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Technical Memorandum

Date:	07/16/2022
To:	Dick Vander Schaaf, Project Manager Associate Coast and Marine Conservation Director The Nature Conservancy of Oregon
From:	Curtis Loeb, PE, Principal Engineer Rowyn Cooper-Caroselli, PE, Lead Modeler Wolf Water Resources Portland, OR
Project:	Porter Tract Restoration - Kilchis Estuary Preserve
Subject:	Hydrodynamic Model Refinements in Response to Hydraulic Review

Introduction

The Nature Conservancy of Oregon (TNC) seeks to continue restoration of tidal wetland habitats along the margins of Tillamook Bay with restoration of the Porter Tract, an approximately 60-acre parcel in the floodplain of the Kilchis River in Tillamook County west of Highway 101 and north of the town of Tillamook. The Porter Tract is located in the lower Kilchis River watershed, one of the five large river tributaries to Tillamook Bay. The restoration site is situated approximately one mile from the mouth of the Kilchis River and is influenced by both river flow and ocean tides. The Porter Tract is north of and adjacent to the recently restored Kilchis Estuary Preserve (former Dooher Property) that was constructed in 2015 by the TNC. The cumulative area of these restoration efforts would result in 127 acres of high functioning estuarine habitat.

The overall goal of the Kilchis Estuary Preserve project is to restore freshwater and tidal hydrologic connections to the Porter Tract wetlands, providing off-channel rearing habitat for salmonids and re-establishing spruce swamp habitat. Specific objectives and constraints of the project are described in the Basis of Design Report (W2r 2019).

Restoration measures proposed for the Porter Tract Restoration include:

- Tidal channel creation,
- Restoration / expansion of the connector channel between the Hathaway Slough tributary channel and Stasek Slough,
- Filling linear drainage ditches,
- Removing man-made dikes and berms along sloughs,
- Removal of water control structures (tidegates, culverts, and berms),
- Two new pedestrian bridges for vegetation maintenance,
- Wood habitat structures in the tidal channels as cover habitat and organic substrate for rearing habitat for juvenile salmonids,
- Site revegetation with native grasses, shrubs, and woody plants

The scope and purpose of this memo is to update and improve the hydrodynamic model based on technical review comments by a third-party (NHC 2021; referred to herein as Hydraulic Review, see Attachment A). This Hydraulic Review was conducted as part of the Tillamook County project review process for the Porter Tract. The Hydraulic Review included review of (1) observed water levels and the hydrodynamic model developed for Kilchis/Porter Tracts, (2) Dooher Tract impacts, and (3) Porter Tract impacts. The scope of this technical response memo considers comments on item (1), potential refinements or limitations of the restoration and hydrodynamic model. This response memo also considers item (2) potential refinements of the Porter Tract Restoration design that would benefit habitat or reduce inundation frequencies or extents. These improvements and investigation of changes were considered in a series of test scenarios using the hydrodynamic model originally developed to support Porter Tract and Kilchis Wetland designs (W2r 2019a; W2r 2019b; W2r 2017).

In the evaluations presented in this memo, model scenarios were compared against the current (original) Porter Tract Restoration design scenario (documented in W2r 2019a), which is referred to as the base case or baseline scenario. The current or existing conditions (pre-Porter Tract restoration) were not used as the basis for evaluation, as the primary purpose was to consider changes or improvements to the current Porter Tract Restoration actions.

Hydrodynamic Model Development History

A two-dimensional hydrodynamic model was originally developed for the Dooher Property (Kilchis River Estuary Restoration Phase1; ESA 2014). Model geometry or topographic extents along the Kilchis River and Tillamook Bay tidelands are described in the Phase 1 report. This report also describes model calibration to observed water levels, and hydrologic (tidal water level and riverine flow) boundary condition scenario development to examine typical tidal conditions as well as extreme storm events. The Phase 1 model was later updated to reflect Porter Tract Concept Restoration Designs (W2r 2017), and then it was updated for minor revisions associated with the final engineering designs (W2r 2019a and W2r 2019b). An overview of the Porter Tract elements is shown in Figure 1.

Figure 1 Porter Tract restoration site overview indicating restored channels, filled ditches, dike removals, new bridges, and low mounds.

Model Refinements

Comments, questions, and recommendations from the Hydraulic Review included the following:

1. **Winter events**: consider more common or frequent winter river and tide levels rather than extreme or more rare combined events,

2. **Vaughn Creek**: adding tributary flows from Vaughn Creek, located north of the Hathaway Slough drainage, into the model,

3. **Connector Channel**: further widen the Stasek Slough connector channel,

4. **Stasek Berm**: would retaining the Stasek and Hathaway berms (as proposed in the Porter Tract Restoration) reduce inundation upstream,

5. **Highway 101 drainage**: consider new drainage paths or channels between the railroad and Highway 101 embankments,

6. **Stasek sedimentation**: removing sediment from Stasek Slough near the mouth where the 2015 storm deposited sediment in the channel,

7. **Other potential refinements** to improve drainage especially during common winter periods.

Model scenarios were developed to address items 1, 2, 3, 6, and 7. Item 4, Stasek Berm, was not evaluated further because it is clear through inspection of prior model results that these low, discontinuous berms do not impede overland or in-channel flows from tidal events or Kilchis River overflows. Item 5, Highway 101 drainage, was also not considered explicitly as the current Porter Tract Restoration (base case) already includes a new drainage channel and removal of drainage impairments (old tide gate and earthen berm), and it was unsure how to improve drainage further from this region. Item 7 includes evaluation of bank treatments along the Kilchis River where the levee was removed as part of the Kilchis Restoration (Phase 1, or Dooher Tract Restoration) – see Model Refinements Section of this memo. A summary map showing model changes and/or elements considered is shown in Figure 2.

Hydrologic Time Period

The hydrologic scenario of January 2017 (ESA 2014; W2r 2017; NHC 2021) was selected for this re-analysis for several reasons. It includes peak flows in the Kilchis River much lower than the 2015 and other events previously analyzed. It also allows for convenient comparison to prior modeling results, and it includes tides and river flows (before and after the peak of the scenario) that occur for long periods of time during the winter – the recommended focus hydrology from the Hydraulic Review.

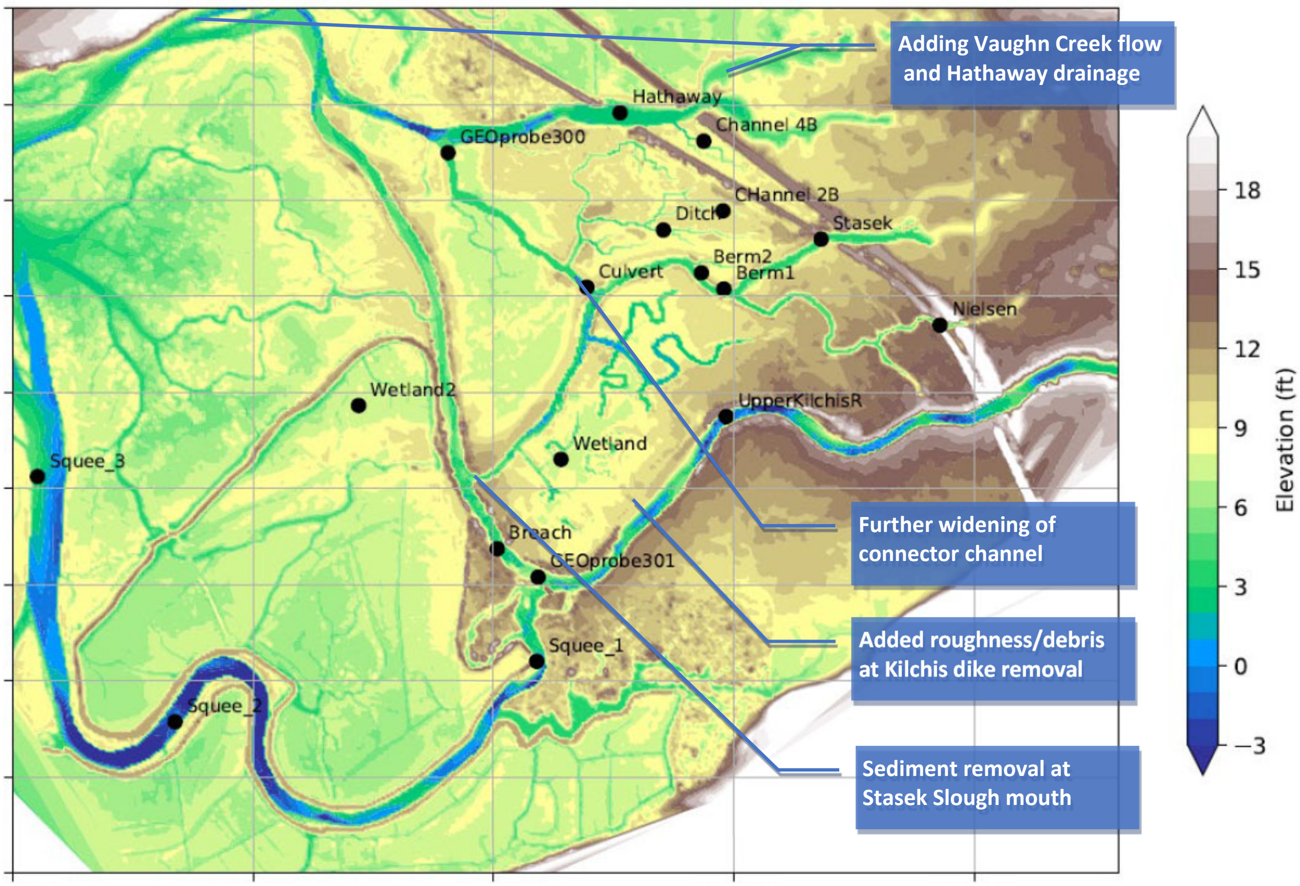

Figure 2 Summary of actions/ model scenarios developed to refine and improve the Porter Tract Restoration; model output locations are also shown for reference.

Vaughn Creek and Hathaway Slough Drainage

Vaughn Creek and Hathaway Slough (unnamed drainage that flows into the slough) flows were added to the January 2017 hydrologic scenario. The Hathaway Slough drainage was added even though not mentioned in the Hydraulic Review because its contributing watershed area is not insignificant compared to Vaughn Creek, and including this drainage would make results more conservative -- further elucidating any limitations from originally not including these local, northeast, freshwater inputs. Vaughn Creek and Hathaway flows were estimated using USGS Streamstats regression results (Risley J. et al 2008), and the 95% chance exceedance flows for the month of January were entered into the model at a constant flow rate over the simulation period.

Kilchis Riverbank Roughening / Large Wood Addition

In another model scenario, large wood structures were added to the crest of the Kilchis River bank where the levee was removed in 2015, intending to roughen (i.e., dissipate energy) from overflows that top the river banks. The intention of this test scenario was to allow natural overtopping and hydrologic connectivity, but to do so in a manner similar to that which occurs in mature forested tidal wetlands – where energy is dissipated and distributed broadly near the river bank by thick vegetation and/ or logs that have rafted onto the bank (similar to those that washed up and remain from the 2015 event). Typically in mature forested wetlands, high energy flows would be impeded immediately, likely reducing the overall magnitude of flows and total volume of water flowing across and through the wetland. This has been observed and simulated with a similar hydraulic model at the Fort Columbia Tidal Wetland in the Lower Columbia River Estuary (restored in 2011; Columbia River Estuary Study Taskforce).

The geometric representation of this scenario in the hydrodynamic model is shown in Figure 3.

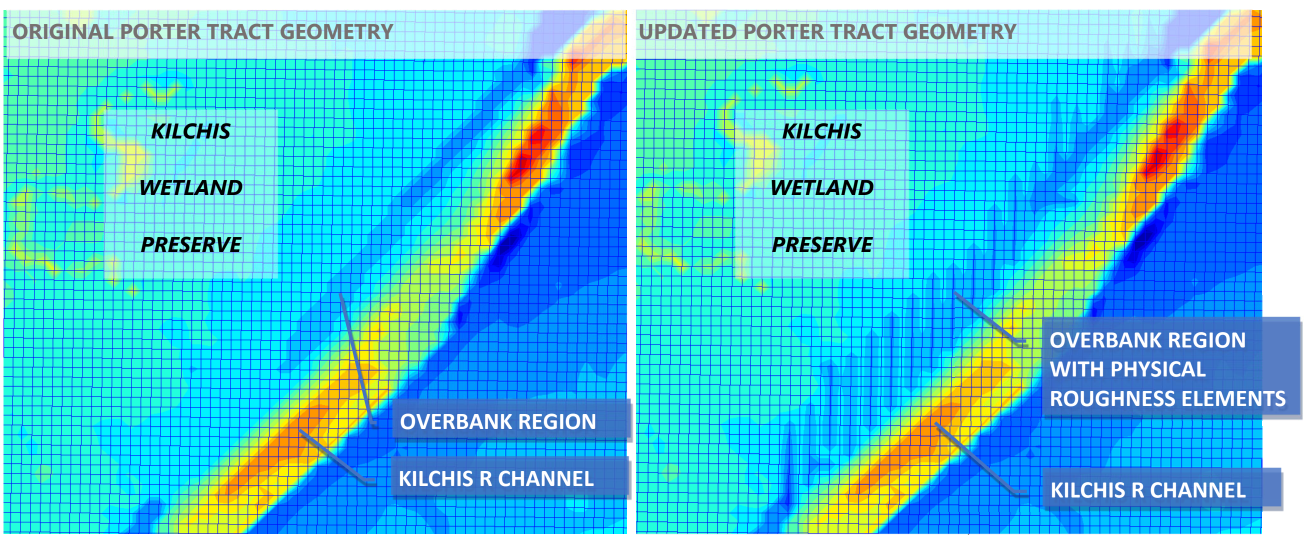

Figure 3 Representation of large wood roughness elements in the hydrodynamic model (without obstructions – left) as physical obstructions (right) that allow overbank flow between elements.

Stasek Slough Mouth Sediment Removal

Sediment that deposited at the mouth of Stasek Slough and in the general vicinity (from the 2015 storm) was also removed as a test scenario. The intent of this scenario was to evaluate if sediment removal would improve drainage through this slough during any parts of the simulation. Elevations of the slough that were not affected by deposition (generally in the 0 to 1 feet NAVD88 range as originally constructed in the Kilchis Restoration) were continued along the channel bottom along Stasek Slough and along affected portions of the river in this scenario.

Model results

From the revisions described in the previous section, three new model scenarios were developed:

- **Scenario 1:** Vaughn Creek and Hathaway drainage flows were added (otherwise the same as the base case scenario);

- **Scenario 2**: Roughness elements added at the Kilchis levee removal location; this scenario also includes the added Vaughn and Hathaway flows in Scenario 1; and

- **Scenario 3**: Sediment removal at the Stasek Slough mouth (also includes changes in Scenarios 1 – which are considered a model improvement and thus included in Scenarios 2 and 3. This scenario does not include the roughness elements of Scenario 2.

Results of these scenarios were compared to the base case scenario, which is the Porter Tract Restoration scenario (W2r 2017) at two locations: Figure 4 at Stasek Slough and Figure 5 at Hathaway Slough. Results are also shown alongside observed tidal water levels at the NOAA South Beach Station (nearest observed tidal station in Yaquina Bay) for reference. Both figures also show water levels in the Kilchis River at Squeedunk Slough to understand the river stages relative to general land surface elevations and elevations of the Kilchis River bank where the levee was removed (and roughness elements were added in Scenario 2). To note, Kilchis bank elevations are in the range of 10 to 12 feet NAVD88 where the levee was removed (i.e., river stages above 10 to 12 feet NAVD88 will flow into the Preserve and towards Stasek Slough and the other tidal channels).

Several key observations are made from the comparison of simulated water levels across the scenarios:

1. **Vaughn Creek**: the addition of flow inputs at Vaughn Creek (and Hathaway Slough drainage) does not appear to have appreciable effects on water levels. At both Stasek and Hathaway locations, the thin blue line (Vaugh + Hathaway) is slightly higher than the base case (bold blue line) for a brief period of time when water levels are just below 10 feet NAVD88 which occurs for a day after 1/19/2017. There are also a few other brief periods during low tides when water levels are also very slightly elevated above the base case towards the end of the simulation.

   Although results are not particularly sensitive to the creek inputs, this model refinement is warranted as there may be other time periods or conditions when creek inflows may have effects on nearby water levels. Subsequent simulations will incorporate the same or perhaps refined (non-constant) creek inflows so that water levels during low tide periods are not underestimated.

2. **Kilchis Riverbank roughness**: of the test evaluations considered, adding roughness to the river bank at the location of the prior levee removal has the strongest effect on reducing water levels at Stasek and Hathaway Sloughs compared to the based case and the preceding Scenario 1 Vaughn and Hathaway flows inputs. The red curves at Stasek and Hathaway show significant declines of up to 0.5 feet at Stasek and slightly less at Hathaway relative to the base case and Vaugh/Hathaway scenarios. The reduction in water levels is due to less conveyance of overbank flows when river stages are above and just below 10 feet NAVD88.

   One very important note is that while the model scenario assumed physical roughness elements on the bank of the river via addition of large wood (primarily due to a limitation in the hydrodynamic model's ability to represent variable ground roughness values), roughness (flow resistance) could also occur due to vegetation such as willows and other woody shrubs such as those currently growing along the bank and throughout the Kilchis Preserve (Dooher Tract). In fact, vegetation is currently very robust throughout the restored wetland – such that the flow resistance assumed in the model scenario may already exist or may develop at some point in the near future. In other words, this scenario may already be representing existing conditions rather than a hypothetical scenario.

   Further, as wetland vegetation continues to establish and mature, bank roughness will continue to increase commensurately. With this, the associated water level impacts (reductions reflected by this scenario) are likely to continue to increase to moderate – if not significant – degrees. Future storms bringing sediment, nutrients, and additional logs are expected to further support wetland habitat and vegetation health which in turn will buffer and dissipate high water levels in the same manner demonstrated by the hydrodynamic model.

3. **Stasek sediment removal**: this scenario had minor effects on water levels relative to the preceding Scenario 2 (Kilchis bank roughness). At both locations, the green curves representing the sediment removal scenario is essentially the same as results from Vaughn + Hathaway (which show slightly higher water levels than the base case due to the additional flow inputs which are also a part of this scenario).

4. **Connector channel widening**: although it is not shown here, initial review of base case simulation results at the connector channel between Stasek and Hathaway Sloughs shows no

local increase in velocities or gradients in water surface during peak ebb or flood tides. A local acceleration of flows or drop in water surface would suggest a constriction and be reason to consider further widening. As mentioned, this channel is already being widened significantly and to similar dimensions as the downstream Hathaway tributary channel to which it connects.

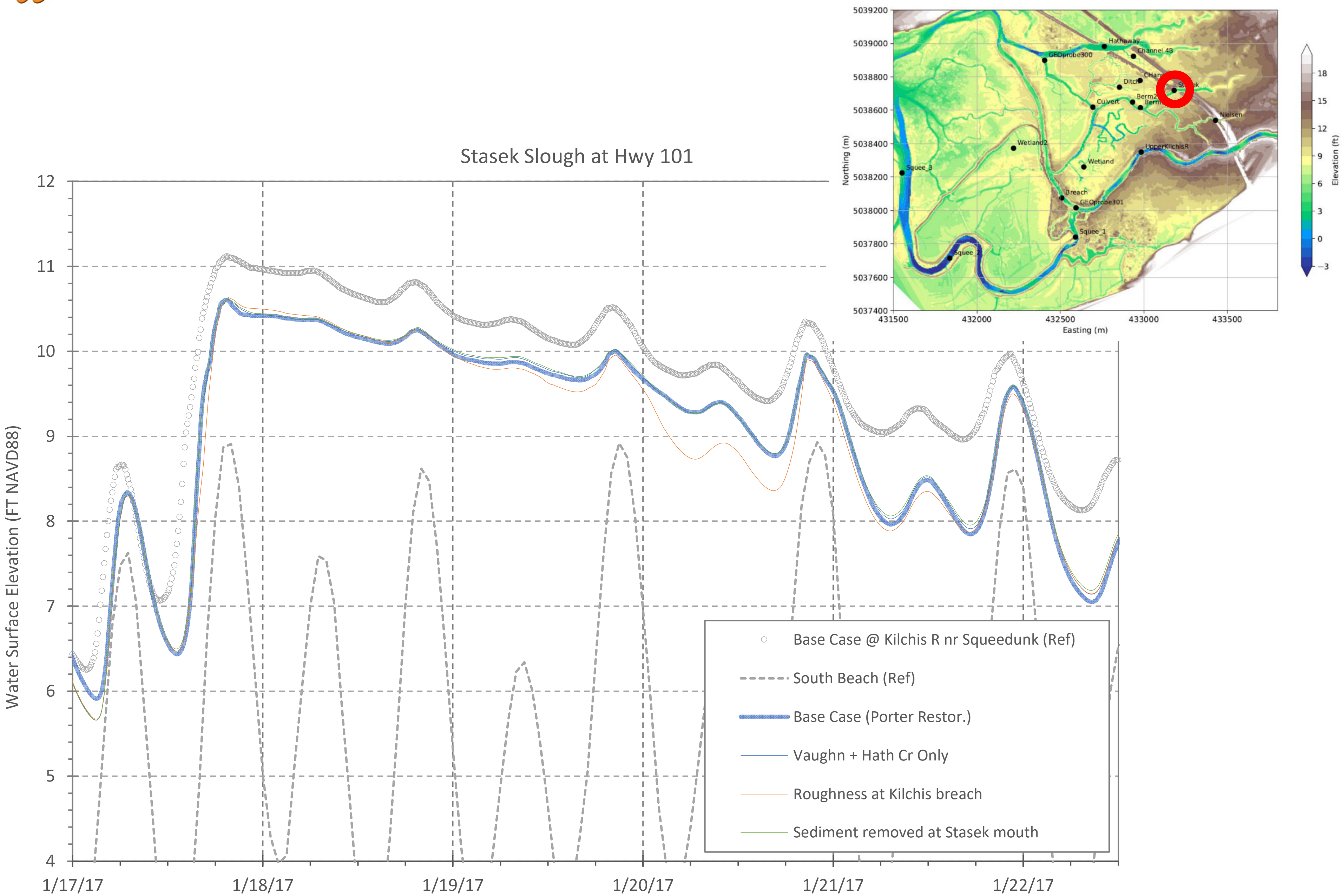

Figure 4 Comparison of simulated water surface elevations between the base case and the test scenarios in Stasek Slough at Highway 101.

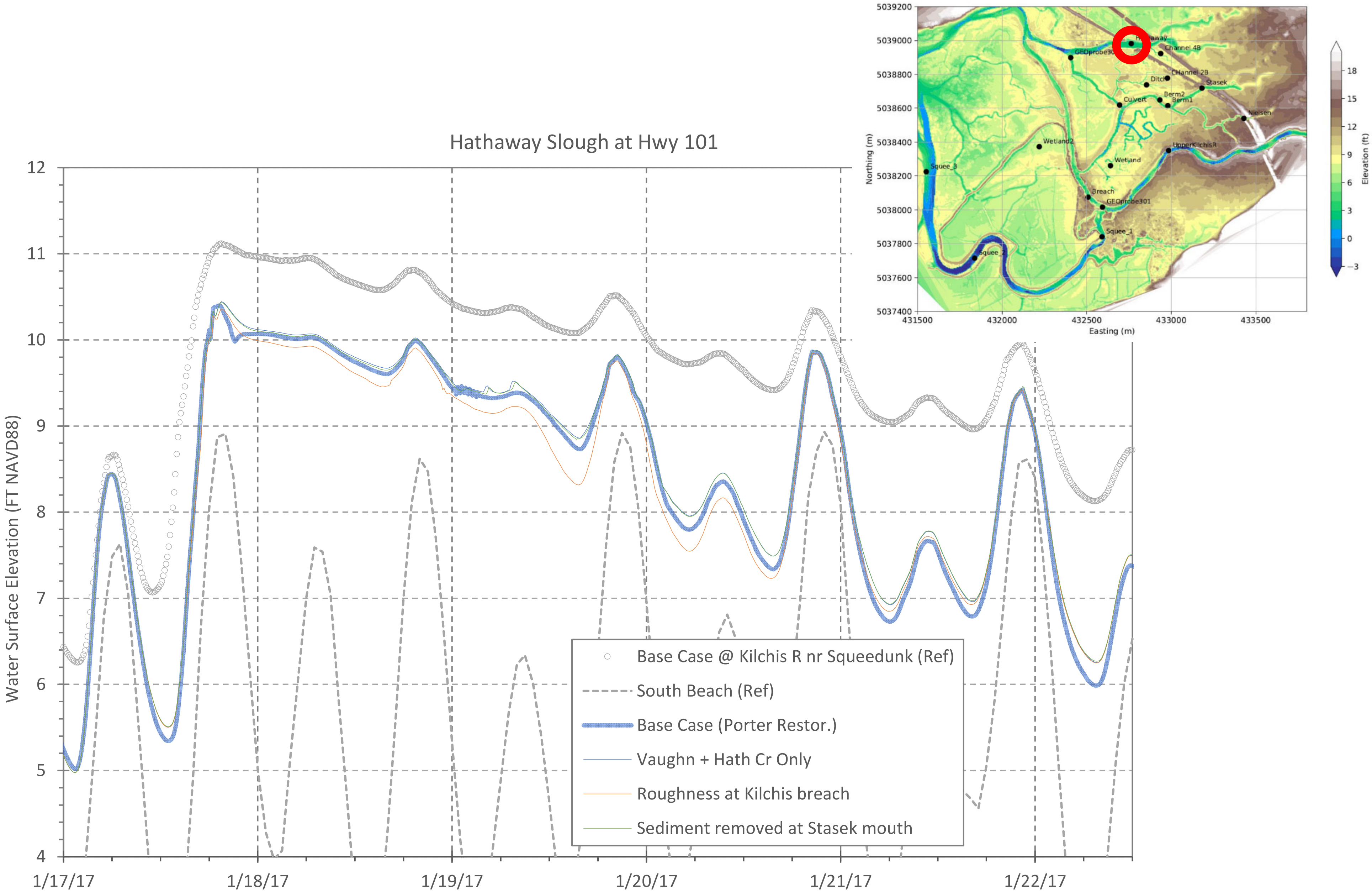

Figure 5 Comparison of simulated water surface elevations between the base case and the test scenarios in Hathaway Slough at Highway 101.

Cumulative Water Level Frequency Curves

To highlight the subtle differences in water level results shown in Figure 4 and Figure 5, cumulative water level frequency curves were developed for the Hathaway Slough results (see Figure 6 below). This figure shows the percentage of time that water levels are exceeded over the simulation periods for each scenario. For example, higher water levels on the left of the figure correspond to low frequencies of exceedance, and lower water levels on the right of the figure are exceeded a higher percent of the time; the curves thus slope down and to the right.

Results shown from Figure 6 correspond to those from the preceding figures, with the Kilchis bank roughness scenario showing lower frequencies (lower percentage of time) that water levels are at a given stage (i.e., the red curve is generally below the others except when water levels are below about 7.5 feet NAVD88).

Winter Days When Water Levels are Above a Threshold

Another benefit of the cumulative frequency curves described above is that frequencies can be converted into number of days in a particular period for a more familiar comparison of results. Exceedence frequencies shown in Figure 6 were converted to “number of days exceeded” by assuming the simulation was representative or could reoccur over a 90-day winter period. This assumption may be true in some years, but it may not be true in others (when winter water levels might be either higher or lower than the January 2017 sequence). It is believed to be mostly representative, but if the 2017 event were to be higher in stage for example than the true typical winter, this analysis would show a higher number of days at a particular threshold. However, the relative differences between number of days between scenarios will be accurate regardless of the 2017 period being higher or lower than an average winter.

Results of the conversion of water level frequencies are shown in Table 1. Three water level criteria were selected to draw out the number of days at or above that level: elevations 10, 9, and 8 feet NAVD88. This range is considered meaningful, as the differences between scenarios at water levels above 10 appear to diminish. Also, water level frequencies below 8 feet NAVD88 are also believed to be less important when considering inundation, as most ground elevations in areas of interest are above elevation 8 feet NAVD88.

To illustrate the conversion from frequency to number of days, red text and arrows indicate that the Kilchis bank roughness scenario (red line in Figure 6) is above elevation 9.0 feet NAVD88 for approximately 42% of the time. And, 42% of 90 days is equal to 37.5 days, as shown in the orange column and middle row of Table 1.

The Vaughn/Hathaway flow and sediment removal scenarios in the medium blue and green columns, respectively, show number of days over the winter exceeding the water level thresholds that are very similar to the base case; there is only a 1 to 3 day difference (increase) when these either the flow inputs or sediment removal actions are considered.

In contrast, the Kilchis bank roughness scenario shows a significant reduction in days exceeding the thresholds compared to the base and Vaughn scenarios. At elevation 10 feet NAVD88 which is mostly likely closest to that affecting lands upstream of Highway 101, the number of days is reduced in half, from 9.5 and 10.5 to just over 4 days. The changes at lower water surface elevations from additional roughness start to diminish.

It is important to note that the specific number of days reported in the table should not be the focus, as the number of days at a given water level will vary depending on the particular water year - especially the Kilchis River flow regime. Instead, the differences or relative change in number of days across the scenarios is more important to consider.

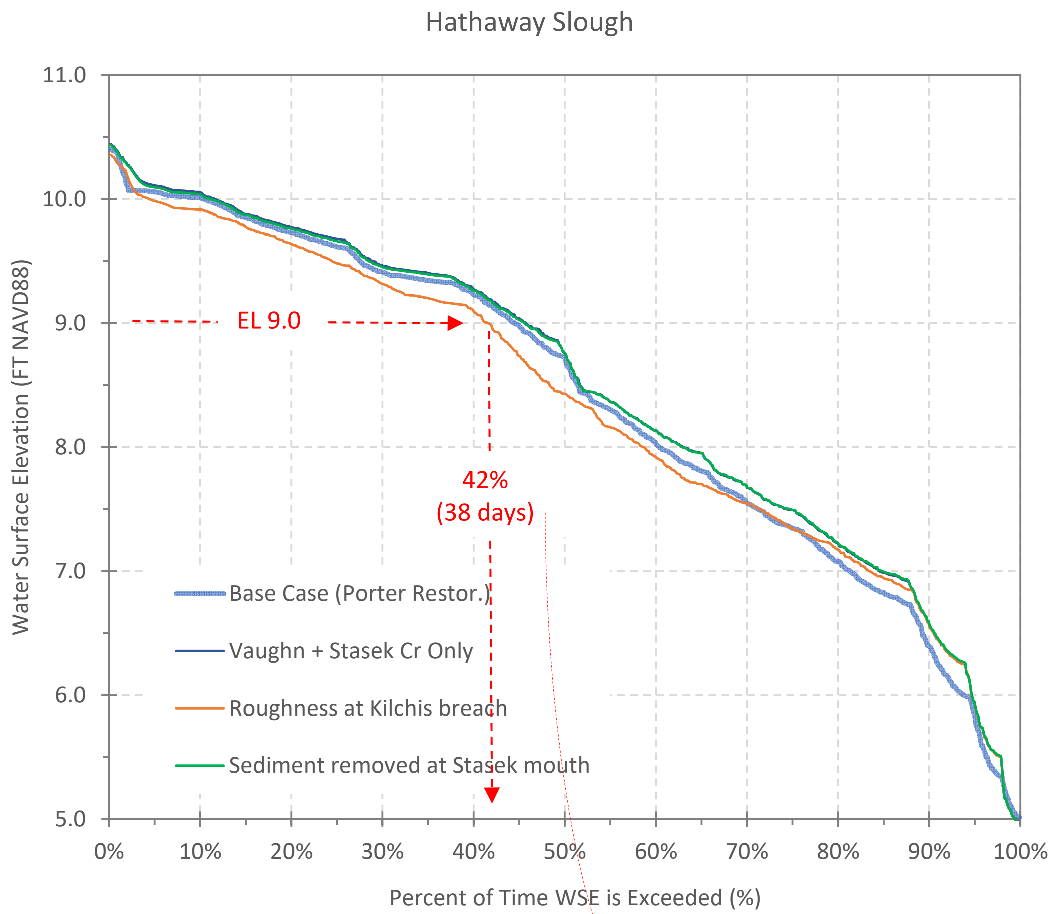

Figure 6 Cumulative water surface elevation (WSE) frequency exceedence curves at Hathaway Slough for the various scenarios.

Table 1 Number of winter days that simulated water surface elevations exceed various thresholds in Hathaway Slough.

`	# of Winter Days* That WSE Exceeds Elevation Criterion			
Water Surface Elevation (WSE) Criterion (FT NAVD88)	***Base Case (Porter Restor.)***	***Vaughn + Hath. Cr Only***	***Roughness at Kilchis breach***	***Sediment removed at Stasek mouth***
10.0	9.5	10.5	4.1	10.1
9.0	39.9	41.0	37.5	41.0
8.0	54.3	56.8	52.8	56.7

**Specific number of days is less important than relative differences in days between scenarios.*

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Attachment A – NHC Technical Hydraulic Review

Kilchis River Estuary Porter Tract Restoration – Detailed Design, Hydrodynamic Model Results, Northwest Hydraulic Consultants, revised 7/8/2019.