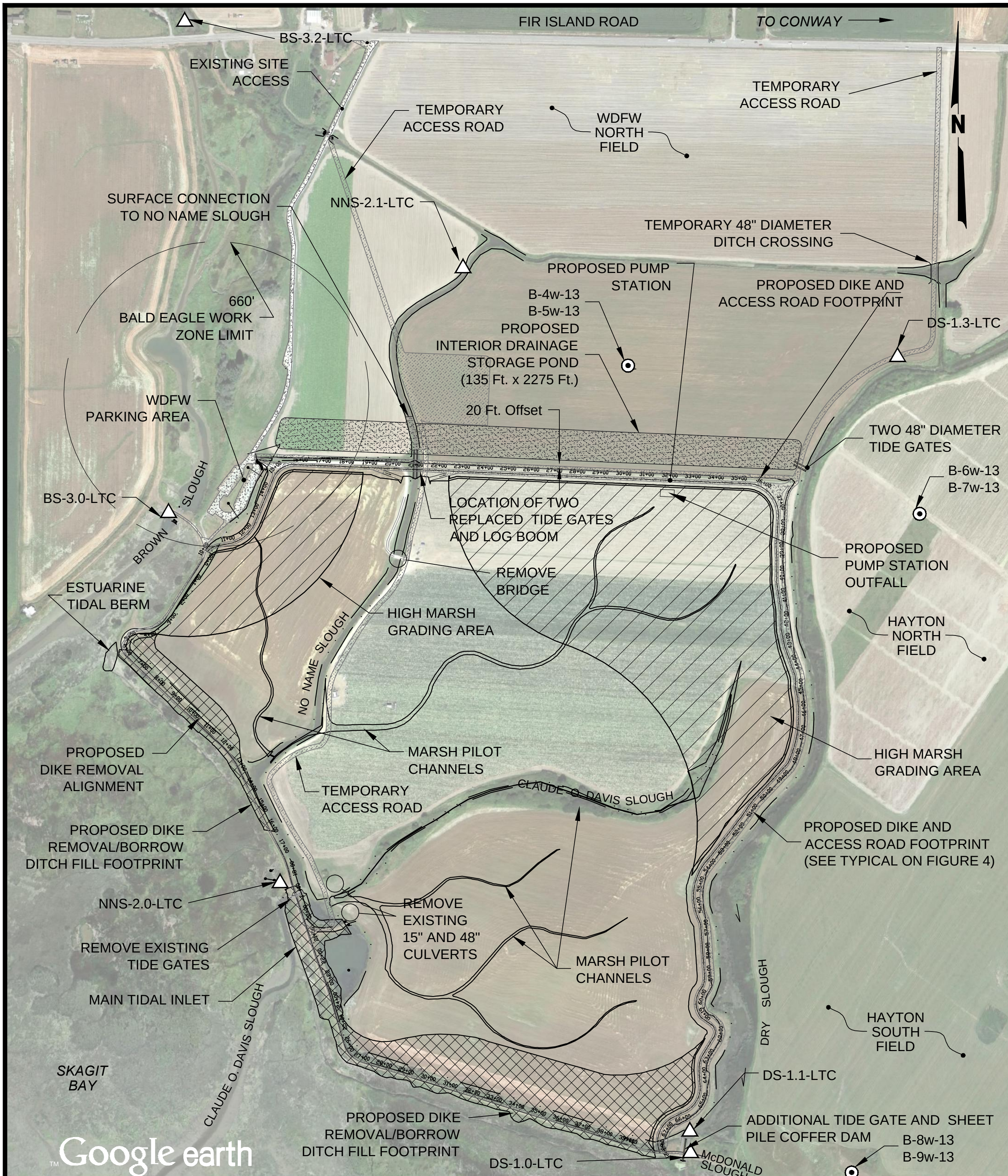
Shannon & Wilson, Inc. (Shannon & Wilson), 2014, Draft coastal engineering report WDFW – Fir Island Farm Snow Goose Reserve, Skagit County, Washington: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., January.

Washington State Department of Ecology (Ecology), 2014, Ecology Well Log Viewer Website. https://fortress.wa.gov/ecy/waterresources/map/WCLSWebMap/

Washington State Department of Health (WDOH), 2014, Division of Environmental Health, Office of Drinking Water Website: https://fortress.wa.gov/doh/eh/dw/swap/maps/default.cfm?action=initsearch&CFID=70072&CFTOKEN=16804635

Western Washington Continuous Simulation Hydrology Model (WWHM), 2012, http://www.ecy.wa.gov/programs/wq/stormwater/wwhmtraining/summary2012updates.html

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center, 2010, River analysis system, HEC-RAS (v. 4.1): January, available: http://www.hec.usace.army.mil/software/hec-ras/hecras-download.html.



0 600 1200

Scale in Feet

LEGEND

Monitoring Well Designation and Location

Data Logger Designation and Location

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, Image U.S. Geological Survey, Image Island County, reproduced by permission granted by Google Earth ™ Mapping Service.

Fir Island Farm
Estuary Restoration Project
Skagit County, Washington

PROJECT SITE PLAN

NOVEMBER 2014 21-1-12318-216

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FIG. 1

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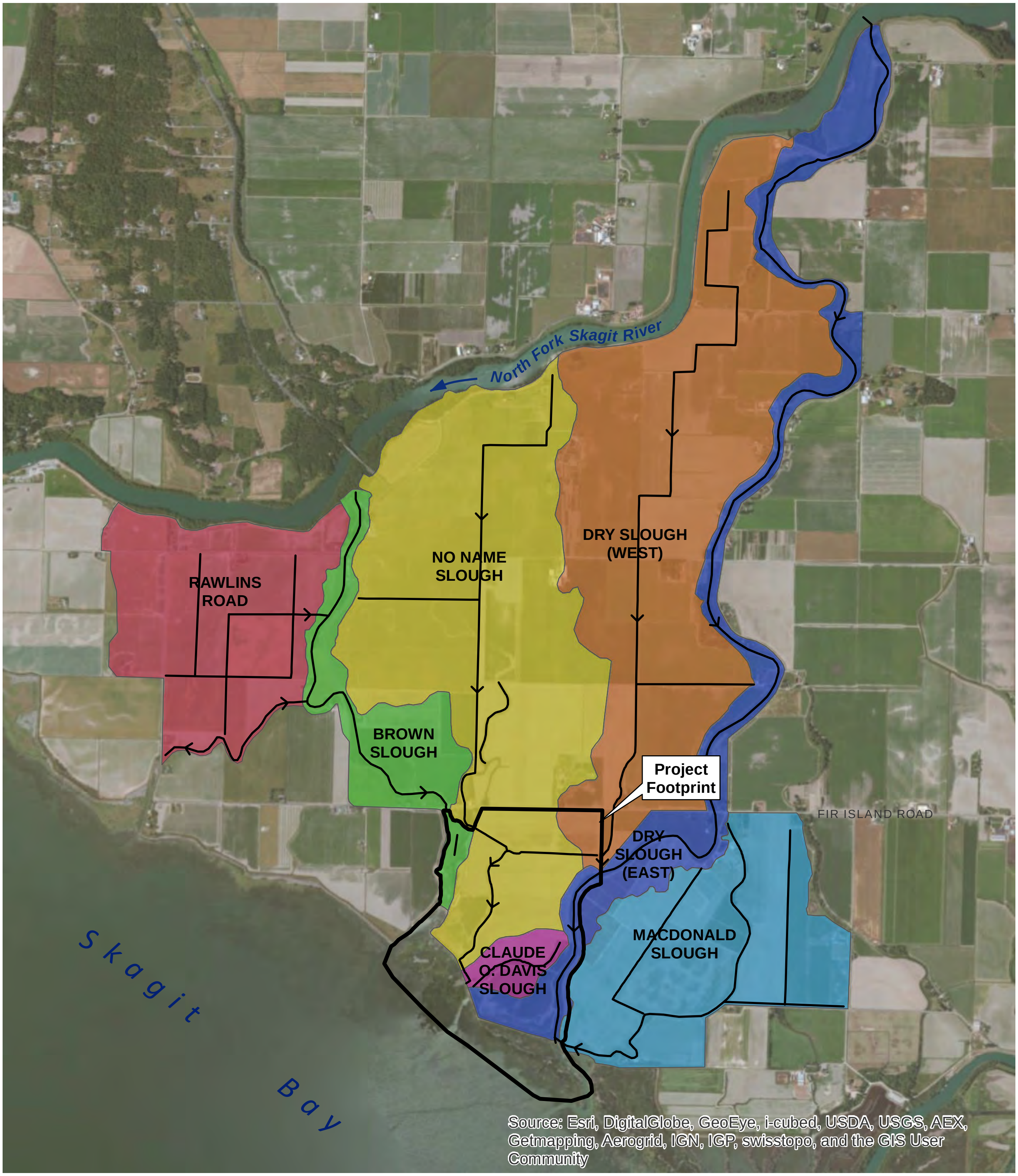

Project Boundary

Interior Drainage Channel

N W E S

0 3,000 6,000 Feet

Fir Island Farm Restoration Project
Mount Vernon, Washington

INTERIOR DRAINAGE BASINS

November 2014 21-1-12318-216

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FIG. 2

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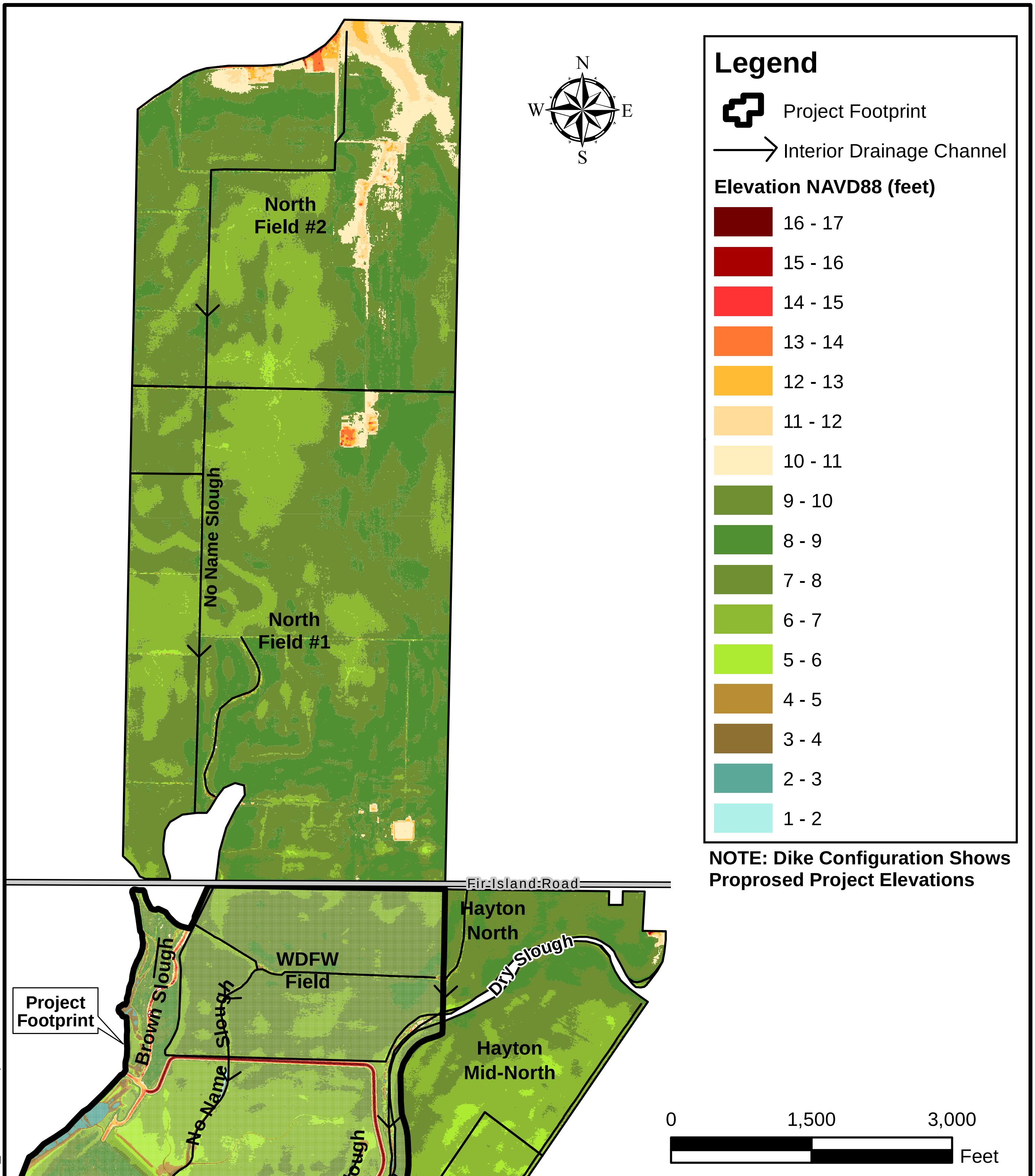

Fir Island Farm Restoration Project
Mount Vernon, Washington

POTENTIAL EFFECT ON FARM FIELDS IN NO NAME & DRY SLOUGH BASINS

November 2014 21-1-12318-216

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FIG. 3

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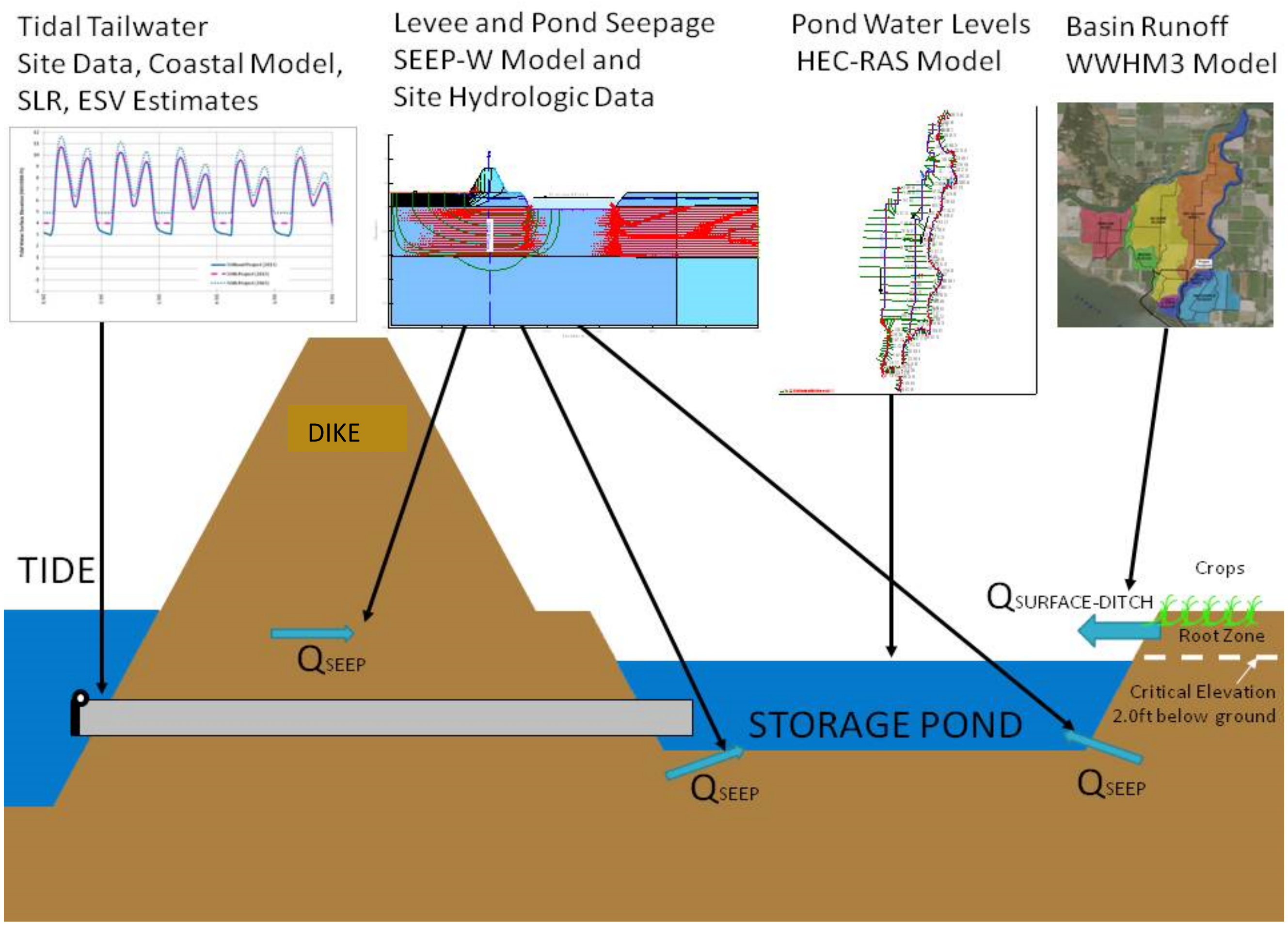

Fir Island Farms Restoration

Skagit County, WA

Hydrologic and Hydraulic Conceptual Model

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. 4

Fig. 4

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APPENDIX A

HYDROLOGIC MONITORING

APPENDIX A

HYDROLOGIC MONITORING

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TABLE

PHOTOGRAPHS

PHOTOGRAPHS (cont.)

FIGURES

APPENDIX A

HYDROLOGIC MONITORING

A-1 INTRODUCTION

Shannon & Wilson, Inc. (S&W), in collaboration with the Washington Department of Fish and Wildlife (WDFW), installed the new, and reinstalled and reconfigured the existing, groundwater and surface water hydrologic monitoring network (Figure A-1). The purpose of the monitoring network is to: 1) document baseline conditions for use in engineering design and modeling calibrations, and 2) monitor and track post-project effects for use with future adaptive management decision making.

For this project phase, S&W installed seven surface water data loggers, three pairs of groundwater data loggers (six data loggers total), and one barometric data logger. Locations and identification are shown in Figure 1. The data loggers record water pressure (elevation), temperature, and conductivity (salinity).

A.1.1 Data Logger Installations

A total of 14 Solinst brand data loggers were used for the project (groundwater and surface water data loggers). They include 12 Solinst Model 3001 LTC surface water data loggers, which measure pressure (used to calculate water surface elevation), temperature, and conductivity (used with temperature to calculate the salinity of the water), and one Model 3001 LT surface water data logger, which measures pressure and temperature only. One barometric data logger, which measures air pressure and temperature only, was also deployed to collect data used to compensate for air pressure readings of the water pressure data loggers. Prior to deployment, each of the data loggers with conductivity sensors was calibrated using the manufacturer's recommended procedure and calibration solutions. Pressure and temperature sensors are factory calibrated and checked during data downloads and compared with measured water depths. All data loggers were set to record data at a 15-minute interval, on the hour.

S&W deployed the surface water and groundwater data loggers in June and July 2013 and has collected data current through September 2014. All of the data loggers were installed within locked 2-inch polyvinyl chloride (PVC) pipes. The cap is locked to the pipe with a commercial padlock. WDFW surveyed a vertical reference point for each data logger unit. The three data loggers deployed on the bay side of the levee each have a staff gage, which was used to measure the water elevation, at each data logger download. The remaining surface water data loggers utilize the top of the black plastic cap for the reference elevation. The groundwater data loggers utilize the top of the lid of the well monument as the reference elevation. The water surface elevation for these installations at download was measured from the top-of-cap elevation. The staff gages and reference points were surveyed by WDFW and were tied to local survey control. Table A-1 summarizes the pertinent information related to the data loggers. Photographs A-1 through A-13 show installations and descriptions of each of the groundwater and surface water data logger.

A.1.2 Groundwater Monitoring

Previous groundwater monitoring for the project was performed along the east side of Dry Slough from the existing levee northward for about 2,000 feet, and is described in the feasibility study documents (S&W, 2011). Data were collected from August 2010 through September 2011. These wells were removed by the landowner in 2011, but not properly decommissioned with well closure records with the Washington State Department of Ecology.

Current groundwater observation well installations and monitoring include three pairs of (dual-depth) observation wells on the Hayton and WDFW properties (Figure 1). Each well paring was installed with one well in the shallow, estuarine, slightly clayey SILT/upper farm soil layer, and the second well in the underlying, slightly silty SAND, alluvial layer.

A.1.2.1 Observation Well Installation

S&W subcontracted with Boart Longyear, Inc. (Boart) of Fife, Washington, to install three pairs of observation wells (six total) at the site (Figure 1). Boart used a CME 850 track-mounted drill rig to drill and install the wells between June 17 and 20, 2013. Each pair of wells consisted of one well drilled to 21.5 feet below ground surface (bgs) and one well drilled 3 to 4.5 feet bgs. Generally, the upper farm soil layer ends between 4 and 6 feet bgs. Generally, farm field elevations range between 5 feet and 7 feet (North American Vertical Datum of 1988 [NAVD88]) (S&W, 2013).

Each of the observation wells consists of a 2-inch-diameter PVC well casing with a portion that is slotted to allow groundwater inflow. Slots are 0.01 inch wide (No. 10 slot). Slotted sections are about 10 feet long in the deeper wells B-4w-13, B-6w-13, and B-8w-13. Slotted sections are 1.3 feet long in the shallower well B-5w-13, 2.3 feet long in B-7w-13, and 0.8 foot long in B-9w-13. A sand pack (size 10–20) was placed around the slotted portion of the pipe to act as a filter against the adjacent soil. The depth of the slotted section for each well was selected based on soil units encountered in the boring and anticipated groundwater levels. A sump is attached to the bottom of the slotted section. A steel monument was placed aboveground to protect the top of the pipe. Four concrete ecology blocks were placed around each pair of monuments to protect the wells from farming activities. For reference, deeper wells are even numbered and shallow wells are odd numbered. Information regarding groundwater observation well locations is summarized in Table A-1.

A.1.2.2 Observation Well Development

S&W developed the observation wells on June 21, 2013. Well development increases the hydraulic connection between the well and the aquifer by reducing skin effects from drilling and removing fines from the filter pack and formation adjacent to the well screen. We purged approximately 35 gallons at deeper well locations (B-4w-13, B-6w-13, and B-8w-13). At the time of development, the shallow wells (B-5w-13, B-7w-13, and B-9w-13) did not have enough groundwater present to develop them. Therefore, approximately 5 gallons of tap water was added to each of the shallow wells to flush the fines out of the filter pack. The added water was then surged and pumped by the same method as the groundwater well development at the deep wells. Between 5 and 10 gallons were removed from each of the shallow wells. Development continued until our field representative did not observe sediment in the discharge water.

A.1.2.3 Groundwater Level, Temperature, and Salinity Measurements

Groundwater observation wells B-4w-13 and B-5w-13 are located in the WDFW North Field, north of the proposed setback dike and new interior drainage storage pond. The field elevation at the WDFW North Field groundwater observation wells is 6.9 feet. The average groundwater level measured in the deeper and shallow wells B-4w-13 and B-5w-13 were elevations 3.6 feet and 3.9 feet respectively (Figure A-1). Groundwater elevations were observed above the 2 foot root zone depth (described later in the report) 13 percent of the time in the shallow well for the entire monitoring period. During the fall-winter wet season (November through February), groundwater elevations were observed above the 2 foot root zone depth 32 percent of the time, with an average groundwater elevation during the fall/winter period of 4.5 feet. During the spring and summer growing season (March through October), groundwater elevations were above the 2 foot root zone depth 6 percent of the time, with an average groundwater elevation during the spring/summer period of 3.4 feet. Groundwater was on average 4 feet below ground surface (bgs) (ground elevation 6.9 feet) at the well location.

Groundwater observation wells B-6w-13 and B-7w-13 are located in the Hayton North berry field on the east side of Dry Slough. The field elevation at the WDFW North Field groundwater observation wells is 7.1 feet. Groundwater elevations ranged from 2.5 to 5.9 feet and an average elevation of 3.6 feet (measured in the shallower well B-7w-13) for the monitoring period (Figure A-2). The deep and shallow groundwater well elevations had little to no difference in observed elevations. The shallow well was periodically elevated 0.2 to 0.4 foot above the deep well measurements. Groundwater was on average 3.6 feet bgs (ground elevation 7.1 feet) at the well location. Groundwater elevations were observed above the 2 foot root zone depth (described later in the report) 6 percent of the time in the shallow well, with an average groundwater elevation of 3.6 feet. During the fall-winter wet season (November through February), groundwater elevations were observed above the 2 foot root zone depth 14 percent of the time, with and average groundwater elevation of (4.3 feet). During the spring and summer growing season (March through October), groundwater elevations were above the 2 foot root zone depth 3 percent of the time, with an average groundwater elevation during the spring/summer period of 3.3 feet.

Groundwater observation wells B-8w-13 and B-9w-13 are located in the Hayton South “Bay” Field, on the east side of Dry Slough. The field elevation at the WDFW North Field groundwater observation wells is 6.1 feet. The measured groundwater levels ranged from elevations 2.9 to 5.2 feet, and the average groundwater level was elevation 3.7 feet (measured in the deeper well B-8w-13, as part of the B-9w-13 shallow well data collected was erroneous) (Figure A-3). During the summer groundwater measurement period, the groundwater was an average of 2.4 feet bgs (ground elevation 6.1 feet). Groundwater elevations were observed above the 2 foot root zone depth (described later in the report) 19 percent of the time on average in the shallow well for the monitoring period. During the fall-winter wet season (November through February), groundwater elevations were observed above the 2 foot root zone depth 38 percent of the time, with an average groundwater elevation during the fall/winter period of 4.0 feet. During the spring and summer growing season (March through October), groundwater elevations were above the 2 foot root zone depth 3 percent of the time, with an average groundwater elevation during the spring/summer period of 3.6 feet. Toward the end of the June through September 2013 period, B-9W-13 shallow well data appeared to drift. We have since replaced the data logger, in February 2014. During the summer groundwater measurement period, the groundwater was an average of 2.5 feet bgs (ground elevation 6.1 feet). The Hayton South field measured average groundwater elevations are nearly 1 foot lower than the measured Hayton North and WDFW North field average groundwater elevations.

Groundwater salinity in the WDFW North Fields (B-4w-13 and B-5w-13) ranged from 0.0 to 5.1 practical salinity units (psu) and averaged 0.4 psu, which is considered slightly brackish (Figure A-4).

Groundwater salinity in the Hayton North field (B-6w-13 and B-7w-13) ranged from 0.0 to 4.5 practical salinity units (psu) and averaged 0.4 psu, which is considered slightly brackish (Figure A-5).

Groundwater salinity from the deeper well in the Hayton South “Bay” field (B-8w-13 and B-9w-13) ranged from from 11.5 to 21.4 psu. Measurements reported are from the deeper well as the shallower datalogger had malfunctioned during the data collection period (Figure A-6).

Groundwater temperature in the three well parings were similar with shallow groundwater well temperatures ranging from 4 to 15 ºC and deeper groundwater well temperatures ranging hovering around 10 ºC (Figures A-7 through A-9).

A.1.3 Surface Water Monitoring

Historic surface water monitoring for the project was performed during the feasibility study in locations similar to current installations, from August 2010 through May 2011. Monitoring did not continue during the remaining 2011 through 2012 period. The data loggers were refurbished and reinstalled in new locations with secure installations in 2013 (Figure 1).

A.1.3.1 Surface Water Level, Temperature, and Salinity Measurements

The average water surface elevation in Dry Slough (DS-1.1-LTC) was 3.6 feet, which matches the measured surface water elevations measured at DS-1.3-LTC (upstream from the tidegates) (Figure A-10), and is 0.1 feet lower than the average groundwater elevation observed in the Hayton South field (B-8) deep groundwater well. The average water surface elevation in Dry Slough DS-1.3 was 3.6 feet, which matches the average groundwater elevation in the Hayton North field (B-7) shallow groundwater well. Data collected during summer months 2013 and 2014 captured the surface water effects of irrigation channel check dams. These surface water operations collect surface water in the ditches for use in crop irrigation operations, and locally influence surface and groundwater elevations along the WDFW North, Hayton North and Hayton South fields.

The average water surface elevation in No Name Slough NNS-2.1-LTC (upstream from the tidegates) was 3.8 feet during the monitoring period, which is 0.1 feet lower than the average shallow well groundwater elevations in WDFW North field (B-5w-13) next to the No Name Slough gauge (Figure A-11).

The average water surface elevation for Brown Slough (BS-3.1-LTC) was 3.6 feet (Figure A-12).

Salinity in Dry Slough (SW-DS-1.1-LTC) ranged from 5 to 8 psu which is considered brackish (Figure A-13). Further upstream, salinity in Dry Slough (DS-1.3) ranged from 0.1 to 2.0 psu, which is considered slightly brackish. The salinity in No Name Slough (NNS-2.1-LTC) ranged from 2.5 to 10.2 psu, which is considered brackish (Figure A-14). The salinity in Brown Slough Slough (NNS-2.1-LTC) ranged from 5.0 to 11.0 psu, which is considered brackish (Figure A-15). All of these ditches are situated immediately along existing farm operations.

Temperature in Dry Slough upstream of the tidegates (SW-DS-1.1-LTC) ranged from 10 to 14 ºC (Figure A-16). Temperature in No Name Slough upstream of the tidegates (SW-NNS-2.1-LTC) ranged from 8 to 17 ºC (Figure A-17). Temperature in Brown Slough upstream of the tidegates (SW-BS-3.1-LTC) ranged from 10 to 17 ºC (Figure A-18).

Downstream from the tidegates, the average Skagit Bay tidal elevation at the Dry Slough DS-1.0-LTC gauge was 5.6 feet; at the No Name Slough NNS-2.0-LTC gauge the average tidal elevation was 5.5 feet; at Brown Slough BS-3.0-LTC gauge the average tidal elevation was also 5.5 feet. The tidal gages along Skagit Bay have similar water surface elevations. The tidal data collected along Skagit Bay exhibited mixed tides (indicating typical two highs and two lows per tidal cycle) with a truncated low tide. The truncated low tide elevation is similar to tidal flow conditions observed along the Skagit River delta. Skagit River flows, groundwater conditions, and delta marsh geomorphology do not allow for full drainage down to the Puget Sound low tide elevations. This truncated low tide condition is termed river "surge".

Surface water salinity measurements in the Skagit Bay data loggers (DS-1.0, NNS-2.0, and BS-2.0) ranged from 0.1 to 29.0 psu, which range from freshwater, to brackish, to salt water salinity levels. The lowest periods of salinity for the data loggers located in the Skagit Bay occurred from May through August in 2014. Observed salinity levels differ between Dry Slough, No Name Slough and Brown Slough.

Surface water data loggers installed in the Skagit Bay area collected tidal water temperature measurements. Dry Slough (DS-1.0-LTC) water temperatures ranged from 4 to 26 ºC. No Name Slough (NNS-2.0-LTC) water temperatures ranged from 0 to 28 ºC. Brown Slough (BS-3.0-LTC) water temperatures ranged from 0 to 28 ºC. Peak water temperature measurements occurred in late June 2013.

A.1.3.2 Data Quality Assurance

Data were downloaded from all of the data loggers on July 19, August 23, and October 9, 2013. The data verify that the data loggers were installed and operating correctly, except as noted below. The following observations regarding data anomalies are noted:

- The water levels in Dry Slough (Figure A-10) were influenced by irrigation operations during the collection period.
- Well B-5 was dry for a portion of the collection period.
- Well B-7 was dry for a portion of the collection period.
- The groundwater level readings at well B-6 did not correlate with values measured manually when the data were downloaded. Diagnostic tests on the data logger indicated the pressure sensor had malfunctioned. The logger was returned to the manufacturer for repair and has since been replaced.
- The water level readings at well B-9 appear to drift and the data logger has since been replaced.
- A survey discrepancy was found in SW-DS-1.3-LTC. WDFW resurveyed the casing and the data files were updated.
- Prior to October 9, the SW-BS-3.1-LTC upstream gage may have a slight survey or water measurement error that was corrected when the new LT gage was installed.

A.1.3.3 Future Data Collection Schedule

Data will be downloaded from the data loggers by S&W and WDFW, approximately monthly. The next scheduled data download is December 2014. Data downloads need to occur prior to the data loggers exceeding the logger data capacity, which is typically a five-month period collecting data at 15-minute intervals. After the 2014 data collection period, WDFW will be assuming data collection and data reporting responsibilities. These responsibilities include quarterly data logger downloads, data processing and publishing, and repair and maintenance of data logger equipment. If these data monitoring activities do not continue, information needed to make informed management decisions, and to avoid or refute potential landowner claims regarding project effects, could be lost.

A-2 REFERENCES

Shannon & Wilson, Inc., 2011, Fir Island Snow Goose Reserve, restoration feasibility study, Washington Department of Fish and Wildlife, Fir Island Washington: Report prepared by Shannon & Wilson. Inc, Seattle, Wash., 21-1-12318-003, for Washington Department of Fish and Wildlife, Olympia, Wash., December.

Shannon & Wilson, Inc., 2013, Draft Geotechnical and Hydrogeologic Data Report – Fir Island Farm Estuary Restoration; Report prepared by Shannon & Wilson, Inc., Seattle, Wash., January.

Shannon & Wilson, Inc., 2014, Draft coastal engineering report WDFW – Fir Island Farm Snow Goose Reserve. Skagit County, Washington: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., January.

TABLE A-1
GROUNDWATER AND SURFACE WATER DATA LOGGER INFORMATION

ID	Date of Deployment	S/N	Type	Location Description	Northing	Easting	TOC Elevation (NAVD88)	Notes
B-04w-13-LTC	27-Jun-13	1E+06	LTC	North of new interior drainage storage area (West, Deep Well)	1,257,925.92	491,729.61	9.20	
B-05w-13-LTC	27-Jun-13	1E+06	LTC	North of new interior drainage storage area (East, Shallow Well)	1,257,929.85	491,728.70	9.18	
B-06w-13-LTC	27-Jun-13	1E+06	LTC	In Field, approximately 1,000 feet east of new dike at Sta. 40+00 (South, Deep Well)	1,259,192.70	491,087.87	9.09	
B-07w-13-LTC	27-Jun-13	1E+06	LTC	In Field, approximately 1,000 feet east of new dike at Sta. 40+00 (North, Shallow Well)	1,259,189.53	491,091.47	8.77	
B-08w-13-LTC	17-Jul-13	1E+06	LTC	Field side of existing dike east of Dry Slough (West, Deep Well)	1,258,897.08	488,241.99	7.50	
B-09w-13-LTC	17-Jul-13	1E+06	LTC	Field side of existing dike east of Dry Slough (East, Shallow Well)	1,258,900.88	488,240.05	7.40	4
DS-1.0-LTC	19-Jun-13	1E+06	LTC	Dry Slough - Bay side of existing dike	1,258,201.26	488,322.24	N/A	1
DS-1.1-LTC	19-Jun-13	1E+06	LTC	Dry Slough - Field side of existing dike	1,258,200.41	488,415.86	8.64	
DS-1.3-LTC	19-Jun-13	1E+06	LTC	Dry Slough - Field, downstream of DS/DSW confluence	1,259,107.21	491,757.77	7.42	
NNS-2.0-LTC	20-Jun-13	1E+06	LTC	No Name/COD Slough - Bay side of existing dike	1,256,475.59	489,460.55	N/A	1
NNS-2.1-LTC	20-Jun-13	1E+06	LTC	No Name Slough - Field side of proposed dike	1,257,236.42	492,173.63	9.58	
BS-3.0-LTC	20-Jun-13	1E+06	LTC	Brown Slough - Bay side of tidegates	1,255,955.34	491,077.75	12.62	2
BS-3.1-LTC	20-Jun-13	1E+06	LTC	Brown Slough - North of Fir Island Road	1,256,026.14	493,256.49	7.45	3
BARO	20-Jun-13	2E+06	Baro	Near NNS-2.0, at top of left bank	1,256,461.33	489,408.05	N/A	

Notes:

1. Staff gage is NAVD88.
2. Subtract 2.64 feet from staff gage reading to get NAVD88 elevation.
3. Logger is Solinst Level/Temperature Conductivity (LTC); conductivity is uncalibrated and should be disregarded.
4. Logger pressure data began to drift in October 2013, affecting data and should be disregarded.

COD = Claude O. Davis

DS/DSW= Dry Slough (West)

N/A = not applicable

NAVD88 = North American Vertical Datum of 1988

NNS = No Name Slough

S/N = serial number

Sta. = Station

TOC = top of cap

TABLE A-2
SHALLOW GROUNDWATER OBSERVATION WELL, ELEVATION DATA

Groundwater Observation Well	Location	Entire Period			Fall/Winter (November - February)			Spring/Summer (March - October)		
		Minimum WSE[1] (NAVD88[2]-ft)	Average WSE (NAVD88-ft)	Maximum WSE (NAVD88-ft)	Minimum WSE (NAVD88-ft)	Average WSE (NAVD88-ft)	Maximum WSE (NAVD88-ft)	Minimum WSE (NAVD88-ft)	Average WSE (NAVD88-ft)	Maximum WSE (NAVD88-ft)
B-05w-13-LTC	WDFW North Field	2.6	3.9	6.2	3.1	4.5	6.2	2.6	3.4	6.0
B-07w-13-LTC	Hayton North Field	2.4	3.6	5.9	3.0	4.3	5.9	2.4	3.3	5.8
B-08w-13-LTC[3]	Hayton South Field	2.8	3.7	5.5	3.2	4.0	5.5	2.9	3.6	5.0

Notes:

[1] WSE - Water Surface Elevation

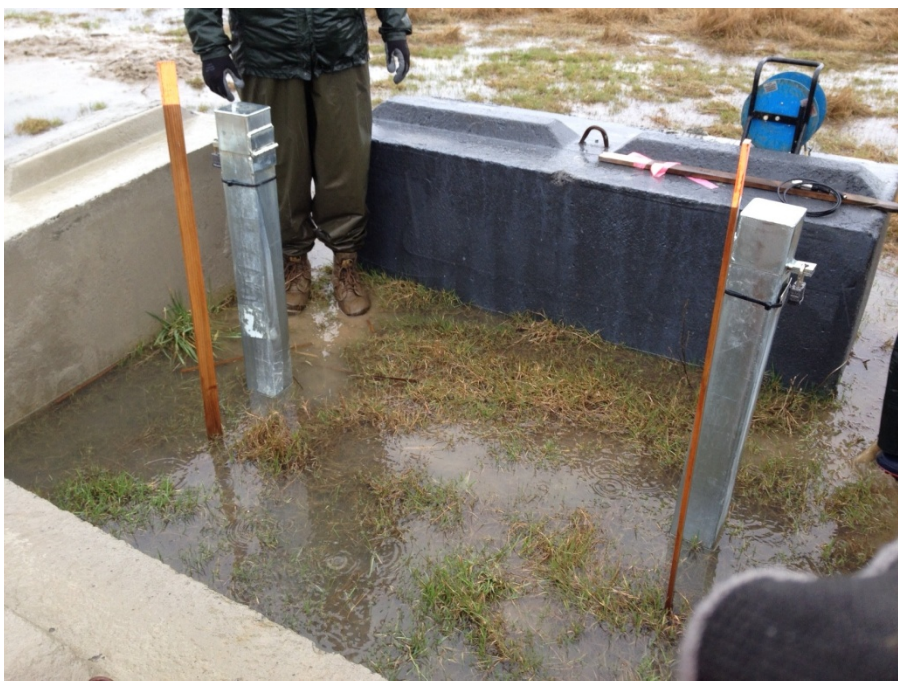
[2] NAVD88 - North American Vertical Datum 1988

[3] Deep well (B-08) data used because shallow well data logger malfunctioned.

Photograph A-1. Drilling, boring and groundwater observation wells B-4W-13 and B-5W-13 (WDFW Field)

Photograph A-2. Completed groundwater observation wells B-4W-13 and B-5W-13 (WDFW Field)

Photograph A-3. Completed groundwater observation wells B-6W-13 and B-7W-13 (Hayton North Field)



Photograph A-4. Completed groundwater observation wells B-8W-13 and B-9W-13 (Hayton South Field)

Photograph A-5. Dry Slough (SW-DS-1.0-LTC) surface water datalogger installation on east (left) bank looking south, Skagit Bay side of tidegates.

Photograph A-6. Dry Slough staff gage installation on west (right) tidegate headwall (photo looking west), Skagit Bay side of tidegates.

Photograph A-7. Dry Slough (SW-DS-1.1-LTC) surface water datalogger installation on boardwalk looking north, farm side of tidegates.

Photograph A-8. Dry Slough (SW-DS-1.3-LTC) surface water datalogger installation right (west) bank, photo looking east.

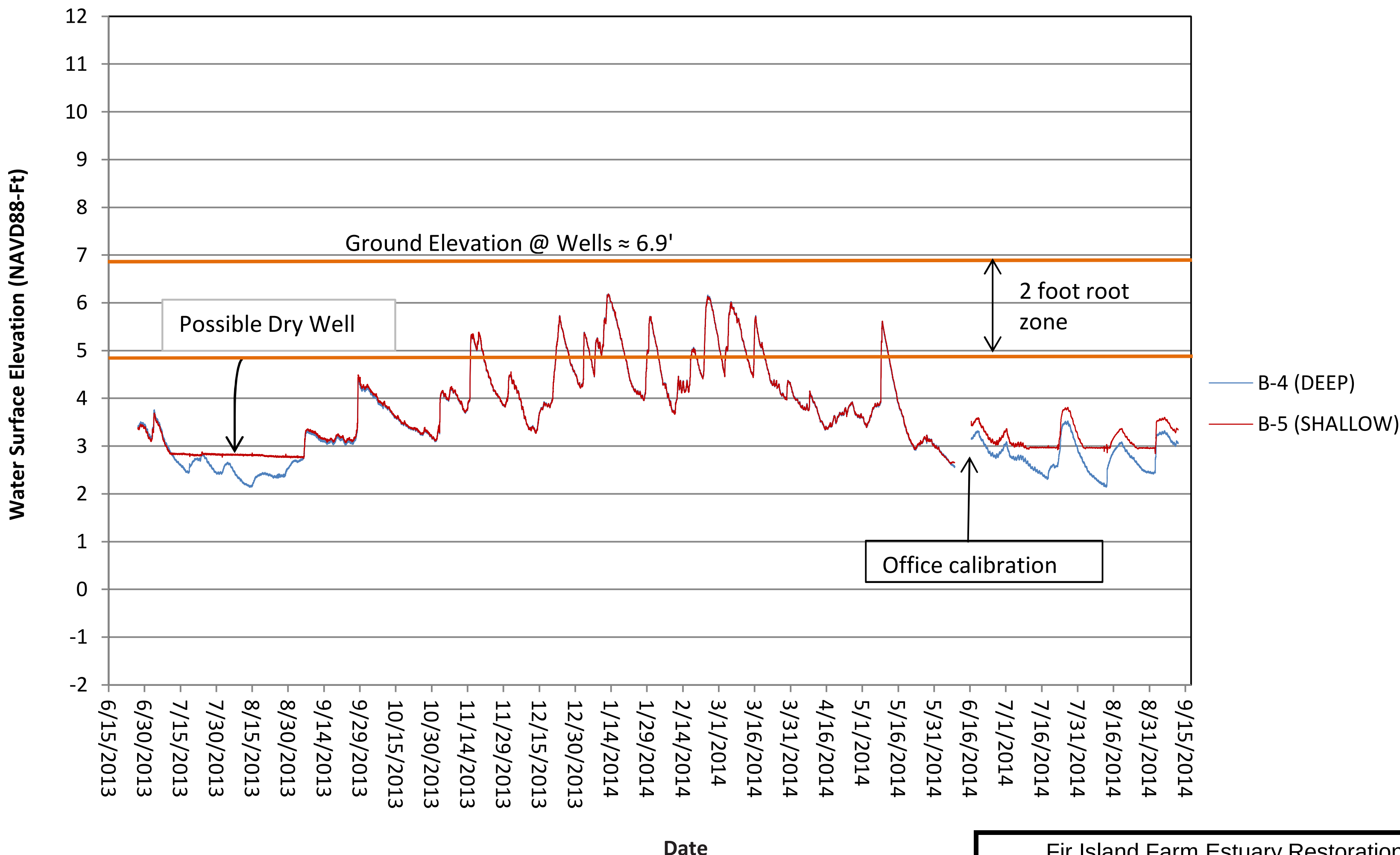
Photograph A-9. Davis (No Name Slough, SW-NNS-2.0-LTC) surface water datalogger installation right side (west) of tidegates, photo looking southwest.

Photograph A-10. Davis (No Name Slough) staff gage installation on timber pile downstream of tidegates, left (east) bank, photo looking southwest.

Photograph A-11. No Name Slough (SW-NNS-2.1-LTC) surface water datalogger installation on left (east) bank, north of WDFW farm road and gate from parking lot, photo looking south.

Photograph A-12. Brown Slough (SW-BS-3.0-LTC) surface water datalogger installation on far (west) side of trash rack screen, photo looking west.

Photograph A-13. Brown Slough (SW-BS-3.1-LTC) surface water datalogger installation on left (east) side of channel, north of Fir Island Road, photo looking south.



Average WSE for Time Period

B-4w-13	**3.62**	ft
B-5w-13	**3.89**	ft

Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
WDFW NORTH FIELD (B-4w-13 & B-5w-13)
WATER LEVELS
JUNE 2013 - SEPTEMBER 2014

November 2014 21-1-12318-216

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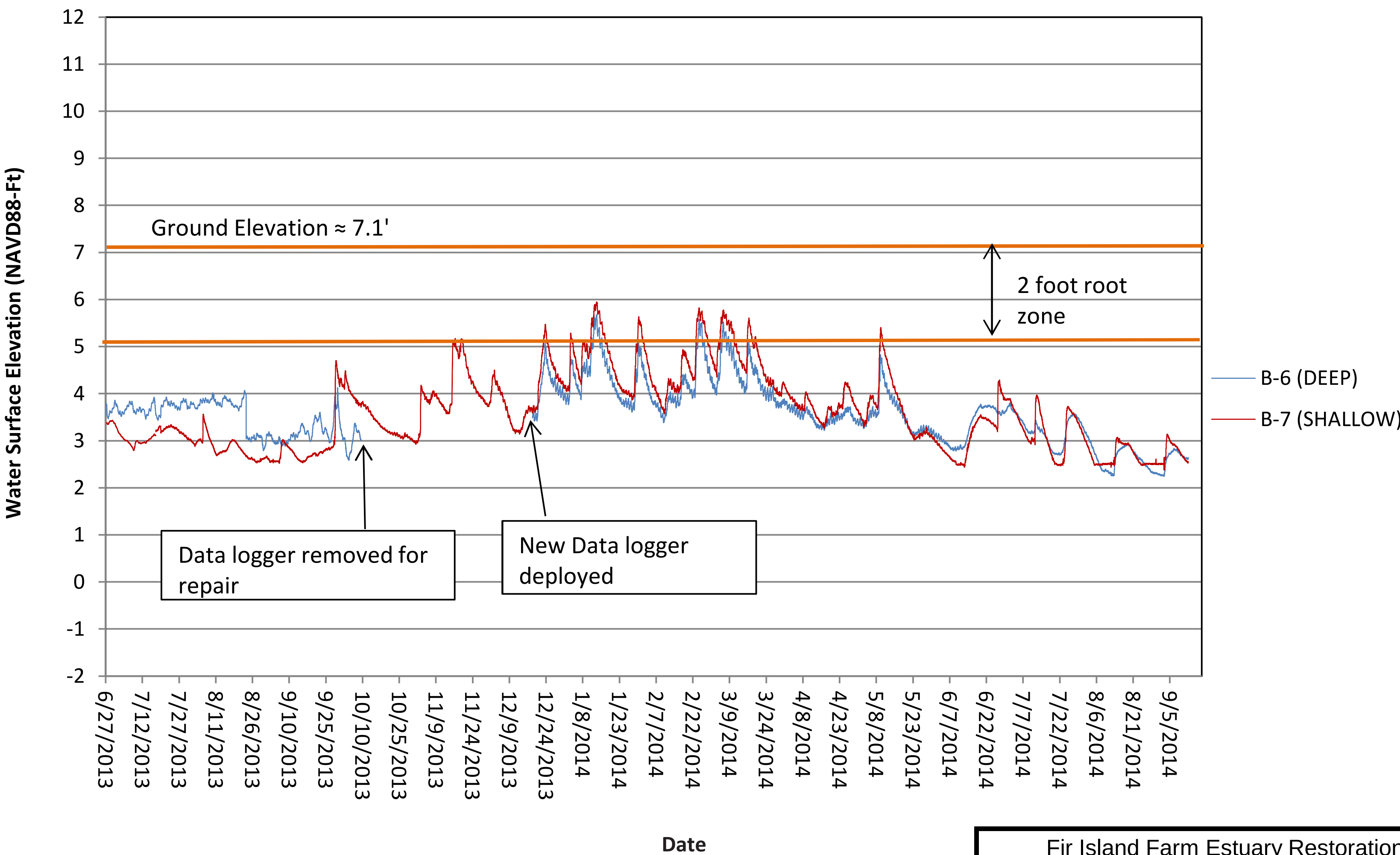
FIG. A-1

FIG. A-1

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA1.B4-B5_WSE>



Note: B-6 WSE are suspect, levelogger has failed pressure sensor as of 10-11-2013

Average WSE for Time Period

B-6w-13	**3.58**	ft
B-7w-13	**3.61**	ft

FIG. A-2

Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
HAYTON NORTH FIELD (B-6w-13 & B-7w-13)
WATER LEVELS
JUNE 2013 - SEPTEMBER 2014

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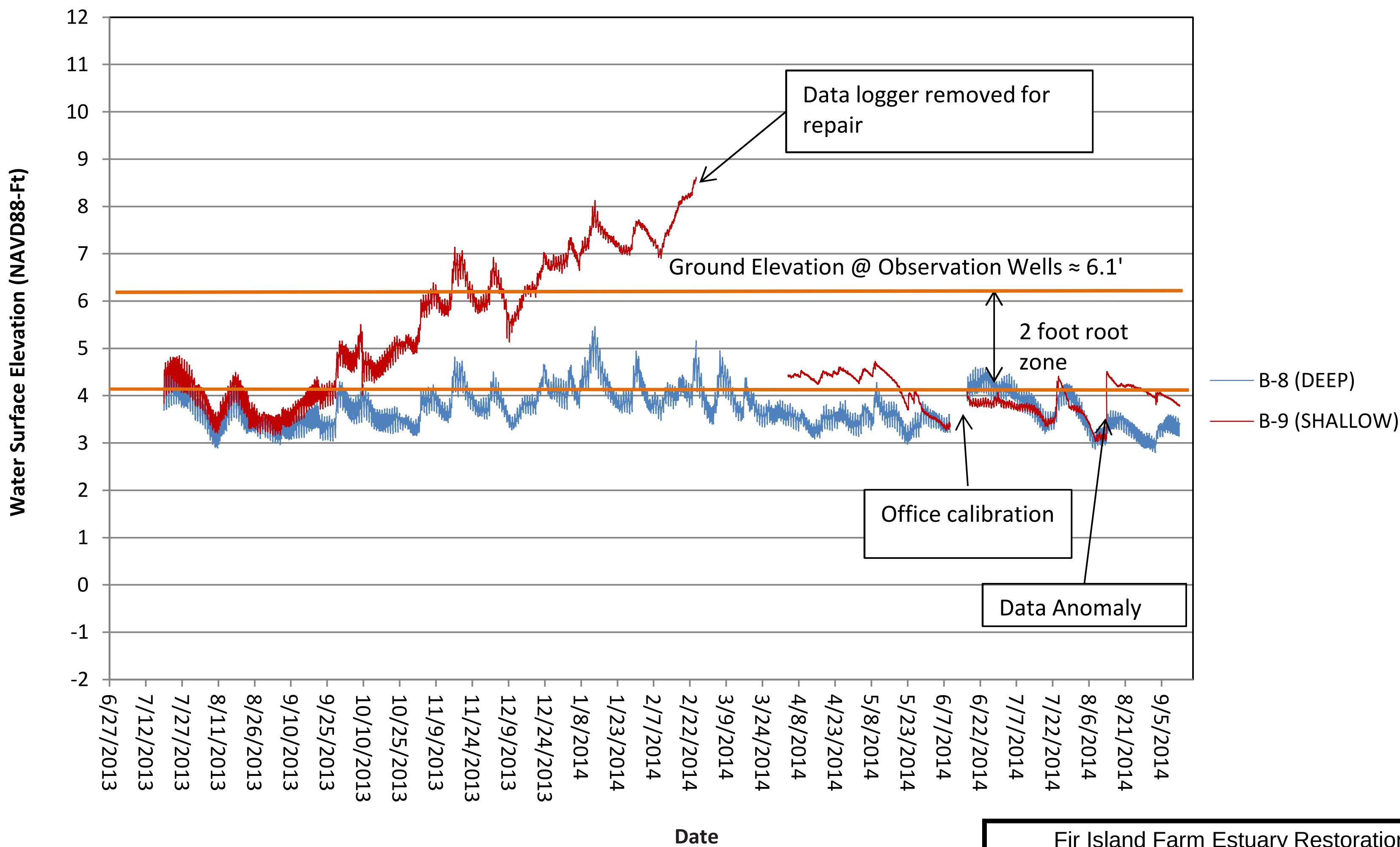
FIG. A-2

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA2.B6-B7_WSE>



Average WSE for Time Period

B-8w-13	**3.74**	ft
B-9w-13	**N/A**	ft

Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
HAYTON S. FIELD (B-8w-13 & B-9w-13)
WATER LEVELS
JUNE 2013 - SEPTEMBER 2014

November 2014 21-1-12318-216

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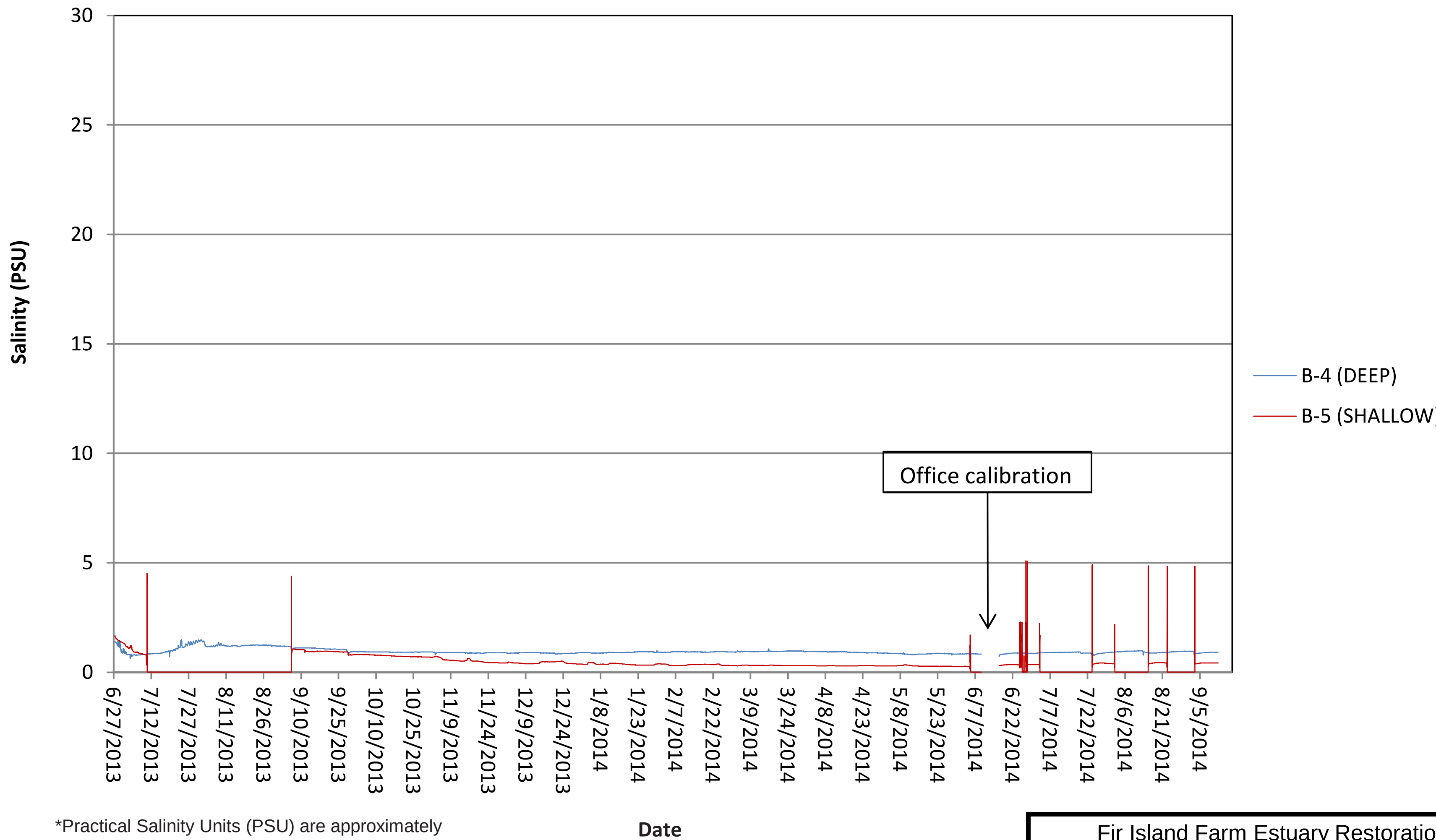
FIG. A-3

FIG. A-3



*Practical Salinity Units (PSU) are approximately equivalent to Parts Per Thousand (ppt)

Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
WDFW NORTH FIELD (B-4w-13 & B-5w-13)
SALINITY
JUNE 2013 - SEPTEMBER 2014

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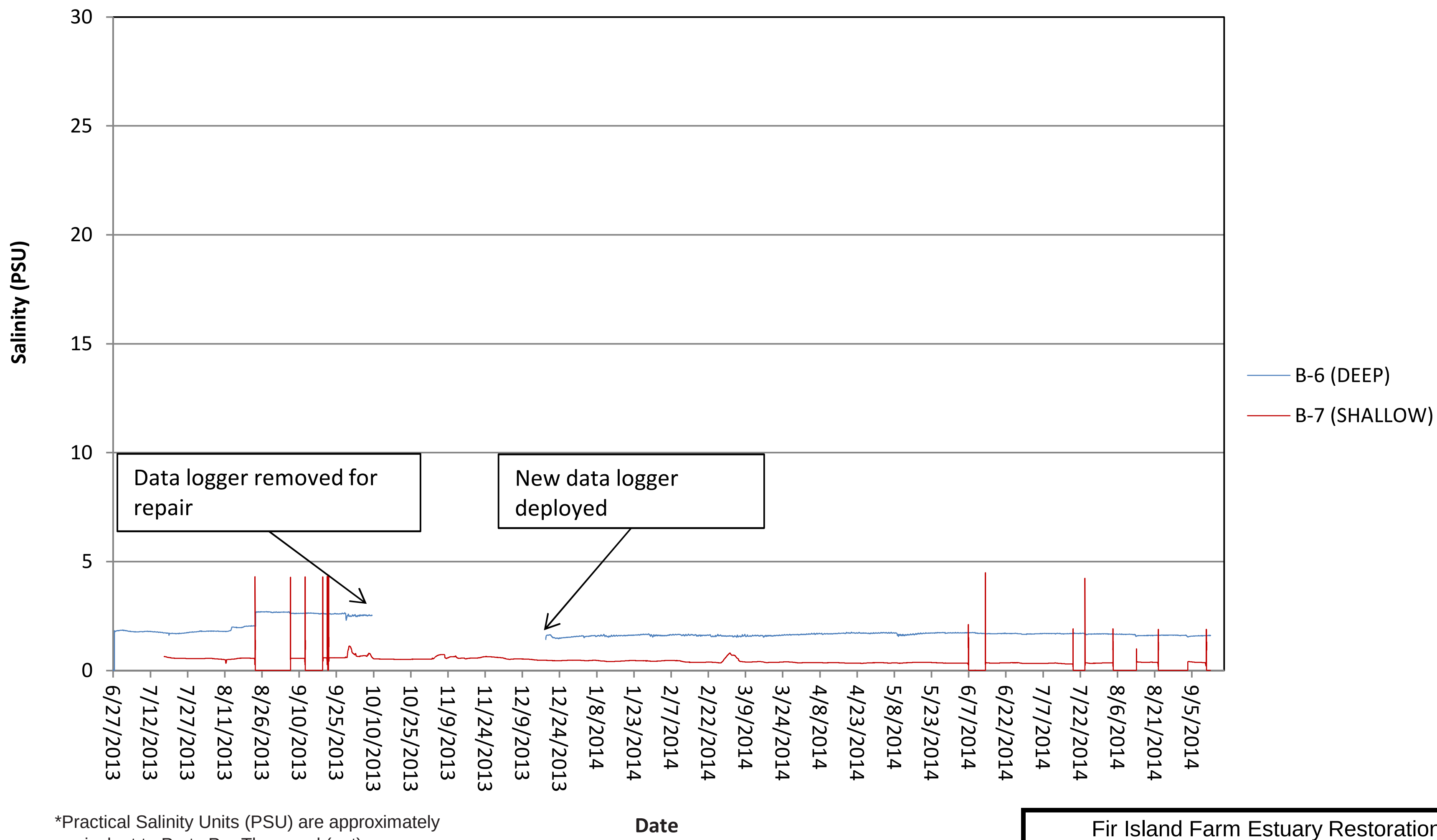
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-4

FIG. A-4

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA4.B4-B5_SALINITY>



*Practical Salinity Units (PSU) are approximately equivalent to Parts Per Thousand (ppt)

Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
HAYTON NORTH FIELD (B-6w-13 & B-7w-13)
SALINITY
JUNE 2013 - SEPTEMBER 2014

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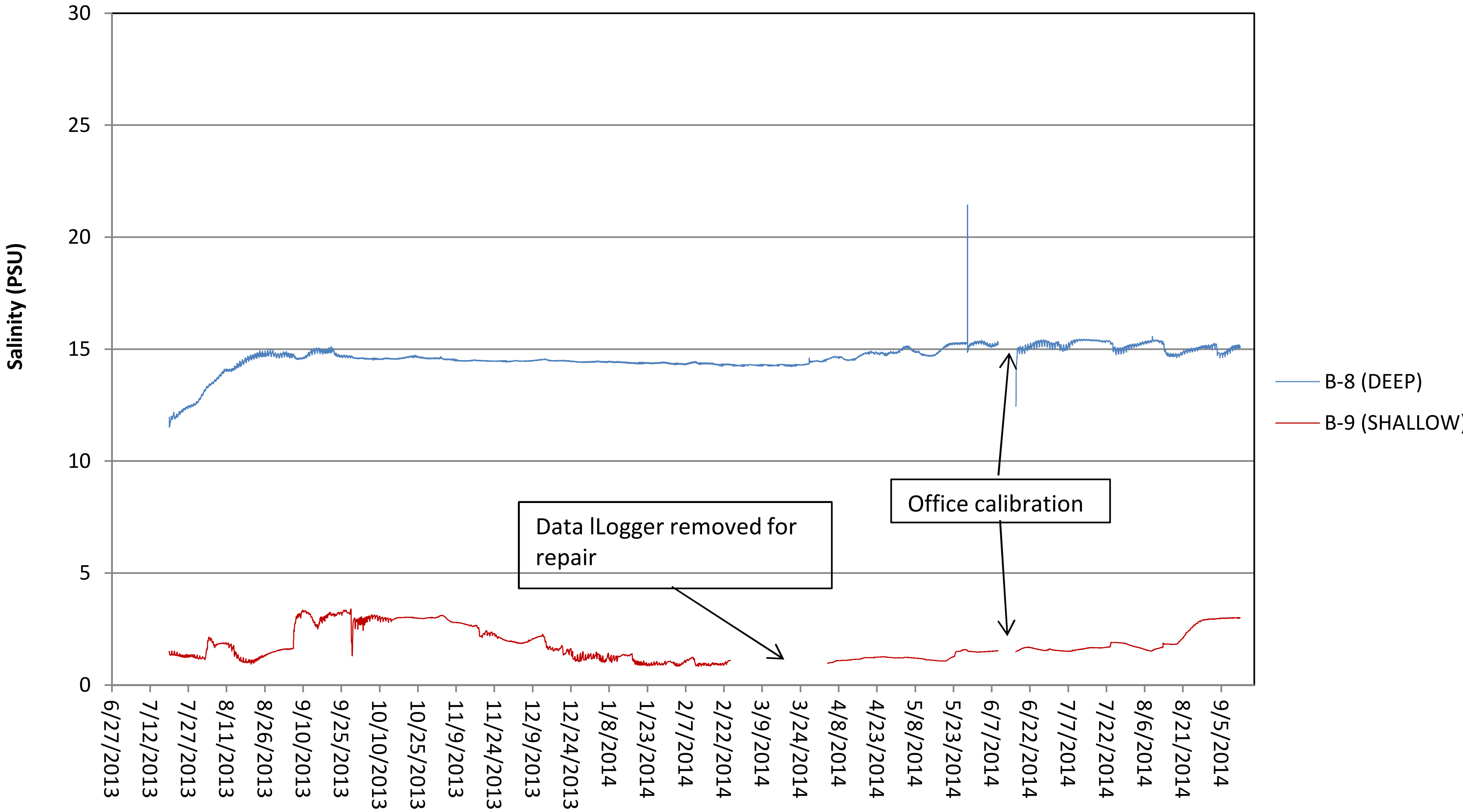
FIG. A-5

FIG. A-5



*Practical Salinity Units (PSU) are approximately equivalent to Parts Per Thousand (ppt)

Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
HAYTON SOUTH FIELD (B-8w-13 & B-9w-13)
SALINITY
JUNE 2013 - SEPTEMBER 2014

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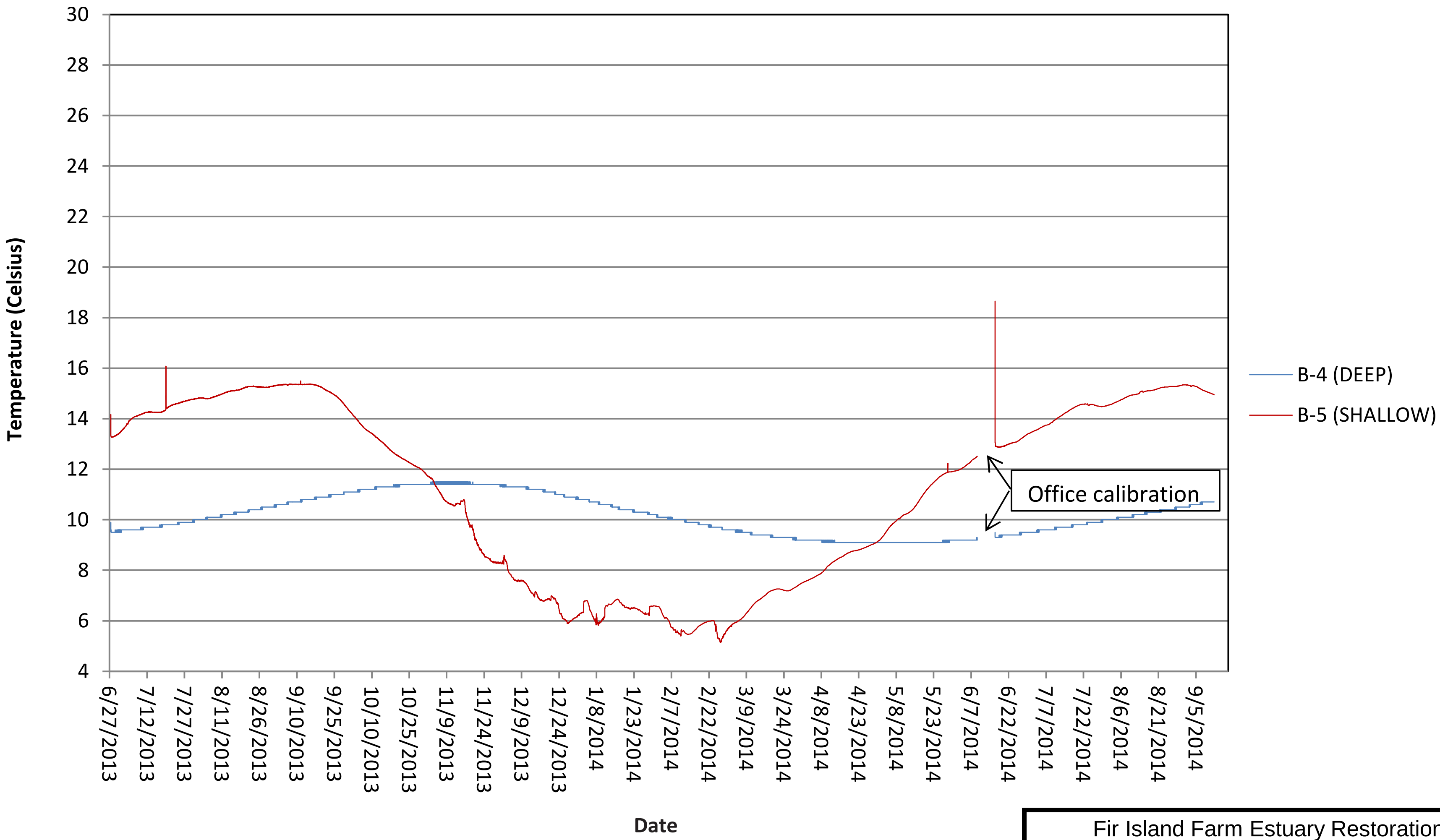
FIG. A-6

FIG. A-6

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA6.B8-B9_SALINITY>



Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
WDFW NORTH FIELD (B-4w-13 & B-5w-13)
TEMPERATURE
JUNE 2013 - SEPTEMBER 2014

November 2014 | 21-1-12318-216

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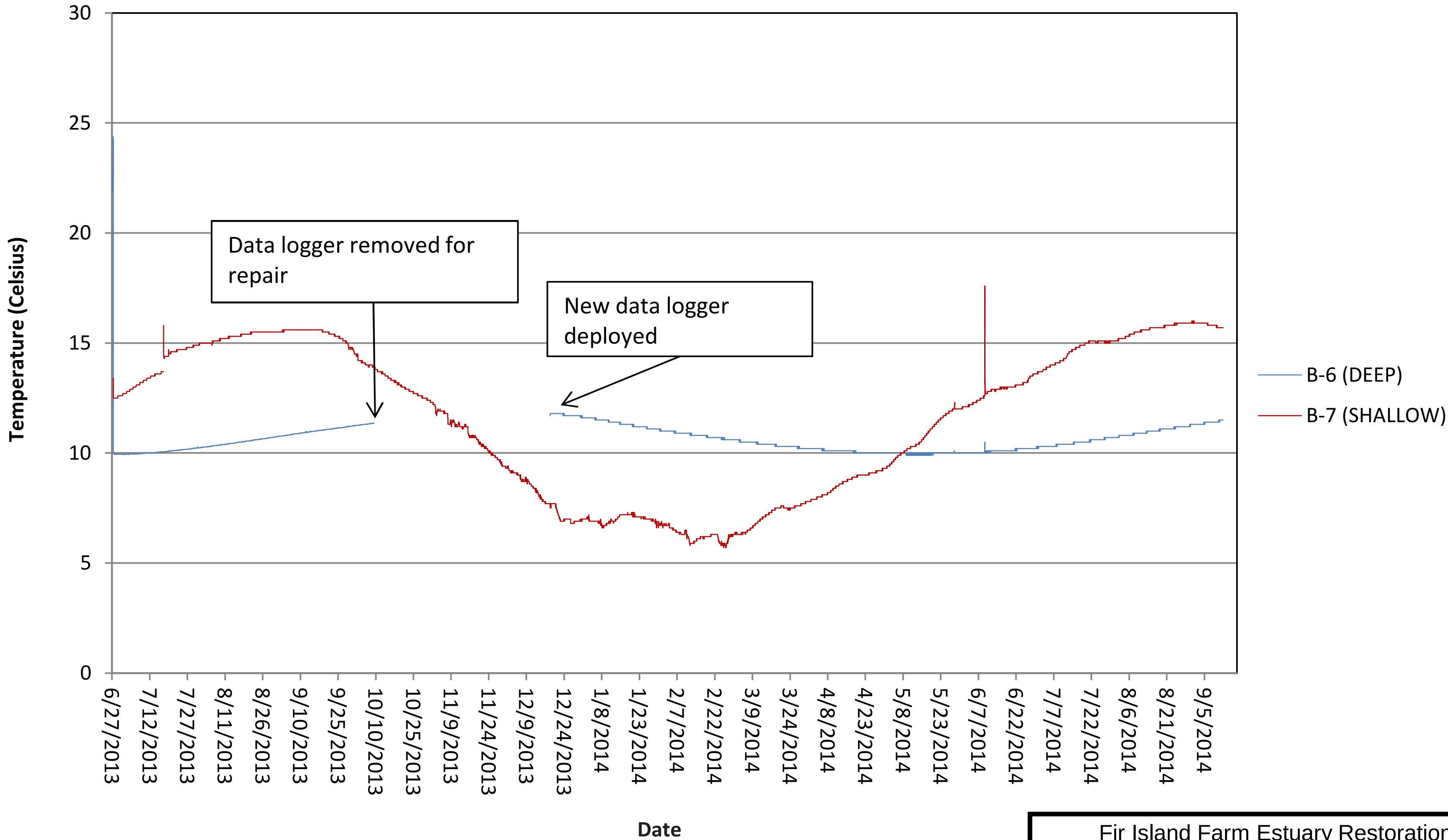
FIG. A-7

FIG. A-7



Fir Island Farm Estuary Restoration

Skagit County, WA

GROUNDWATER WELLS
HAYTON NORTH FIELD (B-6w-13 & B-7w-13)
TEMPERATURE
JUNE 2013 - SEPTEMBER 2014

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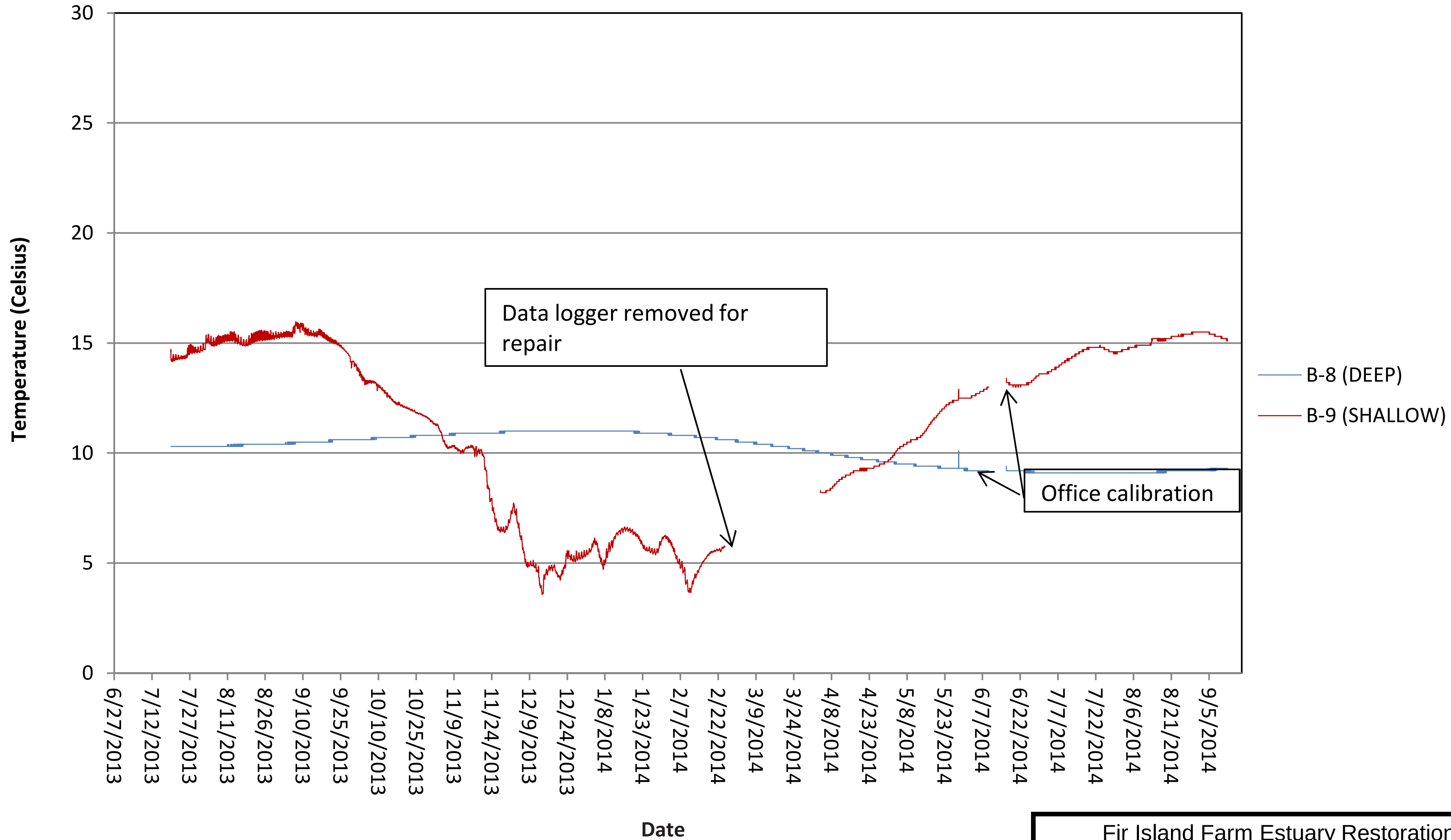
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-8

FIG. A-8

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA8.B6-B7_TEMP>



Fir Island Farm Estuary Restoration

Skagit County, WA

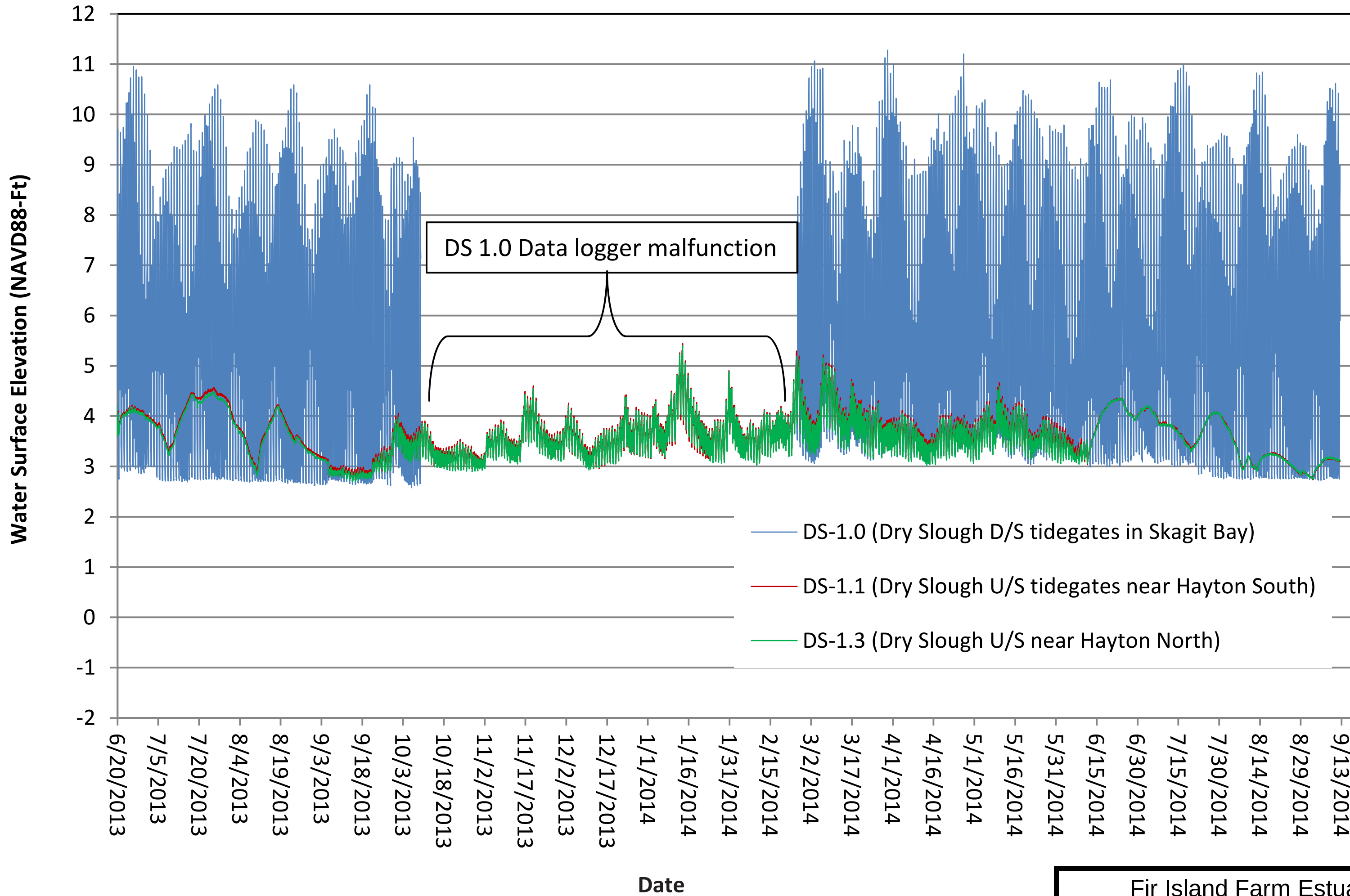
GROUNDWATER WELLS
HAYTON S. FIELD (B-8w-13 & B-9w-13)
TEMPERATURE
JUNE 2013 - SEPTEMBER 2014

November 2014 21-1-12318-216

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-9

FIG. A-9



Average WSE for Time Period

DS-1.0-LTC	**5.59**	ft
DS-1.1-LTC	**3.62**	ft
DS-1.3-LTC	**3.58**	ft

Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

DRY SLOUGH
WATER LEVELS
JUNE 2013 - SEPTEMBER 2014

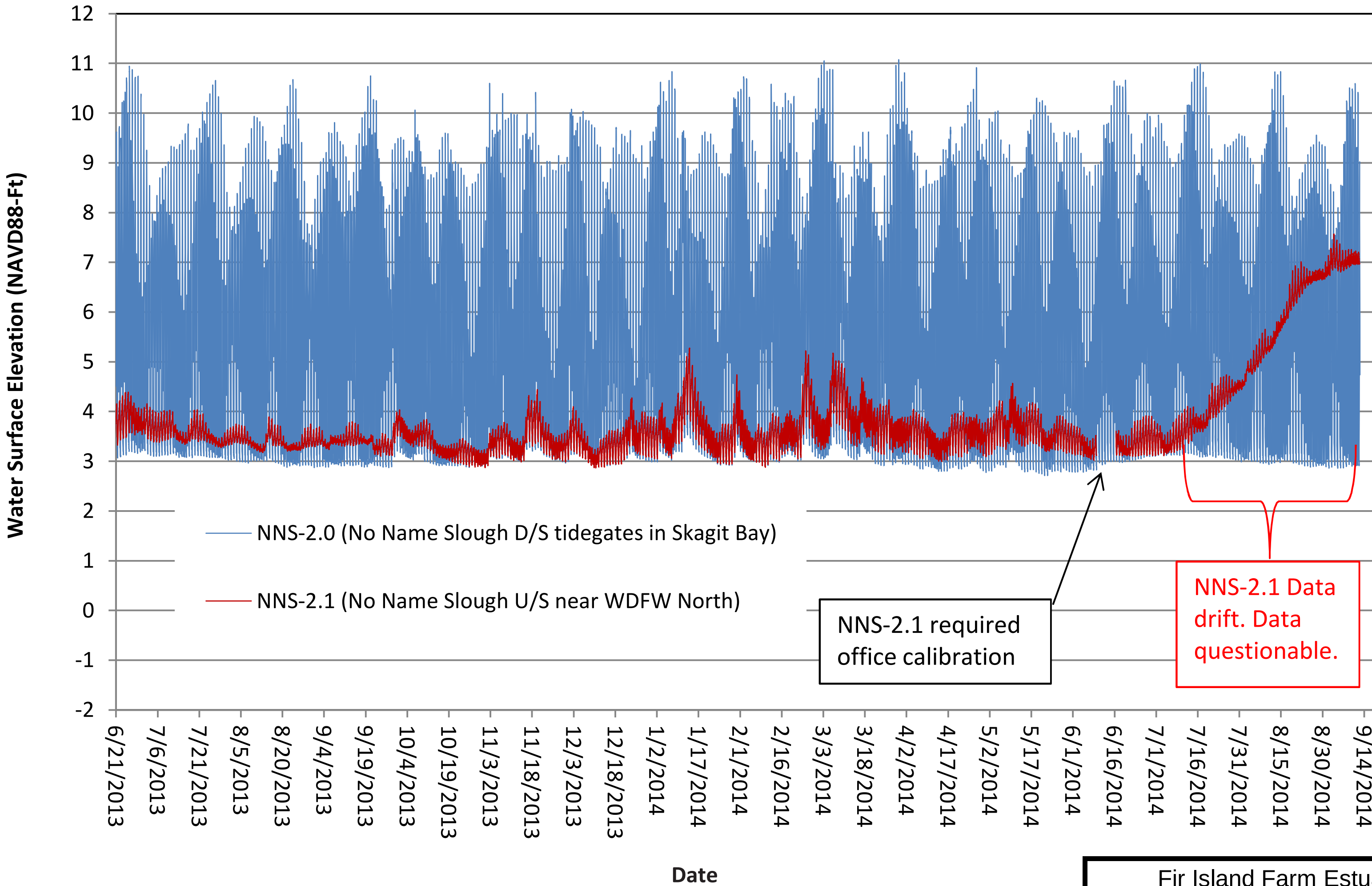
November 2014 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-10

FIG. A-10

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA10.DS_WSE>



Average WSE for Time Period

NNS-2.0-LTC	**5.53**	ft
NNS-2.1-LTC	**3.81**	ft

Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

NO NAME SLOUGH WATER LEVELS JUNE 2013 - SEPTEMBER 2014

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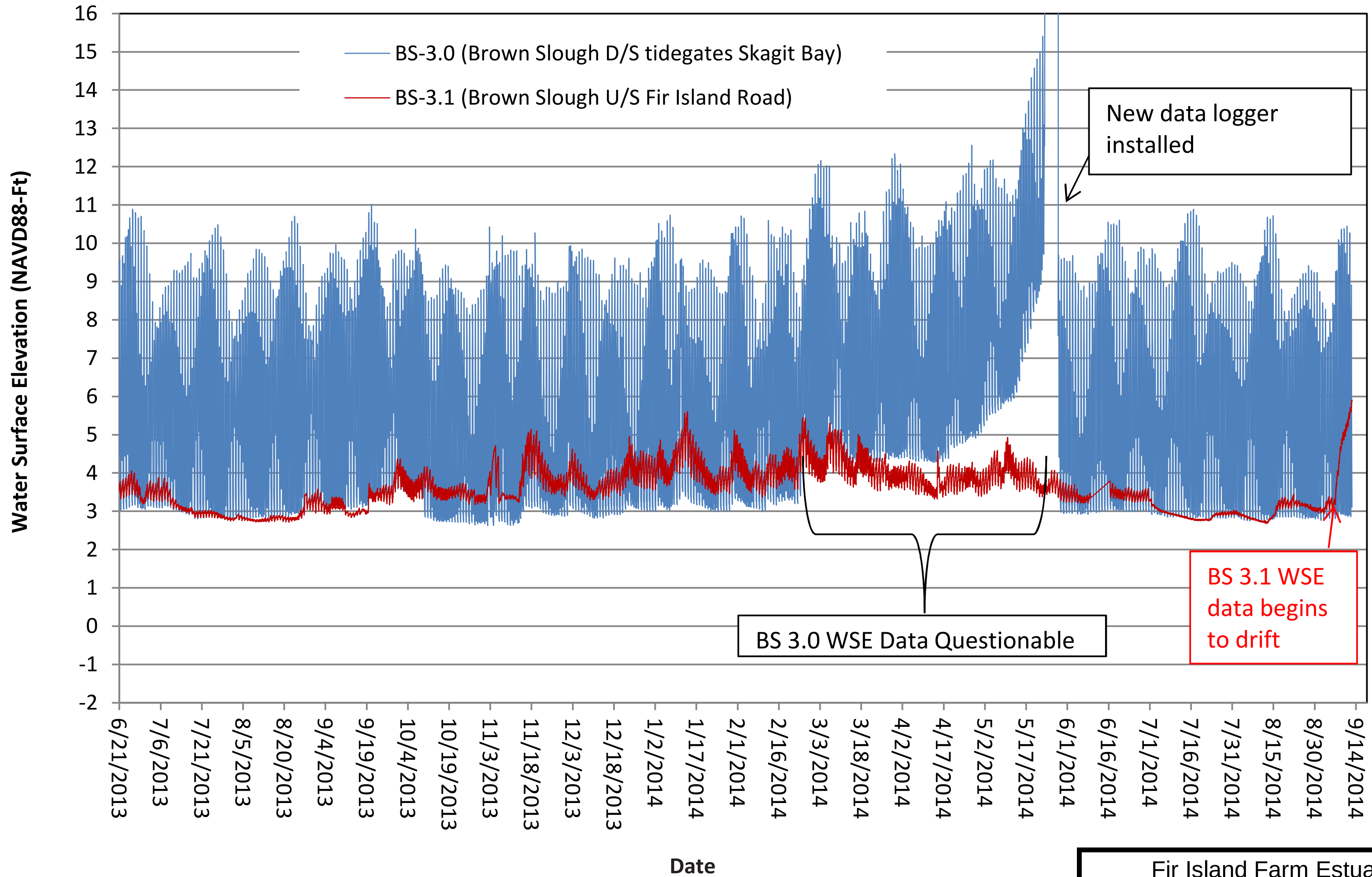
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-11

FIG. A-11

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA11.NNS_WSE>



Average WSE for Time Period

BS-3.0-LTC	**5.49**	ft
BS-3.1-LTC	**3.57**	ft

Notes:

U/S - Upstream

D/S - Downstream

Note: Averages are for data periods without error or drift.

Fir Island Farm Estuary Restoration

Skagit County, WA

BROWN SLOUGH WATER LEVELS JUNE 2013 - SEPTEMBER 2014

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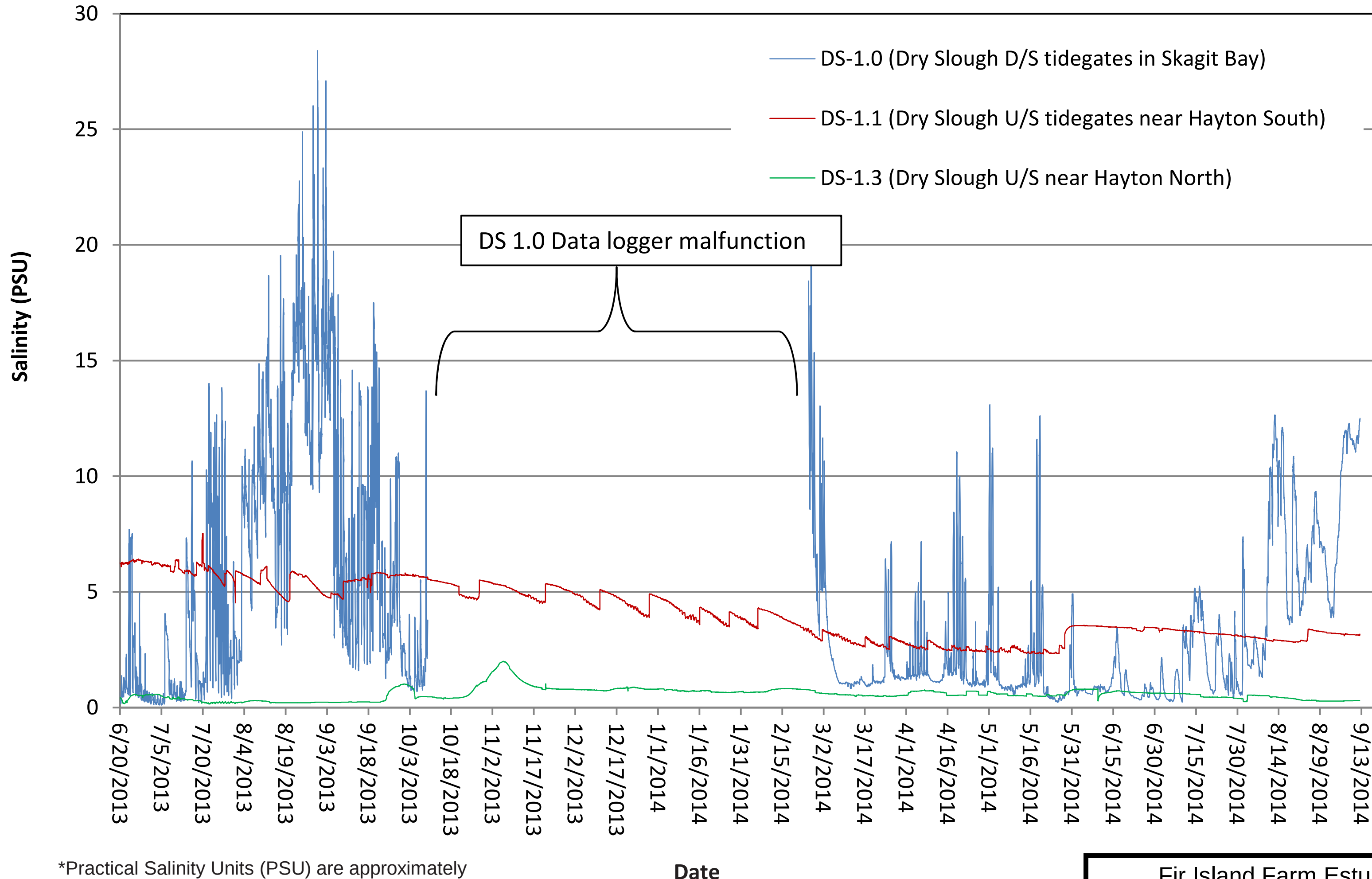
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-12

FIG. A-12

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA12.BS_WSE>



*Practical Salinity Units (PSU) are approximately equivalent to Parts Per Thousand (ppt)

Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

DRY SLOUGH SALINITY JUNE 2013 - SEPTEMBER 2014

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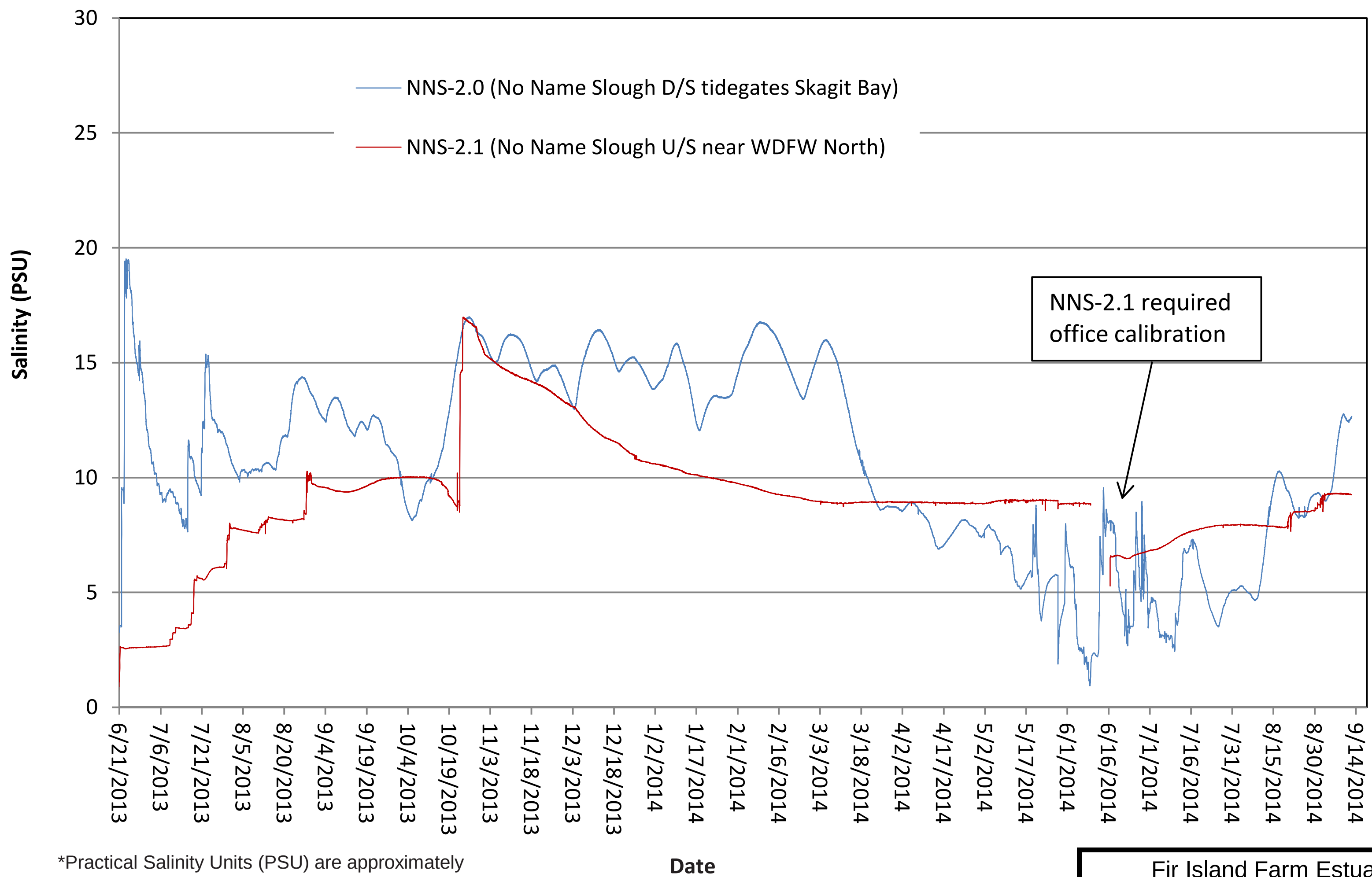
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-13

FIG. A-13

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA13.DS_SALINITY>



*Practical Salinity Units (PSU) are approximately equivalent to Parts Per Thousand (ppt)

Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

NO NAME SLOUGH SALINITY JUNE 2013 - SEPTEMBER 2014

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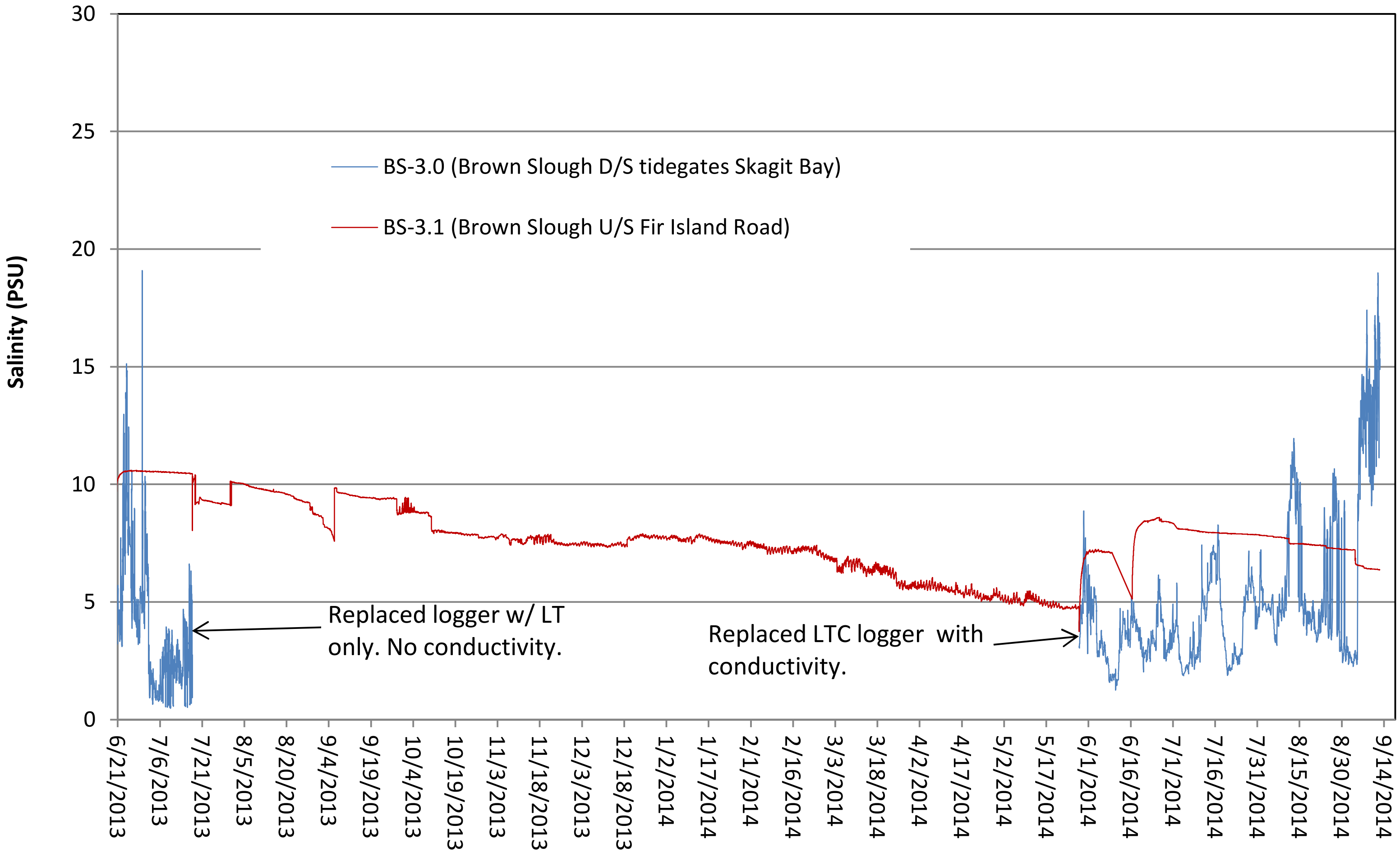
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-14

FIG. A-14



*Practical Salinity Units (PSU) are approximately equivalent to Parts Per Thousand (ppt)

Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

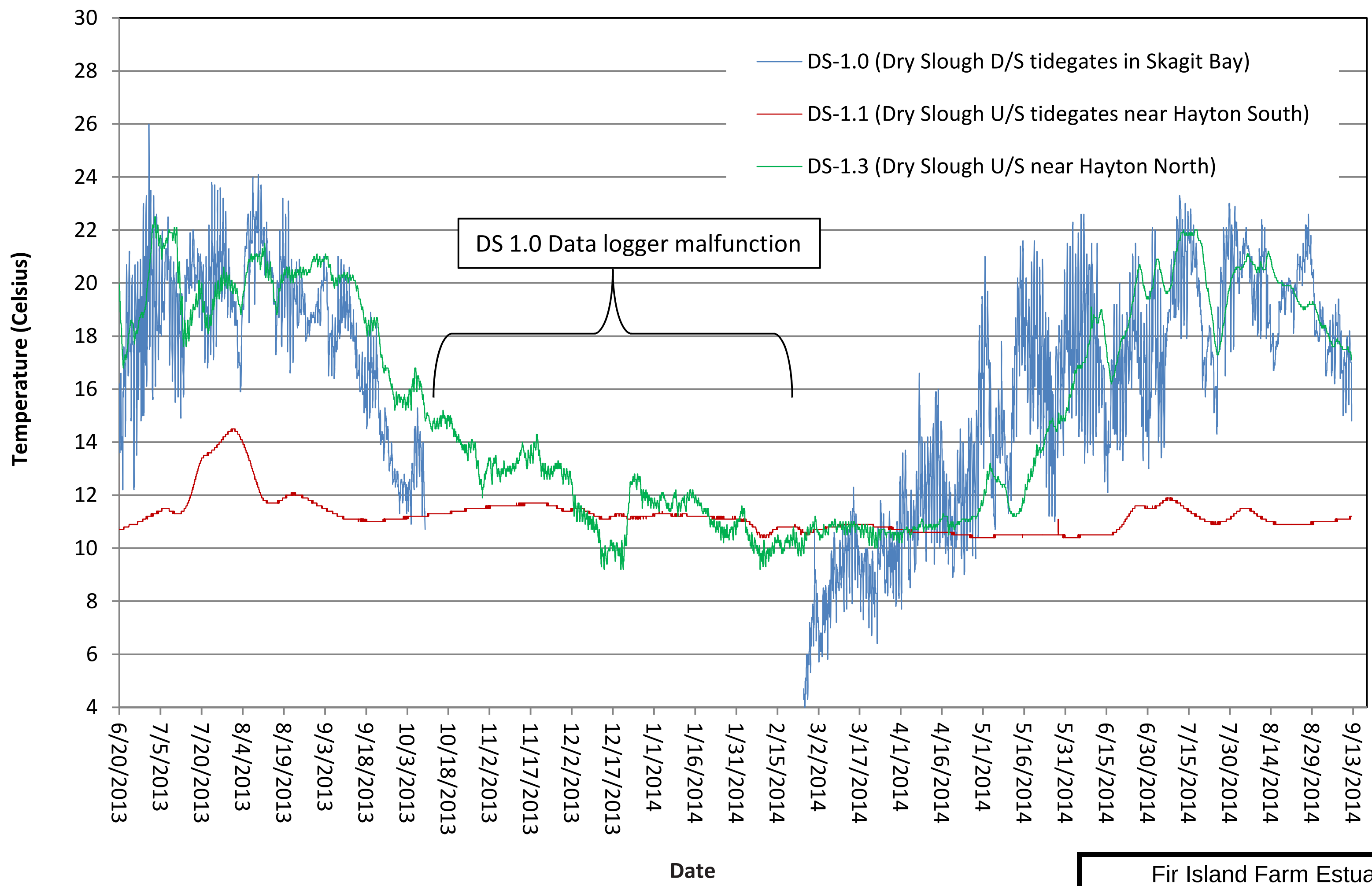
BROWN SLOUGH SALINITY JUNE 2013 - SEPTEMBER 2014

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-15

FIG. A-15



Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

DRY SLOUGH TEMPERATURE JUNE 2013 - SEPTEMBER 2014

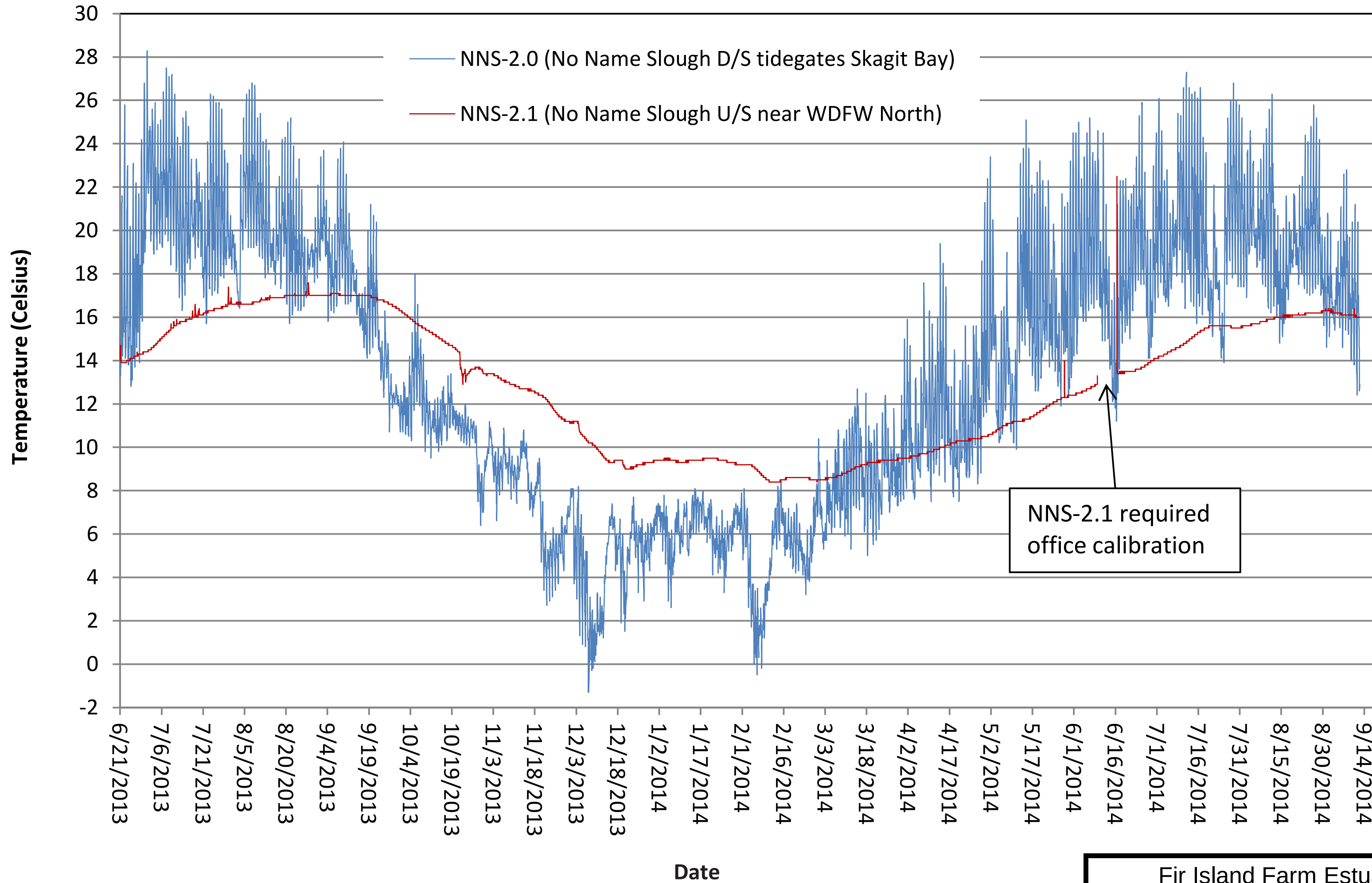
November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-16

FIG. A-16

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA16.DS_TEMP>



Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

NO NAME SLOUGH TEMPERATURE JUNE 2013 - SEPTEMBER 2014

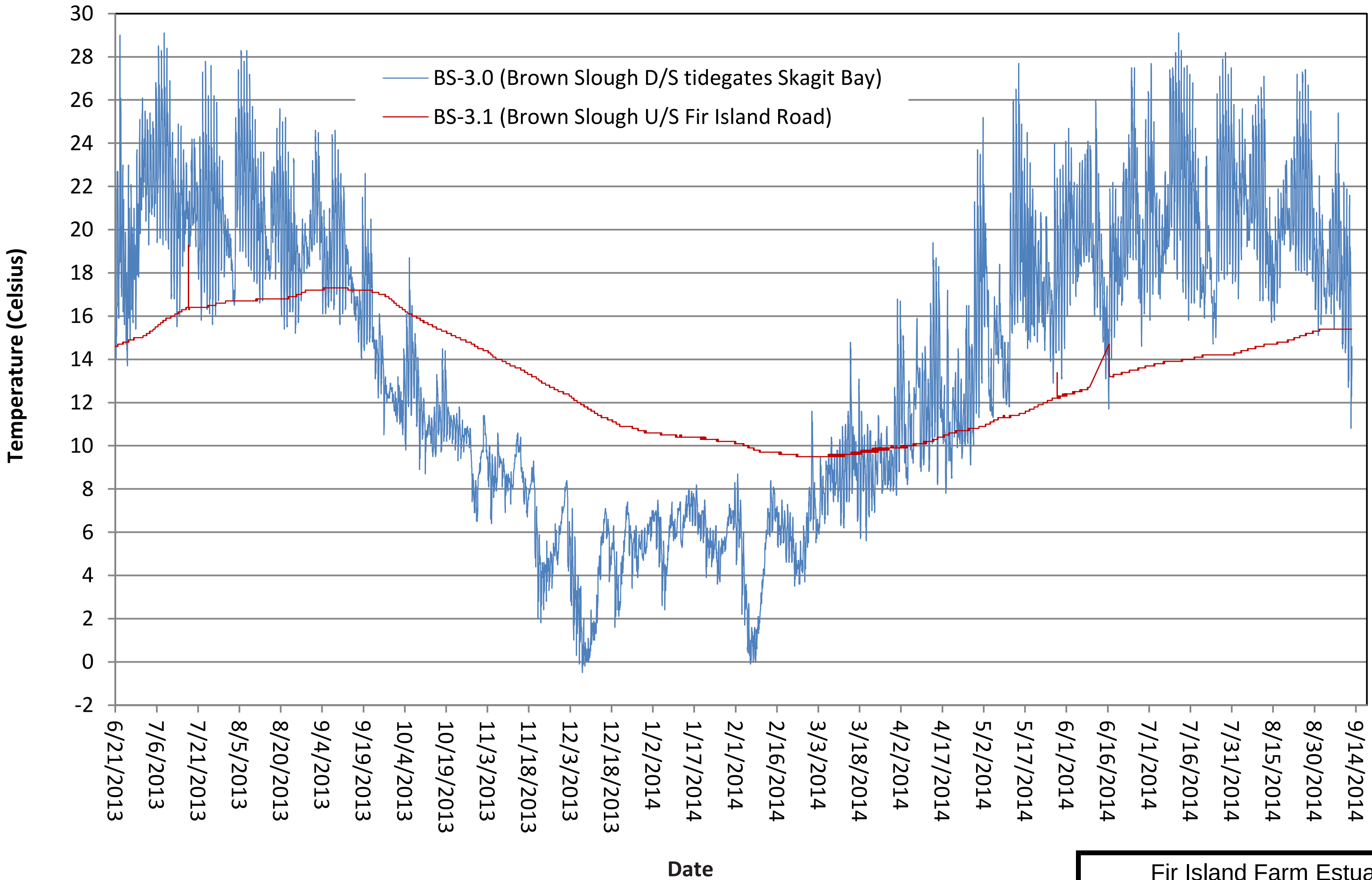
November 2014 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-17

FIG. A-17

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA17.NNS_TEMP>



Notes:

U/S - Upstream

D/S - Downstream

Fir Island Farm Estuary Restoration

Skagit County, WA

BROWN SLOUGH TEMPERATURE JUNE 2013 - SEPTEMBER 2014

October 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. A-18

FIG. A-18

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_A\21-1-12318-216-R1-AA_FA1-A18 <FIGA18.BS_TEMP>

APPENDIX B

SEEPAGE ANALYSIS

APPENDIX B

SEEPAGE ANALYSIS

TABLE OF CONTENTS

TABLES

FIGURES

FIGURES (cont.)

APPENDIX B

SEEPAGE ANALYSIS

B.1 OBJECTIVE

A seepage analysis using SEEP/W was performed to evaluate seepage effects of the proposed setback dike, including:

- Calculated water seepage through and below the existing and proposed dikes. The seepage rates (flux) were used as inflow parameters for interior drainage surface water modeling, which were used to predict surface and groundwater conditions on adjacent farm properties;
- Evaluated groundwater levels for the adjacent farm properties; and
- Provided seepage information for salinity mixing calculations of the interior drainage storage pond and adjacent farm fields.

B.2 CONCEPTUAL MODEL DEVELOPMENT

The conceptual model of the subsurface system at the project site included establishing hydraulic properties of the soil units and quantifying surface water flow rates under existing conditions.

B.2.1 In Situ Hydraulic Conductivity Analysis

Shannon & Wilson, Inc. (S&W) performed slug tests at monitoring wells B-4w-13, B-6w-13, and B-8w-13 (the deep wells), which are completed in the loose, slightly silty, sand soil layer (Holocene alluvium, Ha). The shallow monitoring wells B-5w-13, B-7w-13, and B-9w-13, which are completed in the upper soil layer (Hm), lacked sufficient water to perform a slug test. Slug testing is a method for calculating the in situ hydraulic conductivity of the saturated material surrounding an observation well. Slug tests have a small radius of influence. Unlike pumping tests, slug tests do not provide data regarding large-scale aquifer properties, aquifer geometry, or boundary conditions affecting groundwater flow.

Slug testing involves rapidly raising or lowering the water level in a well and measuring the subsequent recovery in water level to the original static position. Raising the water level in a well is achieved by quickly lowering a slug (in this case a sealed 1.25-inch-diameter polyvinyl chloride pipe filled with silica sand) into the well to displace water within the well casing. The subsequent falling of the water level to the original static position is referred to as a falling head slug test. Removing the slug and monitoring the rising water level constitutes a rising head slug test. A pressure transducer and data logger records the water level in the well during the slug tests.

The slug test analysis consists of plotting the water level versus time, fitting a line to the data, and using an analytical solution to calculate the hydraulic conductivity based on the fit line (S&W, 2013). Several analytical solutions exist for calculating the hydraulic conductivity from a slug test. The analytical solution used to calculate the hydraulic conductivity depends on the well construction details and the nature of the aquifer. We interpret that the aquifer we tested is partially confined, due to the presence of alluvial silts and clayey silts overlying silty sand, which results in higher groundwater pressures in deeper soil layers than observed in shallow soil layers.

We used two solutions to analyze the slug test data. The solutions are the Bouwer and Rice method (Bouwer, 1989), which is used for analyzing slug tests in confined aquifers, and the Butler (1998) method, which is used for analyzing slug tests in a confined aquifer with an under-damped response. We used the computer program AQTESOLV to plot the slug test results, match the fit line to the results, and calculate the hydraulic conductivity using different solutions. A summary of the hydraulic conductivity calculated from the slug tests and the data plots with fit lines was provided in the Geotechnical Data Report (S&W, 2013). We selected the results derived from the Bower and Rice to be used for seepage analysis modeling. The Bower and Rice hydraulic conductivities and calculated seepage inflow rates better matched site-observed surface and groundwater inflows to the tidegates. The range of hydraulic conductivities for the Ha sand unit using the Bouwer and Rice method is 57 to 283 feet/day (ft/day) (0.02 to 0.11 centimeters per second [cm/sec]), and the overall geomean is 132 ft/day (0.05 cm/sec) (Table B-1).

B.2.2 Hydraulic Conductivity Analysis on Soil Grain Sizes

Table B-2 presents the analysis we performed to calculate horizontal hydraulic conductivities based on grain-size gradation data. This approach involved using six empirical methods to analyze 45 soil samples collected from test pits and soil borings at the site. Not all of the six solutions were valid for all samples. Therefore, the average hydraulic conductivity values presented for each sample are based only on the valid results. The calculated geomean hydraulic conductivities for the upper soil unit (Hm), the middle unit (Ha) and the lower unit (He) are 0.04 ft/day, 31 ft/day and 0.09 ft/day, respectively.

The range for the Ha unit soils (5 to 278 ft/day) is greater than the range calculated for the slug tests. The geomean (31 ft/day) is a factor of four lower than the geomean for the slug tests.

B.2.3 Seepage Estimates from Hydrologic Monitoring Data

Hydrologic monitoring data were used to estimate existing condition seepage inflow to the No Name Slough drainage system. The estimate was performed by calculating the change in interior drainage channel storage volume while the tidegates are shut on each cycle. Seepage inflows include both existing dike seepage and upstream groundwater drainage inflows. Using the hydrologic monitoring data for the site, we estimated a seepage inflow of 1 cubic foot per second (cfs) (449 gallons per minute [gpm]).

A backcheck was performed to confirm the 1-cfs seepage inflow to the interior drainage storage pond. The procedure used to estimate seepage inflows is summarized as follows:

- Data from No Name Slough 2.0 (NNS-2.0 located on the tide side of the dike) and 2.1 (NNS-2.1 located interior to the dike) were used to measure the change of interior water surface levels on interior side of the dike.
- NNS-2.0 and NNS-2.1 water level data were used to calculate when the tidegates were open and closed.
- When the tidegates were closed, the rise in interior water surface elevations (NNS-2.1) were measured during each drainage cycle.
- The volume of inflow was calculated along two ditch sections; the ditch along the existing dike and the No Name Slough ditch running from the existing dike upstream to Fir Island Road. The volume of inflow was calculated using the wetted surface area (top width times ditch length) and multiplied by the change in water level for each drainage cycle.
- Periods with rainfall were removed from the calculation. Rainfall data were provided courtesy of the Washington State University, AgWeatherNet website for the Fir Island weather station (http://weather.wsu.edu/awn.php).
- The period of analysis was July 1 – August 30, 2013.

The results of the analysis are shown in Figure B-1. The results indicate that the use of 1 cfs as inflow to the interior storage drainage pond is reasonable and likely conservative. The calculated average seepage inflow for the July – August 2013 period of record was 0.3 cfs (143 gpm) and 0.4 cfs (192 gpm) for the ditch along the existing dike, and No Name Slough ditch between the dike and Fir Island Road, respectively. These seepage rates are less than one half of the seepage inflows of 1 cfs (449 gpm) used to model proposed project conditions for the No Name Slough interior drainage system. The maximum calculated seepage inflows for July – August 2013 period were 0.9 cfs (406 gpm) and 1.2 cfs (556 gpm) for the two ditches, supporting the statement that the constant seepage inflow rate of 1 cfs used in the surface water model is likely conservative.

B.3 SEEP/W MODEL

B.3.1 Overview

We evaluated groundwater conditions across the dike by constructing a numerical seepage flow model using the two-dimensional, finite-element seepage analysis program SEEP/W, which simulates fluid flow and pressure distribution in saturated and unsaturated porous media. SEEP/W is part of the GeoStudio 2007 software package developed by Geo-Slope International (2007).

We constructed three seepage analysis models to evaluate existing and proposed groundwater conditions. Geologic sections A-A' and B-B' from the Geotechnical Data Report (S&W, 2013) were used, along with soils data along the existing dike and setback dike, to estimate soil properties in the models along various dike zones. Cross section elevation data was obtained from existing ground surveys and proposed dike geometry. Surface water elevations and boundary conditions were obtained from monitoring data obtained at the site.

To represent the heterogeneous conditions in the project area, we divided the existing and proposed dike into three representative areal zones, each represented by generalized geologic sections in these zones (Figure B-2):

- Existing dike from Brown to Dry Slough (Existing Condition) Stations 0+00 to 39+00.
- North zone (running east-west) setback dike (Proposed Condition) Stations 10+00 to 37+50.
- East zone (running north-south) of the proposed setback dike (Proposed Condition) Stations 37+50 to 68+00.

The following sections of the report describe the SEEP/W model structure, numerical model application, and modeling results.

B.3.2 Land Surface

The model land surface is based on the 2003 Light Detection and Ranging data for the site existing conditions, and preliminary design plans developed in the feasibility study (and modified for this study) for proposed setback dike and interior drainage pond conditions.

B.3.3 Soil Layers and Hydraulic Conductivity Estimates

Estimates of hydraulic conductivity were performed for the four representative soil layers in the SEEP/W model. Modeling soil layers include: 1) dike/dike fill, 2) combined upper soil units (Hm and Agricultural) soil layer, 3) underlying Holocene alluvium (Ha), and 4) underlying Holocene estuarine soils (He), as characterized in S&W, 2013.

The seepage model soil and groundwater properties were based on soil, groundwater, and surface water data collected during the geotechnical field exploration and hydrologic monitoring program. The estimated hydraulic conductivity estimates were based on soil type and grain size analyses collected from previous geoprobe, boring, and test pit soil samples during this phase of study and from previous feasibility phases of study. Table B-3 summarizes the soil permeability factors used for each zone and soil layers used in the SEEP/W model. We assigned a porosity of 0.25 and an anisotropy ratio (vertical/horizontal hydraulic conductivity) of 0.5 to the soil based on a literature review (Freeze and Cherry, 1979) and our past experience in similar geologic environments.

B.3.4 Surface and Groundwater Boundary Conditions

Surface and groundwater boundary conditions were developed based on the data collected during this current phase of study. Seepage through and underneath the existing dikes is assumed to be a quasi-steady state condition, whereby the exterior average tide is higher than the interior drainage surface water condition, right at the existing dike. Therefore, a seepage gradient exists inland towards the farm areas across the existing dike.

Observed average surface and groundwater elevations from the June through September 2013 period were used as boundary conditions to estimate steady-state seepage inflows for existing and proposed conditions, as summarized below (Figures B-3 through B-5):

- The No Name Slough (SW-NNS-2.0-LTC) average observed tidal water elevation of 5.6 feet (North American Vertical Datum of 1988 [NAVD88]) is the tidal water elevation boundary condition.
- The No Name Slough (SW-NNS-2.1-LTC) interior drainage water elevation of 3.5 feet (NAVD88) is the interior drainage surface water elevation boundary condition.
- The average groundwater elevations in observation wells B-8w-13 were 3.8 feet (NAVD88) for the deep well.
- Soil layers and boundary conditions in the three models are shown in Figures B-6 through B-8.

B.3.5 Seepage Modeling Scenarios

Steady-state seepage analyses were performed for the three generalized zones (Existing, North and East) as modeled sections. Low- and high-hydraulic conductivity scenarios were performed for each section (Table B-4).

- For the Hm/Agricultural unit and He units, we based the modeled low horizontal hydraulic conductivities on the average results from the representative grain-size analyses for each section. We increased these low values by a factor of up to 2.5 to derive the high modeled values.
- For the Ha unit, we based the low horizontal hydraulic conductivity values on the results of the grain-size analyses. We assigned the high hydraulic conductivities to equal the geomean of the representative slug test results.

We performed a scenario to evaluate the seepage rate if the shallower interior drainage pond is not directly connected to the underlying sand layer (Ha) in the northern zone. The analysis involved the low- and high-hydraulic-conductivity cases but 2 feet of Hm soil (silt) maintained below the pond invert.

We performed additional sensitivity analyses, based on feedback from the local farm community, Consolidated Diking District 22 (CDD22), and the Independent Technical Review team. The upper Agricultural and Hm upper soil unit hydraulic conductivities were changed from a silt to sand hydraulic conductivity properties. The point of increasing the upper layer soil hydraulic conductivity was to test hydraulic conductivity and seepage sensitivity.

We also performed analysis of a sheetpile cutoff wall to evaluate the effectiveness and feasibility of reducing seepage inflows to the interior drainages. The analysis was performed as a response study request by CDD22.

B.3.6 Seepage Results

Table B-4 and Figures B-9 through B-11 present the range of seepage modeling results using low and high soil hydraulic conductivities. The results indicate the following:

- Existing condition seepage flux across the 3,300-foot-long dike was calculated to range from approximately 270 to 700 gpm.
- For the proposed project, the seepage flows through and underneath the dike to interior drainages will be lower than under existing conditions. Predicted steady-state seepage fluxes for the dike sections are as follows:
  - North zone – 16 to 20 gpm for the 2,400-foot-long section;
  - North zone with additional 2-foot silt layer on bottom of pond – 14 to 17 gpm;
  - East zone – 46 to 100 gpm for the 2,900-foot-long section; and
  - Combined – 62 to 120 gpm for the entire setback dike section.

The seepage rate to the No Name Slough interior drainage pond used the seepage and groundwater inflow estimates derived from the project surface water monitoring of existing ditch baseflow condition of 1 cfs (450 gpm) for both No Name and Dry Sloughs.

For Dry Slough, a similar seepage inflow rate of 1 cfs (450 gpm) inflow to Dry Slough was augmented with an additional seepage flux of 0.2 cfs (100 gpm). This addition reflects the calculated seepage rates for the new 3,000 feet of dike along Dry Slough, based on the SEEP-W modeling results. These values are conservative as the SEEP/W model indicates that seepage rates to the interior storage pond and Dry Slough will likely be less for proposed conditions than the existing conditions. Also, the Project has reduced interior drainage channel lengths and drainage areas, as compared to existing conditions, and would therefore likely have less upstream groundwater baseflow inflow to the system.

B.3.7 Response Study – Cutoff Wall Analysis

We evaluated the potential effect to the interior drainage system of including a cutoff wall in the dike. A range of cutoff wall scenarios were analyzed and compared with the no-cutoff-wall scenario (Table B-6, Figures B-12 through B-23). The cutoff wall scenarios replace the Hm/Agricultural upper soil unit hydraulic conductivity properties with the underlying Ha sand unit hydraulic conductivity properties for the analysis, to test cutoff wall effectiveness for areas where the soils may be predominately sand, without the overlying silt / agricultural layer. Table B-6 and associate d Figures B-12 through B-23, therefore do not the same low/high seepage rates as earlier modeling scenarios shown in Table B-4 and Figures B-7 and B-8.

The modeling results indicate that a cutoff wall less than 10 feet deep would reduce the seepage flux underneath the dike by between 10 and 15 percent. Increasing the cutoff wall depth to 40 feet would result in a seepage reduction by between 70 and 99 percent. Table B-7 provides cost estimates for a range of cut-off wall depths. The approximate cost estimates range from $524k for a 10-foot-deep cutoff wall, to $2.1M for a 40-foot-deep cutoff wall.

B.4 REFERENCES

Bouwer, H., 1989, The Bouwer and Rice slug test – an update: Ground Water, v. 27, no. 3, p. 304-309.

Butler, J.J., Jr., 1998, The design, performance, and analysis of slug tests: Lewis Publishers, CRC Press, Boca Raton, Florida.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, NJ (Prentice-Hall).

Geo-Slope International Ltd., 2007, Seepage modeling with SEEP/W 2012.

S&W, 2013, Fir Island Farm, final design and permitting, draft geotechnical and hydrogeologic data report, Skagit County, Washington: Report prepared by Shannon & Wilson. Inc, Seattle, Wash., 21-1-12318-215, for Washington Department of Fish and Wildlife, Olympia, Wash., December.

TABLE B-1
SLUG TESTING RESULTS

Observation Well	Date Tested	Test Number	Static Water Level Depth[a] (feet bgs)	Hydraulic Conductivity Calculated Using the Bouwer and Rice Method		Interpreted Primary Geologic Unit Tested[b]
				ft/day	cm/sec	
B-04W-13	6/26/2013	Falling Head Test 1	2.6	113	4.0E-02	Ha
		Falling Head Test 2		170	6.0E-02	
		Falling Head Test 3		142	5.0E-02	
		Falling Head Tes 4		113	4.0E-02	
		Rising Head Test 1		85	3.0E-02	
		Rising Head Test 2		113	4.0E-02	
		Rising Head Test 3		170	6.0E-02	
		Rising Head Test 4		142	5.0E-02	
		Geomean		**128**	**4.5E-02**	
B-06W-13	6/26/2013	Falling Head Test 1	3.1	57	2.0E-02	Ha
		Falling Head Test 2		113	4.0E-02	
		Falling Head Test 3		142	5.0E-02	
		Falling Head Test 4		57	2.0E-02	
		Rising Head Test 1		85	3.0E-02	
		Rising Head Test 2		113	4.0E-02	
		Rising Head Test 3		113	4.0E-02	
		Rising Head Test 4		113	4.0E-02	
		Geomean		**94**	**3.3E-02**	
B-08W-13	6/26/2013	Falling Head Test 1	1.2	170	6.0E-02	Ha
		Falling Head Test 2		198	7.0E-02	
		Falling Head Test 3		283	1.0E-01	
		Falling Head Test 4		170	6.0E-02	
		Rising Head Test 1		170	6.0E-02	
		Rising Head Test 2		198	7.0E-02	
		Rising Head Test 3		198	7.0E-02	
		Rising Head Test 4		170	6.0E-02	
		Geomean		**192**	**6.8E-02**	

Notes:

[a] Static water level measured just prior to the start of slug testing.

[b] If a well was screened across more than one interpreted geologic unit, the most pervious unit was considered to be the unit tested.

bgs = below ground surface

cm/sec = centimeters per second

ft/day = feet per day

TABLE B-2
HYDRAULIC CONDUCTIVITY RESULTS BASED ON GRAIN-SIZE ANALYSES

Boring	Sample	Depth	USCS Soil Type	Soil Properties										Hazen (cm/sec)	Kozeny-Carman (cm/sec)	Breyer Equation (cm/sec)	Slitcher (cm/sec)	Alyamani and Sen (1993) (cm/sec)	USBR (cm/sec)	Hydraulic Conductivity - Based on Averages of Equations	
				GRAVEL (%)	SAND (%)	FINES (%)	D10 (mm)	D20 (mm)	D50 (mm)	D60 (mm)	Cu Ratio (Coefficient of Uniformity)	Porosity (n) (from Vukovic and Soro)	I_0 (mm)							(cm/sec)	(ft/day)
Borings in Zone 1 - Existing Levee																					
B-9w-13	S-1	2.0	ML	0	14	86	0.0015	0.0035	0.017	0.027	18.0	0.26	0.001	*1.4E-06*	6.2E-07	*1.9E-06*	2.8E-07	2.2E-06	*1.1E-06*	1.0E-06	0.003
TP-26-13	S-3	3.0	ML	0	7	93	0.001	0.003	0.009	0.015	15.0	0.27	0.001	*6.5E-07*	3.0E-07	*9.0E-07*	1.3E-07	9.1E-07	*7.4E-07*	4.5E-07	0.001
TP-37-13	S-3	3.0	SM	0	78	22	0.035	0.08	0.2	0.25	7.1	0.32	0.02	1.2E-03	7.3E-04	*1.3E-03*	2.9E-04	1.1E-03	1.4E-03	9.4E-04	2.647
TP-33-13	S-3	3.5	SM	0	78	22	0.03	0.07	0.21	0.3	10.0	0.29	0.02	*7.1E-04*	3.8E-04	*9.0E-04*	1.6E-04	7.9E-04	*1.0E-03*	4.4E-04	1.252
TP-32-13	S-3	4.5	SM	0	75	25	0.03	0.05	0.17	0.2	6.7	0.33	0.02	*8.9E-04*	5.8E-04	*9.9E-04*	2.3E-04	7.9E-04	*4.8E-04*	5.3E-04	1.506
TP-36-13	S-3	5.0	SM	0	81	19	0.04	0.08	0.17	0.25	6.3	0.33	0.03	*1.6E-03*	1.1E-03	*1.8E-03*	4.3E-04	1.5E-03	*1.4E-03*	1.0E-03	2.817
TP-23-13	S-3	8.5	ML	0	3	97	0.001	0.003	0.007	0.01	10.0	0.29	0.001	*7.9E-07*	4.2E-07	*1.0E-06*	*1.8E-07*	8.8E-07	*7.4E-07*	6.5E-07	0.002
B-8w-13	S-5	10	SP-SM	2	92	6.2	0.15	0.2	0.4	0.5	3.3	0.39	0.12	3.1E-02	3.0E-02	2.9E-02	1.0E-02	2.3E-02	1.2E-02	2.2E-02	63.240
B-8w-13	S-7	15	SP	0	97	3.5	0.2	0.22	0.33	0.35	1.8	0.44	0.18	6.6E-02	8.8E-02	5.8E-02	2.6E-02	4.9E-02	1.4E-02	5.0E-02	141.570
GP-02-10		15	SP-SM	2	93	5	0.15	0.23	0.4	0.52	3.5	0.39	0.12	3.0E-02	2.9E-02	2.9E-02	9.9E-03	2.3E-02	1.6E-02	2.3E-02	64.357
GP-01-10		16	SP	1	96	3	0.19	0.25	0.4	0.43	2.3	0.42	0.16	5.6E-02	6.6E-02	5.0E-02	2.1E-02	4.0E-02	1.9E-02	4.2E-02	118.781
GP-01-10	S-6	25	SP-SM	0	91	9	0.1	0.17	0.33	0.36	3.6	0.39	0.07	1.3E-02	1.2E-02	1.3E-02	4.3E-03	9.6E-03	8.0E-03	1.0E-02	28.323
GP-02-10		25	SP-SM	0	95	5	0.15	0.23	0.4	0.5	3.3	0.39	0.12	3.1E-02	3.0E-02	2.9E-02	1.0E-02	2.3E-02	1.6E-02	2.3E-02	65.317
Borings in Zone 2 - Northern Section of Proposed Levee																					
TP-4-13	S-1	2.0	ML	0	3	97	0.001	0.002	0.009	0.015	15.0	0.27	0.001	*6.5E-07*	3.0E-07	*9.0E-07*	1.3E-07	9.1E-07	*2.9E-07*	4.5E-07	0.001
TP-6-13	S-2	2.5	ML	0	15	85	0.004	0.008	0.035	0.042	10.5	0.29	0.002	*1.2E-05*	6.4E-06	*1.6E-05*	2.7E-06	1.4E-05	*7.1E-06*	7.9E-06	0.022
TP-7-13	S-2	2.5	ML	0	19	81	0.005	0.01	0.035	0.05	10.0	0.29	0.003	*2.0E-05*	1.0E-05	*2.5E-05*	4.4E-06	2.2E-05	*1.2E-05*	1.2E-05	0.035
B-5w-13	S-13	3.0	ML	0	33	67	0.0025	0.006	0.042	0.06	24.0	0.26	0.001	*3.6E-06*	1.6E-06	*4.8E-06*	7.1E-07	7.4E-06	*3.6E-06*	3.2E-06	0.009
TP-9-13	S-2	3.0	ML	0	29	71	0.0055	0.015	0.04	0.055	10.0	0.29	0.003	*2.4E-05*	1.3E-05	*3.0E-05*	5.3E-06	2.7E-05	*3.0E-05*	1.5E-05	0.042
TP-3-13	S-2	3.5	ML	0	11	89	0.0028	0.007	0.021	0.03	10.7	0.29	0.002	*6.0E-06*	3.1E-06	*7.7E-06*	1.3E-06	6.9E-06	*5.2E-06*	3.8E-06	0.011
TP-8-13	S-3	4.0	ML	0	47	53	0.009	0.02	0.07	0.09	10.0	0.29	0.005	*6.4E-05*	3.4E-05	*8.1E-05*	1.4E-05	7.2E-05	*5.8E-05*	4.0E-05	0.113
TP-5-13	S-2	3.5	SM	0	85	15	0.04	0.1	0.17	0.2	5.0	0.36	0.03	1.8E-03	1.4E-03	*1.9E-03*	5.2E-04	1.5E-03	2.4E-03	1.6E-03	4.464
TP-2-13	S-3	3.5	SP	1	98	1	0.28	0.31	0.45	0.5	1.8	0.44	0.25	1.3E-01	1.7E-01	1.1E-01	5.1E-02	9.6E-02	3.2E-02	9.8E-02	277.897
TP-11-13	S-3	3.5	SP-SM	0	94	6	0.15	0.17	0.2	0.21	1.4	0.45	0.14	3.9E-02	5.6E-02	3.4E-02	1.6E-02	3.0E-02	8.0E-03	3.0E-02	85.973
TP-10-13	S-3	5.0	SW-SM	0	90	10	0.08	0.15	0.4	0.5	6.3	0.33	0.05	*6.6E-03*	4.4E-03	7.2E-03	1.7E-03	5.7E-03	*6.0E-03*	4.7E-03	13.422
B-1-13	S-5	10	SP	0	96	4	0.16	0.25	0.38	0.42	2.6	0.41	0.13	3.8E-02	4.2E-02	3.4E-02	1.4E-02	2.7E-02	1.9E-02	2.9E-02	82.112
GP-06-10		10	SM	0	96	4	0.15	0.2	0.3	0.32	2.1	0.43	0.13	3.5E-02	4.3E-02	3.1E-02	1.3E-02	2.5E-02	1.2E-02	2.7E-02	75.501
B-4w-13	S-5	10.5	SP	0	97	3	0.15	0.19	0.3	0.33	2.2	0.42	0.13	3.5E-02	4.2E-02	3.1E-02	1.3E-02	2.5E-02	1.0E-02	2.6E-02	74.126
B-4w-13	S-6	12.5	SP-SM	1	94	5	0.15	0.2	0.4	0.48	3.2	0.40	0.12	3.1E-02	3.1E-02	2.9E-02	1.0E-02	2.3E-02	1.2E-02	2.3E-02	64.246
B-1-13	S-9	20	SM	2	61	37	0.006	0.025	0.1	0.15	25.0	0.26	0.003	*2.1E-05*	9.1E-06	*2.8E-05*	4.1E-06	4.3E-05	*9.7E-05*	1.9E-05	0.053
B-1-13	S-13	35	SM	0	75	25	0.022	0.07	0.09	0.1	4.5	0.36	0.02	5.8E-04	4.7E-04	*5.8E-04*	1.7E-04	4.4E-04	1.0E-03	5.4E-04	1.531
Borings in Zone 3 - Eastern Section of Proposed Levee																					
B-3-13	S-2	2.5	ML	0	22	78	0.007	0.015	0.04	0.05	7.1	0.32	0.005	*4.7E-05*	2.9E-05	*5.3E-05*	1.2E-05	4.3E-05	*3.0E-05*	2.8E-05	0.079
TP-9-13	S-2	3.0	ML	0	29	71	0.0055	0.015	0.04	0.055	10.0	0.29	0.003	2.4E-05	1.3E-05	*3.0E-05*	5.3E-06	2.7E-05	*3.0E-05*	1.5E-05	0.042
TP-13-13	S-3	3.5	SP-SM	0	88	12	0.07	0.09	0.15	0.18	2.6	0.41	0.06	7.3E-03	8.1E-03	6.6E-03	2.6E-03	5.4E-03	1.9E-03	5.3E-03	15.040
TP-15-13	S-2	3.5	SP-SM	0	94	6	0.1	0.14	0.22	0.3	3.0	0.40	0.08	1.4E-02	1.5E-02	1.3E-02	4.9E-03	1.1E-02	5.1E-03	1.0E-02	29.562
TP-11-13	S-3	3.5	SP-SM	0	94	6	0.15	0.17	0.2	0.21	1.4	0.45	0.14	3.9E-02	5.6E-02	3.4E-02	1.6E-02	3.0E-02	8.0E-03	3.0E-02	85.973
GP-08-10		5.0	SP-SM	1	92	7	0.13	0.15	0.24	0.29	2.2	0.42	0.11	2.6E-02	3.1E-02	2.3E-02	9.8E-03	2.0E-02	6.0E-03	1.9E-02	54.862
TP-10-13	S-3	5.0	SW-SM	0	90	10	0.08	0.15	0.4	0.5	6.3	0.33	0.05	*6.6E-03*	4.4E-03	7.2E-03	1.7E-03	5.7E-03	*6.0E-03*	4.7E-03	13.422
B-2-13	S-4	7.5	SP	1	95	4	0.15	0.25	0.5	0.65	4.3	0.37	0.11	2.8E-02	2.3E-02	2.7E-02	8.3E-03	2.2E-02	1.9E-02	2.1E-02	59.997
GP-04-10		10	SP	1	97	2	0.2	0.33	0.6	0.7	3.5	0.39	0.15	5.4E-02	5.1E-02	5.1E-02	1.7E-02	3.9E-02	3.7E-02	4.1E-02	117.232
B-3-13	S-6	12.5	SP	0	96	4	0.18	0.25	0.4	0.45	2.5	0.42	0.15	4.9E-02	5.5E-02	4.4E-02	1.8E-02	3.5E-02	1.9E-02	3.7E-02	103.632
GP-03-10		14.5	SP	0	96	4	0.2	0.28	0.4	0.5	2.5	0.42	0.17	6.0E-02	6.8E-02	5.4E-02	2.2E-02	4.5E-02	2.5E-02	4.6E-02	129.313
GP-03-10		21	SP	0	97	4	0.15	0.2	0.3	0.33	2.2	0.42	0.13	3.5E-02	4.2E-02	3.1E-02	1.3E-02	2.5E-02	1.2E-02	2.6E-02	74.735
B-2-13	S-11	30	SP-SM	0	90	10	0.08	0.1	0.18	0.19	2.4	0.42	0.07	9.7E-03	1.1E-02	8.7E-03	3.6E-03	6.9E-03	2.4E-03	7.1E-03	20.127
B-3-13	S-12	35	SM	1	66	33	0.007	0.03	0.13	0.15	21.4	0.26	0.003	*2.9E-05*	1.3E-05	*3.9E-05*	5.7E-06	6.3E-05	*1.5E-04*	2.7E-05	0.076
B-2-13	S-13	40	ML	0	13	87	0.0025	0.008	0.035	0.04	16.0	0.27	0.001	*4.0E-06*	1.8E-06	*5.5E-06*	8.1E-07	6.7E-06	*7.1E-06*	3.1E-06	0.009

Notes:

Upper Soil Unit - Hm/Agricultural

Middle Soil Unit - Ha

Lower Soil Unit - He

Indictates anlytical method not valid for soil sample

cm/sec = centimeters per second

ft/day = feet per day

mm = millimeter

USBR = U.S. Bureau of Reclamation

USCS= Unified Soil Classification System

% = percent

TABLE B-3
SEEP/W MODEL SELECTED HYDRAULIC CONDUCTIVITY BY SOIL LAYER

ID	Sample/Test	Depth (ft)	USCS	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)	Formation	Averaged K (cm/sec)	Averaged K (ft/day)
Borings in Zone 1 - Existing Levee								
B-9w-13	S-1	2.0	ML	1.0E-06	*0.003*	Topsoil and Hm	6.9E-04	2.0
TP-37-13	S-3	3.0	SM	9.4E-04	2.651			
TP-33-13	S-3	3.5	SM	4.4E-04	1.254			
TP-23-13	S-3	8.5	ML	6.5E-07	*0.002*			
B-8w-13	S-5	10	SP-SM	2.2E-02	63.344	Ha	2.8E-02	80.4
B-8w-13	S-7	15	SP	5.0E-02	141.802			
GP-02-10	-	15	SP-SM	2.3E-02	64.463			
GP-01-10	-	16	SP	4.2E-02	118.976			
GP-01-10	S-6	25	SP-SM	1.0E-02	28.369			
GP-02-10	-	25	SP-SM	2.3E-02	65.424			
B-08-w13	Slug Test[(1)]	10 - 20	SP-SM/SP	6.8E-02	192.000	Ha	6.8E-02	192.0
Borings in Zone 2 - Northern Section of Proposed Levee Along Interior Storage Pond								
TP-4-13	S-1	2.0	ML	4.5E-07	*0.001*	Topsoil and Hm	1.4E-05	0.0
TP-6-13	S-2	2.5	ML	7.9E-06	0.022			
TP-7-13	S-2	2.5	ML	1.2E-05	0.035			
B-5w-13	S-13	3.0	ML	3.2E-06	0.009			
TP-9-13	S-2	3.0	ML	1.5E-05	0.042			
TP-3-13	S-2	3.5	ML	3.8E-06	0.011			
TP-8-13	S-3	4.0	ML	4.0E-05	0.113			
TP-5-13	S-2	3.5	SM	1.6E-03	4.471	Ha	3.0E-02	84.9
TP-2-13	S-3	3.5	SP	9.8E-02	278.353			
TP-11-13	S-3	3.5	SP-SM	3.0E-02	86.114			
TP-10-13	S-3	5.0	SW-SM	4.7E-03	13.444			
B-1-13	S-5	10	SP	2.9E-02	82.247			
GP-06-10	-	10	SM	2.7E-02	75.625			
B-4w-13	S-5	10.5	SP	2.6E-02	74.247			
B-4w-13	S-6	12.5	SP-SM	2.3E-02	64.351			
B-06-w13	Slug Test[(1)]	8 - 18	SP	3.5E-02	99.000	Ha	3.5E-02	99.0
B-1-13	S-9	20	SM	1.9E-05	0.095	He	2.8E-04	0.8
B-1-13	S-13	35	SM	5.4E-04	1.550			
Borings in Zone 3 - Eastern Section of Proposed Levee Along Dry Slough								
B-3-13	S-2	2.5	ML	2.8E-05	0.101	Topsoil and Hm	2.1E-05	0.1
TP-9-13	S-2	3.0	ML	1.5E-05	0.061			
TP-13-13	S-3	3.5	SP-SM	5.3E-03	15.040	Ha	2.3E-02	64.1
TP-15-13	S-2	3.5	SP-SM	1.0E-02	29.562			
TP-11-13	S-3	3.5	SP-SM	3.0E-02	85.973			
GP-08-10	-	5.0	SP-SM	1.9E-02	54.862			
TP-10-13	S-3	5.0	SW-SM	4.7E-03	14.872			
B-2-13	S-4	7.5	SP	2.1E-02	59.997			
GP-04-10	-	10	SP	4.1E-02	117.232			
B-3-13	S-6	12.5	SP	3.7E-02	103.632			
GP-03-10	-	14.5	SP	4.6E-02	129.313			
GP-03-10	-	21	SP	2.6E-02	74.735			
B-2-13	S-11	30	SP-SM	7.1E-03	20.127			
B-04-w13	Slug Test[(1)]	10 - 20	SP-SM/SP	4.5E-02	128.000	Ha	4.5E-02	128.0
B-3-13	S-12	35	SM	4.9E-05	0.140	He	2.7E-05	0.1
B-2-13	S-13	40	ML	4.3E-06	0.012			

Notes:

[1] Slug test values are geomean of all results for each well.

cm/sec = centimeters per second; ft/day = feet per day

USCS= Unified Soil Classification System

TABLE B-4
SEEP/W MODEL RESULTS

Zone	Permeability Case[1]	Inputs							Results				
		Horizontal Hydraulic Conductivities[1] (ft/d)				Water Level (ft)		Levee Length (ft)	Seepage - Flux		Velocity at Center of Levee (ft/day)	Gradient at Toe of Levee (ft/ft)	Water Level at Center of Levee (ft)
		Dike Fill	Hm/ Agricultural	Ha	He	Bay Side	Land Side		Per linear ft (ft^3/d/ft)	Entire Levee (gpm)			
Existing (Zone 1)	Low	1.50	1.50	80	0.80	5.6	3.5	3,300	16.0	274	0.70	0.04	4.0
	High	3.60	3.60	192	1.92	5.6	3.5	3,300	40.6	696	1.80	0.04	4.0
Northern (Zone 2)	Low	1.50	0.04	85	0.80	5.85	3.5	2,400	1.3	16	0.07	0.03	3.6
	High	1.75	0.05	99	0.93	5.85	3.5	2,400	1.6	20	0.08	0.01	3.6
	Low - 2 feet of Hm at bottom of pond	1.50	0.04	85	0.80	5.85	3.5	2,400	1.1	14	0.06	0.30	3.6
	High - 2 feet of Hm at bottom of pond	1.75	0.05	99	0.93	5.85	3.5	2,400	1.4	17	0.07	0.30	3.6
Eastern (Zone 3)	Low	1.50	0.08	64	0.10	5.85	3.5	2,900	3.0	46	0.15	0.01	3.6
	High	3.00	0.16	128	0.20	5.85	3.5	2,900	6.6	100	0.30	0.01	3.6

Notes:

[1] K was estimated on average of grain size analysis and slug tests.

[2] Assumed values.

Modeled porosity = 0.25 (25 percent). Modeled Kz/Kh ratio = 0.5.

Porosity = 0.25, Kv/Kh = 0.5

1 ft/day = 3.5E-4 cm/sec

cm/sec = centimeters per second

ft/day = feet per day

ft/ft = feet per feet

ft^3/d/ft = cubic feet per day per foot

gpm = gallons per minute

TABLE B-5
RANGES OF HYDRAULIC CONDUCTIVITY

Zone/Data Sources	Statistics	Dike Fill		Hm and Agricultural		Ha		He	
		Grain Size, Slug Test, CPT	SEEP-W Modeled	Grain Size, Slug Test, CPT	SEEP-W Modeled	Grain Size, Slug Test, CPT	SEEP-W Modeled	Grain Size, Slug Test, CPT	SEEP-W Modeled
		(K in ft/day)							
Existing (Zone 1) / Grain size and Slug Test	Count	0	1.5-3.6	4	1.5-3.6	12	80-192	0	0.8-1.92
	Maximum	-		2.8		192		-	
	Mean	-		1.2		96		-	
	Median	-		0.9		65		-	
	Minimum	-		0.002		28		-	
Northern (Zone 2) / Grain size and Slug Test	Count	0	1.5-1.75	7	0.04-0.05	14	85-99	2	0.8-0.93
	Maximum	-		0.2		278		1.6	
	Mean	-		0.04		85		0.8	
	Median	-		0.03		75		0.8	
	Minimum	-		0.002		4		0.09	
Eastern (Zone 3) / Grain size and Slug Test	Count	0	1.5-1.75	2	0.08-0.16	17	64-128	2	0.1-0.2
	Maximum	-		0.1		129		0.14	
	Mean	-		0.08		64		0.08	
	Median	-		0.08		60		0.08	
	Minimum	-		0.061		15		0.01	
Northern and Eastern (Zones 2 and 3) / CPT	Count	0	-	185	-	997	-	1250	-
	Maximum	-		36.7		145		0.81	
	Mean	-		1.87		17		0.017	
	Median	-		0.38		12		0.0012	
	Minimum	-		0.001		0.001		0.0001	

Notes:

[1] K was based on grain size analysis, CPT, and slug test.

1 ft/day = 3.5E-4 centimeters per second

CPT = cone penetrometer test

ft/day = feet per day

$ft^3/d/ft$ = cubic feet per day per foot

gpm = gallons per minute

TABLE B-6
CUTOFF WALL SEEPAGE RATES

	Proposed Levee Sections and Simulations	Cutoff Wall Depth (ft)	Hydraulic Conductivities (ft/d): Dike Fill	Agricultural Layer/ Hm	Ha	He	Water Level (ft): Bay Side	Land Side	Seepage Flux: Per linear ft (ft^3/d/ft)	Levee Length (ft)	Levee Section (gpm)	Seepage Reduction (gpm)	Seepage Reduction (%)
Average Estimated Hydraulic (Low) Conductivity	North, Zone 2, S10	0	1.7	0.04	85	0.8	5.85	3.23	1.3	2,400	16	-	-
	North, Zone 2, S11	6							1.2		15	1	9%
	North, Zone 2, S12	10							1.2		15	2	10%
	North, Zone 2, S13	20							1.2		15	2	11%
	North, Zone 2, S15	30							0.6		8	9	54%
	North, Zone 2, S14	40							0.4		5	11	67%
	East, Zone 3, S10	0	1.7	0.08	64	0.2	5.85	3.23	2.8	2,900	42	-	-
	East, Zone 3, S11	6							2.4		36	6	15%
	East, Zone 3, S12	10							2.4		36	6	15%
	East, Zone 3, S13	20							2.3		35	7	17%
	East, Zone 3, S15	30							0.3		4	38	90%
	East, Zone 3, S14	40							0.2		2	40	94%
Maximum Estimated Hydraulic (High) Conductivity	North, Zone 2, S4	0	1.7	85	85	0.8	5.85	3.23	42.0	2,400	524	-	-
	North, Zone 2, S5	6							38.0		474	50	10%
	North, Zone 2, S6	10							35.5		443	81	15%
	North, Zone 2, S7	20							27.0		337	187	36%
	North, Zone 2, S8	30							1.2		15	509	97%
	North, Zone 2, S9	40							0.7		8	515	98%
	East, Zone 3, S4	0	1.7	85	64	0.2	5.85	3.23	29.1	2,900	439	-	-
	East, Zone 3, S5	6							26.3		396	43	10%
	East, Zone 3, S6	10							24.7		373	66	15%
	East, Zone 3, S7	20							19.2		289	150	34%
	East, Zone 3, S8	30							0.3		5	434	99%
	East, Zone 3, S9	40							0.2		3	436	99%

Notes:

1 K was based on grain size analysis and slug test

2 Maximum X-Velocity was obtain from the highest flow layer in the model

3 Simulation S9 represent cutoff wall 3 ft into He material

1 ft/day = 3.5E-4 cm/sec

Porosity = 0.25, Kv/Kh = 0.5

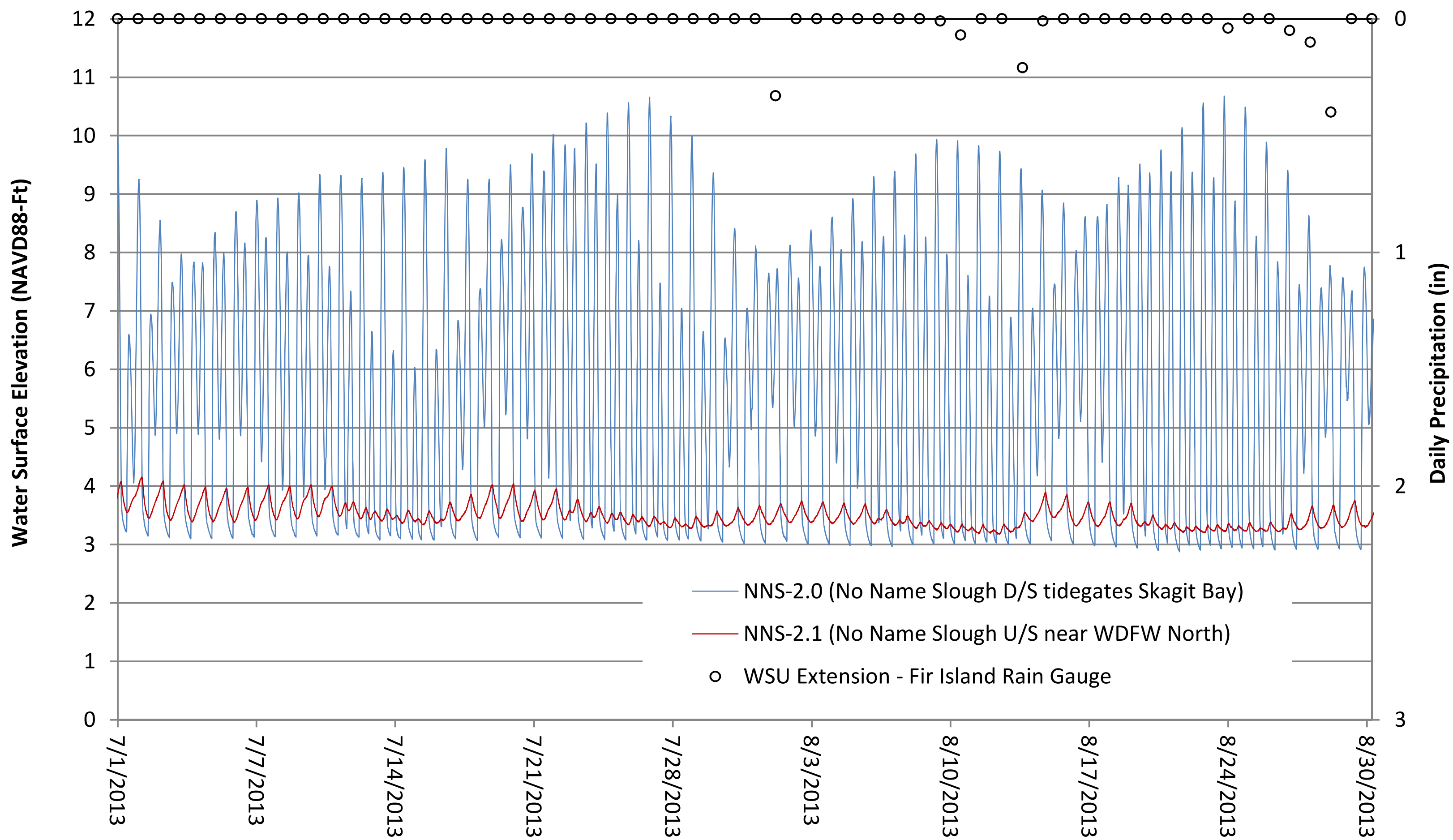
% = percent

TABLE B-7
CUTOFF WALL COSTS

Cutoff Wall Depth (ft)	Unit Price[1] ($/sf)	Length (ft)	Cost ($)
0	$9.89	5,300	
6			$ 314,000
10			$ 524,000
20			$ 1,048,000
30			$ 1,572,000
40			$ 2,096,000

Notes:

[1] Unit price based on Fisher Slough cutoff wall escalated from 2010 to 2015 prices.
$/sf = cost per foot



Seepage	Exist Dike Ditch		No Name Slough	
	cfs	gpm	cfs	gpm
Max	0.91	406.2	1.24	556.1
Mean	0.32	143.2	0.43	192.4
Min	-0.04	-19.9	-0.26	-118.1

Fir Island Farms Restoration

Skagit County, WA

NO NAME SLOUGH WATER LEVELS JUNE 2013 - AUGUST 2013

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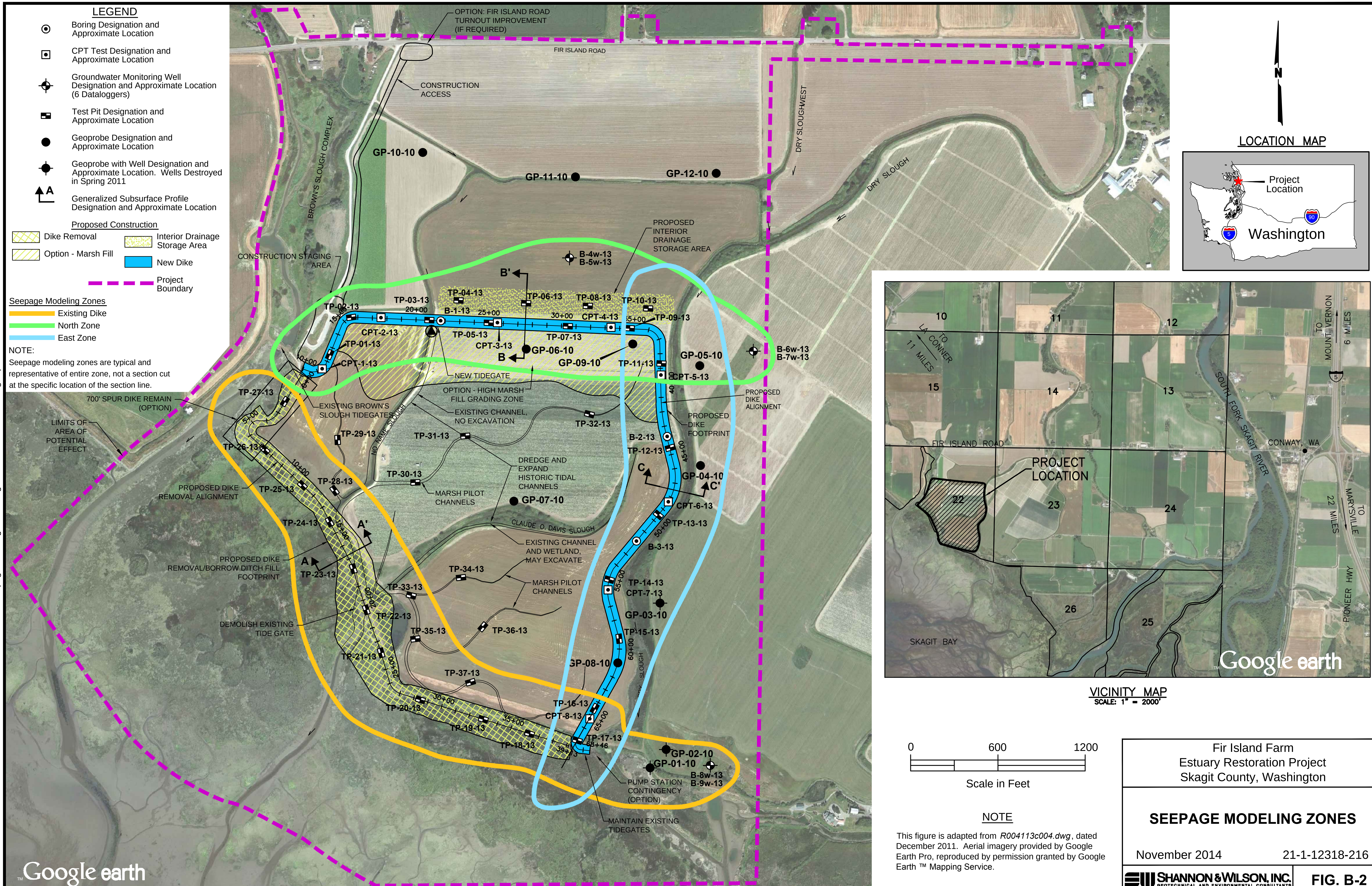
FIG. B-1

FIG. B-1



0 600 1200

Scale in Feet

NOTE

This figure is adapted from *R004113c004.dwg*, dated December 2011. Aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

Fir Island Farm
Estuary Restoration Project
Skagit County, Washington

SEEPAGE MODELING ZONES

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FIG. B-2

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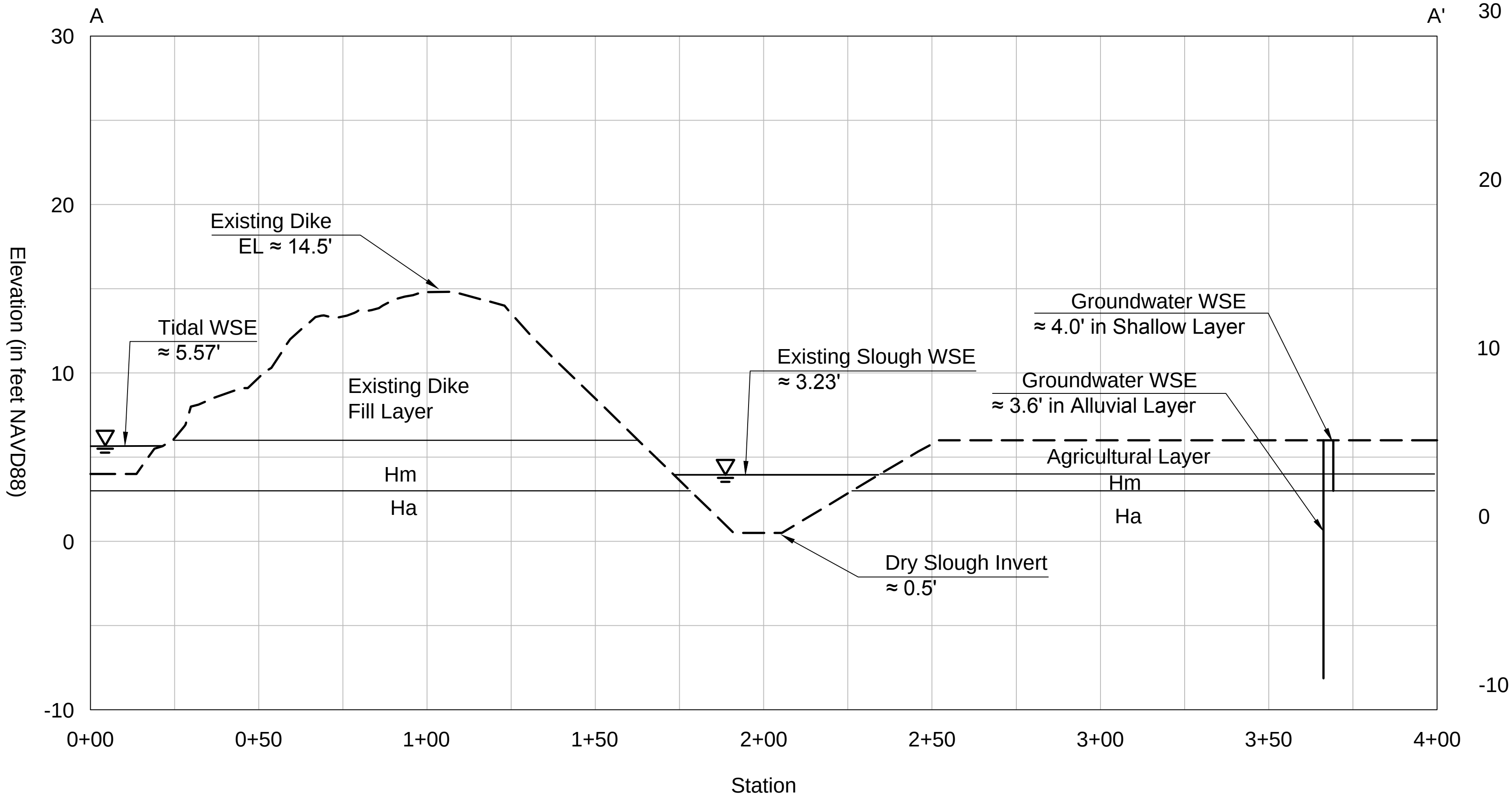

TYPICAL - SECTION A-A'

NOTES

1. Tidal water surface elevation (WSE) is based on average from NNS-2.0 for period 6-19-2013 through 10-9-2013
2. Slough WSE is based on average from NNS-2.1 for period 6-19-2013 through 10-9-2013
3. Groundwater WSE is based on average from B-8 and B-9 for period 6-19-2013 through 10-9-2013
4. Geologic profile is based on TP-18 and TP-19
5. Section is typical and represents typical soil conditions along existing levee and not soil conditions along section cut location.

Fir Island Farm
Estuary Restoration Project
Skagit County, Washington

SEEPAGE ANALYSIS
TYPICAL SECTION EXISTING DIKE

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FIG. B-3

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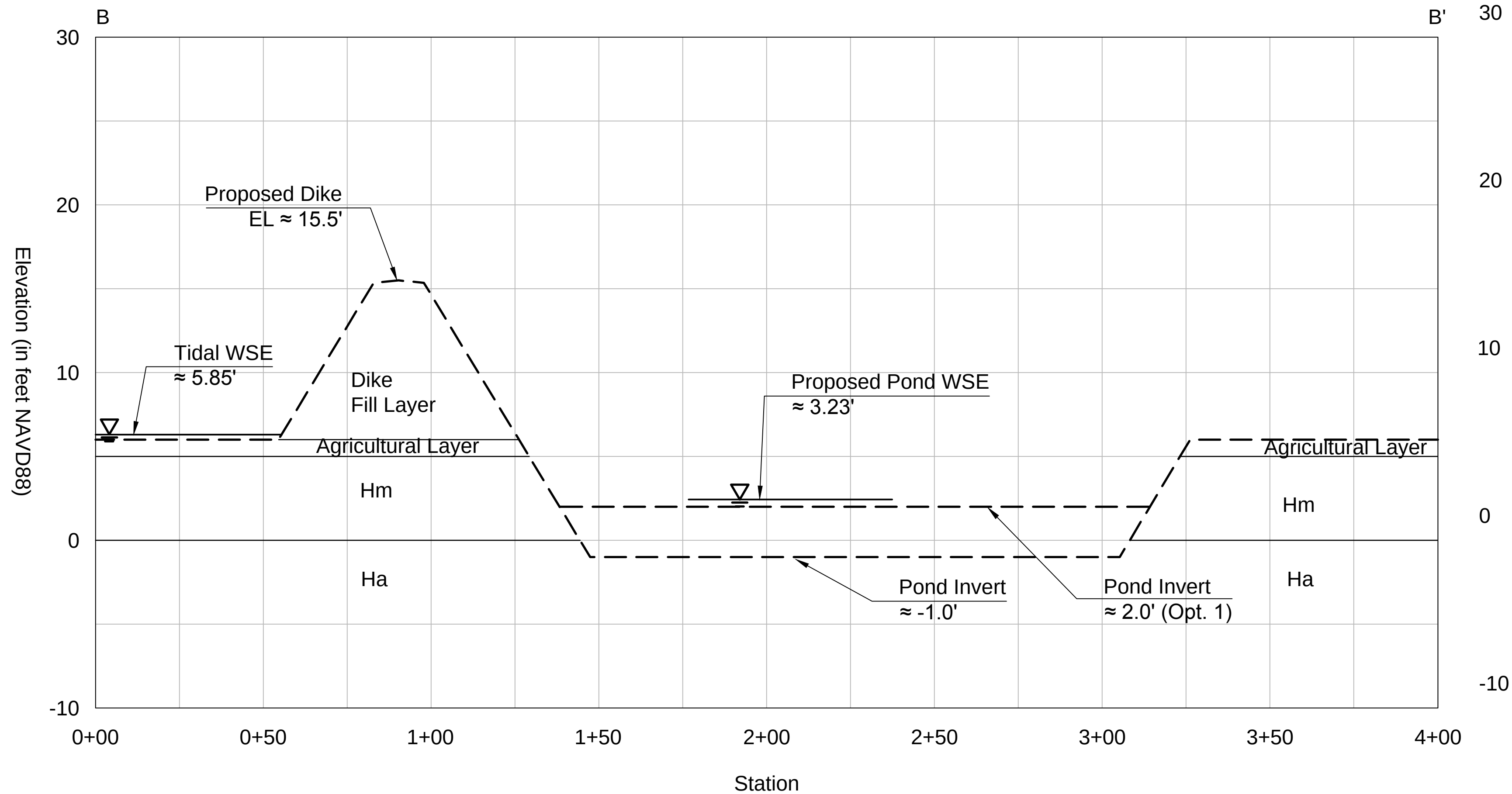

TYPICAL SECTION B-B'

NOTES

1. Tidal water surface elevation (WSE) is based on average from NNS 2.0 for period 6-19-2013 through 10-9-2013, with troughs raised 0.75 feet based on Battelle modeling results
2. Slough WSE is based on average from NNS-2.1 for period 6-19-2013 through 10-9-2013
3. Groundwater WSE is based on average from B-8 and B-9 for period 6-19-2013 through 10-9-2013
4. Geologic profile is based on TP-18 and TP-19

Fir Island Farm
Estuary Restoration Project
Skagit County, Washington

SEEPAGE ANALYSIS
TYPICAL SECTION PROPOSED
NORTH ZONE STORAGE POND

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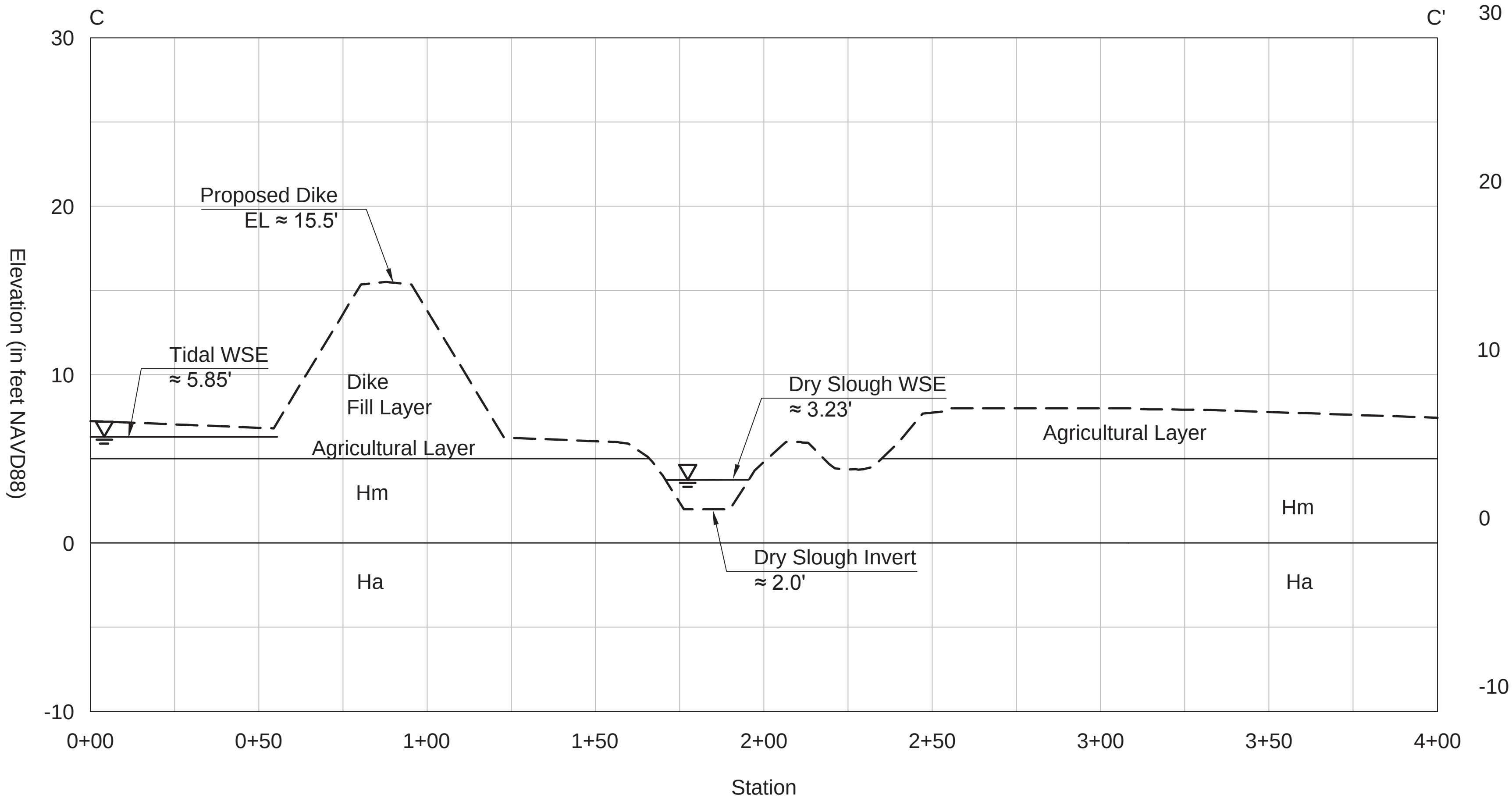
FIG. B-4



TYPICAL SECTION C-C'

NOTES

1. Tidal water surface elevation (WSE) is based on average from NNS 2.0 for period 6-19-2013 through 10-9-2013, with troughs raised 0.75 feet based on Battelle modeling results
2. Slough WSE is based on average from NNS-2.1 for period 6-19-2013 through 10-9-2013
3. Groundwater WSE is based on average from B-8 and B-9 for period 6-19-2013 through 10-9-2013
4. Geologic profile is based on TP-18 and TP-19

Fir Island Farm
Estuary Restoration Project
Skagit County, Washington

SEEPAGE ANALYSIS
TYPICAL SECTION PROPOSED
EAST ZONE DRY SLOUGH

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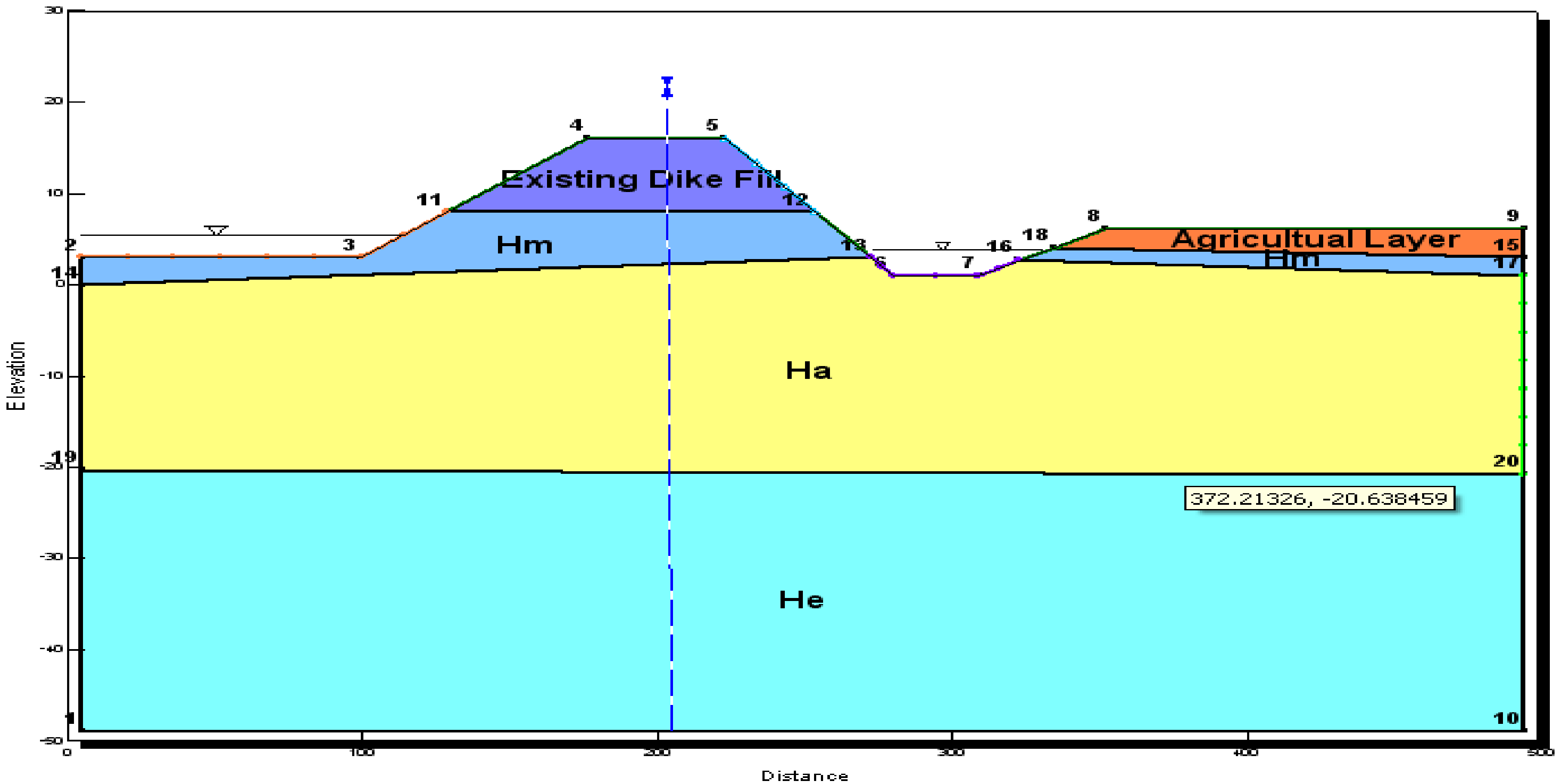
FIG. B-5



Fir Island Farms Restoration

Skagit County, WA

SEEP/W
MODELED SOIL PROFILE
EXISTING DIKE

November 2014 21-1-12318-216

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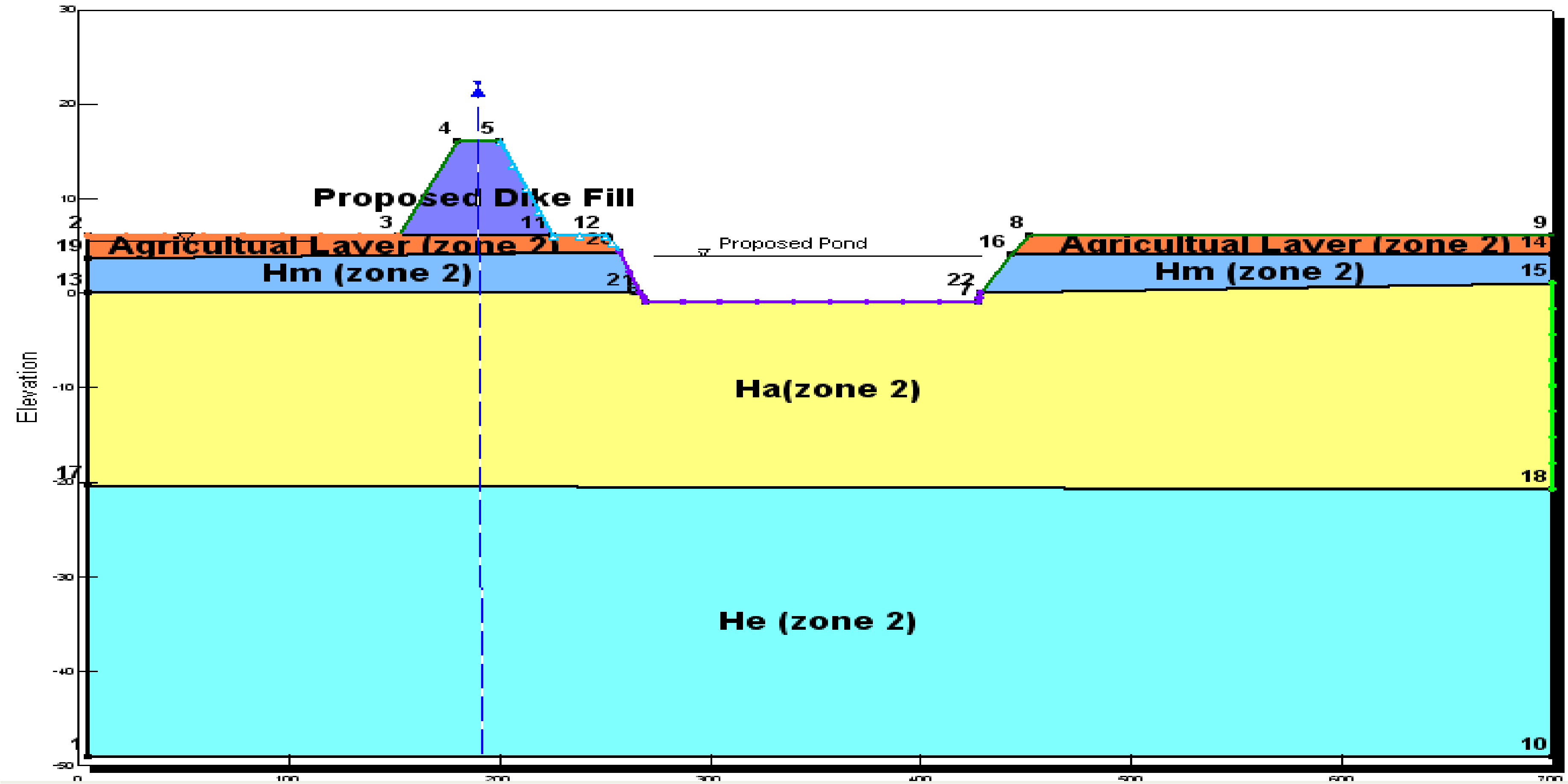
FIG. B-6

FIG. B-6

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB1,6-B11 <FIGB6.SEEP-GEO-EXIST>



Fir Island Farms Restoration

Skagit County, WA

SEEP/W
MODELED SOIL PROFILE
PROPOSED DIKE NORTH ZONE

November 2014 | 21-1-12318-216

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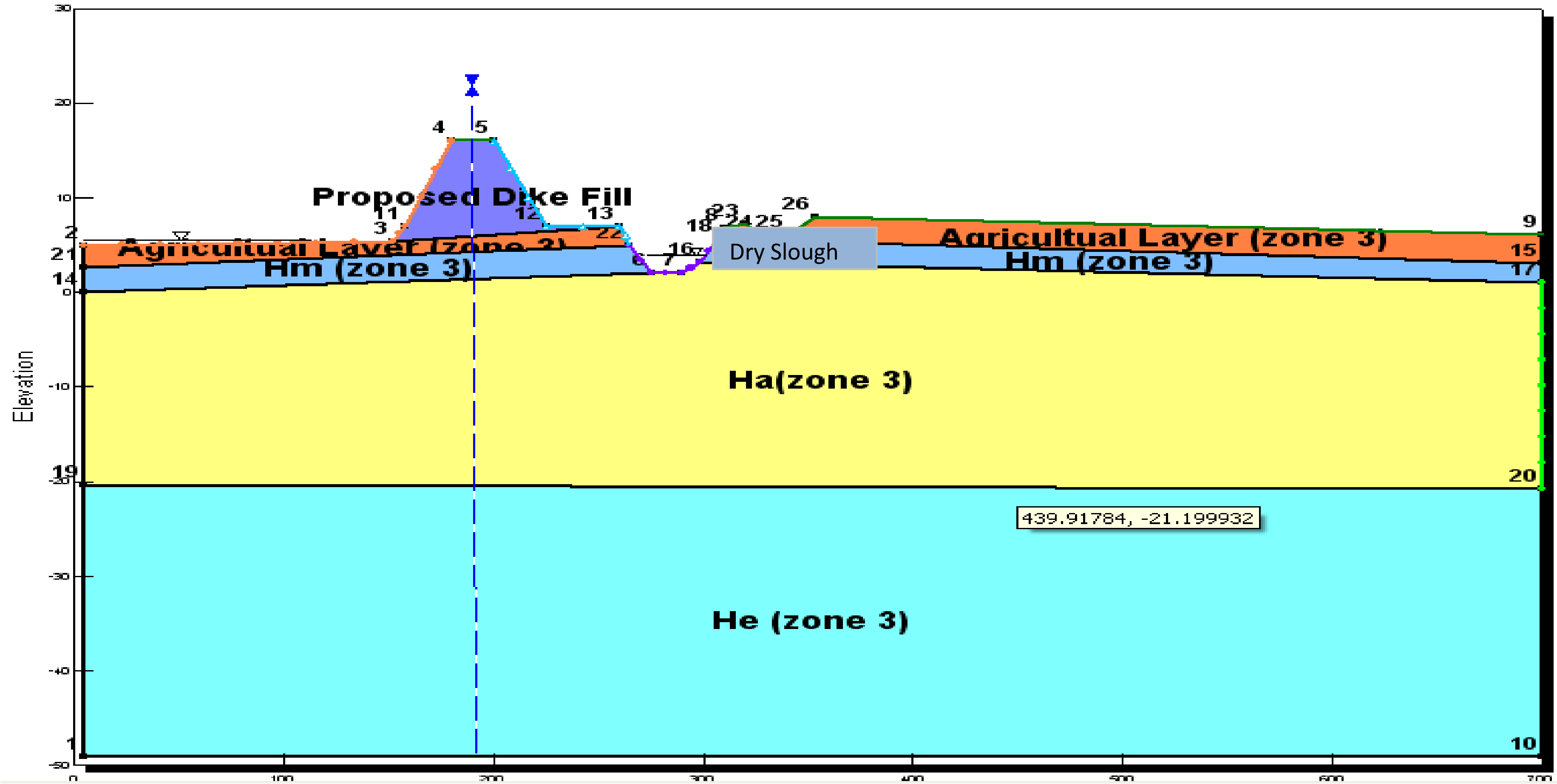
FIG. B-7

FIG. B-7

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB1,6-B11 <FIGB7.SEEP-GEO-NORTH>



Fir Island Farms Restoration

Skagit County, WA

SEEP/W
MODELED SOIL PROFILE
PROPOSED DIKE EAST ZONE

November 2014 | 21-1-12318-216

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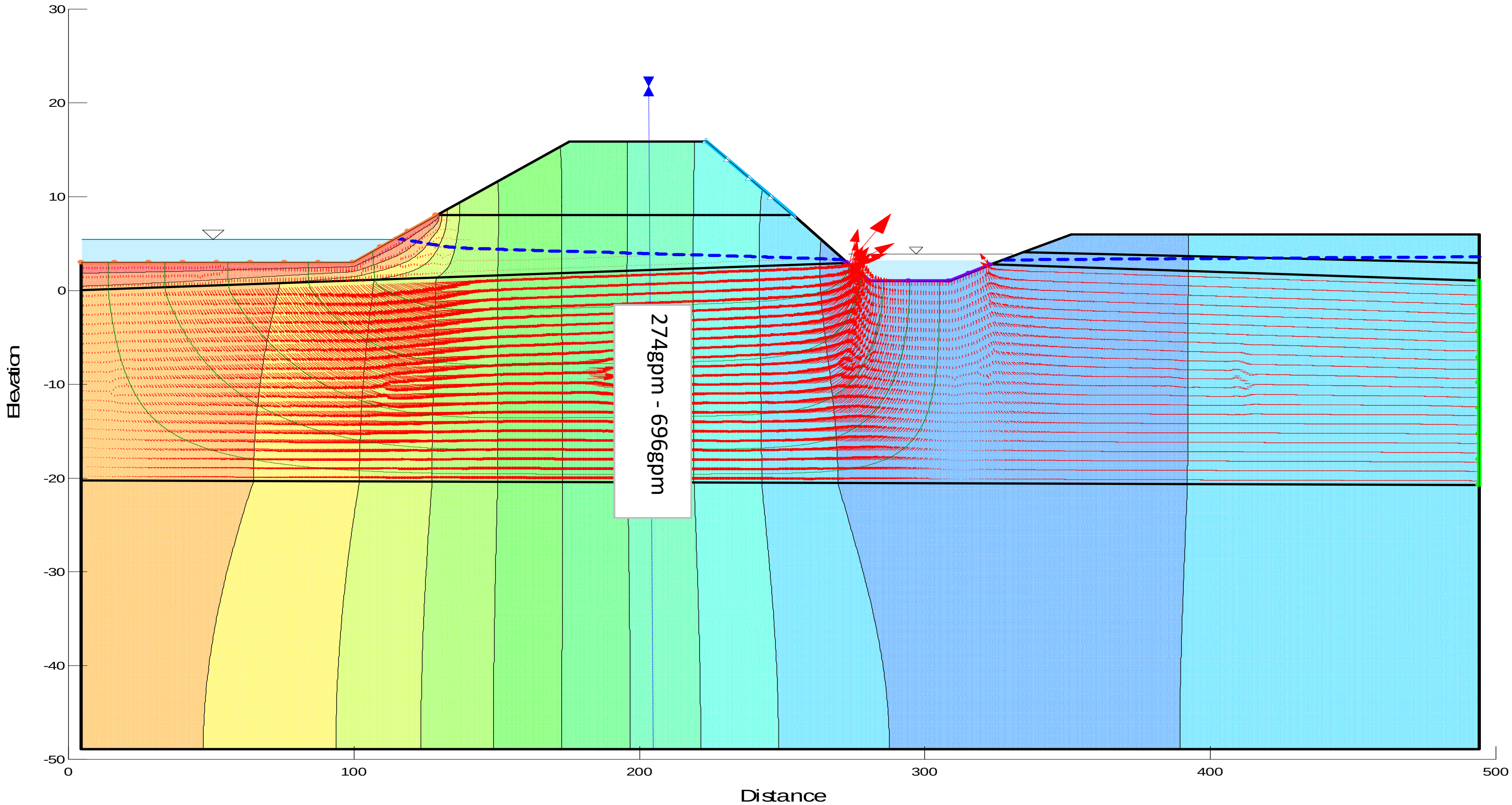
FIG. B-8

FIG. B-8

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB1,6-B11 <FIGB8.SEEP-GEO-EAST>



Notes:

Hydraulic Velocity Vectors Magnification = 5

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 3,300 foot long dike.

Fir Island Farms Restoration

Skagit County, WA

SEEP/W
MODELED SEEPAGE FLUX
EXISTING DIKE

November 2014

21-1-12318-216

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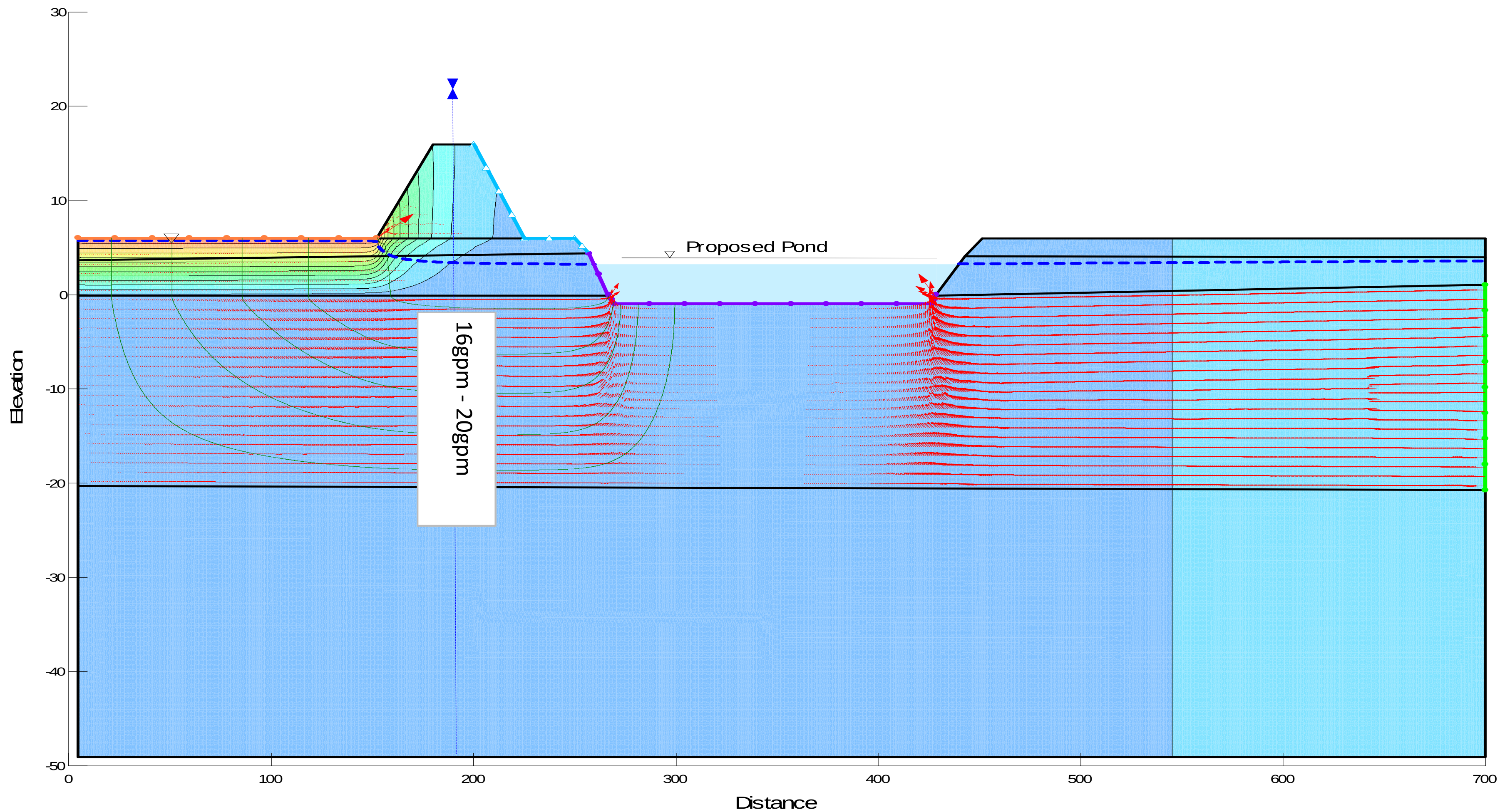
FIG. B-9

FIG. B-9



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,400 foot long dike.

Fir Island Farms Restoration

Skagit County, WA

MODELED SEEPAGE FLUX
PROPOSED DIKE - NORTH ZONE

November 2014 | 21-1-12318-216

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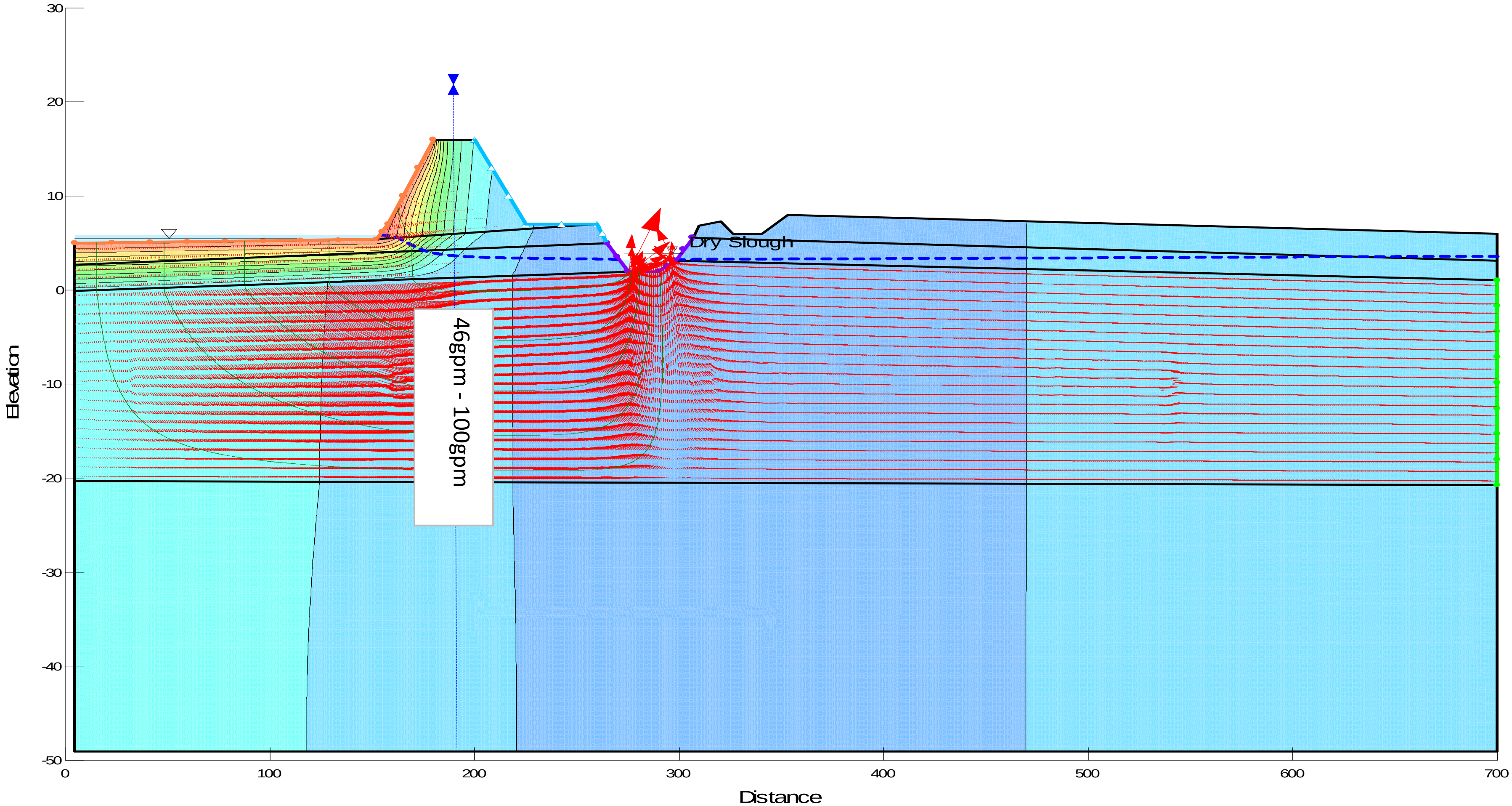
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. B-10

FIG. B-10

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB1,6-B11 <FIGB10.SEEP-RESULT-NORTH>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,900 foot long dike.

Fir Island Farms Restoration

Skagit County, WA

MODELED WATER FLUX
PROPOSED DIKE
EAST ZONE

November 2014 | 21-1-12318-216

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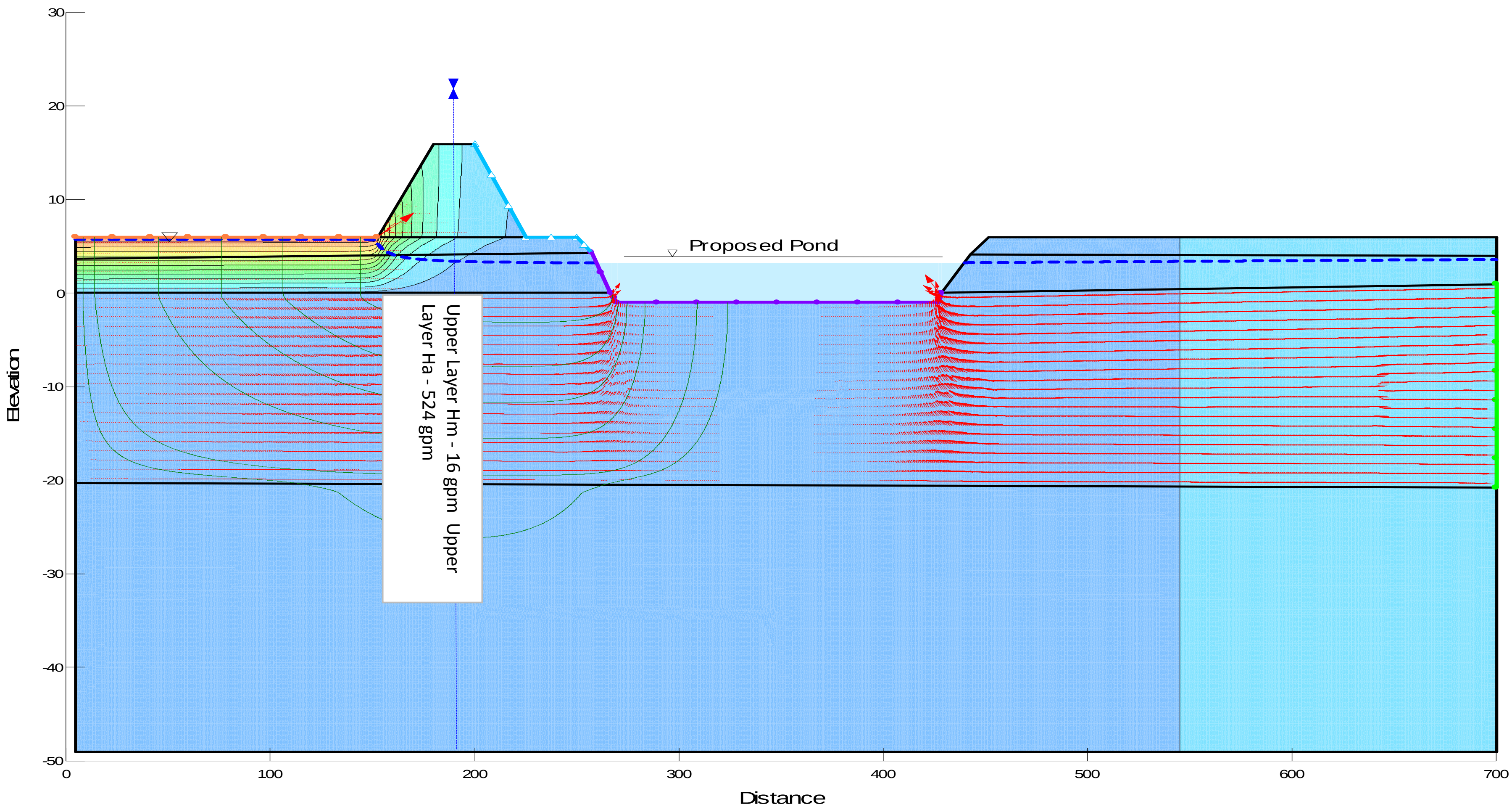
FIG. B-11

FIG. B-11

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB1,6-B11 <FIGB11.SEEP-RESULT-EAST>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,400 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED SEEPAGE FLUX
PROPOSED DIKE - NORTH ZONE
0FT CUTOFF WALL

November 2014 | 21-1-12318-216

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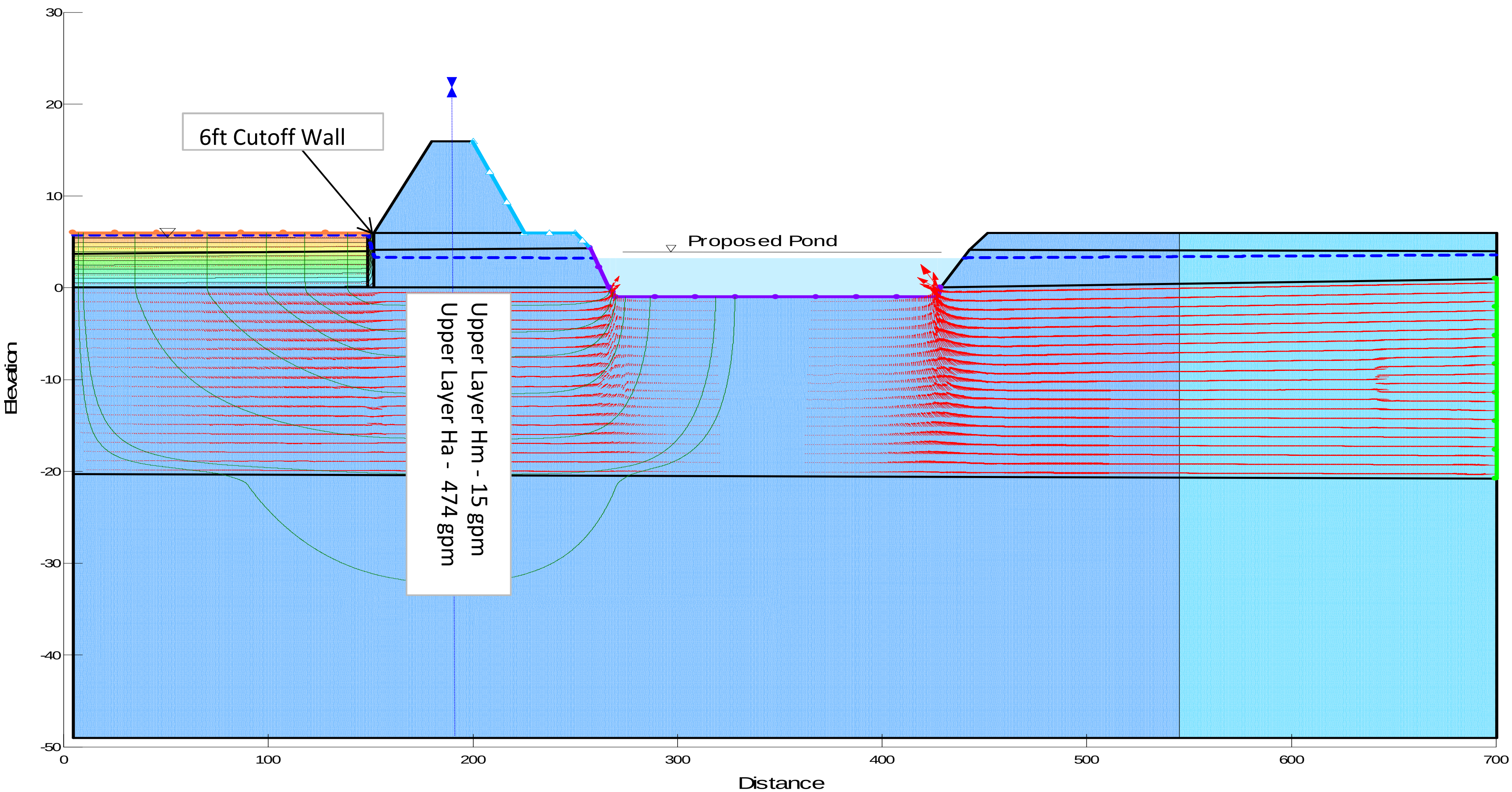
FIG. B-12

FIG. B-12

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB12.SEEPN-OFT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,400 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED SEEPAGE FLUX
PROPOSED DIKE - NORTH ZONE
6FT CUTOFF WALL

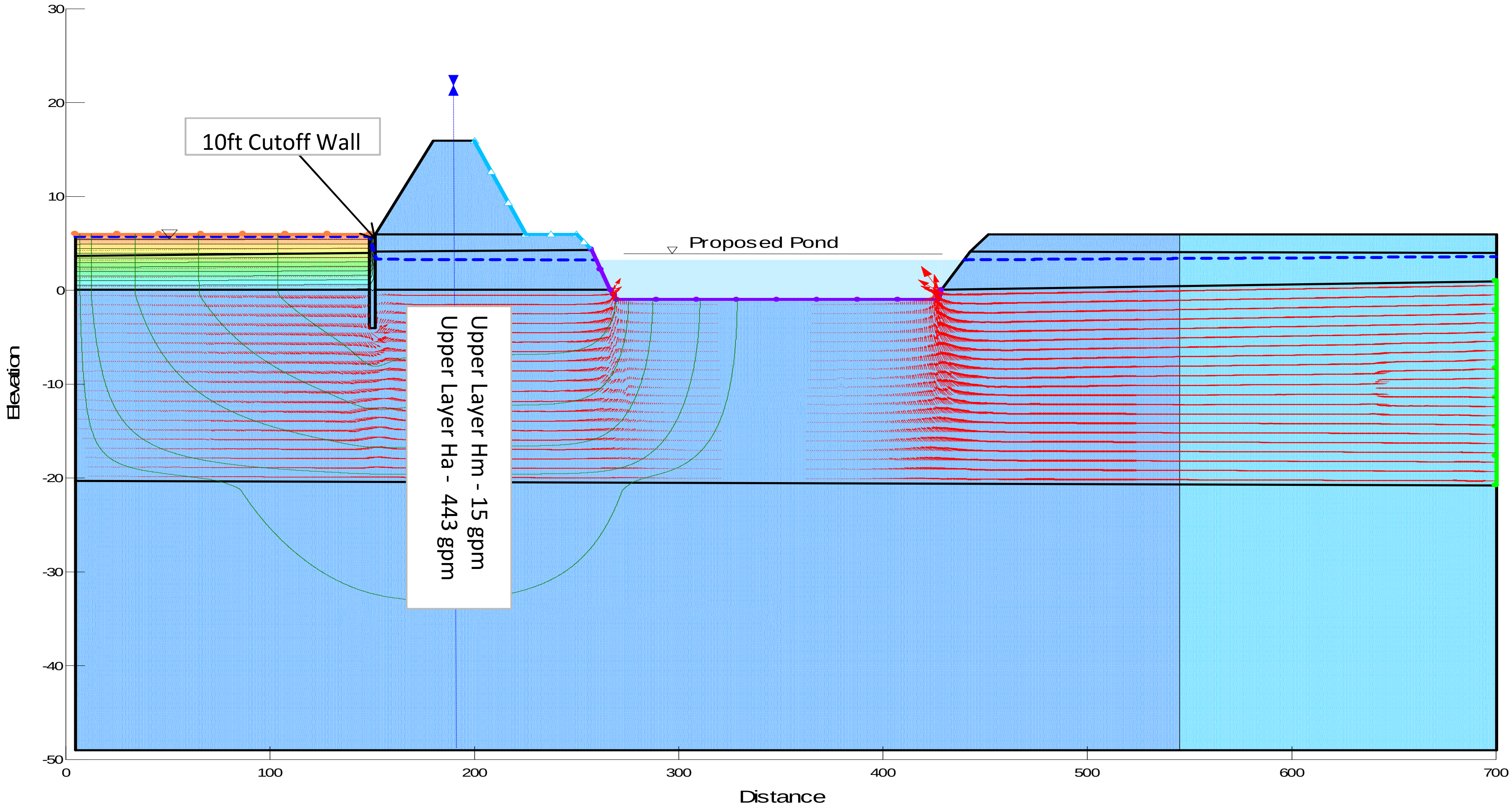
November 2014 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. B-13

FIG. B-13

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB13.SEEPN-6FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,400 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED SEEPAGE FLUX
PROPOSED DIKE - NORTH ZONE
10FT CUTOFF WALL

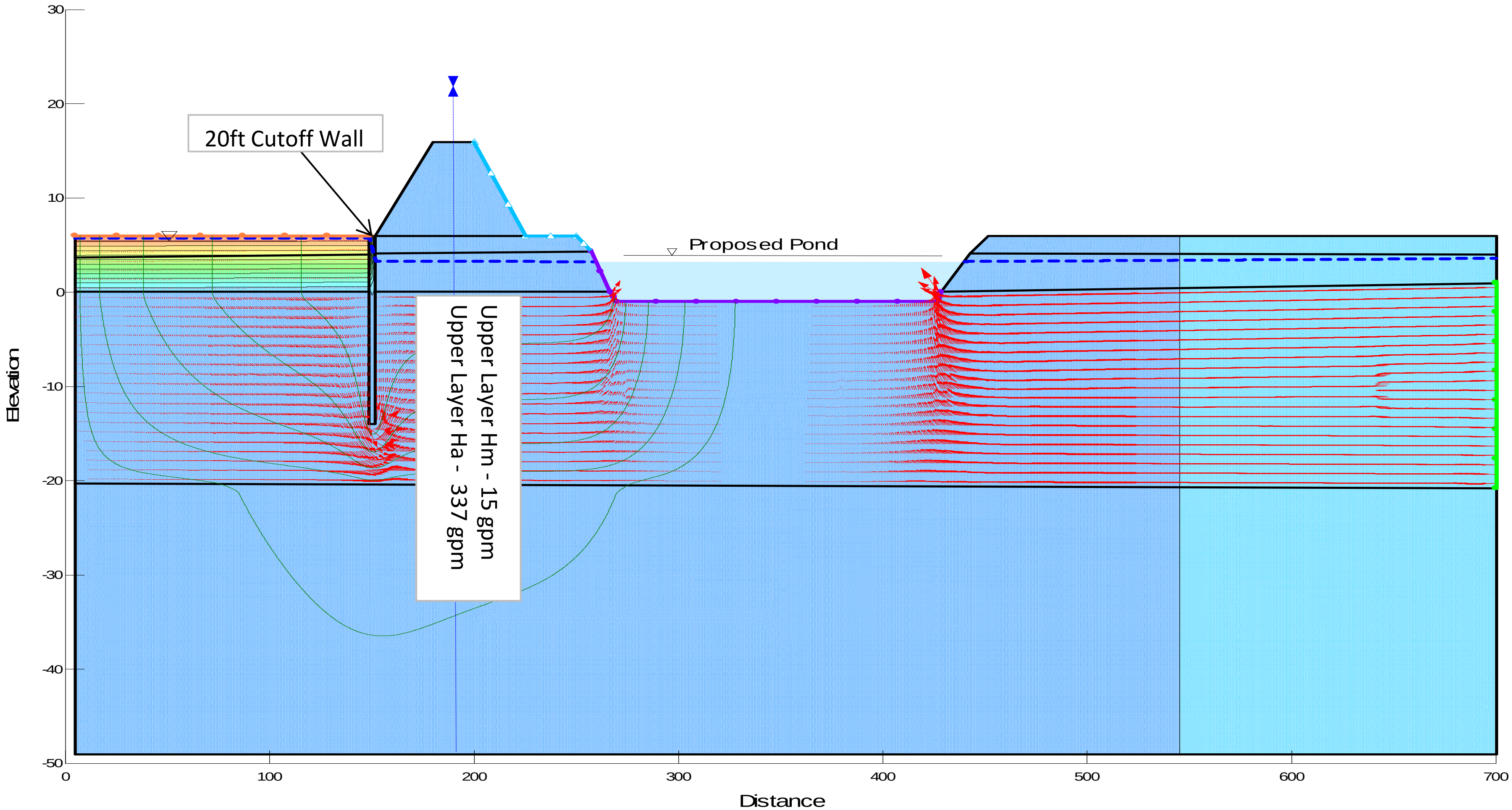
November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. B-14

FIG. B-14

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB14.SEEPN-10FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,400 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED SEEPAGE FLUX
PROPOSED DIKE - NORTH ZONE
20FT CUTOFF WALL

November 2014 | 21-1-12318-216

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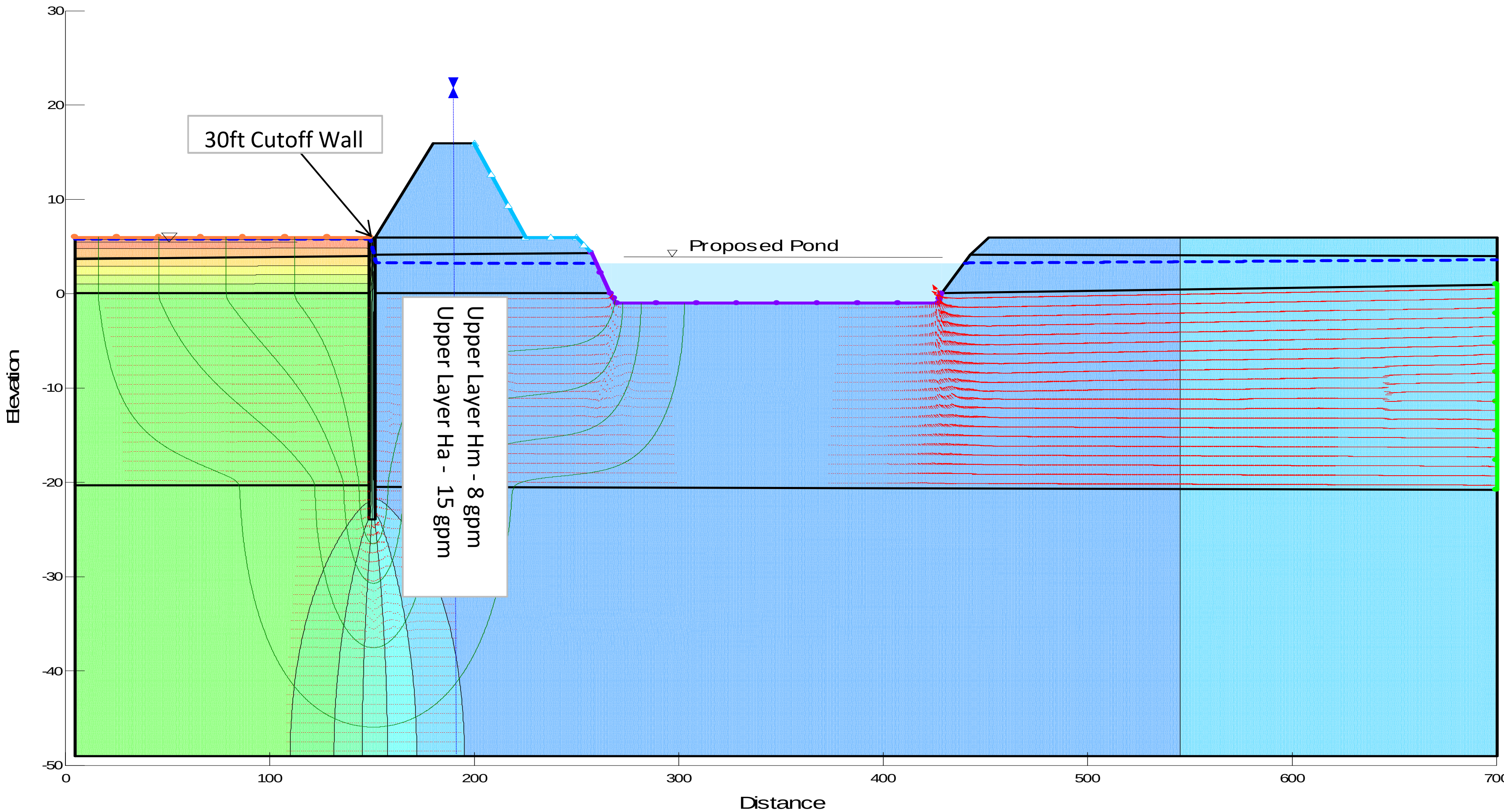
FIG. B-15

FIG. B-15

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB15.SEEPN-20FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,400 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED SEEPAGE FLUX
PROPOSED DIKE - NORTH ZONE
30FT CUTOFF WALL

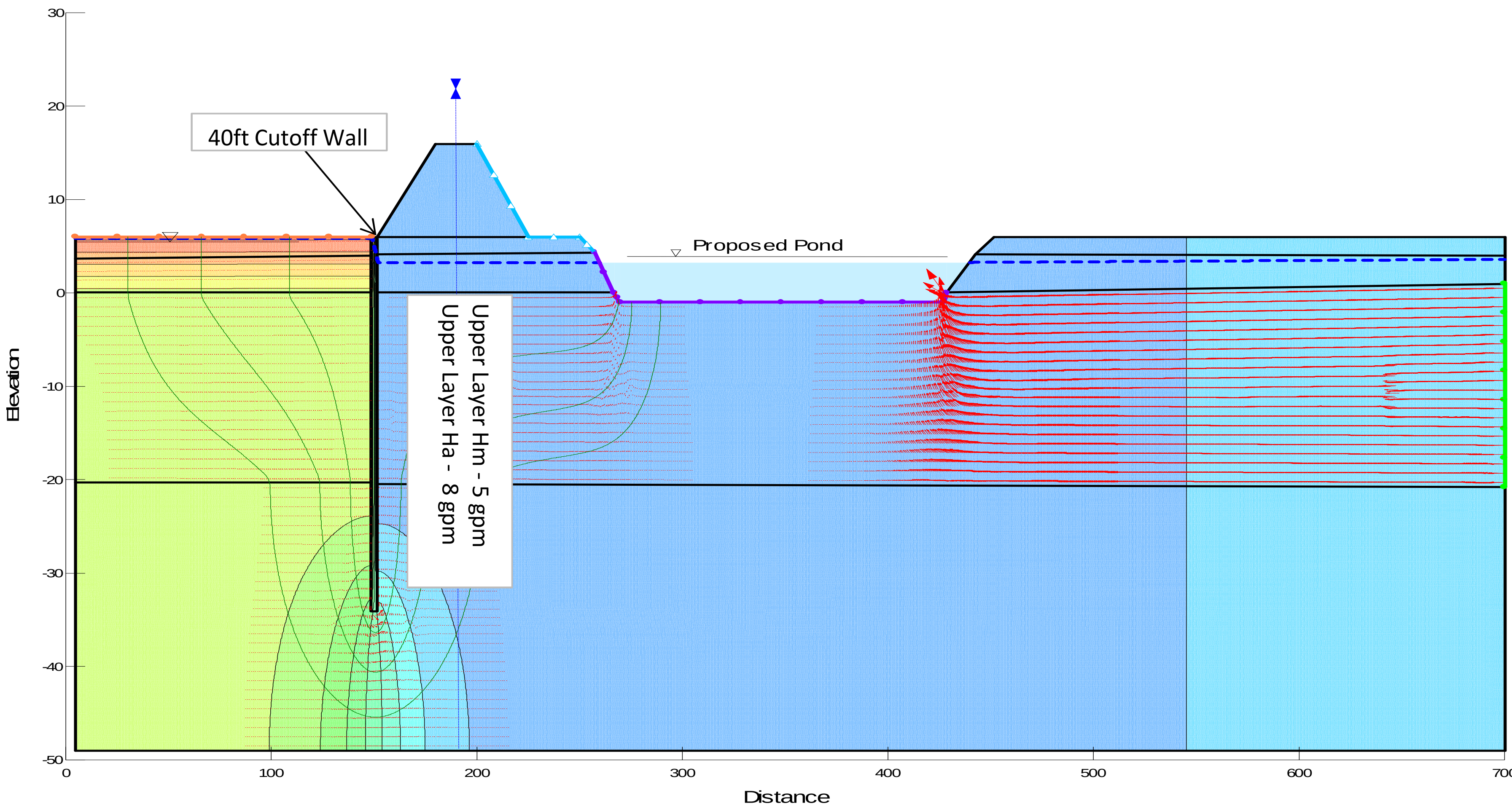
November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. B-16

FIG. B-16

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB16.SEEPN-30FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,400 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED SEEPAGE FLUX
PROPOSED DIKE - NORTH ZONE
40FT CUTOFF WALL

November 2014 | 21-1-12318-216

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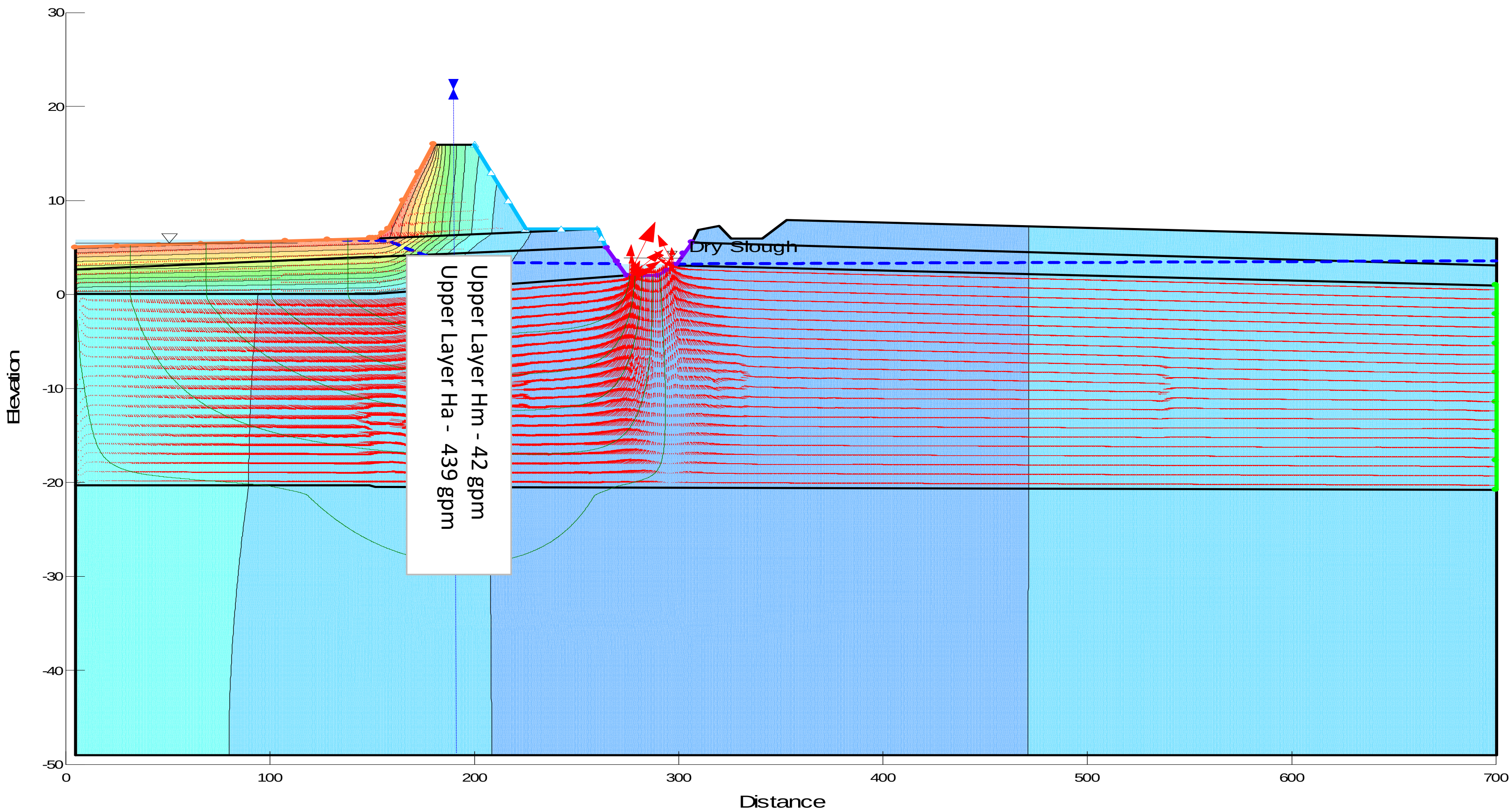
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. B-17

FIG. B-17

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB17.SEEPN-40FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,900 foot long levee.

FIG. B-18

Fir Island Farms Restoration

Skagit County, WA

MODELED WATER FLUX
PROPOSED DIKE - EAST ZONE
0FT CUTOFF WALL

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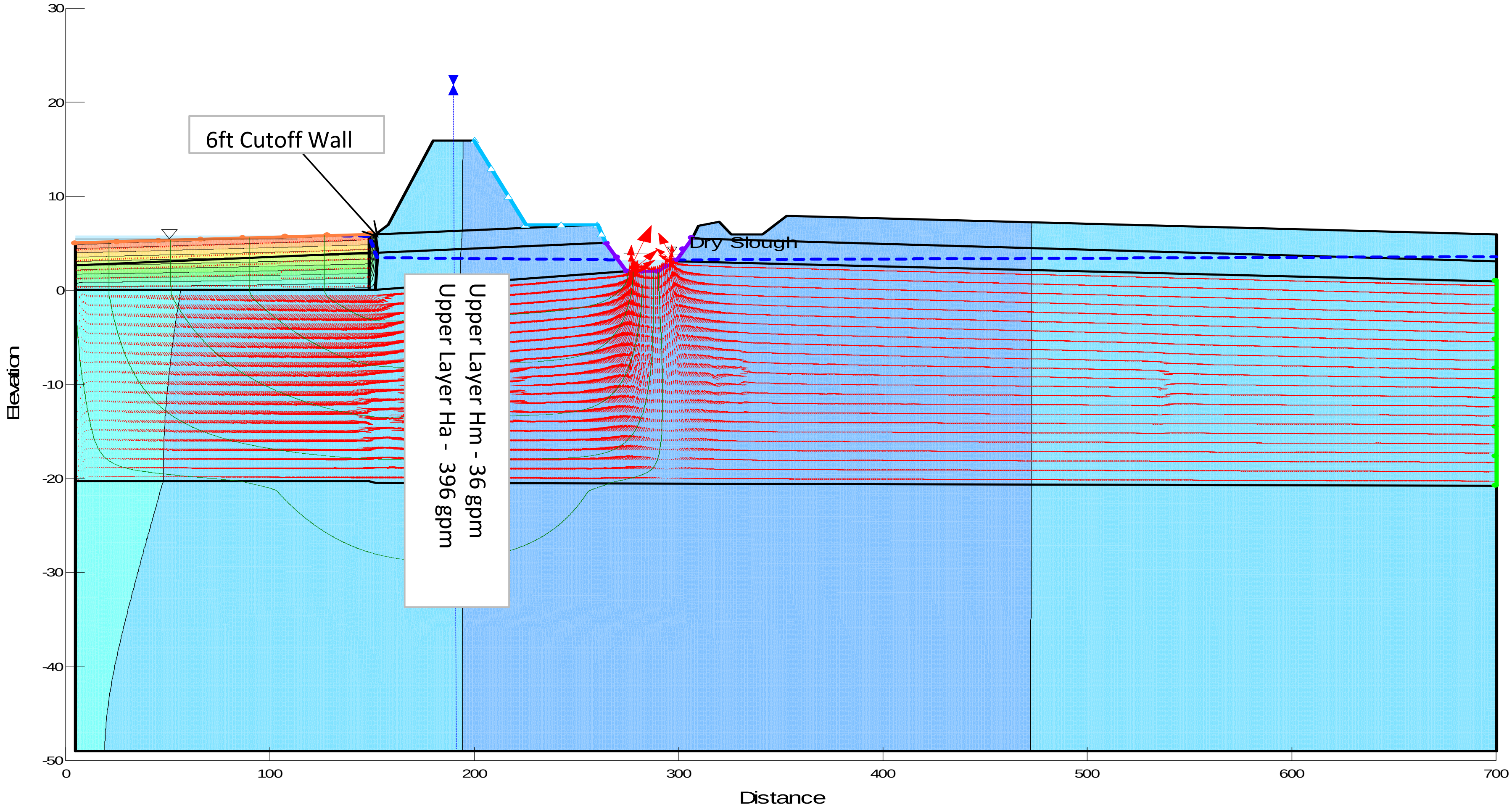
FIG. B-18

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB18.SEEPE-0FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,900 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED WATER FLUX
PROPOSED DIKE - EAST ZONE
6FT CUTOFF WALL

November 2014 | 21-1-12318-216

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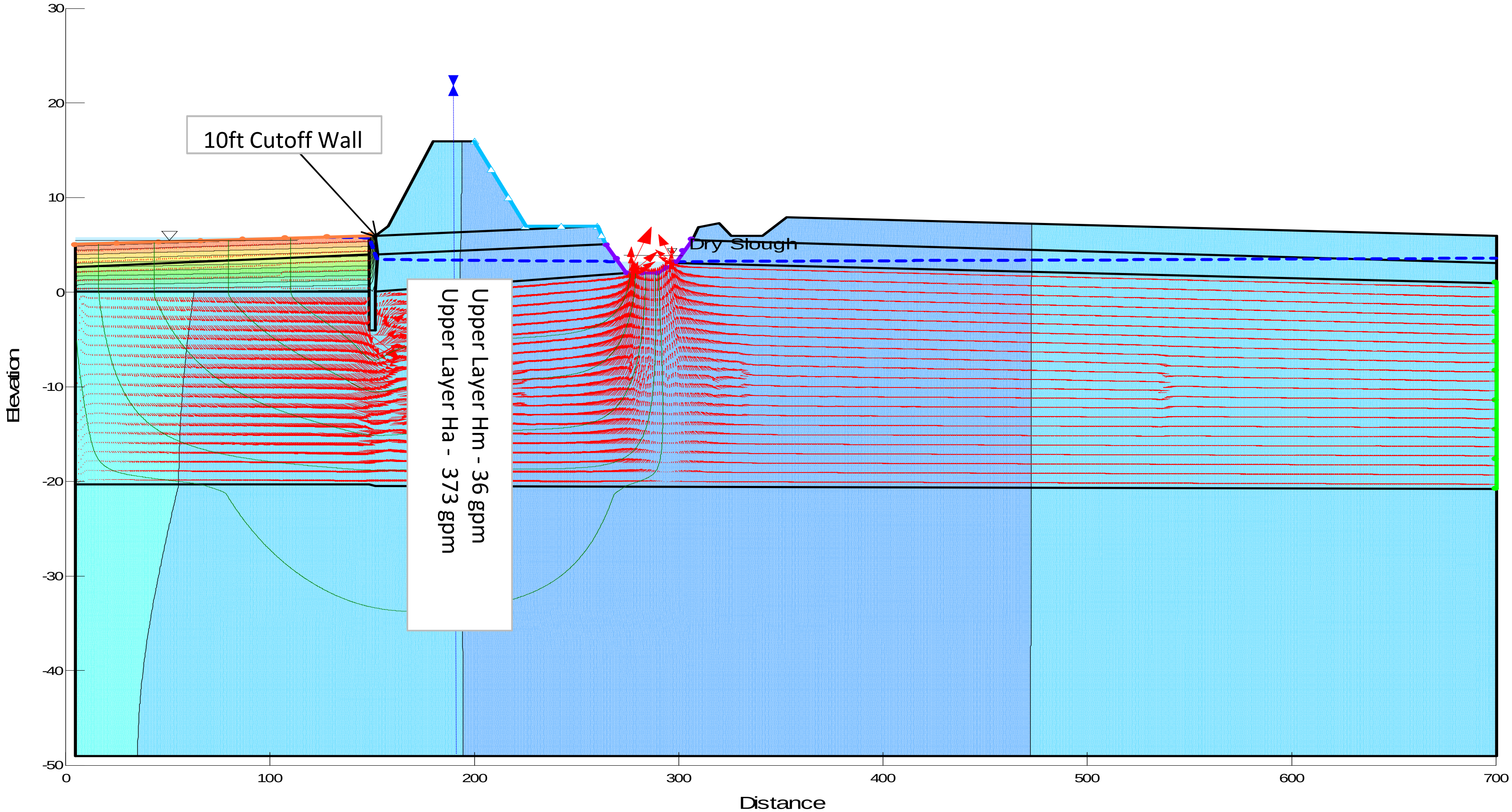
FIG. B-19

FIG. B-19

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB19.SEEPE-6FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,900 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED WATER FLUX
PROPOSED DIKE - EAST ZONE
10FT CUTOFF WALL

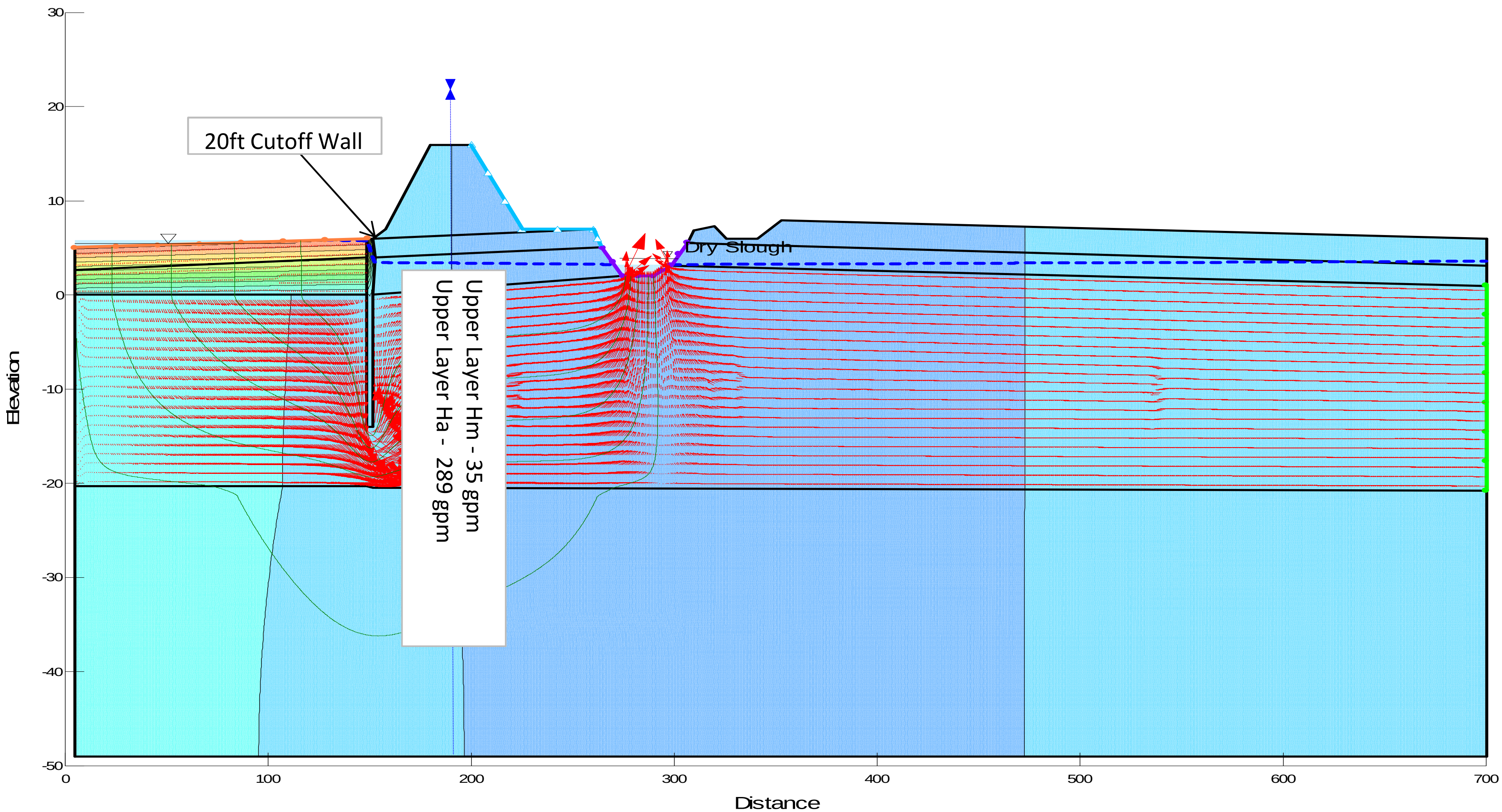
November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. B-20

FIG. B-20

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB20.SEEPE-10FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,900 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED WATER FLUX
PROPOSED DIKE - EAST ZONE
20FT CUTOFF WALL

November 2014 | 21-1-12318-216

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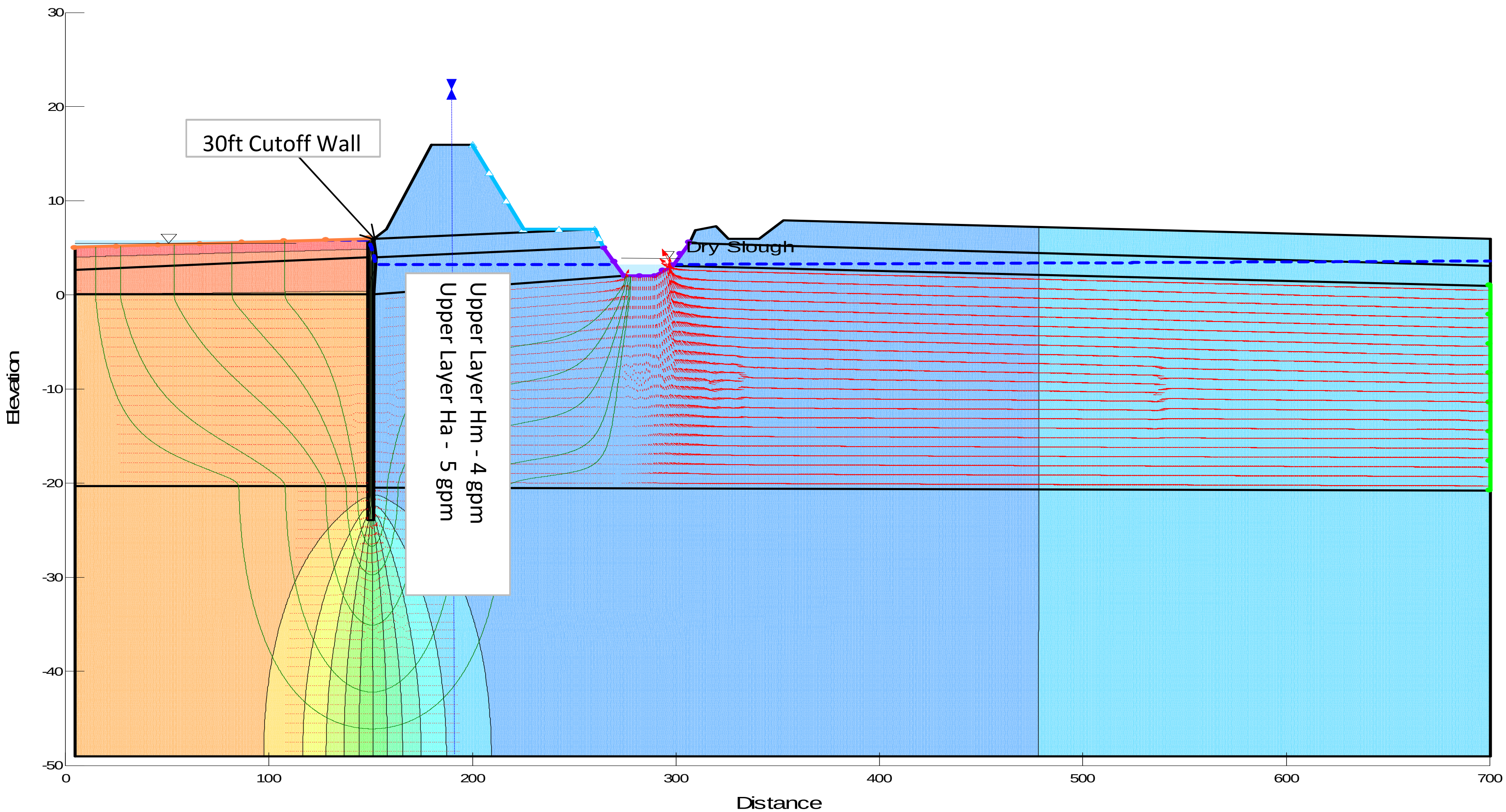
FIG. B-21

FIG. B-21



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,900 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED WATER FLUX
PROPOSED DIKE - EAST ZONE
30FT CUTOFF WALL

November 2014 | 21-1-12318-216

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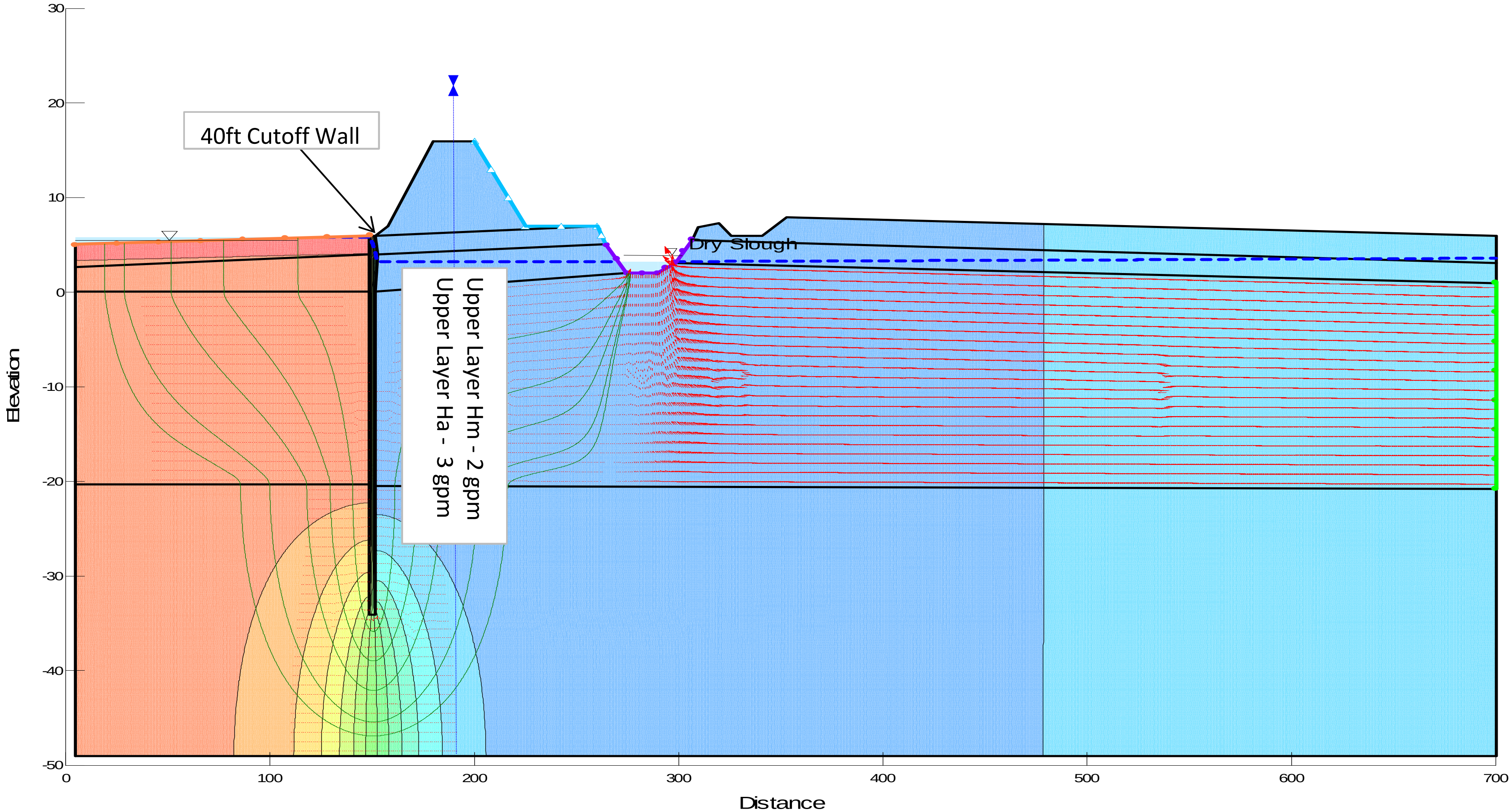
FIG. B-22

FIG. B-22

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB22.SEEPE-30FT>



Notes:

Hydraulic Velocity Vectors Magnification = 20

Hydraulic Velocity Vector (ft/d)

Flow Paths

Seepage rate for 2,900 foot long levee.

Fir Island Farms Restoration

Skagit County, WA

MODELED WATER FLUX
PROPOSED DIKE - EAST ZONE
40FT CUTOFF WALL

November 2014 | 21-1-12318-216

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FIG. B-23

FIG. B-23

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_B\21-1-12318-216-R1-FB12-23 <FIGB23.SEEPE-40FT>

APPENDIX C

SURFACE WATER MODELING

APPENDIX C

SURFACE WATER MODELING

TABLE OF CONTENTS

TABLES

TABLES (cont.)

FIGURES

APPENDIX C

SURFACE WATER MODELING

Surface water modeling for the project involves hydrologic runoff modeling combined with hydraulic open-channel flow modeling. These models are used to calculate interior drainage and pond water surface elevations that occur upstream from the system drainage tidegates. We performed existing “Without Project” and proposed “Project” conditions modeling to compare average pond elevations and salinity conditions during key farm operation, planting and growing seasons. The modeling analyses include a 50-year dike and drainage lifecycle period of 2013 through 2063. A variety of factors were analyzed as part of the sensitivity analysis. These factors include Sea Level Rise (SLR), marsh erosion, sedimentation and vegetation (ESV) effects on drainage tailwater conditions, and possible changes to interior drainage pond vegetation and roughness conditions that may affect storage pond capacity (SPC) over time with varying degrees of drainage maintenance.

C.1 HYDROLOGIC AND HYDRAULIC MODEL

A combined hydrologic and hydraulic model was developed to evaluate the project effects on the interior drainage system water surface elevations. The components of this model are described in the following text, and schematically shown in Figure C-1.

C.2 HYDROLOGIC RUNOFF MODELING

Hydrologic runoff modeling of the drainage basins was performed using the Western Washington Hydrology Model 2012 (WWHM2012) (Figure 2 – main report). WWHM is a continuous-simulation hydrology model developed for Western Washington by the Washington Department of Ecology. The model utilizes 60 years of recorded rainfall data and is calibrated for typical watersheds in the region. The study uses the first 50 years of modeling record to evaluate a 50 year design life of the project. The WWHM model was used to estimate surface water inflows to the No Name Slough and Dry Slough systems. Seepage inflows, discussed in Appendix B, were then added as inflow to the surface water runoff flows to the interior drainage system. The seepage and groundwater inflow of 1 cubic foot per second (cfs) (449 gallons per minute [gpm]) was used. This seepage inflow value is based on hydrologic data collection and measurements of existing conditions base flows during daily tidal cycles.

Brown Slough was not included in the study, as it was concluded during the feasibility study that the primary effects that could occur in Brown Slough were associated with sedimentation and erosion resulting from coastal hydrodynamic conditions of the project. These hydrodynamic conditions and effects were evaluated in the Shannon & Wilson, Inc. (S&W) (2014) and Battelle (2013) Coastal Hydrodynamic Modeling and Coastal Engineering Recommendations Reports. The effects in Brown Slough were mitigated with the inclusion of the spur dike into the project plan.

C.2.1 Drainage Basin Delineations

Drainage basins were delineated for No Name Slough, Claude O. Davis Slough, and Dry Slough (East and West) using Light Detection and Ranging (LIDAR) topography data (Figure 2 – main report). The drainage basins were imported to Watershed Modeling Software 9.1 (WMS) (Aquaveo, LLC, 2013) and overlaid onto soils and land use geographic information system data. The land use data were obtained from Lakes Environmental Software (1983) and the soil data were obtained from the Natural Resources Conservation Service (NRCS) (2012), which generally matches the soil types encountered and conditions observed during S&W field data studies. WMS was used to calculate areas of combined land uses and soil types within each drainage basin. The resulting output from WMS was used to develop a WWHM input file. Basin parameters and WWHM inputs are summarized in Table C-1.

C.2.2 Western Washington Hydrology Model (WWHM) Modeling Results

The WWHM model provides continuous hydrologic runoff flow rate estimates, which were used as input to the hydraulic model for a 50-year time period. Table C-2 is a flood frequency annual exceedance table for the project's contributing and adjacent drainage basins.

C.3 INTERIOR DRAINAGE HYDRAULIC MODELING

An unsteady state HEC-RAS (U.S. Army Corps of Engineers [USACE], 2010) model was created for the No Name/Claude O. Davis Slough and Dry Slough interior drainage systems. HEC-RAS is a one-dimensional hydraulic analysis program designed to model flow through channels. The hydraulic model was used to evaluate the effects of the setback dike on drainage and storage conditions behind the dike. The original model setup and calibration was developed as part of the S&W Fir Island Farm Feasibility Study (S&W, 2011).

For this phase of study, "Without Project" and "Project" conditions were modeled over a 50-year time period to evaluate current and long-term effects on the interior drainage system and adjacent farm properties. A sensitivity analysis was performed by varying modeling parameters and boundary conditions to evaluate the effects of Sea Level Rise (SLR), vegetation and sedimentation in the restored marsh, and vegetation and maintenance conditions on the interior drainage system. The sensitivity analyses includes both "Without Project" (i.e., a hypothetical future scenario where the project is not built) and "Project" conditions as described below.

C.3.1 "Without Project" Conditions Model

The "Without Project" conditions HEC-RAS model geometry was developed using several available data sources, with the following corrections and adjustments:

- Floodplain geometry used data from a triangulated irregular network developed from LIDAR data collected in 2003 and made available by the Skagit River System Cooperative. S&W transformed the original data from North American Datum of 1927, National Geodetic Vertical Datum of 1929 to North American Datum of 1983, and North American Vertical Datum of 1988 (NAVD88) (State Plane Washington North).
- Dry Slough East bathymetric and culvert data use Skagit Conservation District 2009 survey data adjusted to a NAVD88 vertical datum.
- Dry Slough West bathymetric and culvert data use general thalweg adjustments based on comparison of LIDAR and S&W, 2010 surveys of vegetated cross sections in the project area and surveys performed within the project study area. Upstream from Fir Island Road, channel thalweg adjustments and culvert sizes and locations are approximate as no survey data were available in these areas.
- No Name and Claude O. Davis Slough bathymetric and culvert data use general thalweg adjustments based on comparison of LIDAR and S&W, 2010 surveys of vegetated cross sections in the project area and surveys performed within the project study area. Upstream from Fir Island Road, channel thalweg adjustments and culvert sizes and locations are approximate only, as no survey data were available in these areas.

The model was set up to run for the 61-year time span of the WWHM model, which is September 1948 through September 2009. The modeling assumption is that land use and rainfall runoff characteristics for the 1948 through 2009 period will be similar going forward 50 years into the future, using the first 50 years of data from the WWHM model. Changes in Skagit River flows and flood levels for future conditions were not considered in this analysis. Daily inflow rates from the WWHM hydrology model were used as upstream inflow boundary conditions. Because the WWHM data only represent surface water flow, a seepage base flow was added to the WWHM inputs to represent groundwater influences. The base flow rates of 1 cfs (450 gpm) were estimated in Appendix B was used in the model.

Boundary conditions on the downstream end of the model were created from tidal data at the site from October through December 2010 using a one-hour time step. The tidal data were then extrapolated out for the 50-year time period, to match the WWHM modeling period. This assumes typical tidal cycling and no storm surge conditions in the model. The model downstream boundary conditions were then adjusted for Sea Level Rise (SLR) only over the 50 year modeling period for the “Without Project” condition. More information regarding boundary condition adjustments is provided in the sensitivity analysis section of the report.

C.3.2 “Project” Conditions Model

The proposed conditions or “Project” conditions model was created by modifying the “Without Project” conditions model to reflect the revised geometry and seepage conditions of the existing dike removal and new setback dike with an interior drainage storage pond. The geometry was modified by moving the tidegates from the current No Name Slough and Davis Slough confluence at the existing dike, upstream to the proposed No Name Slough tidegates and new crossing location of the setback dike. An interior storage pond was added north of the setback dike. The size of this pond was selected in the 2011 feasibility study with the objective of reducing flood impacts to zero rise for the 25-year flood event. Claude O. Davis Slough was removed from the “Project” conditions model as the setback dike lies to the north of this channel. The pond volumes have since been adjusted to the 150 foot wide by 2,200 foot long feature discussed in the response study alternatives.

Boundary condition adjustments for the “Project” condition model include the following items in the sensitivity analysis:

- Increase in low tide tailwater elevation of 0.75 foot, in accordance with the hydrodynamic effects identified in the Coastal Engineering Recommendations Report (S&W, 2014).
- Increase in seepage along the Dry Slough dike segment (east zone, Stations 37+00 to 67+00) by 100 gpm. Maintain seepage rates No Name Slough from the site observed hydrologic monitoring of base flow conditions along the northern zone (Stations 22+00 to 37+00) dike segment along the interior storage pond. These conservative assumptions are higher than the predicted SEEP/W seepage modeling results. The Dry Slough (east zone) addition was made using the maximum predicted

seepage rate from the modeling, and the northern zone uses a seepage based on hydrologic observations that is higher than the seepage modeling predictions.

- Increase tailwater tidal conditions for a range of predicted Sea Level Rise (SLR) conditions based on the Coastal Engineering Recommendations Report (see Figure C-2).
- Modify tailwater tidal conditions for a range of predicted marsh erosion and sedimentation characteristics based on the Coastal Engineering Recommendations Report (see Table C-3).
- Reduce interior storage pond volumes for potential cattail (emergent) wetland vegetation growth and/or reduction of maintenance on the system over time.

More information is provided below in the following sensitivity analysis section of the report.

C.3.3 Project Effects Evaluation Metrics

The key concern of the adjacent property owners and farmers is that the project will raise water surface elevations in the drainage ditches, thereby impacting groundwater elevations and farming on adjacent property. This study evaluated interior storage pond elevations during early spring (April) planting periods when groundwater tables are highest and most likely to impact planting operations and root zones.

Critical root zone depths depend upon crop types, soil type, drainage, and groundwater conditions. Crops grown on the adjacent Hayton Farm include strawberries, raspberries, blackberries, blueberries, and other berry crops such as marionberries and loganberries. Crops grown on the Washington Department of Fish and Wildlife Snow Goose Reserve property are subject to snow goose foraging winter crop rotations. Spring and summer crops typically include spring-planted vegetable seed crops such as spinach, red beets, and radish, or annual summer crops such as potatoes and broccoli. Root zone depths for the crops listed above range from 6 to 18 inches (NRCS, 1997). The study selected a critical root zone depth of 24 inches (2 feet) to conservatively estimate potential groundwater effects on adjacent farm properties and crops.

The second aspect of the root zone criteria is the duration of root zone inundation. The study assumes that crops can withstand minor increases in root zone inundation. The inundation criteria selected increase the period of inundation of the critical root zone elevation by more than 10 percent of the time during April, comparing “Without Project” to “Project” conditions. If the inundation period increases by more than 10 percent, it would be flagged as a “Project” effect. Using hydraulic conductivity properties of the upper soil layers, we can estimate the groundwater lateral migration rate. Using hydraulic conductivity value of 1.5 feet per day, for the upper soil unit, translates into a maximum groundwater migration distance of 45 feet for a full 30 day inundation period increase. This would represent an extreme case where “Without Project” conditions for month of April have no days above the critical root zone elevations and the “Project” has a full thirty days above the critical root zone. The more likely scenario is an increase of 1 to 2 days above the critical root zone elevation would result in a 3.0 feet of groundwater migration distance from the pond’s edge.

Figure C-3 shows the upstream and adjacent farm areas that may be affected by changes in the interior drainage average April (or early spring) water surface elevations. The “Project” root zone criteria were flagged when the pond water elevations exceed the critical root zone elevation criteria, and when the inundation period increases more than 10 percent of the time as compared to the “Without Project” condition.

Increases in pond and ditch salinity are the second project metric being evaluated for potential farm and property effects. If salinity increases in the pond and ditches, and water surface elevations are above the critical root zone elevation, then there may be project effects. The study considers salinity a secondary (or dependent) criterion because salinity levels in the existing ditches are fairly high and, for impacts to occur, the groundwater elevations need to be higher than the critical root zone elevation criteria. Typically, farm drainage operations focus on keeping the groundwater table low rather than preventing salt water intrusion.

C.3.4 Hydraulic Modeling Results – Storage Pond Water Surface Elevations

The hydraulic modeling results for Sea Level Rise (SLR) scenarios and effects in No Name Slough are summarized in Tables C-4 and C-5. The project effects are limited primarily to No Name Slough, as this is the location subject to the tidal hydrodynamic effect and the sensitivity parameters discussed in Appendix D. Seepage effects are not great enough alone to result in effects on adjacent and upstream farm areas in No Name Slough. Dry Slough will not likely have the same tidal hydrodynamic or sensitivity factor effects, as it is mostly isolated. Minor increases in seepage, were modeled, and can be accommodated by an additional 48-inch tidegate to the existing drainage system.

These results indicate that the proposed project will likely increase storage pond water surface elevations in No Name Slough and have an effect on farm properties in the No Name Slough Basin, for “Project” conditions. The results show that farm properties will be affected by Sea Level Rise (SLR) for both “Without Project” and “Project” conditions. However, the

"Project" Sea Level Rise (SLR) and hydrodynamic conditions could have effects on an additional 106 acres in 2013 and 319 acres in 2063. This is 11 to 32 percent of the drainage basin farm properties. These effects do not consider the uncertainty associated with the Sea Level Rise (SLR) estimates or the key sensitivity factors such as marsh erosion and sedimentation, and storage pond capacity conditions discussed further in Appendix D.

C.3.5 Salinity

A mass balance model was used to estimate salinity effects on the interior drainage storage pond. The mixing parameters included seepage inflow rates along the length of the "Without Project" and "Project" dike sections, base flow groundwater inflows to the storage pond, and average Skagit Bay and No Name Slough salinity concentrations recorded during the 2013 data-collection period. The calculation estimates that salinities in the pond will be slightly lower (Table C-6).

Decreases in seepage rates are based on the observations, and sampling and testing of soil properties along the existing dike and the proposed setback dike alignment. This finding indicates that concerns regarding salinity may not be a major factor and that the primary concern should be focused on limiting effects on storage pond water surface elevations only. It should be noted that the proposed project objectives are to generally maintain groundwater levels below the root zone of the field, which incidentally mitigates salinity impacts. Another item to note is that observed salinity levels in the No Name Slough ditch are relatively high for the current "Without Project" condition. Farming persists in the area and is sustained by keeping ditch water surface and groundwater elevations low enough to protect the crop root zones. This topic is related to seepage-related questions made by Consolidated Diking District 22 (CDD22), and requests for additional review of project dike seepage estimates and the need to evaluate seepage cutoff measures.

C.4 RESPONSE STUDY – POND DRAINAGE ALTERNATIVES

A response study was performed based on the findings and recommendations of the initial study. The key topics addressed in the response study included the following items:

- CDD22 requested that the interior drainage storage pond width be no wider that 150 feet, to allow for drag line dredging from either side of the pond. A modified storage pond was evaluated to confirm that the narrower pond would provide adequate drainage capacity.

- The initial findings of the interior drainage report indicated that adjacent and upstream farm properties and spring planting operations could be impacted in the No Name Slough system due to the 0.75-foot hydrodynamic effect. Two options were evaluated to mitigate these effects:
  - Gravity drainage – CDD22 requested the addition of tidegates from the interior drainage storage pond leading to Dry Slough to drain into the Dry Slough system that will not have the hydrodynamic effect. To date, these systems are isolated in the models and only connected at very high flows for actual conditions.
  - Pump station – Add a pump station in the interior drainage storage pond to lower the pond water surface elevations below the predicted low-tide, hydrodynamic tailwater effect elevations, and match current drainage operations and functions.

The following report sections describe the results of these additional response study analyses.

C.4.1 Pond Geometry Adjustments

The interior drainage storage pond dimensions were changed to a maximum width of 150 feet to allow for sediment dredging using a drag line (75 feet on either side). CDD22 also requested the storage pond be set back from the toe of the proposed setback dike by 20 feet to allow maintenance and repair equipment access.

The “Project” storage pond width was reduced from 200 to 150 feet, and the length expanded westward from 1,600 to 2,200 feet. The longer and narrower pond configuration allows for the same amount of storage volume. This was confirmed by rerunning the 0.0-foot Sea Level Rise (SLR) modeling scenario with the modified storage pond geometry and comparing pond water surface elevation results. The revised pond geometry provides adequate storage compared with the original storage pond configuration.

C.4.2 Dry Slough Third Tidegate

A third 48-inch tidegate was added to the existing tidegates at the connection of Dry Slough and Skagit Bay to allow the passing of additional flows due to seepage and storage pond overflows into Dry Slough. Figure C-4 shows how the third tidegate in Dry Slough provides additional conveyance adequate to manage the additional flows into Dry Slough.

C.4.3 Gravity Drainage from Pond to Dry Slough

Initial modeling efforts represented Dry Slough and No Name Slough as separate drainage features, which is true, except at higher-flow, flood levels where cross drainages connect the two systems. No Name Slough for the "Project" condition will have a 0.75-foot increase in tailwater elevations due to the dike setback hydrodynamic effect. Dry Slough is not likely to experience tailwater increases due to the project. Therefore, tidegates between the systems should allow water to flow from No Name Slough pond to Dry Slough during low tide.

CDD22 requested a study to evaluate the use of gravity drainage tidegates leading from the interior storage pond east into Dry Slough. The response study gravity drainage option analyzes a pair of 48-inch tidegates leading from No Name Slough drainage into Dry Slough. The gates open and discharge into Dry Slough when the Dry Slough water surface elevations are lower than the No Name Slough storage pond water surface elevations. Downstream of this location at the connection of Dry Slough with Skagit Bay, a third 48-inch tidegate was added to the two existing tidegates, to allow the discharge of additional flows to Skagit Bay from the storage pond and additional seepage into Dry Slough.

The results of the Dry Slough gravity drainage (two tidegates) option indicate that gravity drainage can lower the No Name interior drainage pond elevations by approximate 0.1 foot, as shown in Table C-7. This amount is nominal and not enough to compensate for the tidal hydrodynamic tailwater effect on the pond water elevations alone.

C.4.4 Pump Station from Storage Pond

A pump station option was investigated as an alternative to mitigate the 0.75-foot tailwater effects at the storage pond, and to lower pond water surface elevations to match existing "Without Project" conditions. A pump station was added to the HEC-RAS model in the central-east area of the storage pond. Water will be pumped through the dike into the restored marsh area. The pump station option was run in the HEC-RAS model for the "Project" conditions with a pump drawdown occurring from storage pond water surface elevation 3.5 to 3.0 feet. The modeling results indicate that operating two 3,000-gpm pumps for the "Project" conditions. The 3,000-gpm pumps operating range initializing at 3.5 feet and drawing down to 3.0 feet matches existing conditions (Table C-7, Figure C-5). Table C-8 shows how the pump station mitigates the project effects adjacent and upstream farm properties.

The pump size is based on the modeling output that shows pond water elevations need to be lowered 1 foot during a typical tidal cycle. This volume equates to 330,000 cubic feet of water pumped out over a 7-hour period, on average. The combined pump(s) operating flow rate is 13 cfs (5,837 gpm). Two 3,000-gpm pumps can provide this flow rate. We recommend a third pump be installed for swapping out an active pump for maintenance or repair.

The estimated monthly electrical power cost for pump operation is $250 per month on average. The design criteria for dry root zones indicate that critical root zone drawdown is needed in the early spring months of April and May. Pumping operations associated with the project effects are limited to these months. The pumping costs will likely be on the order of $500 per year in 2014 dollars. If pumping occurs year round, and during flood conditions, the costs would be greatly increased to as much as $3,000 per year. Pumping for other flood conditions has been modeled, but is not included in the current design recommendations. If flood pump operations are considered part of the project, the design should also consider whether or not power backup is needed. The operators should be aware that pumping during flood season could be costly. Finally, pumping during winter freshwater flooding in the ditch and farm fields could increase the potential for long term salt water intrusion. Current flooding of the fields provides freshwater “head” that limits salt water intrusion into local groundwater tables. Every 1 foot of freshwater head in the ditches and groundwater limits 40 vertical feet of salt water intrusion. We recommend a winter ditch water surface operating range of 4.5 feet down to 4.0 feet, similar to observed baseline conditions. This will allow freshwater head to limit salt water intrusion.

C.4.5 Combined Gravity and Pump Station Drainage

A combined gravity drainage (additional tidegates into Dry Slough) and pump station option would also match, or have lower water elevations in the pond on average, than existing conditions. The gravity drainage tidegates would work in concert with the pump system (Tables C-7 and C-8, Figure C-5). Gravity drainage tidegates will not on their own meet the drainage mitigation design requirements, whereas the pump station alone can match existing conditions for the proposed “Project.” The benefit tidegates could provide are operational flexibility to CDD22, reduction of pump operations and costs by as much as 20 percent, and as a contingency for pumping during power outages.

C.5 REFERENCES

Aquaveo, LLC, 2013, Watershed modeling system WMS (v. 9.1 beta): Provo, Utah, Aquaveo, LLC.

Battelle, 2013, Hydrodynamic modeling analysis for the Fir Island Farm restoration project in Skagit Bay, Washington: Report prepared by Battelle, Seattle, Washington, PNWD-4398, for Shannon & Wilson, Inc., Seattle, Washington, September

Lakes Environmental Software, 1983, LULC Data (Standard) for Skagit County: Available: http://www.webgis.com/, accessed October 2013.

Natural Resources Conservation Service (NRCS), 1997, Project and farm irrigation water requirements, in National Engineering Handbook, Part 652 Irrigation Guide: Washington, D.C., NRCS, chapter 8, 21 p.

Natural Resources Conservation Service (NRCS), 2012, Soil Survey Geographic (SSURGO) database for Skagit County, Washington: Available: http://soildatamart.nrcs.usda.gov/, accessed October 2013.

Shannon & Wilson, Inc., 2010, Fir Island Farm restoration feasibility study, Fir Island, Washington, technical memorandum 1.1.1 – survey: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., 21-1-12318-111, for Washington Department of Fish and Wildlife, Olympia, Wash., November 19.

Shannon & Wilson, Inc., 2011, Fir Island Snow Goose Reserve, restoration feasibility study, Washington Department of Fish and Wildlife, Fir Island Washington: Report prepared by Shannon & Wilson. Inc, Seattle, Wash., 21-1-12318-003, for Washington Department of Fish and Wildlife, Olympia, Wash., December.

Shannon & Wilson, Inc., 2014, Fir Island Farm final design and permitting, geotechnical and hydrogeologic data report, Skagit County, Washington: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., September.

Shannon & Wilson, Inc., 2014, Draft coastal engineering report WDFW – Fir Island Farm Snow Goose Reserve. Skagit County, Washington: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., January.

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center, 2010, River analysis system, HEC-RAS (v. 4.1): January, available: http://www.hec.usace.army.mil/software/hec-ras/hecras-download.html.

TABLE C-1
DRAINAGE BASIN PARAMETERS

Basin	Soil Type[1]	Land Use Description	WWHM[2] Category	Area (acres)
No Name Slough	B	Cropland and Pasture	A/B, Pasture, Flat	857.7
	C	Streams and Canals	Pond	35.3
	C	Cropland and Pasture	C, Pasture, Flat	60
	B	Nonforested Wetlands	Saturated, Pasture, Flat	4.2
	B	Streams and Canals	Pond	3.5
	D	Cropland and Pasture	Saturated, Pasture, Flat	0.4
		Total		**961.1**
Claude O. Davis Slough	B	Nonforested Wetlands		3.7
	B	Cropland and Pasture		42
		Total		**45.7**
Dry Slough West	C	Streams and Canals	Pond	51
	B	Cropland and Pasture	A/B, Pasture, Flat	813.8
	C	Cropland and Pasture	C, Pasture, Flat	97.9
	B	Residential	B, Lawn, Flat	4.9
	B	Streams and Canals	Pond	7
	C	Residential	C, Lawn, Flat	1.1
	D	Cropland and Pasture	Saturated, Pasture, Flat	0.4
		Total		**976.1**
Dry Slough East	B	Nonforested Wetlands	Saturated, Pasture, Flat	6.4
	B	Cropland and Pasture	A/B, Pasture, Flat	198.1
	D	Cropland and Pasture	Saturated, Pasture, Flat	11.4
	C	Cropland and Pasture	C, Pasture, Flat	120.4
	C	Residential	C, Lawn, Flat	19.2
	B	Residential	A/B, Lawn, Flat	4.3
	C	Other Agricultural Land	C, Pasture, Flat	2.5
	C	Streams and Canals	Pond	24.5
		Total		**386.7**

Note:

TABLE C-2
WESTERN WASHINGTON HYDROLOGY MODEL VERSION 3 -
FLOOD FREQUENCY OUTPUT

Return Interval - Annual Exceedance (%)	Flow Rate (cfs)			
	No Name Slough	Claude O. Davis	Dry Slough West	Dry Slough East
2-year (50%)	14.2	0.0	21.3	10.4
5-year (20%)	19.9	0.1	29.8	15.4
10-year (10%)	24.0	0.1	36.1	19.5
25-year (4%)	29.9	0.1	45.0	25.6
50-year (2%)	34.7	0.1	52.3	31.0
100-year (1%)	39.9	0.2	60.3	37.2

Note:

cfs = cubic feet per second

TABLE C-3
SEA LEVEL RISE VALUES

Year	SLR - Low[1,2] (feet)	SLR - Average[1,2] (feet)	SLR - High[1,2] (feet)
2000	0.00	0.00	0.00
2013	0.01	0.09	0.17
2030	0.03	0.22	0.40
2033	0.06	0.27	0.47
2050	0.20	0.54	0.89
2063	0.43	0.93	1.44
2100	1.07	2.03	2.99

Notes:

[1] Sea level rise (SLR) rates were provided by the National Academy of Science (NAS) 2012 Sea Level Rise for the Coasts of California, Oregon, and Washington, Past, Present, and Future. Estimates include Cascadia subduction zone tectonics and post-glacial isostatic rebound, vertical land rate adjustments.

[2] SLR rates were linearly interpolated for years 2013, 2033, and 2063 from published NAS values in years 2000, 2030, 2050, and 2100.

TABLE C-4
HYDRAULIC MODEL OUTPUT
INTERIOR POND AVERAGE (APRIL) AND MAXIMUM WATER SURFACE ELEVATIONS

2013	Low		Change	Average		Change	High		Change
	Without Project	Project		Without Project	Project		Without Project	Project	
SLR (ft)	0.0	0.0	n/a	0.1	0.1	n/a	0.2	0.2	n/a
Average WSE (ft)	3.3	4.1	0.8	3.4	4.2	0.8	3.5	4.3	0.9
Maximum WSE (ft)	3.8	4.7	0.9	3.9	4.8	0.9	4.0	4.9	0.9
2033	**Low**			**Average**			**High**		
SLR (ft)	0.1	0.1	n/a	0.3	0.3	n/a	0.5	0.5	n/a
Average WSE (ft)	3.4	4.2	0.8	3.6	4.4	0.9	3.8	4.6	0.9
Maximum WSE (ft)	3.9	4.8	0.9	4.1	5.0	0.9	4.3	5.1	0.8
2063	**Low**			**Average**			**High**		
SLR (ft)	0.5	0.5	n/a	0.9	0.9	n/a	1.5	1.5	n/a
Average WSE (ft)	3.8	4.6	0.9	4.2	5.0	0.8	4.8	5.6	0.8
Maximum WSE (ft)	4.3	5.1	0.8	4.7	5.5	0.8	5.2	5.9	0.7

Notes:

ft = foot

n/a = not applicable

SLR = sea level rise

WSE = water surface elevation

TABLE C-5
HYDRAULIC MODELING RESULTS - 2-FOOT CRITICAL ROOT ZONE FARM AREA EFFECTS

Field	Model Node	Elevation Range		Critical Root Zone Depth	Field Elevation	Field Elevation Area	% Total Area	2013 Average SLR				2063 Average SLR			
								% of Time Exceeded (April)			Area Affected	% of Time Exceeded (April)			Area Affected
		Low (ft)	High (ft)	(ft)	(ft)	(acres)		w/o Project SLR Only 5.4 ft	Project SLR+Hyd 6.2 ft	Increase %	(acres)	w/o Project SLR Only 6.2 ft	Project SLR+Hyd 7.0 ft	Increase %	(acres)
North Field #2	NNS XS 11193	6	6.5	2	4	18.4	6%	35%	100%	65%	18.4	100%	100%	0%	0.0
		6.5	7		4.5	32.7	11%	2%	21%	19%	32.7	39%	100%	61%	32.7
		7	7.5		5	51.1	18%	0%	1%	0%	0.0	1%	100%	99%	51.1
		7.5	8		5.5	52.7	18%	0%	0%	0%	0.0	0%	1%	1%	0.0
		8	8.5		6	33.2	12%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	25.7	9%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	22.9	8%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9.5	10		7.5	14.3	5%	0%	0%	0%	0.0	0%	0%	0%	0.0
		10	12		8	28.6	10%	0%	0%	0%	0.0	0%	0%	0%	0.0
North Field #1	NNS XS 6622	6	6.5	2	4	26.1	6%	0%	100%	100%	26.1	91%	100%	9%	0.0
		6.5	7		4.5	62.7	15%	0%	0%	0%	0.0	3%	100%	97%	62.7
		7	7.5		5	93.8	23%	0%	0%	0%	0.0	0%	58%	58%	93.8
		7.5	8		5.5	105.3	26%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	68.9	17%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	32.5	8%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	5.7	1%	0%	0%	0%	0.0	0%	0%	0%	0.0
WDFW Field	NNS XS 3386	6	6.5	2	4	2.6	2%	0%	100%	100%	2.6	89%	100%	11%	2.6
		6.5	7		4.5	19.1	17%	0%	0%	0%	0.0	3%	100%	97%	19.1
		7	7.5		5	57.1	51%	0%	0%	0%	0.0	0%	55%	55%	57.1
		7.5	8		5.5	25.2	23%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	5.0	4%	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton North	DS XS 4899	6.5	7	2	4.5	1.0	2%	25%	37%	12%	1.0	90%	94%	4%	0.0
		7	7.5		5	5.7	14%	1%	1%	0%	0.0	4%	7%	2%	0.0
		7.5	8		5.5	18.5	45%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	10.2	25%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	1.9	5%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	1.4	3%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9.5	10		7.5	0.8	2%	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton Mid-North	DS XS 4899	5.5	6	2	3.5	4.2	5%	100%	100%	0%	0.0	100%	100%	0%	0.0
		6	6.5		4	18.6	20%	100%	100%	0%	0.0	100%	100%	0%	0.0
		6.5	7		4.5	25.5	28%	25%	37%	12%	25.5	90%	94%	4%	0.0
		7	7.5		5	24.5	27%	1%	1%	0%	0.0	4%	7%	2%	0.0
		7.5	8		5.5	10.3	11%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	5.2	6%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	2.1	2%	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton South	DS XS 996	4.5	5	2	2.5	1.5	2%	100%	100%	0%	0.0	100%	100%	0%	0.0
		5	5.5		3	5.1	7%	97%	98%	0%	0.0	100%	100%	0%	0.0
		5.5	6		3.5	20.0	27%	66%	67%	1%	0.0	100%	100%	0%	0.0
		6	6.5		4	31.5	43%	34%	37%	3%	0.0	93%	93%	0%	0.0
		6.5	7		4.5	11.5	16%	6%	9%	3%	0.0	50%	52%	3%	0.0
		7	7.5		5	2.4	3%	0%	0%	0%	0.0	3%	4%	2%	0.0
Total						985.7				11%	106.3			32%	319.1

Note:
ft = foot
SLR = sea level rise
% = percent
(yellow highlight) Indicates effect on farm field

TABLE C-6
SALINITY MIXING
MASS BALANCE MODEL RESULTS

No Name Slough

Scenario	Tidal Seepage (cfs)	Tidal Seepage (ppt)	Upstream Baseflow (cfs)	Upstream Baseflow (ppt)	Total Flow (cfs)	Average Salinity at Tidegate (ppt)
Existing						
Low	0.20	20.00	1.00	7.20	1.20	9.36
High	0.52	25.00	1.00	7.20	1.52	13.26
Proposed						
Low	0.04	20.00	1.00	7.20	1.04	7.64
High	0.04	25.00	1.00	7.20	1.04	7.96

Dry Slough

Scenario	Tidal Seepage (cfs)	Tidal Seepage (ppt)	Upstream Baseflow (cfs)	Upstream Baseflow (ppt)	Total Flow (cfs)	Average Salinity at Tidegate (ppt)
Existing						
Low	0.20	20.00	1.00	7.20	1.20	9.33
High	0.30	25.00	1.00	7.20	1.30	11.31
Proposed						
Low	0.10	20.00	1.00	7.20	1.10	8.39
High	0.22	25.00	1.00	7.20	1.22	10.44

Notes:
cfs = cubic feet per second
ppt = parts per thousand

TABLE C-7
HYDRAULIC MODEL OUTPUT - RESPONSE STUDY OPTIONS
INTERIOR POND AVERAGE (APRIL) AND MAXIMUM WATER SURFACE ELEVATIONS

2013	SLR 0		Change (ft)	Dry Slough Gravity		Change (ft)	Pond Pump Station		Change (ft)
	w/o Project	Project		w/o Project	Project		w/o Project	Project	
SLR (ft)	*0.0*	*0.0*	*n/a*	*0.0*	*0.0*	*n/a*	*0.0*	*0.0*	*n/a*
Average WSE (ft)	3.3	4.1	0.8	3.3	4.1	0.7	3.3	3.3	-0.1
Maximum WSE (ft)	3.8	4.7	0.9	3.8	4.6	0.8	3.8	3.5	-0.3

Notes:

ft = foot

n/a = not applicable

SLR = sea level rise `

WSE = water surface elevation

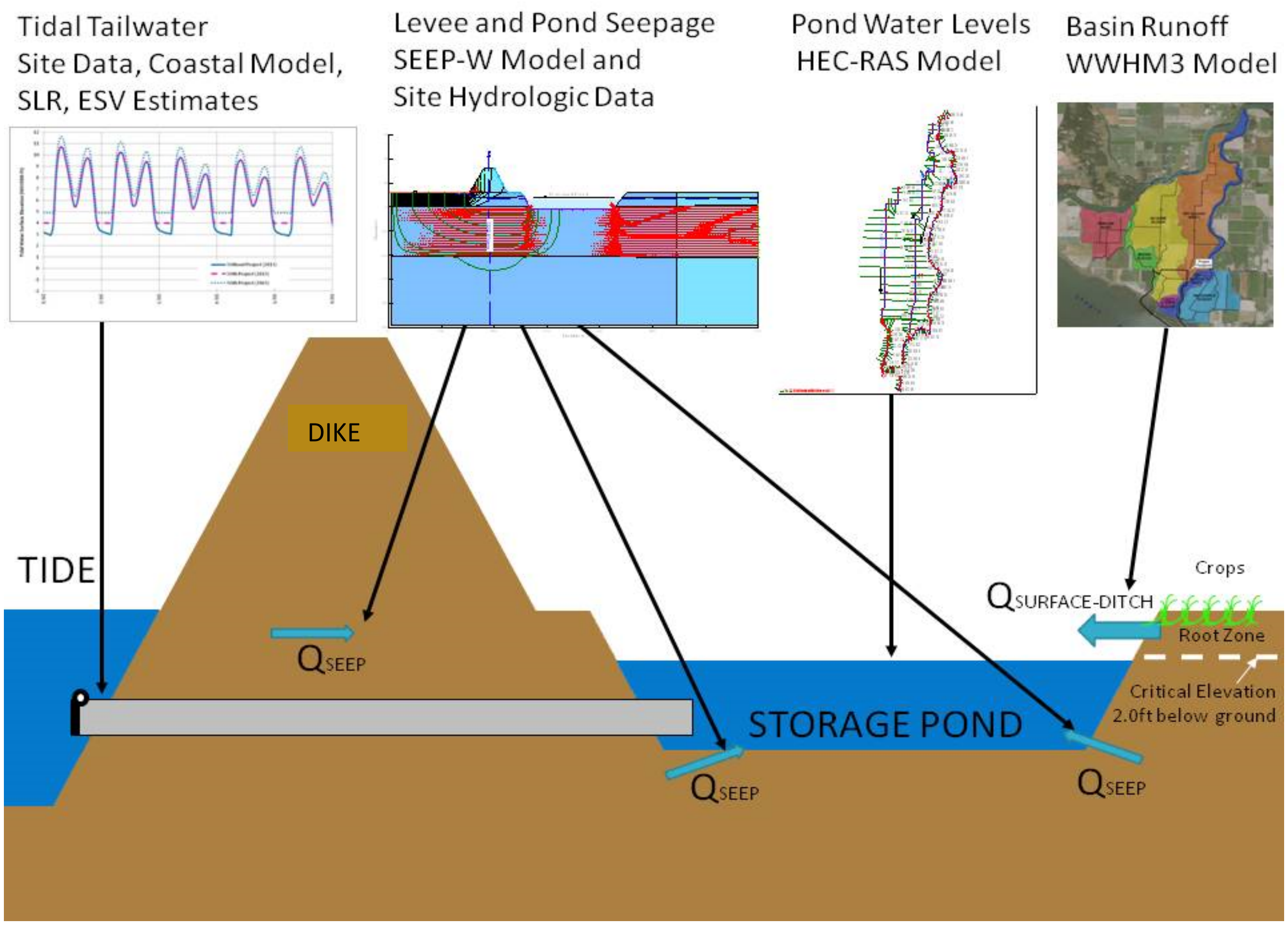
TABLE C-8
HYDRAULIC MODEL OUTPUT - RESPONSE STUDY OPTIONS - 2-FOOT CRITICAL ROOT ZONE FARM AREA EFFECTS

								2013 Average SLR				2013 SLR with Dry Slough Tidegates				2013 SLR with Pump Station			
		Elevation Range		Critical Root Zone Depth	Field Elevation	Field Elevation Area	% Total Area	% of Time Exceeded (April)			Area Affect	% of Time Exceeded (April)			Area Affect	% of Time Exceeded (April)			Area Affect
								w/o Proj.	Project	Change		w/o Proj.	Project	Change		w/o Proj.	Project	Change	
Field	Model Node	Low (ft)	High (ft)	(ft)	(ft)	(acres)		SLR Only	SLR+ Hyd	%	(acres)	SLR Only	SLR+ Hyd	%	(acres)	SLR Only	SLR+ Hyd	%	(acres)
North Field #2	NNS XS 11193	6	6.5	2	4	18.4	6%	35%	100%	65%	18.4	35%	100%	65%	18.4	35%	28%	-7%	0.0
		6.5	7		4.5	32.7	11%	2%	21%	19%	32.7	2%	13%	11%	32.7	2%	2%	0%	0.0
		7	7.5		5	51.1	18%	0%	1%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		7.5	8		5.5	52.7	18%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	33.2	12%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	25.7	9%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	22.9	8%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		9.5	10		7.5	14.3	5%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		10	12		8	28.6	10%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
North Field #1	NNS XS 6622	6	6.5	2	4	26.1	6%	0%	100%	100%	26.1	0%	79%	79%	26.1	0%	0%	0%	0.0
		6.5	7		4.5	62.7	15%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		7	7.5		5	93.8	23%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		7.5	8		5.5	105.3	26%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	68.9	17%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	32.5	8%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	5.7	1%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
WDFW Field	NNS XS 3386	6	6.5	2	4	2.6	2%	0%	100%	100%	2.6	0%	67%	67%	2.6	0%	0%	0%	0.0
		6.5	7		4.5	19.1	17%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		7	7.5		5	57.1	51%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		7.5	8		5.5	25.2	23%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	5.0	4%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton North	DS XS 4899	6.5	7	2	4.5	1.0	2%	25%	37%	12%	1.0	25%	24%	-1%	0.0	25%	21%	-4%	0.0
		7	7.5		5	5.7	14%	1%	1%	0%	0.0	1%	0%	0%	0.0	1%	1%	0%	0.0
		7.5	8		5.5	18.5	45%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	10.2	25%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	1.9	5%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	1.4	3%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		9.5	10		7.5	0.8	2%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton Mid-North	DS XS 4899	5.5	6	2	3.5	4.2	5%	100%	100%	0%	0.0	100%	100%	0%	0.0	100%	100%	0%	0.0
		6	6.5		4	18.6	20%	100%	100%	0%	0.0	100%	100%	0%	0.0	100%	100%	0%	0.0
		6.5	7		4.5	25.5	28%	25%	37%	12%	25.5	25%	24%	-1%	0.0	25%	21%	-4%	0.0
		7	7.5		5	24.5	27%	1%	1%	0%	0.0	1%	0%	0%	0.0	1%	1%	0%	0.0
		7.5	8		5.5	10.3	11%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	5.2	6%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	2.1	2%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton South	DS XS 996	4.5	5	2	2.5	1.5	2%	100%	100%	0%	0.0	100%	100%	0%	0.0	100%	100%	0%	0.0
		5	5.5		3	5.1	7%	97%	98%	0%	0.0	97%	97%	0%	0.0	97%	97%	0%	0.0
		5.5	6		3.5	20.0	27%	66%	67%	1%	0.0	66%	71%	5%	0.0	66%	61%	-6%	0.0
		6	6.5		4	31.5	43%	34%	37%	3%	0.0	34%	40%	6%	0.0	34%	21%	-13%	0.0
		6.5	7		4.5	11.5	16%	6%	9%	3%	0.0	6%	3%	-4%	0.0	6%	2%	-5%	0.0
		7	7.5		5	2.4	3%	0%	0%	0%	0.0	0%	0%	0%	0.0	0%	0%	0%	0.0
Total						985.7				11%	106.3			8%	79.8			0%	0.0

Notes:

Key	Meaning
(yellow)	Indicates effect on farm field
(green)	Indicates effect on farm field mitigated

ft = foot
SLR = sea level rise
% = percent



Fir Island Farms Restoration

Skagit County, WA

Hydrologic and Hydraulic Conceptual Model

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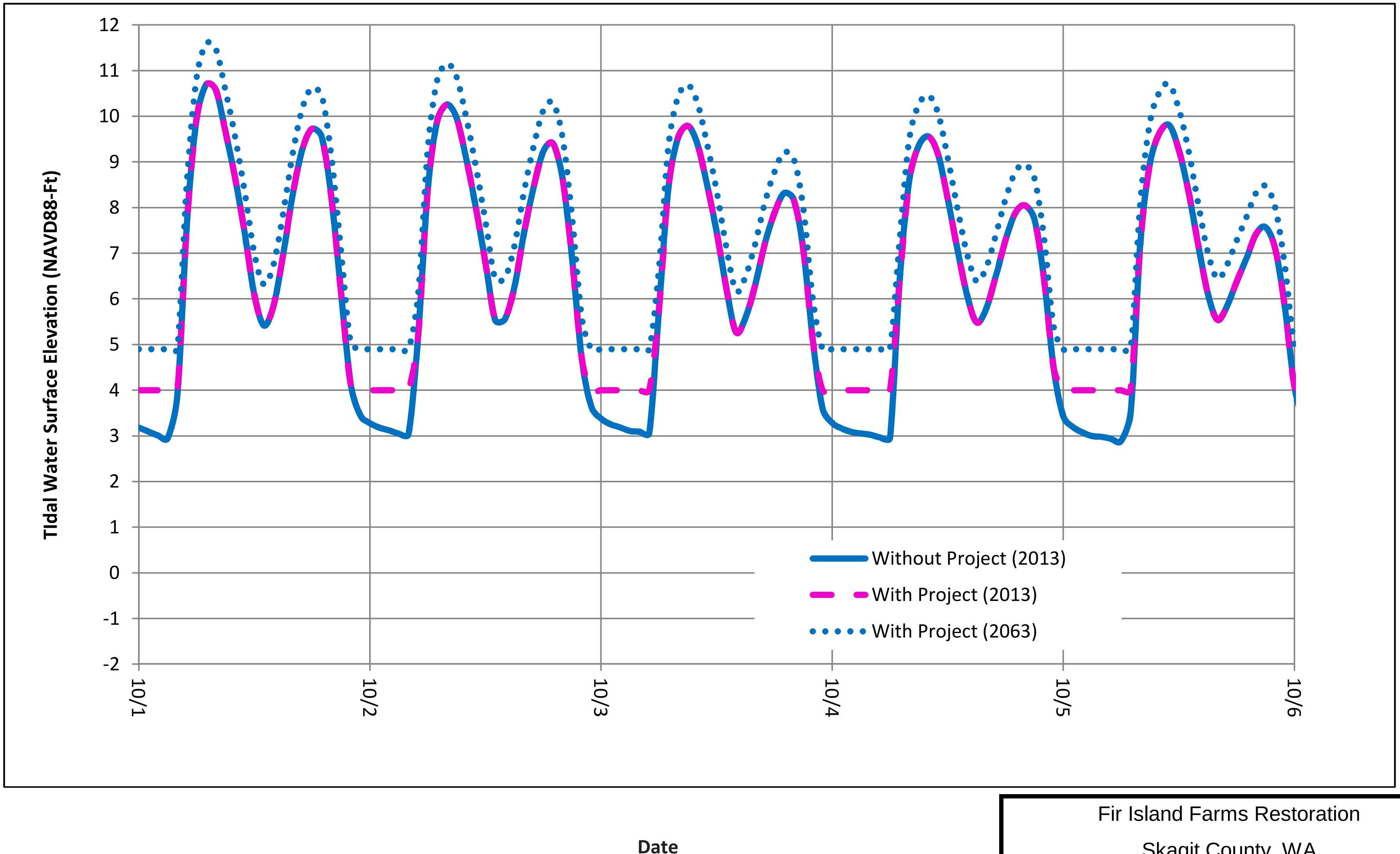
Fig. C-1

Fig. C-1



Fir Island Farms Restoration

Skagit County, WA

Without Project Sea Level Rise and With Project Sea Level Rise and Hydrodynamic Tailwater Effect

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Fig. C-2

Fig. C-2

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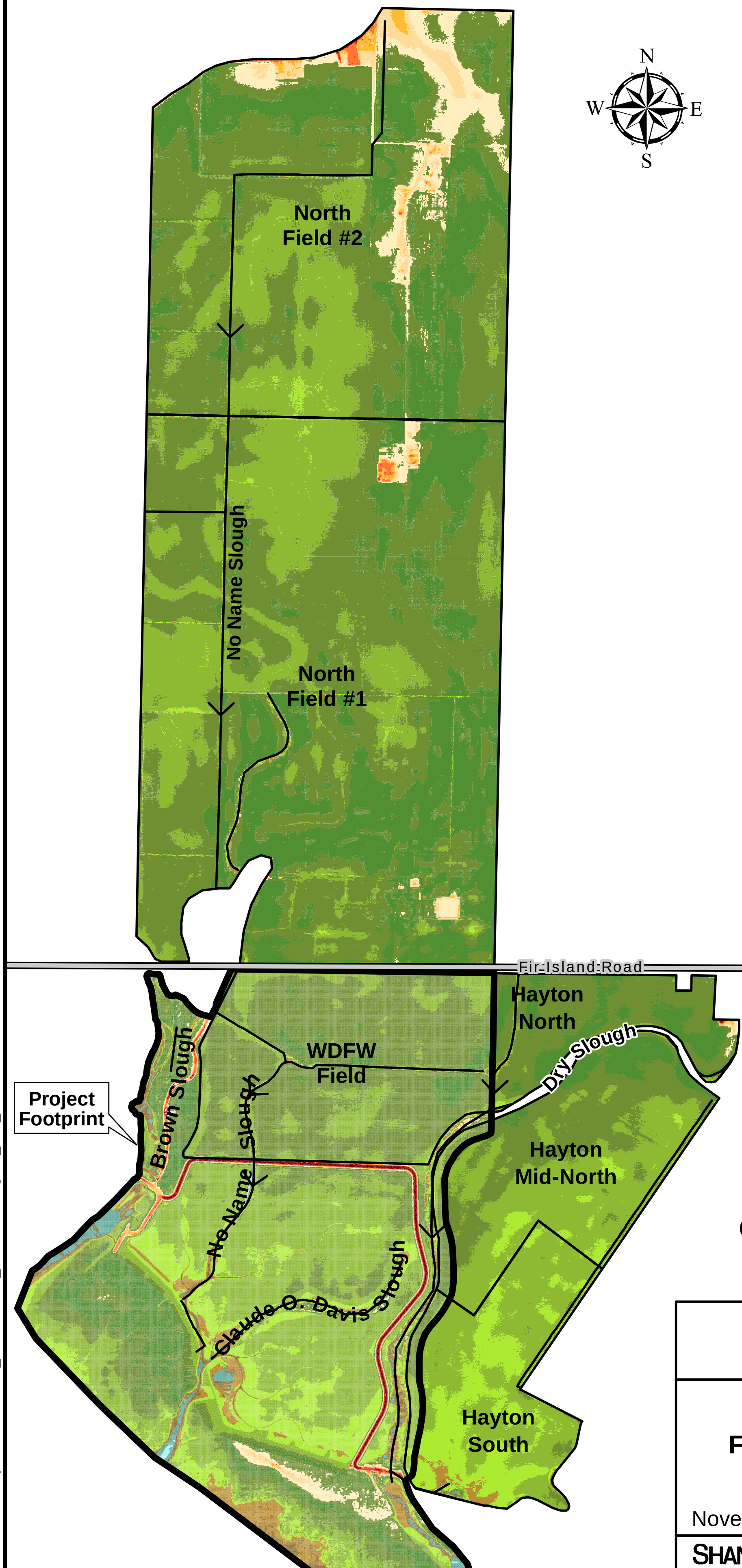

Legend

- Project Footprint
- Interior Drainage Channel

Elevation NAVD88 (feet)

- 16 - 17
- 15 - 16
- 14 - 15
- 13 - 14
- 12 - 13
- 11 - 12
- 10 - 11
- 9 - 10
- 8 - 9
- 7 - 8
- 6 - 7
- 5 - 6
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2

NOTE: Dike Configuration Shows Proprosed Project Elevations

0 1,500 3,000 Feet

Fir Island Farm Restoration Project
Mount Vernon, Washington

POTENTIAL EFFECT ON FARM FIELDS IN NO NAME & DRY SLOUGH BASINS

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FIG. C-3

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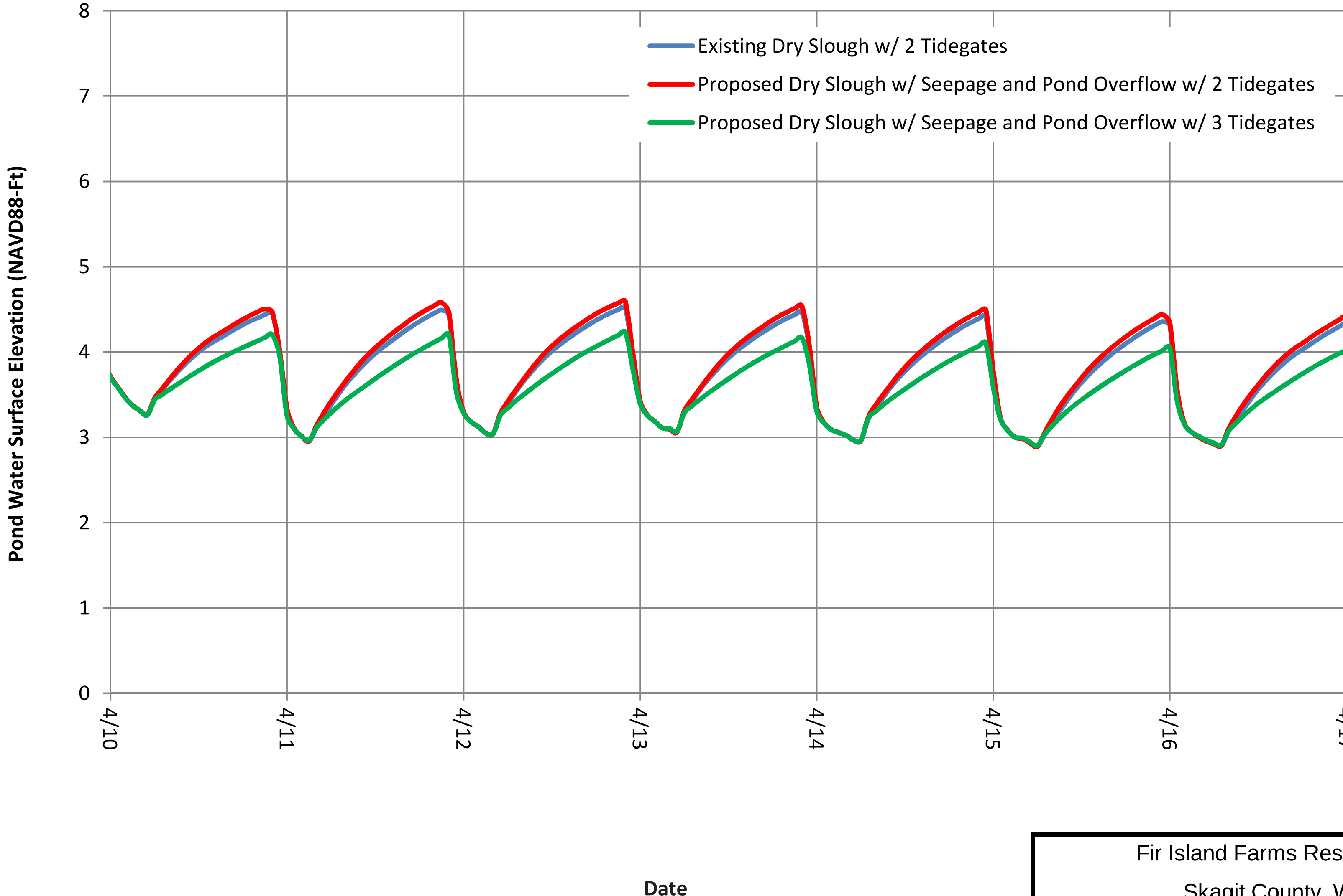

FIG. C-4

Fir Island Farms Restoration

Skagit County, WA

Dry Slough
Without Project and With Project
Sea Level Rise 0.0 Pond with
Additional Third Tidegate for Seepage

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FIG. C-4

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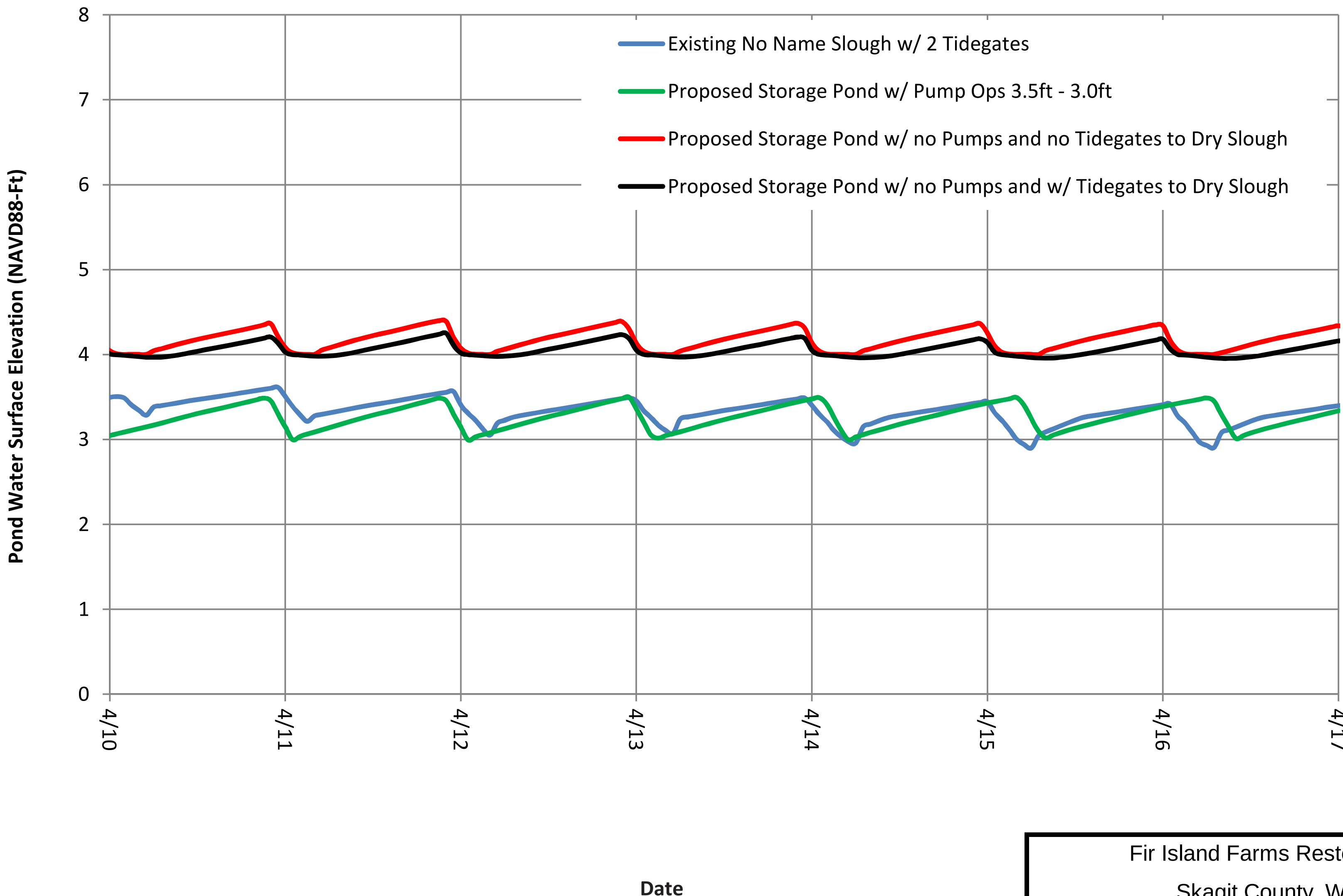

Fir Island Farms Restoration

Skagit County, WA

Interior Storage Pond Without Project and With Project Sea Level Rise 0.0 Pond With and Without Pump Operating from 3.5ft to 3ft

November 2014 | 21-1-12318-216

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FIG. C-5

FIG. C-5

APPENDIX D

SENSITIVITY ANALYSIS

APPENDIX D

SENSITIVITY ANALYSIS

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FIGURES

APPENDIX D

SENSITIVITY ANALYSIS

A sensitivity analysis was performed on the interior drainage system, to evaluate the effects of coastal hydrodynamics, marsh erosion, sedimentation and vegetation, and interior storage pond vegetation and maintenance conditions on its performance. The sensitivity analysis considers how changes in these conditions may occur over a design life period of 50 years. The study uses a Monte Carlo analysis to perform the sensitivity analysis.

D.1 MONTE CARLO METHOD

The Monte Carlo method is a statistical technique used to model the range of expected sensitivity factors (inputs) to characterize the uncertainty of the pond water surface elevation (output). For the Fir Island project, three key sensitivity factors of concern are assumed. These factors are the most likely to affect the interior drainage and storage pond water surface elevations, and the adjacent groundwater elevations (i.e., the primary evaluation metric). The sensitivity analysis is performed by evaluating how changes in each of these factors (independently and combined) can affect the interior drainage storage pond water surface elevations during critical early season growing period water surface elevations. The analysis evaluates the effects over a 50-year project design period.

The following are the project key sensitivity factors of concern:

- Sea level rise (SLR)
- Erosion, sedimentation, and vegetation conditions in the restored marsh that can affect interior drainage system tailwater conditions (ESV)
- Vegetation and maintenance conditions in the interior storage pond that can affect storage pond capacity (SPC)

The effect of each of these factors can be determined from the results of the surface water and hydraulic modeling described in Sections 6.1 and 6.2 of the main report. For example, the effect of a SLR of 0.2 foot on interior storage pond average early growing season water surface elevations can be calculated. However, the magnitude and timing of the potential SLR related to the pond water surface elevation effect is uncertain. The sensitivity factors of concern are assumed to be independent and, therefore, the combined effect of the various sensitivity factors can be calculated by summing the individual factor effects.

The general procedure used to perform the Monte Carlo analyses was as follows:

1. Generate independent SLR, ESV, and SPC log-normal, normal or best fit distributions. SLR and ESV input values are those presented in the Shannon & Wilson, Inc. (S&W) Coastal Engineering Recommendations Report (S&W, 2014).
2. Use a random number generator and select a probability of occurrence for the input value based on the probability distributions defined above.
3. Calculate output value (storage pond elevation) resulting from the selected probabilistic input event.
4. For the "Without Project" condition, repeat steps 2) and 3) for SLR (only) for 10,000 iterations.
5. For the "Project" condition, repeat steps 2) and 3) for SLR (plus the hydrodynamic effect), ESV, and SPC for 10,000 iterations. The independent output values are summed at each iteration.
6. Perform the same steps for each year 2013, 2033, 2063 to generate output values over a 50-year project design timeframe.

The calculated results were analyzed statistically to evaluate the effect of input uncertainty (SLR, ESV, or SPC) on the resulting calculated output uncertainty (interior pond water surface elevations). When the 10,000 iterations were complete for the "Without Project" and "Project" conditions, descriptive statistics of average, standard deviation, skewness, and the average relative contribution of each factor were calculated. A cumulative distribution function curve of interior drainage storage pond water surface elevation versus cumulative probability was plotted at each discrete time interval (2013, 2033, 2063). The Monte Carlo analysis was completed using Microsoft Excel 2007.

D.2 SENSITIVITY FACTORS OF CONCERN

The input parameters that are considered the key factors of concern for the study have been identified as SLR, ESV effects, and SPC volume effects. The uncertainties associated with each of the factors of concern were generated based on data, monitoring, studies, and other anecdotal site information. Many of these were presented in the S&W Coastal Engineering Recommendations Report (S&W, 2014) and are summarized herein.

D.2.1 Sea Level Rise (SLR) Effects

The effects of potential SLR were evaluated for a 50-year levee design lifecycle (the period 2013 through 2063), based on information and predictions provided in the National Academy of Sciences (NAS) (2012) Sea Level Rise report (Table D-1).

Sea level rise effects could be significant at Fir Island because many of the crops grown in the farm fields have root zones that extend near or below the groundwater table elevation on the island. As the sea level rises, the groundwater table will also rise. If the groundwater tables rise and inundate the root zones for too long, crop damage could occur. Groundwater tables are managed at the site through drainage ditches and tidegate systems. SLR will raise the tailwater elevations on the tidegates, which then affects the amount of water that can drain through the tidegate. The negative effects of SLR are expected to occur for both “Without Project” and “Project” conditions.

The “Without Project” uses SLR (only) to the existing, observed tidal tailwater conditions. The “project” conditions use a combination of SLR tidal increases and the 0.75-foot hydrodynamic (water surface elevation increase described in the Fir Island Hydrodynamic Modeling Report [Battelle, 2013] and the Coastal Engineering Recommendations Report [S&W, 2014]). The hydrodynamic effect is on the low-tide trough (shown conceptually in Figure D-1). Results of the hydraulic modeling of the “Without Project” and “Project” alternatives for the average spring (April) period and the maximum predicted water surface elevations are shown in Table D-2.

Table D-3 shows how the hydraulic modeling outputs relate to critical root zone depth (elevation) criteria for the adjacent farm fields. Fields north of the setback levee (i.e., Washington Department of Fish and Wildlife North Field, North Field #1 and North Field #2, and the Hayton Mid-north fields) could have increased water surface elevations above the critical root zone elevation, increasing by more than 10 percent of the time. For the 2013 scenario (if the project were built today), the model predicts that up to 106 acres could be affected by the project, mostly as a result of the hydrodynamic tailwater component of the SLR + Hydrodynamic input variable to the sensitivity analysis. For the 2063 scenario, up to 319 acres could be affected, which is a combination of both SLR and the hydrodynamic tailwater effect.

Storage pond water surface elevations could be more or less than calculated or predicted as described above due to uncertainty. To address SLR-related uncertainty, the sensitivity analysis uses the low, average, and high data inputs and the resulting hydraulic modeling output for April water surface elevations at the yearly study intervals (2013, 2033, and 2063). Figure D-2 shows the SLR input values derived from the NAS (2012) study and the log-normal curve fit to the SLR input data. The curve fitting allows for assignment of a probability distribution function to the SLR input values, as shown in Figure D-3. Both “Without Project” and “Project” conditions have similar input and probability distribution functions related to SLR. The difference between the two is the “Project” condition has an additional 0.75-foot hydrodynamic tailwater effect on the low tide tailwater. These output pond water surface elevation relationships are shown in Figures D-4 and D-5. Computations were then performed to estimate the effect of SLR input uncertainty on corresponding pond water surface elevation outputs. The SLR effects and probabilistic outputs were then combined with other sensitivity factors ESV and SPC for the “project” condition. The combined effects of all of the contributing factors are discussed in the following report sections

D.2.2 Erosion, Sedimentation, and Vegetation Effects (ESV)

The project has the potential for marsh sediment erosion, sedimentation, and vegetation establishment that could affect tidal drainage and marsh drainage conveyance. In contrast, sedimentation and erosion are natural processes key to forming marsh habitat for fish, as well as the need for development of marsh plain surfaces to keep up with Sea Level Rise (SLR) or risk being drowned out. Few tools are available for accurately predicting large-scale tidal marsh restoration erosion, sedimentation, and vegetation trends, and their corresponding effects on the interior drainage system water elevations (without significant study and expense). Therefore, there is uncertainty for project outcomes associated with Erosion, Sedimentation and Vegetation (ESV) effects.

Project hydrodynamic modeling indicates that the tidal prism exchange to the marsh restoration site will provide significant flood and ebb tidal flows, and will have flow conditions along the No Name Slough tidal channel that will mobilize sediment in the bed and banks of the channels. Shear stress modeling indicates that the shear stresses exceed the threshold for mobilizing fine silts and sands present in the Skagit Bay area. If sediment supplies are low, erosion and expansion of the primary tidal channel could occur, which could lower the tidal tailwater elevations. Erosion expansion and degradation of the primary tidal channel was a reported observation at the Nisqually restoration project. There is little information on how tidal channel erosion and scour effects relate to tidal tailwater elevations. For this study, it was assumed that erosion of a larger tidal channel would increase tidal drainage conveyance and the reductions in channel elevation would correlate to reductions in tidal tailwater elevations.

This effect would likely be offset by other project effects that could include sedimentation in the tidal channel and on the marsh surfaces, thereby reducing drainage conveyance. Likely sources of sedimentation include sediment eroded and transported from the newly restored marsh areas, and sediments transported from shoreline drift from mudflat and South Fork Skagit River distributary areas. Excavation of the tidal channels and inlet area will be part of the project, which will reduce the potential for sedimentation. Also, the amount of sediment supply from shoreline drift appears to be low, as described in the Coastal Engineering Recommendations report. Sedimentation of tidal channels and marshes could result in increases of tidal tailwater elevations. Vegetation establishment on the marsh could also reduce tidal drainage conveyance and contribute to elevated tidal tailwater conditions. The Fir Island ESV parameter was based on the Nisqually project marsh sedimentation monitoring data. We would hypothesize that the Fir Island, Skagit Bay sediment transport conditions will be lower than Nisqually. The Fir Island project will have tidal and shoreline sediment supply and transport only, without the influence of historic river distributary sediment transport to the site, which the Nisqually has river sediment distribution to the nearby delta and shoreline. The Fir Island ESV assumes that Nisqually-type marsh sedimentation rates correlate to effects on tidal tailwater conditions, as the basis for estimating ESV effects (Table D-4). These are described further in the S&W Coastal Engineering Recommendations Report (S&W, 2014).

Figures D-6 through D-8 are the numerical transformations of these recommendations into manual (normal) curve fits, probability distribution functions, and hydraulic modeling output regression relationships used for the sensitivity analysis for the ESV factor. The findings and outcomes related to ESV effects to the drainage system are considered in the context of multiple contributing factors and are presented together in the following Monte Carlo report section.

D.2.3 Storage Pond Capacity (SPC) – Vegetation Effects

The design assumes that the Consolidated Diking District 22 will maintain the storage pond and will control establishment of emergent wetland vegetation in the pond to maximize storage capacity and conveyance. This will involve periodic mowing, dredging, and vegetation removal from the storage pond and ditches.

However, certain factors limit these maintenance activities (such as lack of funding), whereby wetland and pond vegetation growth could occur and encroach into the pond and reduce storage pond volume, capacity, and conveyance. A number of existing drainage "ditch" pond conditions were evaluated to represent this potential effect (uncertainty) on pond performance.

The encroachment criteria developed for the project study include varying degrees of vegetation encroachment, described as follows:

- Vegetation-free condition (0 percent encroachment across open water area)
- Minor vegetation encroachment positioned along the channel banks (25 percent encroachment across open water area)
- Major vegetation encroachment into pond beyond the channel banks (50 percent encroachment across open water area)

For the purposes of sensitivity analyses for this study, the proposed interior drainage pond sensitivity analysis assumes the levels of vegetation encroachment gradually increase over the 50-year life of the project (Table D-5). Vegetation encroachment into the pond was modeled as obstructions in pond flow areas.

Figures D-9 through D-11 are the numerical transformations of the recommendations from the Coastal Engineering Recommendations Report (S&W, 2014) into log-normal curve fits, probability distribution functions, and hydraulic modeling output regression relationships used for the sensitivity analysis for the SPC factor. The findings and outcomes related to SPC effects to the drainage system are considered in the context of multiple contributing factors and are presented together in the following Monte Carlo report section.

D.3 MONTE CARLO RESULTS

The “Without Project” SLR Only and “Project” SLR+Hydrodynamic, ESV, and SPC combined effect probability distributions were randomly sampled and analyzed using a Monte Carlo simulation. The resulting range of probable storage pond water surface elevation outputs and statistics are shown as a cumulative distribution functions (Tables D-6 and D-7, Figures D-12 through D-14).

The outcomes characterize the uncertainty associated with project design and the modeling predictions. Also, the uncertainty analysis provides information on the relative proportion (or weight) of the SLR, ESV, and SPC effects. The following is a summary of observations regarding the sensitivity analysis results:

- For 2013, the expected range (10 to 90 percent cumulative probability) of average April pond water surface elevations is:
  - 3.3 to 3.6 feet for the “Without Project,” 100 percent of the effect is SLR

  - 4.1 to 4.4 feet for the "Project," 98 percent of the effect is related to SLR plus the hydrodynamic effect and the remaining 2 percent is ESV and SPC effects.
- For 2033, the expected range (10 to 90 percent cumulative probability) of average April pond water surface elevations is:
  - 3.4 to 3.8 feet for the "Without Project," 100 percent of the effect is SLR
  - 4.1 to 4.9 feet for the "Project," 88 percent of the effect is related to SLR plus the hydrodynamic effect and the remaining 12 percent is ESV and SPC effects.
- For 2063, the expected range (10 to 90 percent cumulative probability) of average April pond water surface elevations is:
  - 3.7 to 5.1 feet for the "Without Project," 100 percent of the effect is SLR
  - 4.4 to 6.2 feet for the "Project," 88 percent of the effect is related to SLR plus the hydrodynamic effect and the remaining 12 percent is ESV and SPC effects.

SLR is expected to affect interior storage pond water surface elevations in early spring for the near term and foreseeable future, for the "Without Project" condition. SLR represents 100 percent of the effect in this analysis. These effects will likely impact drainage functions and farming operations.

The combined effects (SLR+hydro, ESV, and SPC) for the project are expected increase pond water surface elevations during early spring season on the order of 0.8 to 1.2 feet higher than the "Without Project" condition. The primary contributing factor appears to be SLR plus the tidal hydrodynamic effect. ESV and SPC effects are likely only moderate contributing factors to the anticipated tailwater increases. Additional drainage structures are necessary to mitigate these effects.

D.4 REFERENCES

National Academy of Sciences (NAS), 2012, Sea level rise for the Coasts of California, Oregon, and Washington, Past, Present, and Future.

Shannon & Wilson, Inc., 2014, Draft coastal engineering report WDFW – Fir Island Farm Snow Goose Reserve. Skagit County, Washington: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., January.

TABLE D-1
SEA LEVEL RISE VALUES

Year	SLR - Low[1,2] (feet)	SLR - Avg[1,2] (feet)	SLR - High[1,2] (feet)
2000	0.00	0.00	0.00
2013	0.01	0.09	0.17
2030	0.03	0.22	0.40
2033	0.06	0.27	0.47
2050	0.20	0.54	0.89
2063	0.43	0.93	1.44
2100	1.07	2.03	2.99

Notes:

[1] SLR rates were provided by the National Academy of Science (NAS) 2012 Sea Level Rise for the Coasts of California, Oregon, and Washington, Past, Present, and Future. Estimates include Cascadia subduction zone tectonics and post-glacial isostatic rebound, vertical land rate adjustments.

[2] SLR rates were linear interpolated for years 2013, 2033, and 2063 from published NAS values in years 2000, 2030, 2050, and 2100.

SLR = sea level rise

TABLE D-2
HYDRAULIC MODEL OUTPUT
INTERIOR POND AVERAGE (APRIL) AND MAXIMUM WATER SURFACE ELEVATIONS

2013	Low SLR			Average SLR			High SLR		
	Without Project	Project	Change	Without Project	Project	Change	Without Project	Project	Change
SLR (ft)	0.0	0.0	n/a	0.1	0.1	n/a	0.2	0.2	n/a
Average WSE (ft)	3.3	4.1	0.8	3.4	4.2	0.8	3.5	4.3	0.9
Maximum WSE (ft)	3.8	4.7	0.9	3.9	4.8	0.9	4.0	4.9	0.9
2033	**Low SLR**			**Average SLR**			**High SLR**		
SLR (ft)	0.1	0.1	n/a	0.3	0.3	n/a	0.5	0.5	n/a
Average WSE (ft)	3.4	4.2	0.8	3.6	4.4	0.9	3.8	4.6	0.9
Maximum WSE (ft)	3.9	4.8	0.9	4.1	5.0	0.9	4.3	5.1	0.8
2063	**Low SLR**			**Average SLR**			**High SLR**		
SLR (ft)	0.5	0.5	n/a	0.9	0.9	n/a	1.5	1.5	n/a
Average WSE (ft)	3.8	4.6	0.9	4.2	5.0	0.8	4.8	5.6	0.8
Maximum WSE (ft)	4.3	5.1	0.8	4.7	5.5	0.8	5.2	5.9	0.7

Notes:

ft = foot

n/a = not applicable

SLR = sea level rise

WSE = water surface elevation

TABLE D-3
HYDRAULIC MODEL RESULTS - 2 FEET CRITICAL ROOT ZONE FARM AREA EFFECTS

Field	Model Node	Elevation Range Low (ft)	Elevation Range High (ft)	Critical Root Zone Depth (ft)	Field Elevation (ft)	Field Elevation Area (acres)	Percent Total Area	2013 Average SLR: Percent of Time Exceeded (April) Without Project SLR Only 5.4 ft	2013 Average SLR: Project SLR+Hyd 6.2 ft	2013 Average SLR: Increase %	2013 Average SLR: Area Affected (acres)	2063 Average SLR: Percent of Time Exceeded (April) Without Project SLR Only 6.2 ft	2063 Average SLR: Project SLR+Hyd 7.0 ft	2063 Average SLR: Increase (%)	2063 Average SLR: Area Affected (acres)
North Field #2	NNS XS 11193	6	6.5	2	4	18.4	6%	35%	100%	65%	18.4	100%	100%	0%	0.0
		6.5	7		4.5	32.7	11%	2%	21%	19%	32.7	39%	100%	61%	32.7
		7	7.5		5	51.1	18%	0%	1%	0%	0.0	1%	100%	99%	51.1
		7.5	8		5.5	52.7	18%	0%	0%	0%	0.0	0%	1%	1%	0.0
		8	8.5		6	33.2	12%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	25.7	9%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	22.9	8%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9.5	10		7.5	14.3	5%	0%	0%	0%	0.0	0%	0%	0%	0.0
		10	12		8	28.6	10%	0%	0%	0%	0.0	0%	0%	0%	0.0
North Field #1	NNS XS 6622	6	6.5	2	4	26.1	6%	0%	100%	100%	26.1	91%	100%	9%	0.0
		6.5	7		4.5	62.7	15%	0%	0%	0%	0.0	3%	100%	97%	62.7
		7	7.5		5	93.8	23%	0%	0%	0%	0.0	0%	58%	58%	93.8
		7.5	8		5.5	105.3	26%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	68.9	17%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	32.5	8%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	5.7	1%	0%	0%	0%	0.0	0%	0%	0%	0.0
WDFW Field	NNS XS 3386	6	6.5	2	4	2.6	2%	0%	100%	100%	2.6	89%	100%	11%	2.6
		6.5	7		4.5	19.1	17%	0%	0%	0%	0.0	3%	100%	97%	19.1
		7	7.5		5	57.1	51%	0%	0%	0%	0.0	0%	55%	55%	57.1
		7.5	8		5.5	25.2	23%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	5.0	4%	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton North	DS XS 4899	6.5	7	2	4.5	1.0	2%	25%	37%	12%	1.0	90%	94%	4%	0.0
		7	7.5		5	5.7	14%	1%	1%	0%	0.0	4%	7%	2%	0.0
		7.5	8		5.5	18.5	45%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	10.2	25%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	1.9	5%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9	9.5		7	1.4	3%	0%	0%	0%	0.0	0%	0%	0%	0.0
		9.5	10		7.5	0.8	2%	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton Mid-North	DS XS 4899	5.5	6	2	3.5	4.2	5%	100%	100%	0%	0.0	100%	100%	0%	0.0
		6	6.5		4	18.6	20%	100%	100%	0%	0.0	100%	100%	0%	0.0
		6.5	7		4.5	25.5	28%	25%	37%	12%	25.5	90%	94%	4%	0.0
		7	7.5		5	24.5	27%	1%	1%	0%	0.0	4%	7%	2%	0.0
		7.5	8		5.5	10.3	11%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8	8.5		6	5.2	6%	0%	0%	0%	0.0	0%	0%	0%	0.0
		8.5	9		6.5	2.1	2%	0%	0%	0%	0.0	0%	0%	0%	0.0
Hayton South	DS XS 996	4.5	5	2	2.5	1.5	2%	100%	100%	0%	0.0	100%	100%	0%	0.0
		5	5.5		3	5.1	7%	97%	98%	0%	0.0	100%	100%	0%	0.0
		5.5	6		3.5	20.0	27%	66%	67%	1%	0.0	100%	100%	0%	0.0
		6	6.5		4	31.5	43%	34%	37%	3%	0.0	93%	93%	0%	0.0
		6.5	7		4.5	11.5	16%	6%	9%	3%	0.0	50%	52%	3%	0.0
		7	7.5		5	2.4	3%	0%	0%	0%	0.0	3%	4%	2%	0.0
Total						985.7				11%	106.3			32%	319.1

Note:
ft = foot
SLR = sea level rise

TABLE D-4
MARSH AND TIDAL CHANNEL
EROSION, SEDIMENTATION, AND VEGETATION TAILWATER INPUTS

Year	Tailwater Effects Low ESV (ft)	Tailwater Effects Average ESV (ft)	Tailwater Effects High ESV (ft)
2013	-0.1	0.0	0.1
2033	-0.3	0.2	0.3
2063	-0.4	0.3	0.5

Note:

ft = feet

TABLE D-5
INTERIOR DRAINAGE STORAGE POND
VEGETATION ENCROACHMENT AND
STORAGE POND CAPACITY INPUTS

Year	Vegetation Encroachment		
	Low SPC Encroachment (%)	Average SPC Encroachment (%)	High SPC Encroachment (%)
2013	0%	0%	0%
2033	5%	10%	25%
2063	10%	25%	50%

Note:

% = percent

TABLE D-6
MONTE CARLO SENSITIVITY ANALYSIS STATISTICS

2013 - Without Project				2013 - Project			
Statistics	**Sensitivity Factor % Effect on WSE**			**Statistics**	**Sensitivity Factor % Effect on WSE**		
Average	3.43	SLR	100.0%	Average	4.28	SLR+Hydro	97.6%
Std Dev	0.13	ESV	0.0%	Std Dev	0.16	ESV	0.4%
Skewness	3.53	SPC	0.0%	Skewness	1.65	SPC	2.1%

2033 - Without Project				2033 - Project			
Statistics	**Sensitivity Factor % Effect on WSE**			**Statistics**	**Sensitivity Factor % Effect on WSE**		
Average	3.63	SLR	100.0%	Average	4.52	SLR+Hydro	87.9%
Std Dev	0.18	ESV	0.0%	Std Dev	0.34	ESV	9.5%
Skewness	1.88	SPC	0.0%	Skewness	0.32	SPC	2.5%

2063 - Without Project				2063 - Project			
Statistics	**Sensitivity Factor % Effect on WSE**			**Statistics**	**Sensitivity Factor % Effect on WSE**		
Average	4.33	SLR	100.0%	Average	5.32	SLR+Hydro	87.6%
Std Dev	0.61	ESV	0.0%	Std Dev	0.77	ESV	7.9%
Skewness	1.94	SPC	0.0%	Skewness	1.18	SPC	4.5%

Notes:

ESV = erosion, sedimentation, and vegetation

SLR = sea level rise

SPC = storage pond capacity

WSE = water surface elevation

% = percent

TABLE D-7
MONTE CARLO SENSITIVITY ANALYSIS
COMPARISONS OF STORAGE POND WATER SURFACE ELEVATIONS

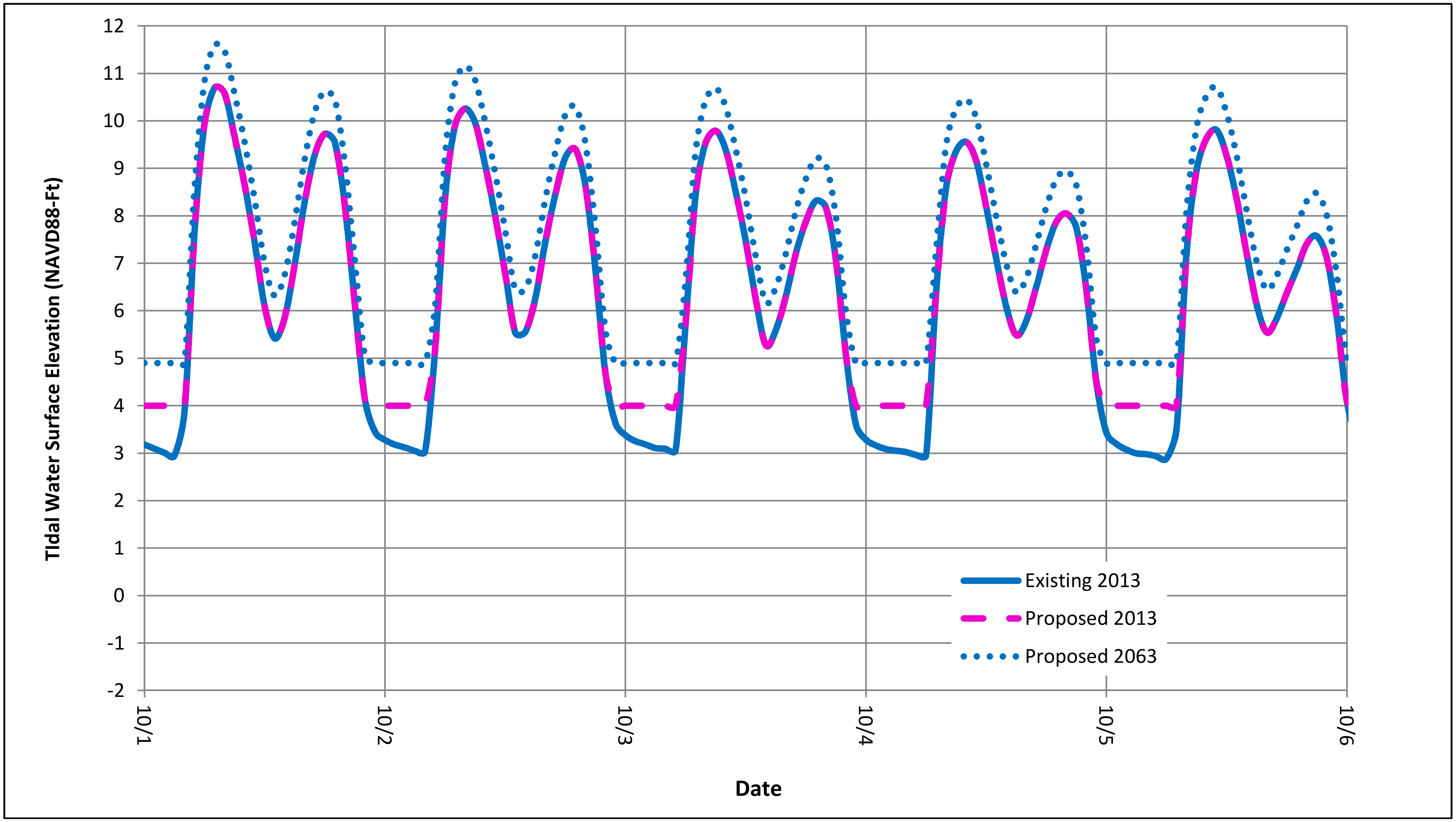
Year	Cumulative Probability	Without Project		Project		Difference (Project to Without Project) (ft)
		April Average Pond WSE	Range (ft) P(10% - 90%)	April Average Pond WSE	Range (ft) P(10% - 90%)	
2013	10%	3.3	0.2	4.1	0.4	0.7
	50%	3.4		4.2		0.8
	90%	3.5		4.4		0.9
2033	10%	3.4	0.4	4.1	0.8	0.6
	50%	3.6		4.5		0.9
	90%	3.8		4.9		1.1
2063	10%	3.7	1.4	4.4	1.8	0.7
	50%	4.2		5.2		1.1
	90%	5.1		6.2		1.2

Notes:

ft = feet

WSE = water surface elevation

% = percent



Fir Island Farm Estuary Restoration

Skagit County, WA

WITHOUT PROJECT SEA LEVEL RISE AND WITH PROJECT SEA LEVEL RISE AND HYDRODYNAMIC EFFECT

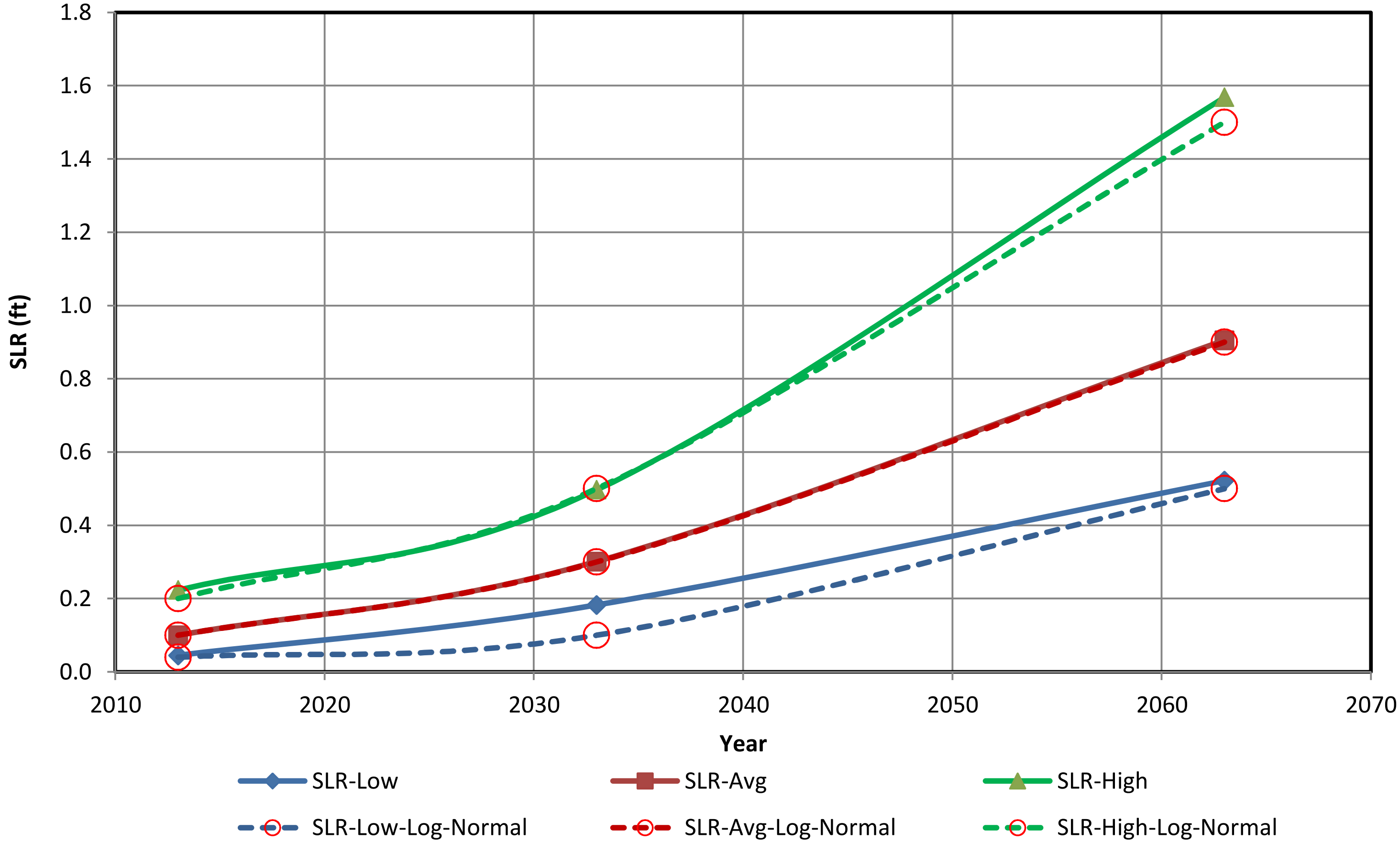
November 2014 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-1

Fig. D-1

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D1_SLR+HYDRO>



SLR = Sea Level Rise

Fig. D-2

Fir Island Farm Estuary Restoration

Skagit County, WA

SEA LEVEL RISE INPUT VALUES
LOG-NORMAL CURVE FIT

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-2

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D2.WO-SLR_LN-FIT>

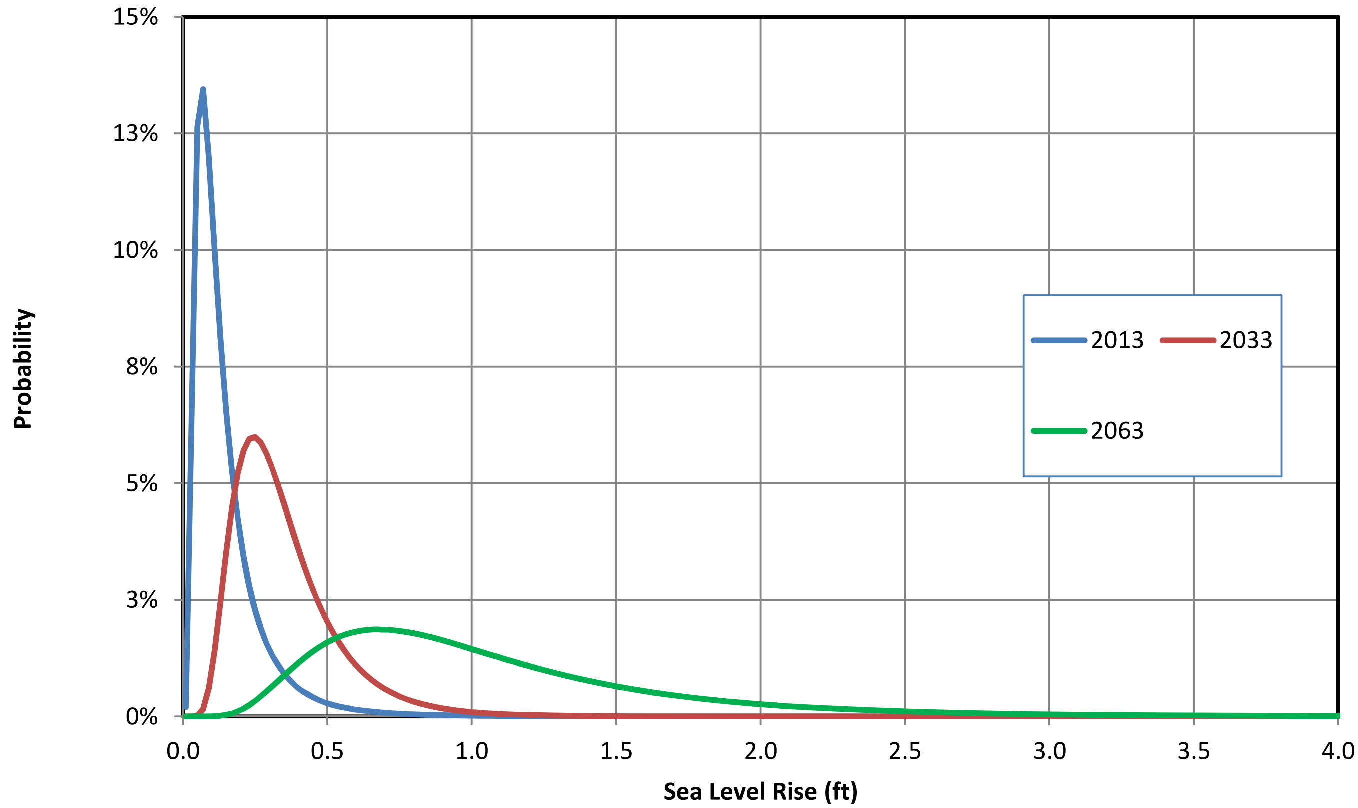


Fig. D-3

Fir Island Farm Estuary Restoration

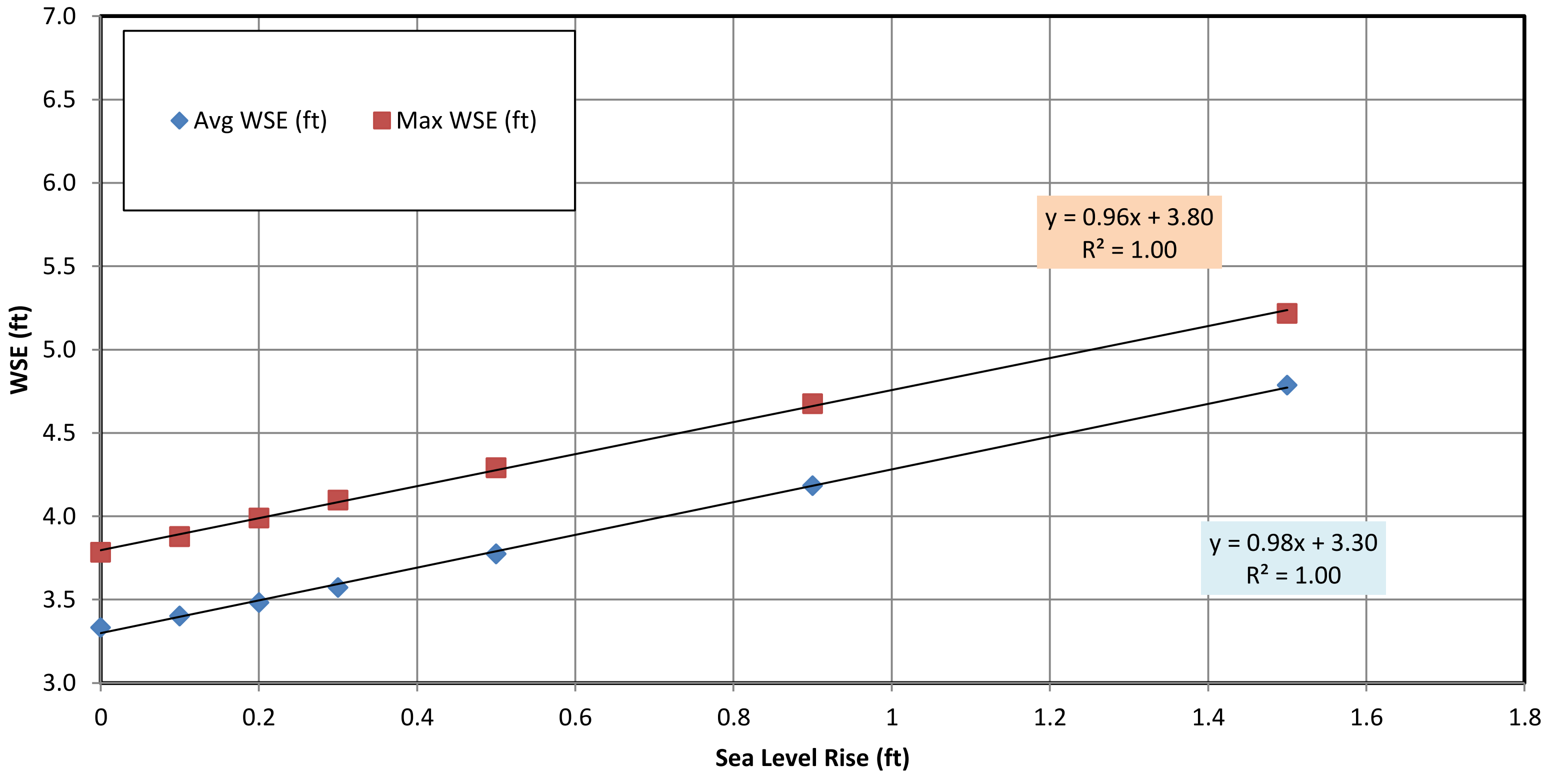
Skagit County, WA

SEA LEVEL RISE DISTRIBUTION

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-3



Fir Island Farm Estuary Restoration

Skagit County, WA

WITHOUT PROJECT
SEA LEVEL RISE (ONLY)
POND (WSE) OUTPUT VALUES

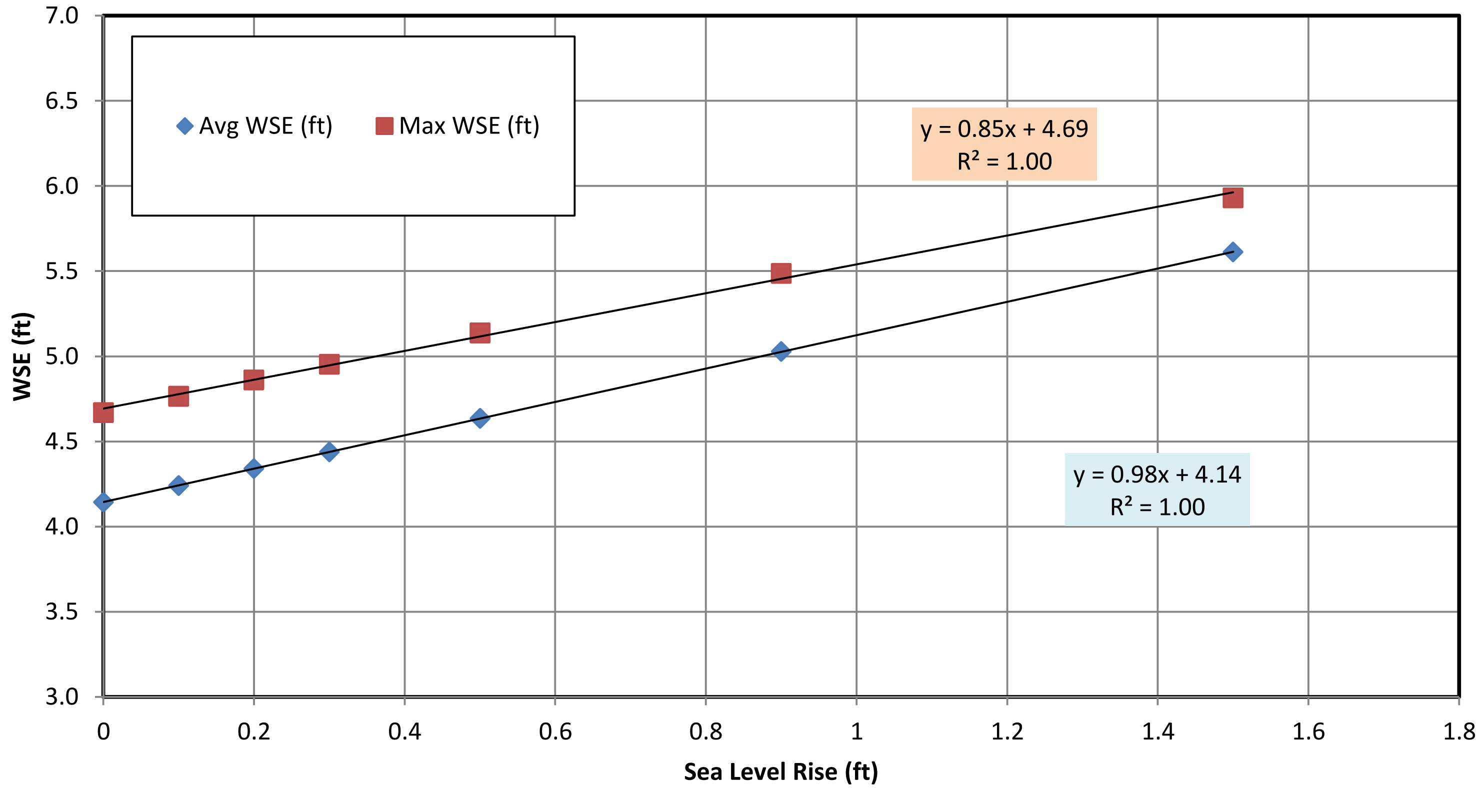
November 2014 | 21-1-12318-216

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-4

Fig. D-4

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D4.WO-SLR_OUTPUT>



Fir Island Farm Estuary Restoration

Skagit County, WA

PROJECT SEA LEVEL RISE + HYDRODYNAMIC EFFECT POND (WSE) OUTPUT VALUES

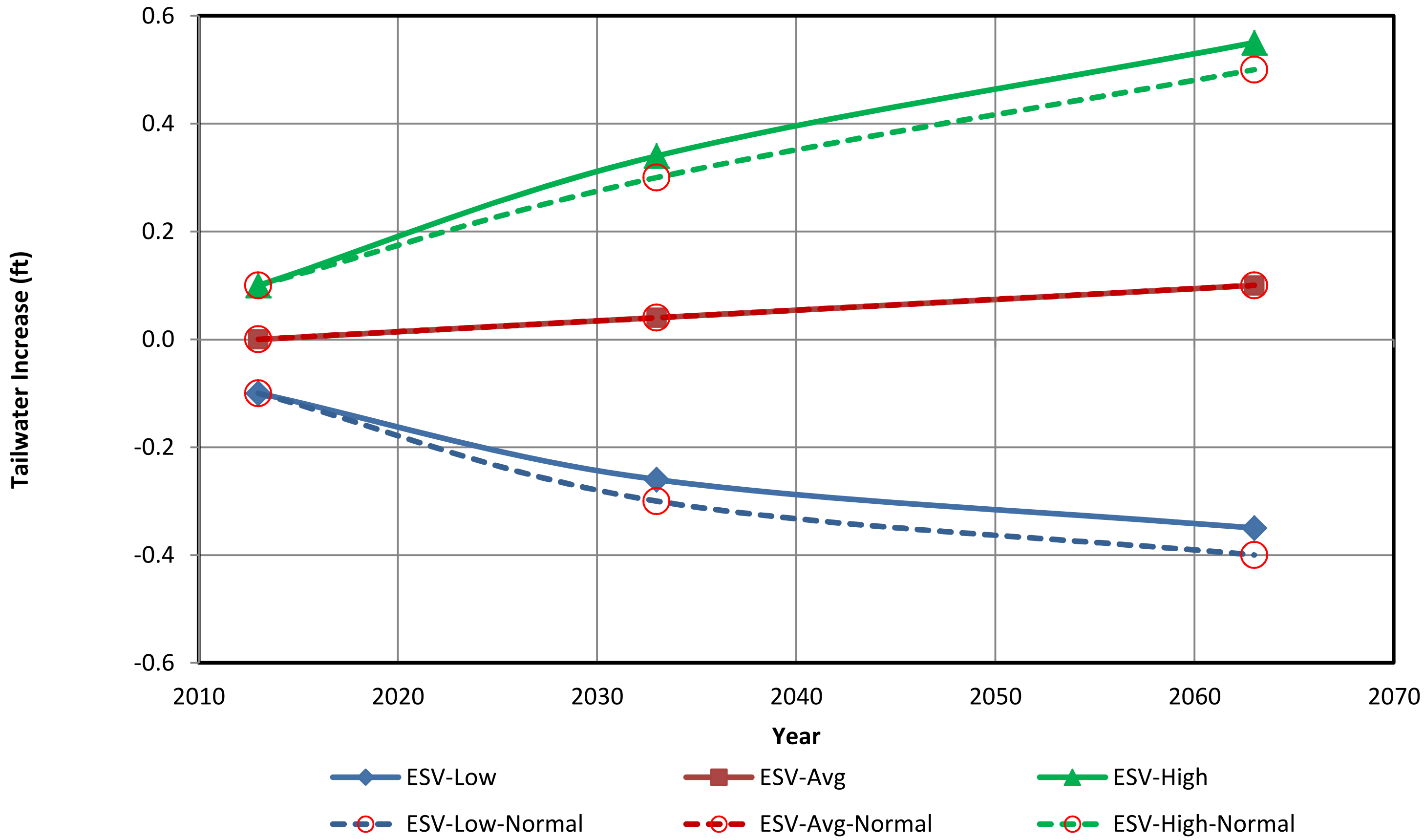
November 2014 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-5

Fig. D-5

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D5.PROJ-SLR_OUTPUT>



ESV = Erosion, Sedimentation, Vegetation

Fir Island Farm Estuary Restoration

Skagit County, WA

PROJECT EROSION-SEDIMENTATION-VEGETATION INPUT VALUES MANUAL CURVE FIT

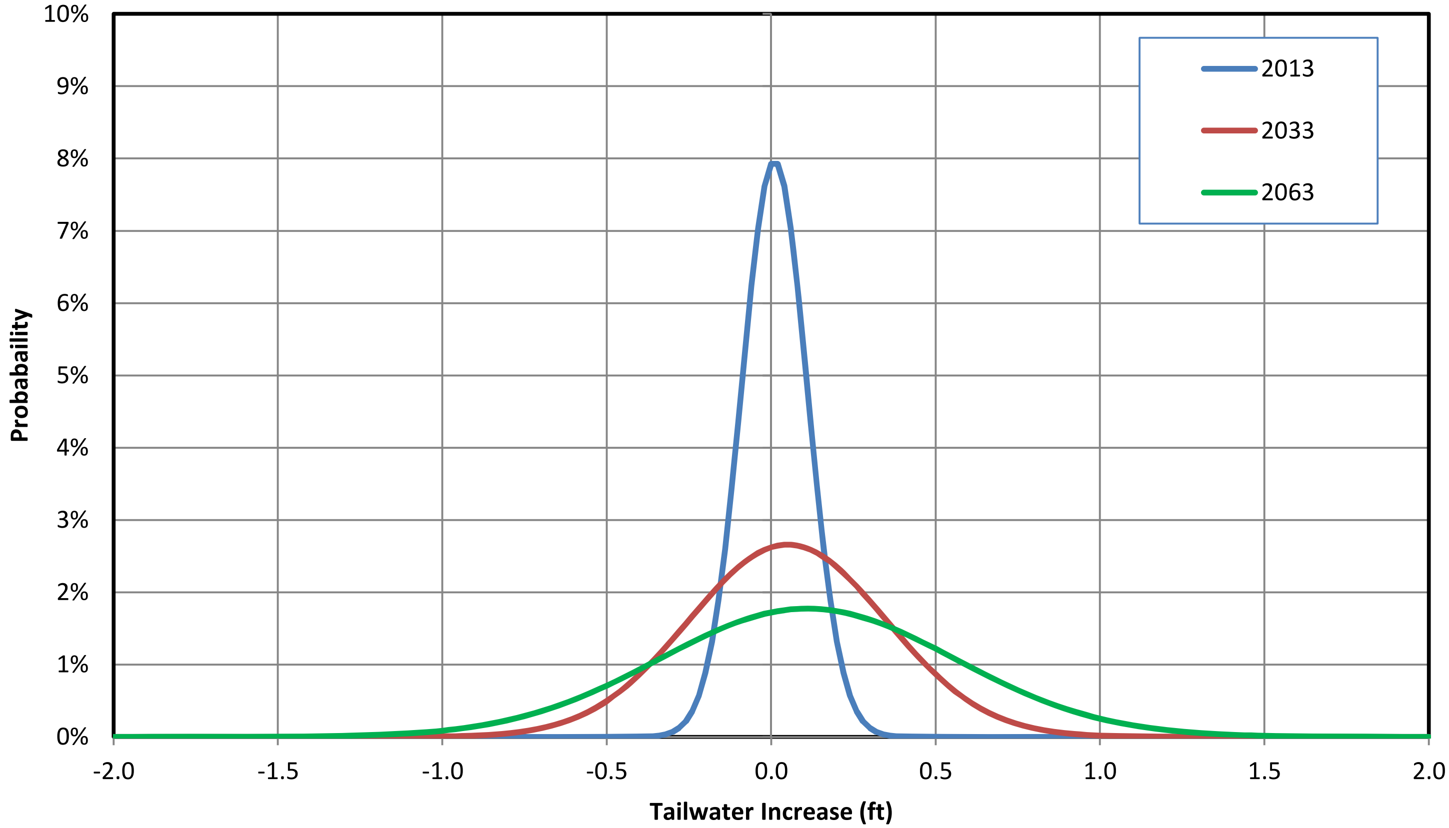
November 2014 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-6

Fig. D-6

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D6.PROJ_ESV_LN-FIT>



Fir Island Farm Estuary Restoration

Skagit County, WA

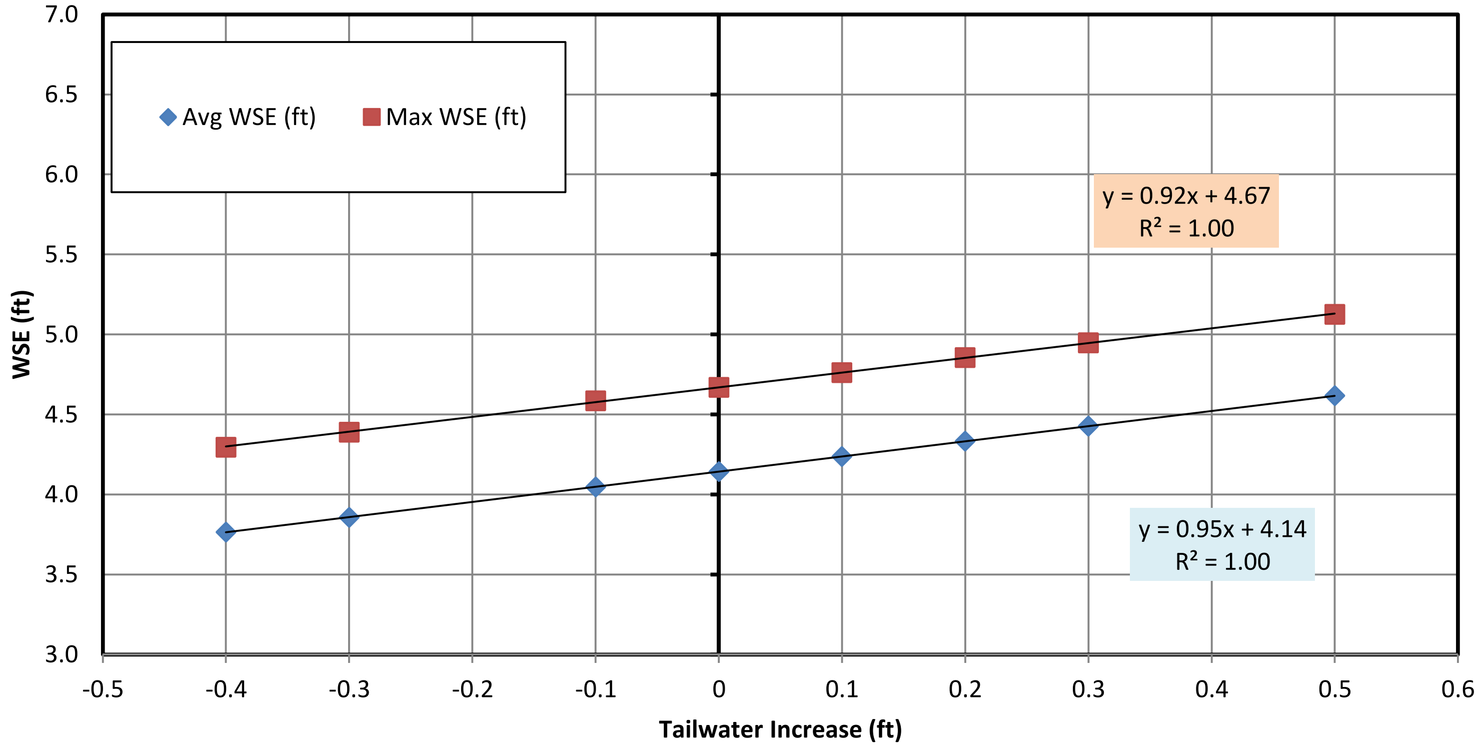
PROJECT EROSION-SEDIMENTATION-VEGETATION DISTRIBUTION

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-7

Fig. D-7



Fir Island Farm Estuary Restoration

Skagit County, WA

PROJECT EROSION-SEDIMENTATION-VEGETATION POND (WSE) OUTPUT VALUES

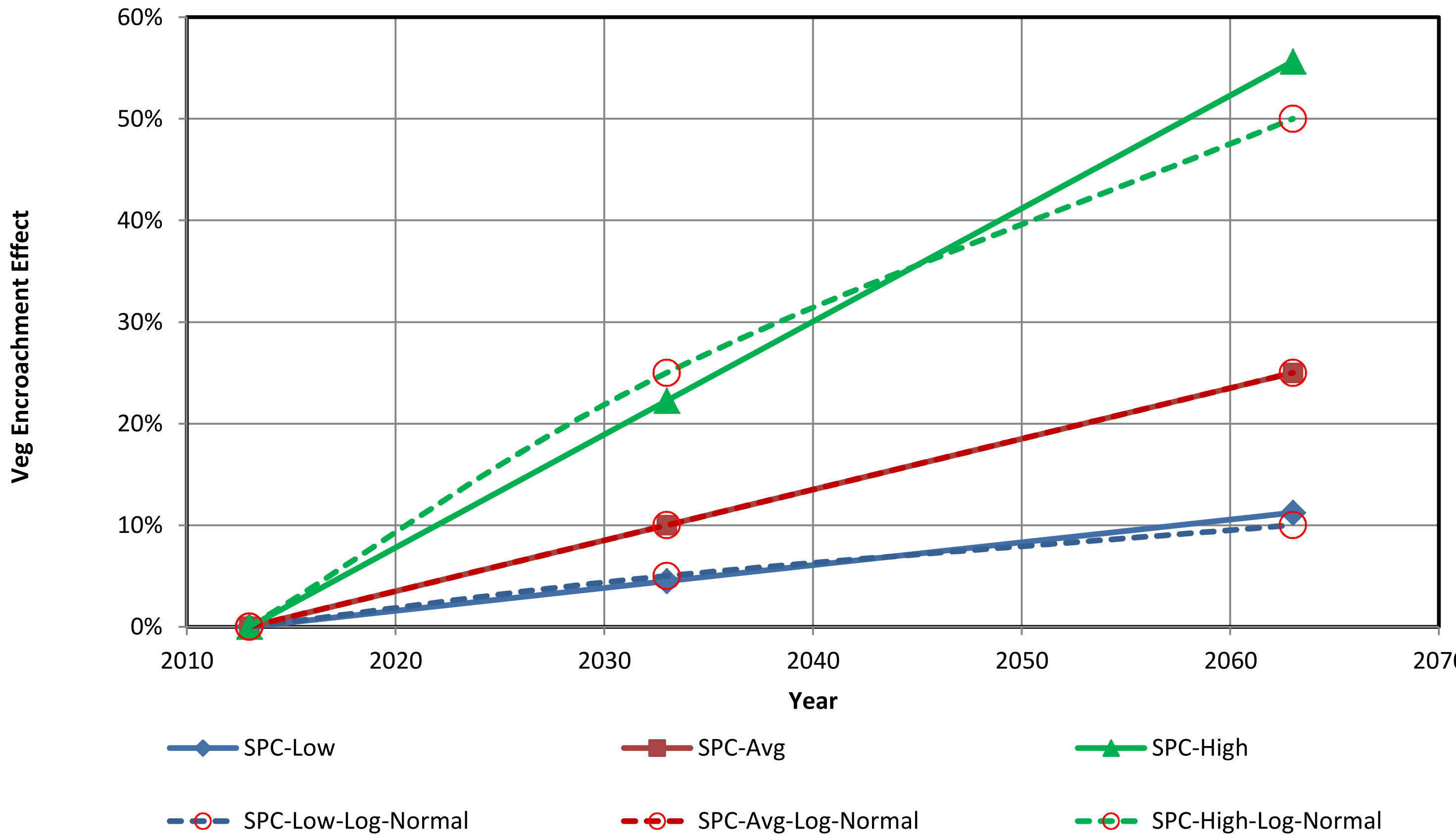
November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-8

Fig. D-8

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D8.PROJ_ESV_OUTPUT>

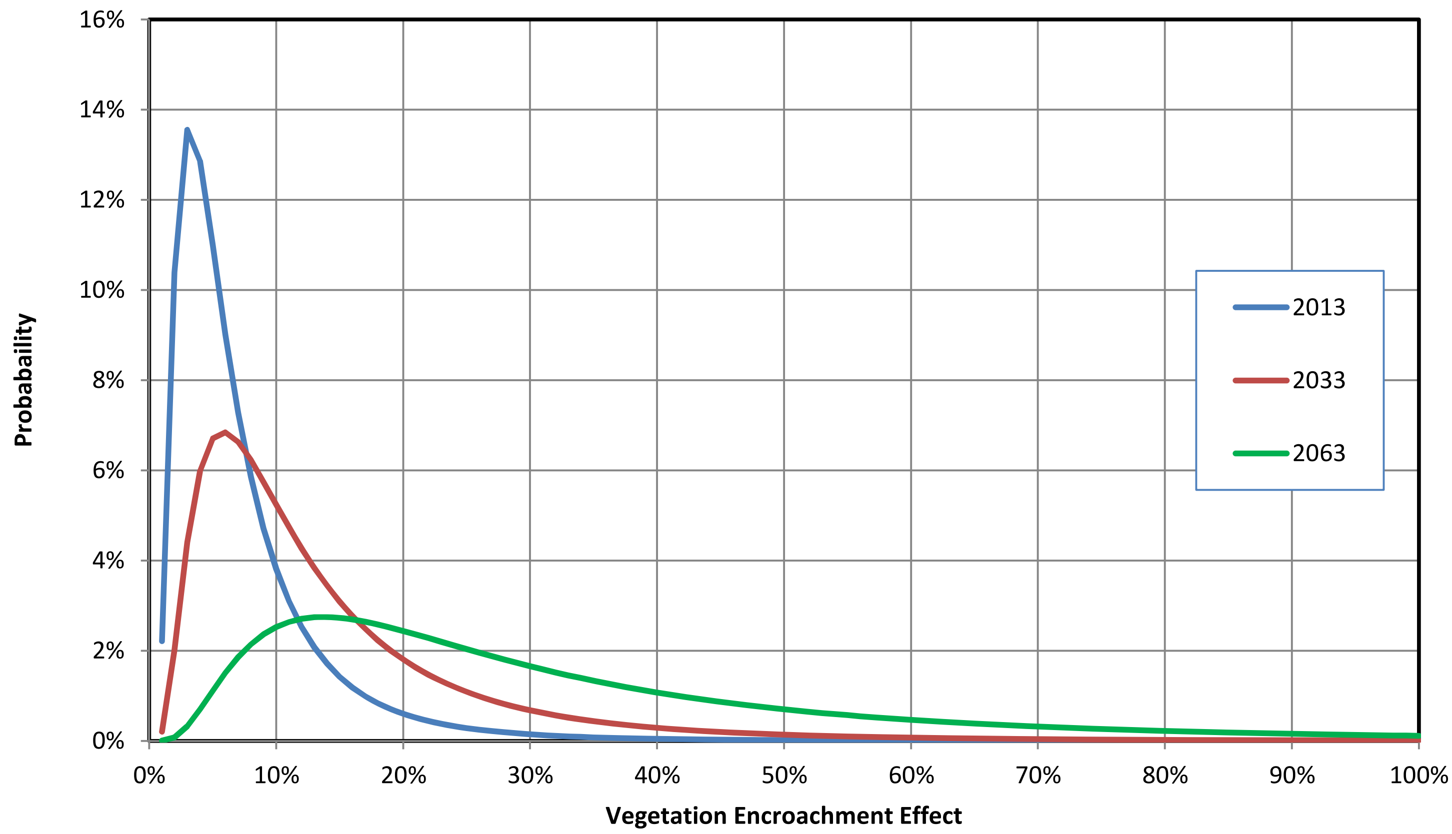


SPC = Storage Pond Capacity

Fig. D-9

Fir Island Farm Estuary Restoration Skagit County, WA	
PROJECT STORAGE POND CAPACITY INPUT VALUES LOG-NORMAL CURVE FIT	
November 2014	21-1-12318-216
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	**Fig. D-9**

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D9.SPC_LN-FIT>



Fir Island Farm Estuary Restoration

Skagit County, WA

PROJECT STORAGE POND CAPACITY DISTRIBUTION

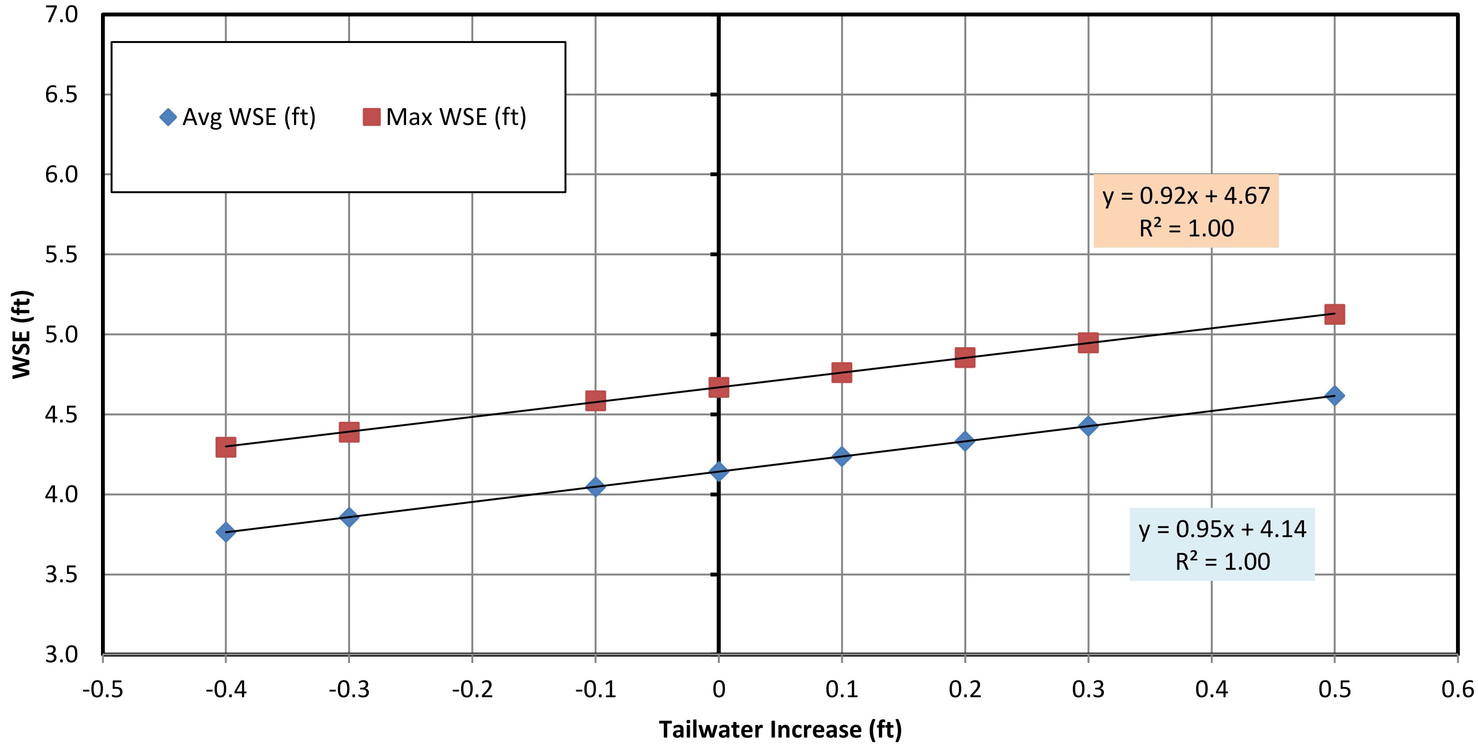
November 2014 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-10

Fig. D-10

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D10.SPC_LN-DIST>



Fir Island Farm Estuary Restoration

Skagit County, WA

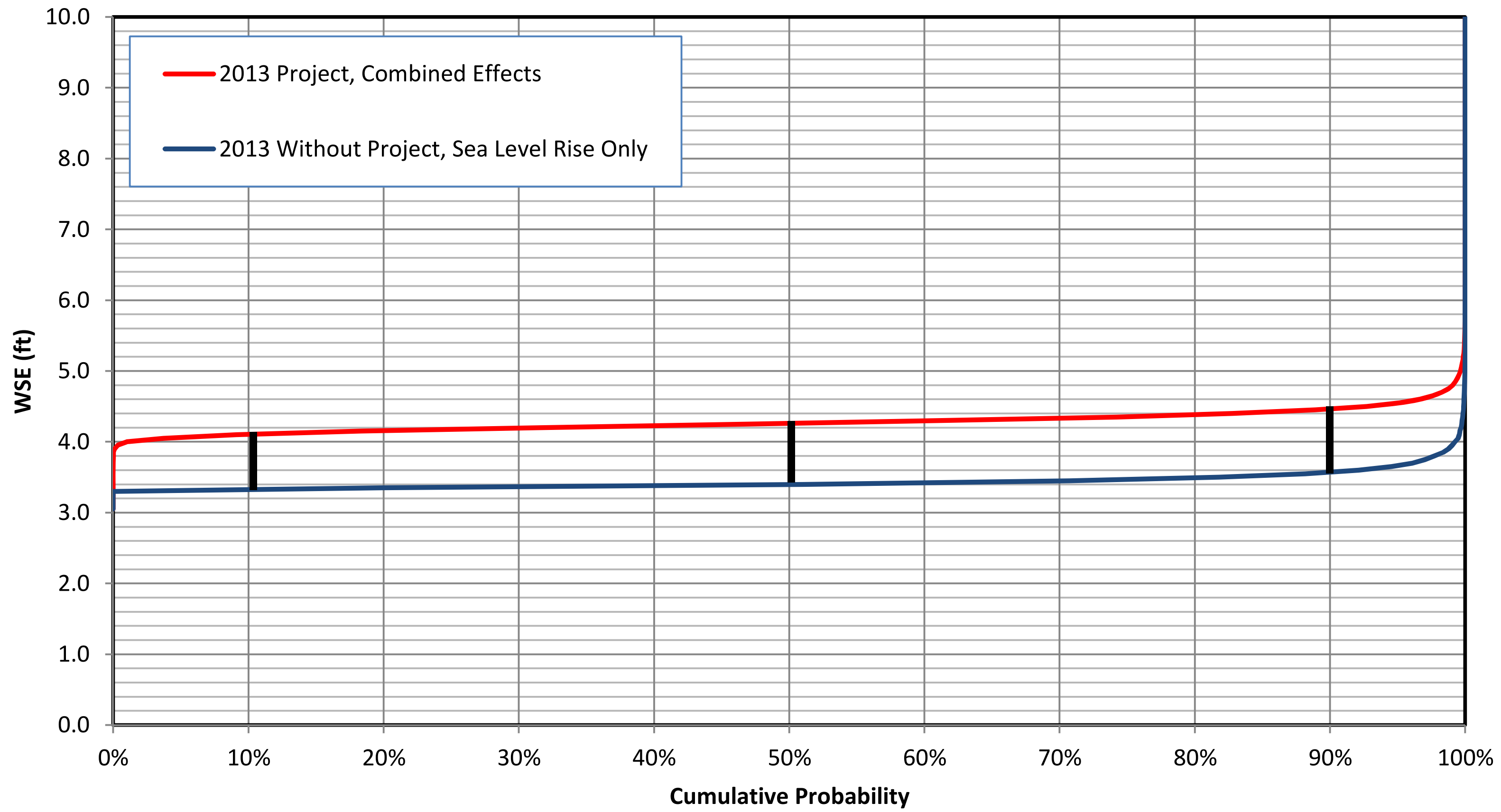
PROJECT
STORAGE POND CAPACITY
POND (WSE) OUTPUT VALUES

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-11

Fig. D-11



Fir Island Farm Estuary Restoration

Skagit County, WA

MONTE CARLO
2013 CUMULATIVE
DISTRIBUTION FUNCTION

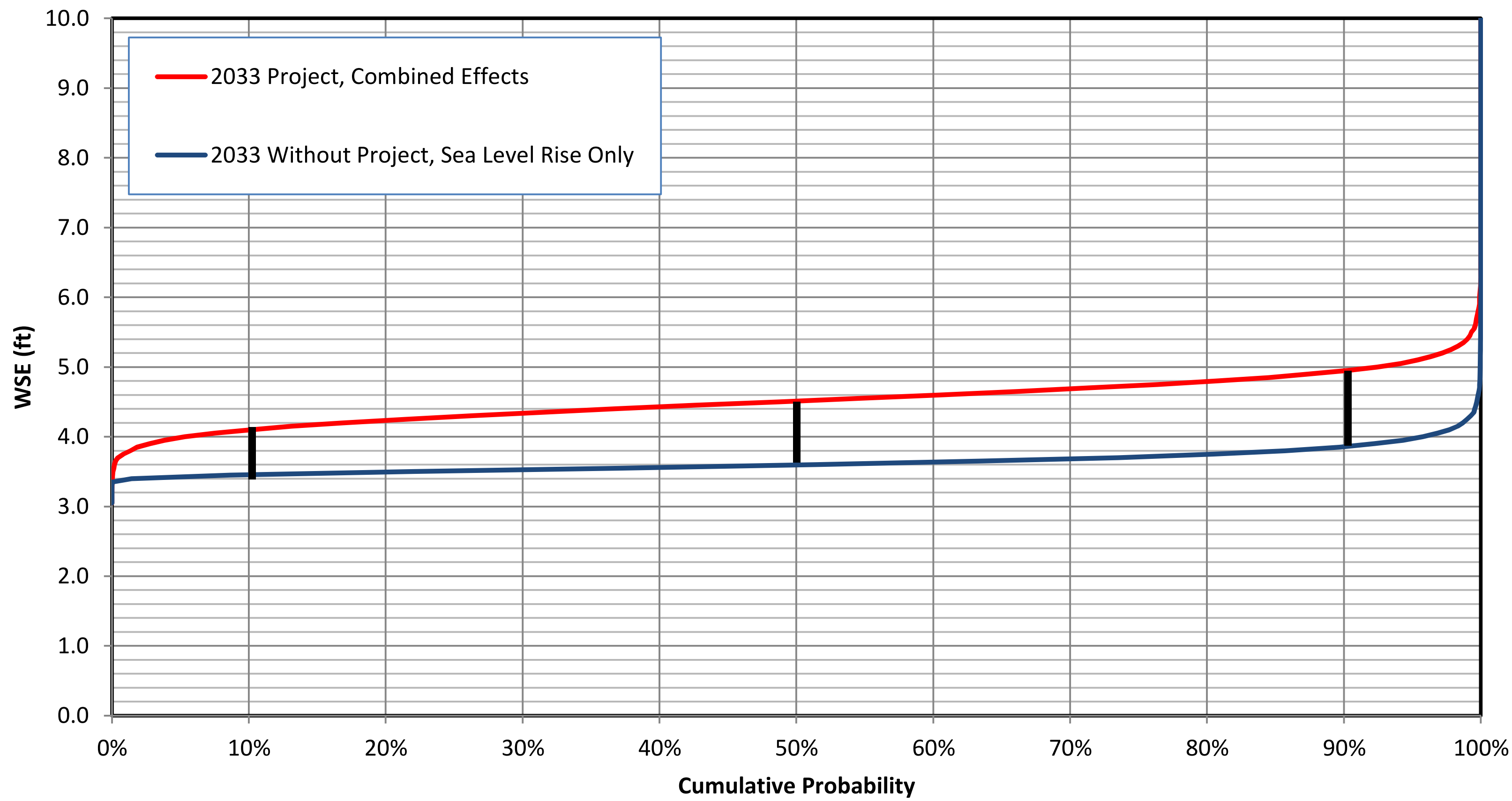
November 2014 | 21-1-12318-216

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-12

Fig. D-12

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D12.2013-MC>



Fir Island Farm Estuary Restoration

Skagit County, WA

**MONTE CARLO
2033 CUMULATIVE
DISTRIBUTION FUNCTION**

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-13

Fig. D-13

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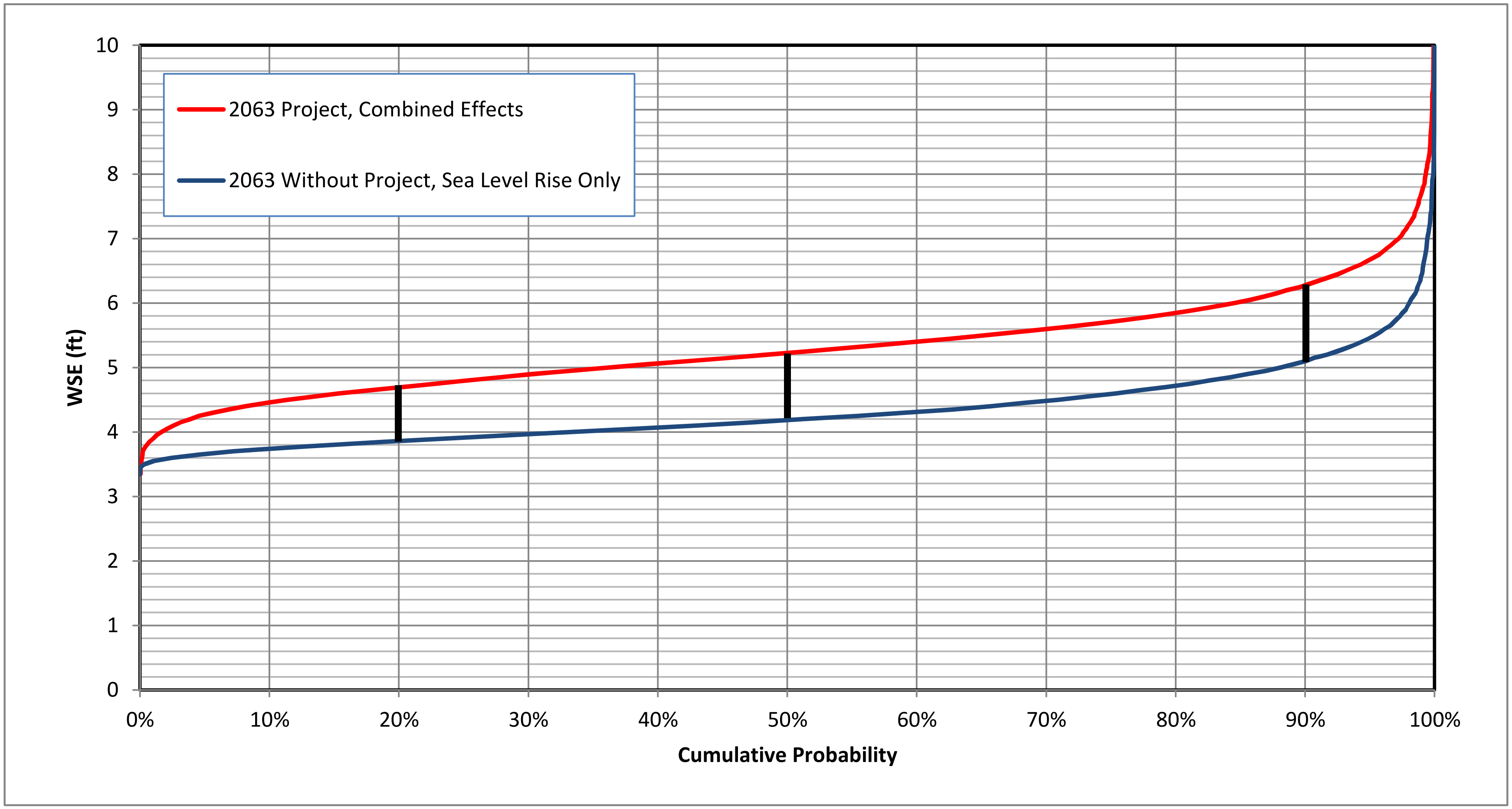

Fir Island Farm Estuary Restoration

Skagit County, WA

MONTE CARLO 2063 CUMULATIVE DISTRIBUTION FUNCTION

November 2014 | 21-1-12318-216

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Fig. D-14

Fig. D-14

I:\WIP\21-1\12318 Fir Island\216_GW-INT DRAINAGE\REPORT\1. NATIVE FILES\21-1-12318-216-APP_D\21-1-12318-216-R1-AD_FD1-D14 <FIG-D14.2063-MC>

APPENDIX E

INDEPENDENT TECHNICAL REVIEW COMMENTS

Independent Review Technical Comment Form

Owner	**Washington Department of Fish & Wildlife**
Project	**Fir Island Farm - Estuary Restoration Project, Final Design and Permitting**
Reviewer Name	**Deb Ladd PE, LHg**
Reviewer Firm	**Golder Associates**
Reviewer Email	dladd@golder.com
Reviewer Phone	425 883 0777 (office) or 206 914 7825 (cell)
Date of Review:	10-Apr-14

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
1	Draft Interior Drainage Engineering Report, February 26, 2014	Limitations	D. Ladd	Golder's review focus was on hydrogeological aspects of the report. However, review of other sections of the report and appendices was needed to understand the hydrogeological aspects of the report. We did not review other portions of the report in detail.	N/A	N/A	N/A
2	Draft Interior Drainage Engineering Report, February 26, 2014	Overall	D. Ladd	The report presents several different technical disciplines and evaluations. It would be helpful to note if any particular discipline/evaluation is more sensitive to predicting project impacts than others are.	DRC	Provided some additional explanations regarding sources and scale of sensitivity.	
3	Draft Interior Drainage Engineering Report, February 26, 2014	Overall	D. Ladd	Clearer statement of purpose and conclusions would be very helpful to the reader. It is difficult to determine what the different modeling is being used for. It appears that the overall goal of the study is to determine if there will be detrimental effects from the project on the remaining agricultural land within the diking district. The critical aspect for agriculture appears to be water quantity (groundwater or flooding) and quality (salinity) within the growing zone during critical periods. Conclusions at the end of the report can then speak to the goal and/or note what type of additional studies/evaluations/data are needed to reach a conclusion.	DRC	Provided additional explanation of report study purpose and objectives clarifying analysis of effects on local drainage systems.	
4	Draft Interior Drainage Engineering Report, February 26, 2014	Overall - Seepage Analyses	D. Ladd	It appears that the seepage analyses were done on a steady state basis assuming average observed groundwater conditions. It should be recognized that this assumed condition will need to be re-examined for future geotechnical levee stability analyses.	DRC	Noted. Geotechnical design report will have transient seepage, stability analyses.	
5	Draft Interior Drainage Engineering Report, February 26, 2014	Multiple locations, text and appendices	D. Ladd	The "calculated existing seepage and groundwater inflow condition of 1 cfs (449 gpm)" is mentioned in several locations (pg. 7, Appendix B, Appendix C, possibly other locations). This is reportedly from hydrologic monitoring data for the site (1st paragraph pg. 7 and Section B.1.2). However, we were unable to confirm any details about this calculation or estimate. Because this value appears to be used repeatedly, it should have more complete background or explanation for the procedures used to determine if the value. It would also be helpful to more clearly describe how this value is used in the project.	DRC	A backcheck was performed and additional information added to Appendix B describing the range of observed seepage / baseflows to the existing ditch system.	
6	Draft Interior Drainage Engineering Report, February 26, 2014	Section 4 Page 4 (or earlier)	D. Ladd	Please note vertical datum for elevations in text (NAVD88?)	DRC	NAD83 / NAVD88 Project survey datums referenced.	
7	Draft Interior Drainage Engineering Report, February 26, 2014	Section 4 Page 4 (and throughout report)	D. Ladd	Editorial - Wells are variously identified as B-4w-13 (note lowercase w) and B-5W-13 (caps). IDs in text should be consistent with well IDs in data report (cap "W")	DRC	Corrections made.	
8	Draft Interior Drainage Engineering Report, February 26, 2014	Section 4 Pages 4 - 5	D. Ladd	In bulleted list it would be helpful to note which shallow wells were dry and (in that case) that the average groundwater level is based on deep well only.	DRC	B-5W-13 was the only well to go dry. This is noted in the text.	
9	Draft Interior Drainage Engineering Report, February 26, 2014	Section 3 Pages 3 - 4	D. Ladd	It would be helpful to provide a statement about groundwater use in the area, e.g., are there any domestic or agricultural groundwater users? If so, are there any concerns for impacts.	DRC	Well logs were reviewed from the Ecology website and the Washington State Dept. of Health, Wellhead Protection Area maps were reviewed. Groundwater uses are for crop and farm irrigation. No drinking water resoureces were identified near the project vicinity. Added language to main body of report to this effect.	
10	Draft Interior Drainage Engineering Report, February 26, 2014	Section 4 Page 5	D. Ladd	It would be helpful to note how groundwater elevations compare to slough elevations (or to reference appendices if the information is contained there).	DRC	Statement added to text comparing groundwater elevation to surface water elevations. For areas further interior to the dikes, the groundwater elevation was ~0.4ft to 0.6ft lower than the ditch surface water elevation. Near the dike in the Hayton Field, the groundwater elevation and surface water average elevations were nearly equal, no difference in elevation.	

Independent Review Technical Comment Form

Owner	**Washington Department of Fish & Wildlife**						
Project	**Fir Island Farm - Estuary Restoration Project, Final Design and Permitting**						
Reviewer Name	**Deb Ladd PE, LHg**						
Reviewer Firm	**Golder Associates**						
Reviewer Email	dladd@golder.com						
Reviewer Phone	425 883 0777 (office) or 206 914 7825 (cell)						
Date of Review:	10-Apr-14						
No.	**Report Name**	**Report Section, Page, Paragraph**	**Reviewer**	**Reviewer Comment**	**Responder**	**Responder Response**	**ITR Backcheck Complete**
11	Draft Interior Drainage Engineering Report, February 26, 2014	Section 4 (end) Page 6	D. Ladd	It would be helpful to provide or forward reference information about "critical root zone elevations" when first mentioned.	DRC	Moved root zone criteria descriptions forward to first mention of critical root zones.	
12	Draft Interior Drainage Engineering Report, February 26, 2014	Section 5 Page 6 bullet list	D. Ladd	It is not clear from this list what items are from model vs from other evaluations. Bullet 2 it is not clear what this estimate is and how it was done. Bullet 3 appears to represent all SEEP/W modeling - it would be helpful to state this if true.	DRC	Added description of numerical modeling vs. data based hydraulic conductivity estimates.	
13	Draft Interior Drainage Engineering Report, February 26, 2014	Section 5 Page 6	D. Ladd	Last paragraph summarizes modeling results. The stated 91 to 232 gpm can be found directly in Table B-4. It would be helpful to include the length of levee system that is incorporated into this value. , but the proposed conditions range (62 to 120 gpm) can be directly linked to a result. Additional information should be provided here or in Appendix B to explain this result. - It would also be helpful to provide rates in cfs for consistency across the report.	DRC	Added levee lengths and referenced "combined" flow rate estimate which can be correlated to Table B-4.	
14	Draft Interior Drainage Engineering Report, February 26, 2014	Section 4 Page 7, 1st paragraph and 2nd paragraph	D. Ladd	The "calculated existing seepage and groundwater inflow condition of 1 cfs (449 gpm)" is mentioned here. See comment 3.	DRC	Added reference to Appendix C, which discusses analysis of surface water data for estimating seepage inflows.	
15	Draft Interior Drainage Engineering Report, February 26, 2014	Section 6 Page 9	D. Ladd	Groundwater inflows are apparently used in the mass balance model. However, the basis of groundwater inflows is not clearly stated here or in Appendix D.	DRC	The basis of the recommended groundwater inflows is the surface water monitoring data at the project, and has been edited in the report.	
16	Draft Interior Drainage Engineering Report, February 26, 2014	Section 7 Page 10	D. Ladd	Sensitivity analysis appears to be for surface water components only. This should be stated.	DRC	Added comment reflecting that seepage sensitivity analyses were not perform as part of Appendix D sensitivity analysis.	
17	Draft Interior Drainage Engineering Report, February 26, 2014	Section 7 Page 13 Last bullet	D. Ladd	Based on information presented in the report and the appendices it is difficult to assess what is the cause or basis of uncertainty in seepage estimates. It would be helpful to present a discussion of uncertainty in Appendix B and discuss what data or evaluations would help to reduce the uncertainty.	DRC	Same as previous comment. Additional description provided discussing sensitivity analysis and seepage.	
18	Draft Interior Drainage Engineering Report, February 26, 2014	Figure 1 Project Site Plan	D. Ladd	Would be helpful to more clearly identify "Dry Slough" (text appears faded). Also McDonald Slough is not obviously identified.	DRC	Corrections made.	
19	Draft Interior Drainage Engineering Report, February 26, 2014	Appendix B	D. Ladd	Overall it is very time consuming to confirm the modeling layout, assumptions, inputs, etc. in part because of inconsistent labeling. Given that the diking district (CDD22) has questioned the seepage rates, clarity of presentation is important.	DRC	Revised labeling on Figures B-2 through B-11 to use consistent terminology.	
20	Draft Interior Drainage Engineering Report, February 26, 2014	Appendix B, B-1 Page B-1	D. Ladd	Editorial - Wells are variously identified as B-4w-13 (note lowercase w) and B-5W-13 (caps). IDs in text should be consistent with well IDs in data report (cap "W")	DRC	Corrections made.	
21	Draft Interior Drainage Engineering Report, February 26, 2014	Appendix B, B-1 Page B-2	D. Ladd	Suggest deleting the 2nd paragraph that notes that the authors interpret the aquifer has an under damped response. The 3rd paragraph then says that the Bower-Rice results better match site data. (Also see comment on S&W 2013 data report.)	DRC	Removed reference to interpretationo of under-damped system.	
22	Draft Interior Drainage Engineering Report, February 26, 2014	Appendix B, B-1 Page B-2 Section B.1.2	D. Ladd	It is not clear where the seepage inflows provided (1 cfs/449 gpm) were determined from o how they relate to later modeling efforts. (see also comment 3)	DRC	See previous response item 5.	
23	Draft Interior Drainage Engineering Report, February 26, 2014	Appendix B, B-1 Page B-3	D. Ladd	The existing conditions (Zone 1) and future conditions (Zones 2 and 3) should be clearly noted in the bullets by "Existing" and "Planned" or similar. It would also be helpful to clearly identify where model sections are located (see comments on Figure B-1).	DRC	Labeled bullets with (Existing) and (Proposed) conditions. Added typical sections to Figure B-1 with note that they represent entire section of levee and are "representative" and not a section specifically cut at that location.	

Independent Review Technical Comment Form

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Project	**Fir Island Farm - Estuary Restoration Project, Final Design and Permitting**
Reviewer Name	**Deb Ladd PE, LHg**
Reviewer Firm	**Golder Associates**
Reviewer Email	dladd@golder.com
Reviewer Phone	425 883 0777 (office) or 206 914 7825 (cell)
Date of Review:	10-Apr-14

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
24	Draft Interior Drainage Engineering Report, February 26, 2014	Section B.2.4, Page B-5	D. Ladd	It would be helpful to identify show the modeled 'sections' on Figure B-1. It would also be helpful to reference a table (Table B-4?) in the discussion.	DRC	Modeled typical sections shown on Figure B-1.	
25	Draft Interior Drainage Engineering Report, February 26, 2014	Section B.2.5 Page B-5 Bullets	D. Ladd	We could not verify the numbers stated in the first bullet and it is not clear if these numbers are directly related to the information in the subsequent bullets. 2nd and 3rd bullet information is contained in Table B-4.	DRC	Bullets revised and more clearly present the seepage estimates in Table B-4.	
26	Draft Interior Drainage Engineering Report, February 26, 2014	Section B.2.5, Page B-5	D. Ladd	The final model results shown on the Figures (B-8, 9, 10) in cfs/ unit length are not clearly correlated to the text because of changing units to gpm. It would be helpful to reference the reader to Table B-4 and the assumed lengths of levees.	DRC	Figures changed to show seepage rates in similar units to Table B-4.	
27	Draft Interior Drainage Engineering Report, February 26, 2014	Appendix B, B-1 Page B-3 and Figure B-1	D. Ladd	The identified zones are not clear on Figure B-1. Locations of modeled cross sections would be very helpful.	DRC	Revised Figure B-1 and included typical sections.	
28	Draft Interior Drainage Engineering Report, February 26, 2014	Table B-2	D. Ladd	Color coding for k not explained (geological units?) Would be helpful to include geological unit in table (or add same color coding to Table B-also with explanation) The slug test data is summarized using GeoMean rather than just an average. Please explain why a geomean is not used for the k values from gradation analyses.	DRC	Color coding indicates soil unit. Color coding noted on Table B-3.	
29	Draft Interior Drainage Engineering Report, February 26, 2014	Table B-3	D. Ladd	- Table should note which values are 'assumed' (e.g., Kz/Kh, porosity) - Add notes indicating source of k values. It appears that some are from averages of sieve analysis ad k correlations and some from Geomean of slug tests. - It is not clear why "k" values from slug tests are not used where available. - The line item for slug test data should be clearly identified as the Geomean of multiple tests. - It is not clear how the max and min k values used in SEEP/W modeling were determined from the data.	DRC	Calculated and assumed values noted. K values from slug tests were averaged with grain size estimates. Geomean vs. mean will not significantly affect the hydraulic conductivity estimates.	
30	Draft Interior Drainage Engineering Report, February 26, 2014	Table B-4	D. Ladd	- How was k of levee construction materials determined for seepage models? - Need to clearly state what parameters are inputs and which are outputs (input = all columns thru water levels) - Why are Kz/Kh values different than in Table B-3? - The seepage analysis model inputs vary by location (existing, north, east). Is there reliable data to show that the conditions vary between these locations? (the variation between locations appears to be less than the variation between samples; it would be simpler to use a single set of inputs). - k values used as model inputs in Table B-4 should be readily supported by data in other tables such as Table B-3. There are many cases where the max or min values (or both) are not directly supported by data. For these cases, justification of the choice of model parameters should be provided in the table (or elsewhere). Specifically- support choice of k values for dike fill (and difference in modeled sections); Hm - some values can be justified from Table B-3, many not; Ha values can be justified from Table B-3 but there is no explanation as to why gradation results are considered appropriate for a "low" k value and slug tests results for the "high" k value; He - cannot determine how "low" and "high" k values were selected.	DRC	1. K of levee materials is based on hydraulic conductivity measurements on similar materials for other levee projects. 2. Inputs and outputs labeled. 3. Kz/Kh ratio was modified to estimate high conductivities for sensitivity analysis. 4. The variability of the seepage analysis model inputs is not significantly different (See new table B-5 with K estimates and model values). The max/min are supported by the data and more clearly shown in Table B-5.	

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Date of Review:	10-Apr-14

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
31	Draft Interior Drainage Engineering Report, February 26, 2014	Appendix B, B-1 Page B-3 and Figure B-1	D. Ladd	- The cross sections (A-A', B-B', C-C') are not referenced in the Appendix and should not be shown on this figure. - It would be helpful to add the locations of the modeled sections (Figs B-2, B-3, B-4) to this figure. - The identified zones are not clear on Figure B-1.	DRC	Figure B-1 is updated showing the typical sections.	
32	Draft Interior Drainage Engineering Report, February 26, 2014	Figures B-2, B-3, B-4	D. Ladd	- The locations of the sections (even if 'typical') should be shown on Figure B-1 - Figure labels should include the "Zone" (or section ID) to help the reader locate the model section. - Acronyms should be explained (e.g. WSE, NNS). (Similar for B-5 through B-10.) - All figures should have similar titles so that the reader can compare the generalized section, to the model sections, and model results. - All units should be clearly identified (e.g., is flux in cfs per linear ft?)	DRC	Relabeled Figures B-2, B-3, B-4.	
33	Draft Interior Drainage Engineering Report,	Figures B-5, 6, 7 and B-8, 9, 10	D. Ladd	Figures B-5, 6, 7 and B-8, 9, 10 should have similar names as Figures B-2, 3, 4 so reader can clearly match results to locations and conditions.	DRC	Relabeled Figures with similar names.	
34	Draft Interior Drainage Engineering Report, February 26, 2014	Figure B-10	D. Ladd	Appears incorrectly labeled "West Section"	DRC	Relabaled figure with correct East Zone name.	
35	Draft Interior Drainage Engineering Report, February 26, 2014	Figures B-8, B-9, B-10	D. Ladd	Results from these figures should be identified in the text in the same units as shown on the figures (figures apparently show cfs/ linear foot and text uses total gpm for a length of levee).	DRC	Relabeled figure outputs with similar seepage rates as in text using GPM.	

Independent Review Technical Comment Form

Owner	**Washington Department of Fish & Wildlife**
Project	**Fir Island Farm - Estuary Restoration Project, Final Design and Permitting**
Reviewer Name	**Susan Tonkin, PhD, PE**
Reviewer Firm	**Moffatt & Nichol**
Reviewer Email	stonkin@moffattnichol.com
Reviewer Phone	206.622.0222
Date of Review:	10-Feb-14

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
1	Draft Interior Drainage Engineering Report, February 26, 2014	General	Susan Tonkin	I am would like to drill deeper into the results / analysis that went into determining the hydrodynamic tailwater effects. See more detailed comments with the Draft Coastal Engineering report.	N/A	N/A	N/A
2	same	Section 1.0, first paragraph	Susan Tonkin	Editorial: It took me a while to work out that "interior" meant "interior to the levees (wherever they are)", not "interior within the project footprint". Could clarify this up front.	DRC	Description of "drainage areas interior to the levee system" provided in Section 1.0.	
3	same	Section 6.0, page 9, paragraphs 2-3	Susan Tonkin	Editorial: It isn't obvious that you are in fact comparing "with project + SLR" with "without project + SLR" (which is what you should be doing, of course). Please clarify in the text.	DRC	Added tet to Section 6.0 introductory paragraph…"Sea level rise was considered for both "Without Project" and "Project" conditions."	
4	same	Section 8.0, page 12, paragraph 1	Susan Tonkin	Editorial: Same issue as the previous comment. Something like: The primary contributing factor apprears to be the predicted hydrodynamic effects… The effects of this factor relative to the without-project condition are increased when SLR is incorporated.	DRC	Added text and language to clarify the project effects with respect to SLR.	
5	same	Section 8.0, page 12, paragraph 1	Susan Tonkin	Editorial: Maybe say "current project design" rather than "proposed project"?	DRC	Disagree - Proposed Project is a common term used throughout the report.	
6	same	Figure 1	Susan Tonkin	It would be helpful to have a figure that shows existing grades	DRC	Overlaying LIDAR elevations on Figure 1.	
7	Draft Interior Drainage Engineering Report, February 26, 2014. Appendix A: Hydrological Monitoring	Section A.1.2.2, page A-4, paragraph 3	Susan Tonkin	Editorial: Change "nearly 1.0 feet lower" to "nearly 1.0 feet less" - "lower" sounds as though the groundwater surface is lower and it's actually higher. Similarly, the statement "the groundwater gradient is towards Skagit Bay" sounds as though seepage flows towards, not away from, the Bay.	DRC	Revised first comment to use the word "Less". Interior farm area groundwater gradient is towards Skagit Bay. Tidal groundwater gradient is towards the farms, only across the dikes, to the ditches on the backside. Two separate groundwater gradients converge in the ditches.	
8	same	Section A.1.2.2, page A-4, paragraph 3	Susan Tonkin	Observed conductivities in the Hayton South groundwater wells - presumably these are not the same as those observed in wells to the north, since the salinity is so much higher.	DRC	Revised this paragraph to better describe observed groundwater elevations and salinities and comparing Hayton North and Hayton South fields.	
9	same	Figures A-1 to A-9	Susan Tonkin	Editorial: Could you add the field name (Hayton South, etc.) to these figures?	DRC	Field location names added to figures.	
10	same	Figure A-4	Susan Tonkin	The average at B-7 doesn't look like 3.47 - can you check this isn't the B-6 average?	DRC	Confirmed, average is calculated from B-7 data.	
11	same	Figure A-15	Susan Tonkin	Editorial: Could you mention the salinity gauge problems in the note here?	DRC	Data processing error. Corrected with most recent data downloads through Feb. 2014.	
12	same	Figure A-15	Susan Tonkin	Are there plans to replace the NNS-2.0 salinity probe, or do you think you have the information you need?	DRC	Data processing error. Corrected with most recent data downloads through Feb. 2014.	
13	Appendix B. Seepage Analysis	Section B.1.2, page B-2, last paragraph on page	Susan Tonkin	The 1 cfs is a very round number - can you provide a range on this?	DRC	A backcheck was performed and additional information added to Appendix B describing the range of observed seepage / baseflows to the existing ditch system.	

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Owner	**Washington Department of Fish & Wildlife**						
Project	**Fir Island Farm - Estuary Restoration Project, Final Design and Permitting**						
Reviewer Name	**Susan Tonkin, PhD, PE**						
Reviewer Firm	**Moffatt & Nichol**						
Reviewer Email	stonkin@moffattnichol.com						
Reviewer Phone	206.622.0222						
Date of Review:	10-Feb-14						

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
14	same	Section B.1.2, page B-2, last paragraph on page	Susan Tonkin	Editorial: You move back and forth between gpm and cfs a lot, without generally giving both values. Please fix on one and/or provide conversions.	DRC	Provided reference to cfs and gpm for each instance.	
15	same	Section B.1.2, page B-2, last paragraph on page	Susan Tonkin	How do these seepage values compare with typical surface water discharge values within the sloughs?	DRC	1cfs (449gpm) is on the high side of observed maximum baseflows into the system, therefore likely conservative.	
16	same	Section B.1.2, page B-2, last paragraph on page	Susan Tonkin	Editorial: You move back and forth between gpm and cfs a lot, without generally giving both values. Please fix on one and/or	DRC	Provided reference to cfs and gpm for each instance.	
17	same	Figure B-10	Susan Tonkin	Where you say Proposed Pond, is this actually Dry Slough? It seems to be the East Section not the West Section?	DRC	Revised label "Dry Slough"	
18	Draft Interior Drainage Engineering Report, February 26, 2014. Appendix C: Surface Water Modeling	Section C.2.2, page C-4, general	Susan Tonkin	It would be helpful to have a block diagram that shows how the different parts of the modeling work together (including where the seepage analysis fits in). I was originally confused as to where exactly you were going with the seepage modeling	DRC	Modeling schematic C-1 has been included in the report.	
19	same	Section C.2.1, page C-5, fourth paragraph on page	Susan Tonkin	Has the 10 percent criterion been vetted by the farmers or other associated stakeholders?	DRC	No, but report has been provided to CDD22. Additional discussion regarding distance of seepage migration based on upper soil layer hydraulic conductivity properties. 10%, 3 days, is likely less than 1ft of seepage front migration from the pond margin.	
20	same	Table C-4	Susan Tonkin	It looks as though this pretty much feeds through the hydrodynamic tailwater effect. Is this right?	DRC	Yes, correct. Some influence from SLR, ESV, SPC, but tidal hydrodynamic tailwater effect dominates.	
21	same	Figure C-1	Susan Tonkin	This seems to assume the marsh will build up in step with the SLR i.e., it will not be drowned. Do you expect this to be the case? Otherwise I would expect the low (muted) elevation to stay more constant.	DRC	It is uncertain whether the marsh accretion will keep pace with SLR or not.	
22	Draft Interior Drainage Engineering Report, February 26, 2014. Appendix D: Sensitivity Analysis	General	Susan Tonkin	Given CDD22's questions about the seepage rates, can you do a sensitivity analysis that investigates changes in these rates?	DRC	See comment responses for Appendix B, in Golder comments.	
23							

Independent Review Technical Comment Form

Owner	**Washington Department of Fish & Wildlife**						
Project	**Restoration Project, Final**						
Reviewer Name	**Deb Ladd, PE, LHg**						
Reviewer Firm	**Golder Associates Inc**						
Reviewer Email	dladd@golder .com						
Reviewer Phone	425-883-0777						
Date of Review:	22-May-14						
No.	**Report Name**	**Report Section, Page, Paragraph**	**Reviewer**	**Reviewer Comment**	**Responder**	**Responder Response**	**ITR Backcheck Complete**
1	Draft Interior Drainage Engineering Report 30 April 2014		DL	Overall - the report provides much better information about the overall project as compared to previous reports. The figures showing field 'names' are helpful. The use of these field names when discussing project impacts could improve the usefulness of the report. (as an example, when discussing project impacts by acreage, which areas are most effected.)	DRC	Added text describing farm fields and areas when discussing project effects and impacts.	
2	Draft Interior Drainage Engineering Report 30 April 2014		DL	Criteria for root zone is well explained. It appears that the focus is on not exceeding a certain pond (thus groundwater elevation) more than 10% more of the time. Has the converse been modeled? (or examine qualitatively) E.g., Are pond/predicted gw levels lower than needed for crop growth?	DRC	Have not modeled it, but it can be controled. Farmers stop log Tide Gates and check up slough flow to use the ponded volume for irrigation. The project won't be draining any more water than existing, so irrigation should be feasible.	
3	Draft Interior Drainage Engineering Report 30 April 2014	Section 6, page 8, last 2 paragraphs	DL	It would be helpful to provide geomean k values for the slug test results to match the soil sample results (such as last sentences from B.2.1). It would be helpful to close this section with the identification of k values that were used in modeling and to reference appendix tables.	DRC	Added slug test geomean seepage rates from Appendix B.2.	
4	Draft Interior Drainage Engineering Report 30 April 2014	Section 6, page 10, 3rd paragraph	DL	Text notes a "recommended seepage rates to No Name Slough". It would be helpful to clarify what "recommended" means - is it a design goal to achieve or not to exceed?	DRC	Replaced with "The selected seepage rate for modeling seepage effects to the No Name Slough interior drainage pond is based on theuses the seepage rates calculated existing seepage and groundwater inflowobserved surface and groundwater monitoring data average of condition of 1 cfs (450 gpm)."	
5	Draft Interior Drainage Engineering Report 30 April 2014	Section 7, page 12 next to last paragraph discussion.	DL	The discussion about the additional acres of "impacts" (106 - 319 acres) is confusing when compared to the discussion about percent of time the root zone is affected in Section 5. Is it possible to add additional information here to put these statements in context?	DRC	Revised discussion to more clearly state additional "project" effects on WDFW field and No Name Slough basin.	
6	Draft Interior Drainage Engineering Report 30 April 2014	Conclusions	DL	It is not clear what the relative importance of seepage (groundwater and thru dike seepage) is as compared to surface water effects. Can conclusions be reached about the relative importance? That would help put issues in context such as the request to consider seepage cutoff systems.	DRC	Added section at the end of Section 6 that describes tidal and flood seepage conditions and the percentage of flows, which is low or small in scale compared to surface water flood runoff events, but larger percentage for daily tidal seepage inflows through and under the dike system.	
7	Draft Interior Drainage Engineering Report 30 April 2014	Conclusions / Appendix A	DL	Page A-4 mentions a 'wet field' and 'marginal' condition for the Hayton South field. Page A-5 also recognizes this area for potential impacts. Have the potential effects on this area been examined closely? It is possible that the ability to predict changes in marginal conditions is limited (due to data limitations and modeling limitations). Depending on the landowner's expectations, this could be a higher risk area for the project.	DRC/Stan	The field is usually very wet, and considered marginal and at times unfarmable in current conditions. The project recommends additional tidegates to accommodate additional seepage flows in Dry Slough from the project. It is difficult to say if the project is higher risk to already existing marginal land, or higher risk to high quality farm areas further upgradient.	

Independent Review Technical Comment Form

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Project	**Restoration Project, Final**						
Reviewer Name	**Deb Ladd, PE, LHg**						
Reviewer Firm	**Golder Associates Inc**						
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Reviewer Phone	425-883-0777						
Date of Review:	22-May-14						

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
8	Draft Interior Drainage Engineering Report 30 April 2014	Conclusions / Appendix A	DL	Page A-5 notes that the Dry Slough is used for irrigation. It seems as if most of the modeling and findings discussions for the proposed project and impacts are focused on groundwater and surface water elevations being the same or lower than existing conditions. Are there effects on Dry Slough that would effect the farmer's ability to pump for irrigation?	DRC	No. Irrigation operations would not likely be impacted as they occur in mid-late summer when the potential for seepage effects is low due to lower groundwater levels later in the growing season.	
9	Draft Interior Drainage Engineering Report 30 April 2014	Appendix B, page B-4, end of B.2.3	DL	Text notes that seepage inflows used for modeling are conservative because they are larger than observed. Is this a conservative case for all conditions ? (e.g., irrigation above)	DRC	Higher seepage rates creates higher surface and groundwater tables that need to be drained through the interior drainage pond, channel and tidegates. Seepage "rates" are highest when the tides are high, and groundwater elevations are low. When irrigation operations occur, the farmers raise the groundwater table and reduce seepage rates and salt-water intrusion. Applying an artifically high seepage rate does not impact the irrigation operations, rather it requires more drainage through the tidegates and pump station.	
10	Draft Interior Drainage Engineering Report 30 April 2014	Appendix B, page B-7, B.3.6	DL	Clarify if results are based on high k or low k modeling? (assume is the same for both existing and proposed project). Appears numbers were rounded slightly - use term "approximately"?	DRC	Figures and results present a range of seepage rates based on low and high soil hydraulic conductivity properties. Provided clarification in text.	
11	Draft Interior Drainage Engineering Report 30 April 2014	Table B-5	DL	It is not clear how or if CPT hydraulic conductivities are used. The data from the CPT seem to have a much larger range in values as compared to other data and the modeled conditions. Perhaps the CPT data should not be presented or should be better explained why the data are not used.	DRC	CPTs in Table 5 for the Northern and Eastern Zones provide hydraulic conductivity rates ranging from 0.001 to 36.7ft/day for Hm, 0.001 to 145ft/day for Ha, and 0.001 to 0.81ft/day for He). The grain size, slug test, and modeled ranges are 0.08 to 3.6ft/day for Hm, 64 to 192 ft/day for Ha, and 0.1 to 1.92 ft/day for He. Only the Hm CPT value of 36.7ft/day falls outside the grain size, slug test, SEEP-W model values. Sensitivity analysis was performed on the upper soil unit by replacing Hm with Ha sand, for which the project drainage structures and pump station could accomodate the increased seepage flows into the interior drainage system.	

Independent Review Technical Comment Form

Owner	**Washington Department of Fish & Wildlife**						
Project	**Restoration Project, Final**						
Reviewer Name	**Deb Ladd, PE, LHg**						
Reviewer Firm	**Golder Associates Inc**						
Reviewer Email	dladd@golder .com						
Reviewer Phone	425-883-0777						
Date of Review:	22-May-14						
No.	**Report Name**	**Report Section, Page, Paragraph**	**Reviewer**	**Reviewer Comment**	**Responder**	**Responder Response**	**ITR Backcheck Complete**
12	Draft Interior Drainage Engineering Report 30 April 2014	Table B-6	DL	Modeled scenarios refer to Northern Zones 2 and 3 in this table. In Table B-4 zones are Northern Zone 2 and Eastern Zone 3 are these the same? It is very difficult to determine how the "maximum" k modeled conditions results in Table B-6 compare to those presented in Table B-4. In particular, predicted flow rates for existing conditions in the maximum case in Table B-6 are much higher than other model predictions (e.g. 524 gpm for 'existing condition, no cutoff wall, Zone 2). It appears that the k value used for the maximum condition for Hm unit is extremely high. It would probably be more appropriate to present model results for the same k cases as presented for the base models reflected in Table B-4. Or delete the 'Maximum" case presentations inn Table B-6 and just present the "average" results because the maximum results are probably unreasonable and not helpful to the comparisons of the effect of a cutoff wall.	DRC	Yes. These are the same zones. Made corrections to reconcile Tables B-4 and B-6.	
13	Draft Interior Drainage Engineering Report 30 April 2014	Table B-7	DL	Delete the Cost/high gpm? See comments on Table B-6	DRC	Deleted cost / gpm as it did not provide a good comparison cost metric to pump station costs.	
14	Engineering Report 30 April 2014	Figure B-2	DL	Editorial - clarify / name North Zone, East Zone = Zones 2 and 3 if applicable	DRC	Removed references in text to Zones 1, 2 and 3 and only refer to Existing, North and East Zones.	
15	Draft Interior Drainage Engineering Report 30 April 2014	Figure B-8	DL	The hydrogeological units and ground surface appear to have a hump near the slough - is this just a plotting/model artifact?	DRC	Dry slough is actually perched because of spreading of spoils along the slough edges. The elevation along the slough is also from deposited sediment	
16	Draft Interior Drainage Engineering Report 30 April 2014	Figures B-9 through B-11	DL	The posted flux rates are very helpful, but they cannot easily all be correlated with information presented elsewhere. For instance the posted flux of 91 to 232 gpm for existing conditions does not compare to Table B-4 flux rates of 274 to 696 gpm. Similarly the posted flux for the North zone of 16 to 202 gpm does not compare to the 16 to 20 or 14 to 17 gpm in Table B-4. (Are these just typos?)	DRC	Corrected values in Figures, that directly correlate with values in Table B-4.	
17	Draft Interior Drainage Engineering Report 30 April 2014	Figure B-12 though B-23	DL	Related to comments above and previous about modeling with cutoff wall and results from the modeling. Suggest that a clearly defined base case be identified with k values before proceeding to models with cutoff walls. Ideally the base case would be the same as used in previous modeling (e.g., model parameters presented in Table B-4 for low and high k values). An alternative would be to just present modeling based on the average k values used in Table B-6. The maximum k value modeling shown in Table B-6 does not seem reasonable and has alarming results for predicted seepage.	DRC	The minimum and maximum hydraulic conductivity properties used in Table B-6 were derived from Table B-4, and represent values used in previous seepage modeling sections. The seepage cutoff rates shown in Table B-6 are reasonable and directly associated with those in B-4, and fall within the range of seepage esimates used in the storage pond surface water modeling.	

Independent Review Technical Comment Form

Owner	**Washington Department of Fish & Wildlife**
Project	**Estuary Restoration**
Reviewer Name	**Susan Tonkin, PhD, PE**
Reviewer Firm	**Moffatt & Nichol**
Reviewer Email	stonkin@moffattnichol.com
Reviewer Phone	206.622.0222
Date of Review:	29-May-14

No.	Report Name	Report Section, Page, Paragraph	Reviewer	Reviewer Comment	Responder	Responder Response	ITR Backcheck Complete
1	Draft Interior Drainage Engineering Report 30 April 2014	Section 10.0, p.16, second to last para	Susan Tonkin	Editorial: The first sentence seems to be missing a verb.	DRC	Revised sentence: Installation of Aa seepage cutoff wall (barrier) along the setback dike would reduce seepage to the interior drainage system.	
2	same	Section 11.0, p. 17	Susan Tonkin	Editorial: Suggest adding that the third tidegate in Dry Slough is at the downstream end	DRC	Revised sentence: Based on the outcomes from the response study alternatives analysis, we recommend including a third tidegate in Dry Slough at the Skagit Bay (downstream) tidegate outlet, adding two 48-inch tidegates from the interior storage pond to Dry Slough and adding a pump station comprised of three, 3,000-gpm pumps.	
3	same	Sect. A.1.2.2, p.A-4, first two paragraphs and more generally	Susan Tonkin	Semi-Editorial: Please add datum to groundwater elevations, so there isn't any doubt whether you are referring to NAVD88 or below ground surface	DRC	Added NAVD88 refernces to groundwater elevations in Section A.1.2.2.	
4	same	Sect. A.1.2.2, p.A-4, last paragraph	Susan Tonkin	I still don't understand how Hayton North and South conductivities can be the same if the salinities are different	DRC	Salinity values between Hayton North and South presented in A.1.2.2 are different, which is correct. The only reference I could find in Appendix A describes how conductivity measurements are used to calculate practical "salinity" units PSUs. There is no statement that conductivities are the same in Appendix A. Maybe referring to conductivity in other groundwater seepage sections, which refers to hydraulic conductivity, not electrolitic conductivity.	
5	same	Sect. B.3.4, p. B-6, second bullet	Susan Tonkin	Editorial: "No Name Slough No Name Slough"	DRC	Corrected.	
6	same	Sect. B.3.6, p. B-7, last paragraph	Susan Tonkin	Editorial: It is unclear what you are saying about Dry Slough seepage rates. The main document (p. 10) explains it better, and you could copy that explanation over.	DRC	Replaced text.	
7	same	Table C-4	Susan Tonkin	Editorial: Please provide a title for Table C-4.	DRC	Reprinted table with Title.	
8	same	Figure C-4	Susan Tonkin	How much is the third tide gate benefiting? Can we see Dry Slough levels with project but with only the existing gates?	DRC	Revised figure C-4. Third tidegate provides definite decreases in Dry Slough WSEs.	
9	same	Figure C-5	Susan Tonkin	What are the existing conditions in this plot?	DRC	Existing conditions are No Name Slough 2.1 Pre-Pond near the WDFW North Field. Provided clarifying text in data legend.	
10	same	Figure C-5	Susan Tonkin	How much do the tide gates between the pond and Dry Slough benefit the project if there is a pump station present? Could you add the case of pump station and no tide gates? It isn't clear that it gains the project much in terms of water surface elevations; is it more an issue of reducing pumping costs?	DRC	They save the pump about 0.1 feet of head. CDD 22 has requested inclusion of tidegates for operational flexibility of drainage system.	

Date: 6/5/2014						
WDFW FIR ISLAND FARM FINAL DESIGN PROJECT						
COMMENT TRACKING TABLE						
Study Sponsor:		**Washington Department of Fish & Wildlife**				
Study Parnters:		**Skagit Conservation District, Seattle City Light, Western Washington Agriculture Association**				
Study Consultant:		**Shannon & Wilson Inc., The Nature Conservancy**				
No.	**Date**	**Party**	**Report Section, Page, Paragraph**	**Party Comment**	**Responder**	**Responder Response**
INTERIOR DRAINAGE STUDY						
2	12/5/2013	Tom Slocum		I believe that Figure A15 has a slight error where it shows the drainage from Dry Slough going north into the existing "Dry Slough East" storage pond, and then going west along a ditch to the No Name system. I've done detailed field measurements in that area and, at least in spring 2009 (?), when I did the measurements, the flow definitely went the opposite direction, i.e. all into Dry Slough. I can provide channel profile survey data on this if it helps. Probably a good idea to confirm this with DD22. So I still think that it would be feasible to include an overflow from your new storage pond going east into the Dry Slough system, if extra drainage capacity were needed.	DRC	I did not find which figure you are referring to, but understand the comment. No Name Slough and Dry Slough are only connected at very high flows, likely above water elevation 5.0ft (NAVD88). This can be observed by comparing Figures A-10 (Dry Slough 1.3) and A-13 (No Name Slough 2.1). These data loggers are essentially at either end of the ditch, and they do not have the same water elevation patterns, therefore are not connected at low flows. At high flows, depending on which ditch is higher, the flow can go either direction. We do not force the water in either direction and let the model solve the directions depeding upon flow conditions in No Name or Dry. An overflow going east into Dry is included.
1	12/5/2013	Tom Slocum		Here is why I think this: the existing tidegates at Claude Davis, plus the overflow from the ditches going east into the "Dry Slough East" storage pond* already handle this drainage pretty well. Even with the time delay caused by moving the new dike to the north (as described in the hydraulic report), it seemed to me from Dave's presentation on Monday that the new pond could store the existing seepage and runoff, and the proposed new tidegates at No Name could drain it. I'd prefer to see a design/ evaluation of additional tidegates installed at No Name (if needed) before doing alot of design on a new pump station.	DRC	We analyzed adding tidegates from the new storage pond to Dry Slough. The data is included in the forthcoming Interior Drainage Report April 2014. Adding the tidegates only nominally lowers the storage pond water elevations by (0.1ft-0.2ft). The primary factor affecting the storage pond water surface elevations is the tailwater on the gates. Also, adding water into Dry Slough could impact the Hayton farm fields.
3	12/2/2013	Tom Slocum		Good meeting today. I like S&W's analysis on interior drainage. I think they asked the right questions and answered them pretty well.	DRC	Thank you.
4	12/2/2013	Tom Slocum		I personally don't want to see $50K spent on the pump station design. In my opinion, the internal drainage study showed that impact to drainage above the existing baseline condition can be dealt with pretty well using the planned storage pond and two new tidegates through the dike at No Name Slough. Since this drainage system is designed primarily for WDFW's land, I don't see the point of upgrading drainage capacity by adding a pump station. The situation is different than Wiley, where the impacts were primarily off-site on private property. If S&W's analysis turns out to be wrong and drainage becomes a problem, then WDFW won't be under the same kind of pressure as at Wiley to immediately mitigate the problem, but can take time to evaluate and do a step by step approach to adjust drainage.	DRC	We disagree. The additional tidegates can nominally lower the storage pond elevations, but a pump station is needed to drain down to existing low tide elevations, because of the tailwater effects. We also looked further upstream and the water elevation effects propogate upstream along almost the entire system and have the potential to impact several hundred acres of low lying land. Also, more water into Dry Slough could impact the Hayton farm fields. We recommend both a pump station and two tidegates to Dry Slough and a third tidegate at the bottom of Dry Slough for the project. Financing retrofits after the fact when problems occur is challenging at best.
5	12/2/2013	Tom Slocum		I can live with adding a 3rd tidegate at the mouth of Dry Slough to improve drainage through Dry Slough. It adds some extra benefit for the Hayton Farm and is a nice gesture to the Haytons and DD21 for a modest additional cost (I assume on the order of $40K to $50K). But the costs of designing, constructing and operating a pump station will be an order of magnitude greater than this. If S&W really thinks some extra drainage capacity is needed on the FIF property, then could they consider designing a high-flow connection over to Dry Slough, to take advantage of the extra capacity of the new tidegate there? As I've mentioned before, I'm concerned about the FIF project becoming a precedent for future SRFB-funded projects, and I don't like the idea of setting a precedent of adding additional drainage or flood protection capacity beyond what's needed to compensate for impacts to the existing condition.	DRC	See previous responses.
4	11/6/2013	SCDD#22		CDD#22 thinks that the existing dikes are placed on top of Tacoma Silt/Clay and that the new dike will be placed on Skagit Silt which has different seepage characteristics. CDD#22 wants us to evaluate the seepage characteristics of the site relative to existing and proposed conditions. Gary Jones	DRC	Soil properties along the existing and proposed dike setback have a fair bit of data. The soils along the setback dike are generally similar in composition and not signficantly less clay or more sandy. Therefore seepage rates will likely be similar to existing conditions.
5	11/6/2013	SCDD#22		CDD#22 asked whether a clay cutoff will be included in the new levee design similar to the Wiley Slough marine dike. Bob Hughes	DRC	We do not recommend clay cutoff as they need to be deep to be effective. We recommend managing seepage flows through the surface water pond and ditch drainage system.
7	11/6/2013	SCDD#22		CDD22 recognizes that a flood return tidegate structure in beyond the responsibility of the restoration project. CDD#22 recognizes that there could be cost efficiencies for the district if they could include a flood return tidegate structure into the restoration permits and levee construction process. CDD#22 are uncertain that building a new flood return tidegate into the restoration project is the best location for this structure on the Fir Island landscape. At this time, CDD#22 was not able to commit to conducting the analysis necessary to determine the optimal location for a flood return tidegate structure(s) or to design this structure to coincide with the FIF design and construction timeline. Stan Nelson	DRC	Comment noted.
8	5/17/2014	Jenny Baker	main report, s 3.0, p 4	I believe spelling is Maynard Axelson, not Maynord.	DRC	Revised
9	5/17/2014	Jenny Baker	main report, s 4.0, p 5	third paragraph - was data collection for a longer time period than June-Oct 2013? App A shows data through Feb 2014. Why are observations provided for only June-Oct 2013?	DRC	Revised. Included current length of monitoring period through September 2014.
10	5/17/2014	Jenny Baker	main report, s 4.0, p 5-6	bulleted surface water observations would be easier to follow with these changes: 1) group observations by groundwater, surface water upstream of tidegates (interior drainages), and surface water d/s of tidegates (skagit bay), 2) provide description of site as well as the site identifier code	DRC	Updated the groundwater and surface water data logger plots using data through early September 2014. Rearranged gaging data descriptions disucssing groundwater and surface water data upstream from the tidegates, and downstream from the tidegates. Also presented new data about percent of time groundwater elevations were above the root zone elevations, by data logger location and adjacent farm fields.
11	5/17/2014	Jenny Baker	main report, s 4.0, p 6	first paragraph -says the Hayton south field GW level was 1 foot lower than the Hayton North and WDFW North field - should this say 1 foot higher?	DRC	Statement corrected. Hayton South field average groundwater elevation is 0.1ft higher than Hayton North field.
12	5/17/2014	Jenny Baker	main report, s 4.0, p 6	last bullet - what is the "surge" effect?	DRC	Provided a description of factors influencing river surge on low tide conditions along the Skagit River delta.
13	5/17/2014	Jenny Baker	main report, s 5.0, p 7-8	Are berries that Haytons grow perennials? If so, why is April the only month of interest? It would be helpful to provide some context as to why you are focused on April only for changes in groundwater elevations and inundation times.	DRC	Removed the reference to month of April in this section. Explanation is provided later in Section 7.0.
14			main report, s 7, p 11	ref to "key farm planting and growing seasons" and another ref to April being important in terms of planting ops and root zones. See comment 6.	DRC	Provided a more detailed description of why the month of April is representative of key high groundwater and high surface water inflow periods when farmers are actively working fields for summer crops.
15	5/17/2014	Jenny Baker	main report, s 7.0, p 12	restate what SLR, ESV and SPC are please	DRC	Included Sea Level Rise, Erosion-Sedimentation-Vegetation, and Storage Pond Capacity references.

Date: 6/5/2014

WDFW FIR ISLAND FARM FINAL DESIGN PROJECT

COMMENT TRACKING TABLE

Study Sponsor:	**Washington Department of Fish & Wildlife**
Study Parnters:	**Skagit Conservation District, Seattle City Light, Western Washington Agriculture Association**
Study Consultant:	**Shannon & Wilson Inc., The Nature Conservancy**

No.	Date	Party	Report Section, Page, Paragraph	Party Comment	Responder	Responder Response
16	5/17/2014	Jenny Baker	main report, s 7.0, p 12	4th paragraph - ref to early growing season (April) - see comment 6.	DRC	See previous responses for this topic.
17	5/17/2014	Jenny Baker	main report, s 7.0, p 12	4th paragraph - Add info regarding follow up actions/design features considered to address the increased WSE on 11-32% of the NNS drainage.	DRC	Provided sentence that indicates impacts to 11-32% of NNS drainage farms can be mitigated through drainage improvements including tidegates and pump stations.
18	5/17/2014	Jenny Baker	main report, s 8.0, p 13	also focused on April - see comment 6	DRC	See previous responses for this topic.
19	5/17/2014	Jenny Baker	main report, s 10.0, p 17	pump timing recommendations - focused on April and May - see comment 6. Also, include observation about FW inputs flushing salinity out of the system in winter and pumping in winter could reduce that effect anad make the system more saline?	DRC	See previous responses for this topic. Added information about the potential increases in salt water intrusion resulting from "extra" pumping during freshwater field flood periods.
20	5/17/2014	Jenny Baker	main report, s 11.0, p 17	clarify locations of additional Dry Slough tidegate (at existing tidegate location) and three 3,000 gpm pumps (between storage pond and restored marsh)	DRC	Added descriptions of additional third tidegate at Dry Slough outlet, two new tidegates from storage pond to Dry Slough, and pump station in storage pond discharging to proposed marsh restoration area.
21	5/17/2014	Jenny Baker	main report, fig. 3	area doesn't match NNS drainage area on Fig 2. - reason?	DRC	Corrected Figure 3 name…Potential Affected Farm Fields in No Name and Dry Slough Basins.
22	5/17/2014	Jenny Baker	Appendix A	identify time period of data collection/analysis for surface water and groundwater loggers	DRC	Added description of data collection period June 2013 through September 2014.
23	5/17/2014	Jenny Baker	Appendix A, figs A-10 through A-18	add site description to site codes in the key for easier understanding of relative locations.	DRC	Relabeled figures A10-A18 with descriptions of gage locations.
24	5/17/2014	Jenny Baker	Appendix A, figs A-10 through A-12	add note regarding early end to DS-1.0 data similar to what's provided on fig. A-18	DRC	Added datalogger notes for Dry Slough gage.
25	5/17/2014	Jenny Baker	Appendix B, Table B-7	what do the 2 right-hand columns represent? Please clarify.	DRC	Originally, these were looking at cost / seepage unit reduction. $/GPM reduced. These columns were difficult to interpret, so I removed them and just stuck with costs only.
26	5/17/2014	Jenny Baker	Appendix B, fig. B-1	provide description of site to accompany code in key and/or link info in table more clearly to codes presented in key	DRC	Added information in legend to clarify data abbreviations.
27	5/17/2014	Jenny Baker	Appendix B, fig. B-3	is the exiting dike wider than the setback dike? It appears so from this figure (as compared to following figures)	DRC, CMH	Yes, existing dike in certain locations is wider at the crest than the proposed dike. The proposed dike is also taller and has a higher design elevation. It has similar widths at elevation 13ft. For example, with 2.5H:1V sideslopes, the dike is 10 feet wider at a position 2 feet lower than elevation 15ft. Therefore, at elevation 13ft, both existing and proposed dikes have similar widths.
28	5/17/2014	Jenny Baker	Appendix B, fig. B-4	20-foot setback between setback dike and storage pond is not shown. Was this arrangement analyzed during seepage analysis? Would this change make a marked diff. in results?	SDT	Model seepage rates were analyzed using original 20ft setback for interior drainage seepage studies. A longer setback distance of 40ft from dike to pond will reduce seepage rates. However, the model uses seepage rates (1cfs ~450gpm) based on site monitoring data, and not the SEEP-W modeling estimates. The pond modeling approach is therefore conservative.
29	5/17/2014	Jenny Baker	Appendix C, intro and s C.3.3	see comment 6	DRC	Main report describes why April is the "representative" worst case condition due to high groundwater levels, higher surface water flow rates, and farmers needs to work fields for summer crop planting.
30	5/17/2014	Jenny Baker	Appendix C, p. c-3	last paragraph - discussion of landuse and runoff characteristics being the same in future as they have been 1948-2009. My understanding is that your analysis is for the Fir Island interior drainages only and does not incorporate river flood levels/dynamics and any changes that might occur there in the future. If that is true, does it need to be clarified here?	DRC	Provided statement that future changes in Skagit River flow and flood conditions were not considered.
31	5/17/2014	Jenny Baker	Appendix C, s. C.4.2	state conclusion? (third tidegate alone does not mitigate project effects)	DRC	C.4.2 does provide conclusion that Dry Slough 3rd tidegate provides adequate conveyance to accommodate additional flows (seepage and storage pond overflow) into Dry Slough.
32	5/17/2014	Jenny Baker	Appendix C, s. C.4.4, p. C-10	1st Paragraph - and pumping in winter might possibly increase salinity over time by reducing winter freshwater flushing effect?	DRC	Added clarifying statement regarding potential for winter flood pumping to increase potential for salt water intrusion.
33	5/17/2014	Jenny Baker	Appendix C, Table C-1	What are soil types B, C and D?	DRC	Hydrologic soil groups (A, B, C, D) were characterized by the Soil Conservation Service (now the Natural Resources Conservation Service - National Engineering Handbook Part 630 Chapter 7 - Hydrology). Rainfall runoff modeling refers to these types of soil groups to calculate the amount of soil infiltration, excess, and surface water runoff. Group A—Soils in this group have low runoff potential when thoroughly wet. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Group D—Soils in this group have high runoff potential when thoroughly wet. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures, and include soils with depth to groundwater less than 20 inches.
34	5/17/2014	Jenny Baker	Appendix C, Table C-4	Need a table title - what is this table showing us? What does "low" "average" and "high" refer to?	DRC	Table title was cutoff in printing and now corrected. Low, Average, High refer to Sea Level Rise (SLR) predictions over 50 year timeframe.
35	5/17/2014	Jenny Baker	Appendix C, Table C-7	Need a table title - what is this table showing us?	DRC	Table title was cutoff in printing and now corrected. Changed title headings to be more clear. Table shows differences between April average and maximum water surface elevations in pond for 1. No Pump Station/No Tidegate, 2. 2 Tidegates to Dry Slough, 3. Pump Station and 2 Tidegates to Dry Slough. Shows increases in pond elevations from existing to proposed conditions, and that 2 tidegates alone to Dry Slough cannot mitigate project effects.
36	5/17/2014	Jenny Baker	Appendix C, Table C-8	2013 average SLR is confusing - is this currnet conditions or some future SLR scenario?	DRC	Agree. Removed 2013. Modeled 50 year scenario starting in 2013.

Date: 6/5/2014						
WDFW FIR ISLAND FARM FINAL DESIGN PROJECT						
COMMENT TRACKING TABLE						
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No.	**Date**	**Party**	**Report Section, Page, Paragraph**	**Party Comment**	**Responder**	**Responder Response**
37	5/17/2014	Jenny Baker	Appendix D, s D.2.2, p D-5	1st paragraph - This section makes it sound like all sedimentation is bad, but don't we expect and want sedimentation on the marsh plain in order to match the height of outside marshes and keep up with SLR? And won't the channels tend to be areas of high sheer stress and erosion, not deposition? Also, I thought in the Coastal engineering report you stated that sediment quantity available at Nisqually is more like Wiley and less like FIF. If so, can it be used for comparison/analysis at FIF?	DRC	Added statements that sedimentation and erosion, while having potential to affect farm drainage, is actually beneficial for fish habitat and SLR purposes. The site may have lower sediment supply, and Nisqually not completely identical to Fir Island. If this is the case, then sedimentation rates will be on the lower side, which is reflected in the ESV sensitivity computations (it is in the range...but maybe on the lower side). We do not have the modeling tools or data to confidently analyze erosion, sedimentation and vegetation conditions. Nisqually data is the best available data at the time of this analysis.
38	5/17/2014	Jenny Baker	Appendix D, Tables	I found the tables difficult to follow - perhap that's due to my lack of familiarity with Monte Carlo analyses. Specific questions/comments presented in lines below.	DRC	OK
39	5/17/2014	Jenny Baker	Appendix D, Table D-2	Table title? Add column headings for three groups of results?	DRC	Table title was cutoff in printing and now corrected. Low, Average, High refer to Sea Level Rise (Added SLR) predictions over 50 year timeframe.
40	5/17/2014	Jenny Baker	Appendix D, Table D-4	what do "low "average" and "high" refer to? Are the results increases/descreases in WSE? Are you presenting analysis inputs or outputs?	DRC	Low, Average and High changes in tailwater elevations resuling from Erosion, Sedimentation and Vegetation conditions in the marsh. These are tailwater "inputs" to the storage pond model (stated in the title).
41	5/17/2014	Jenny Baker	Appendix D, Table D-5	what are the percentages? Reduction in storage pond capacity? Please define. Are you presenting analysis inputs or outputs?	DRC	Values are the percent encroachment of vegetation on the storage pond margins. These are inputs to the storage pond model (stated in the title).
42	5/17/2014	Jenny Baker	Appendix D, Table D-6	Please label individual columns for easier comprehension. % = percent of what?	DRC	Labeled colums (Sensitivity Factor % Effect on WSE), for clarification purposes.
43	5/17/2014	Jenny Baker	Appendix D, Table D-7	what is 10-90%?	DRC	10% and 90% probability of occurrence. Represents likely "range" of outcomes.

APPENDIX F

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

Attachment to and part of Report 21-1-12318-216

Date: November 7, 2014
To: Mr. Brian Williams
Washington Department of Fish and Wildlife

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland