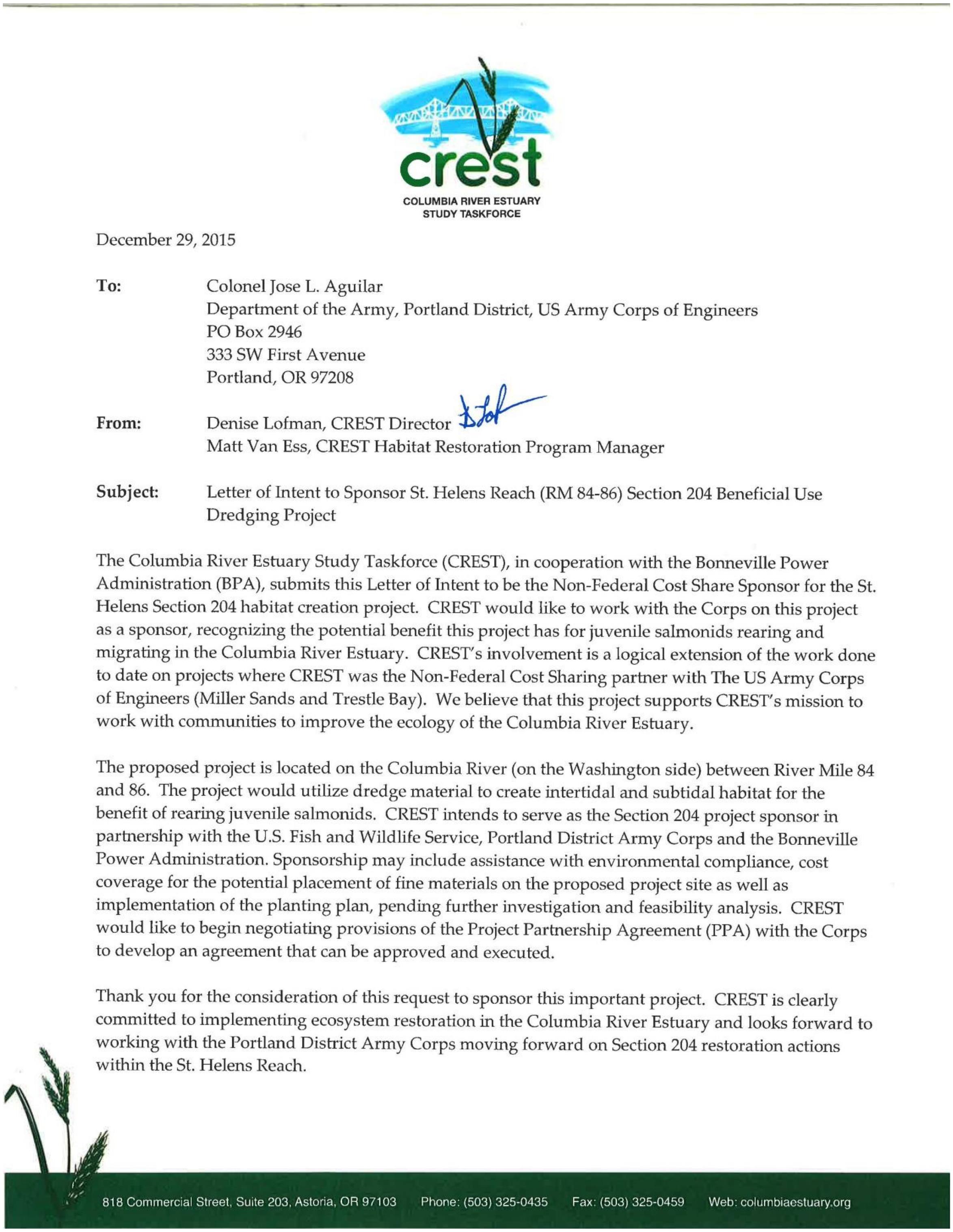
Appendix A – Federal Partner's Letter of Intent



crest
COLUMBIA RIVER ESTUARY
STUDY TASKFORCE

December 29, 2015

To: Colonel Jose L. Aguilar
Department of the Army, Portland District, US Army Corps of Engineers
PO Box 2946
333 SW First Avenue
Portland, OR 97208

From: Denise Lofman, CREST Director
Matt Van Ess, CREST Habitat Restoration Program Manager

Subject: Letter of Intent to Sponsor St. Helens Reach (RM 84-86) Section 204 Beneficial Use Dredging Project

The Columbia River Estuary Study Taskforce (CREST), in cooperation with the Bonneville Power Administration (BPA), submits this Letter of Intent to be the Non-Federal Cost Share Sponsor for the St. Helens Section 204 habitat creation project. CREST would like to work with the Corps on this project as a sponsor, recognizing the potential benefit this project has for juvenile salmonids rearing and migrating in the Columbia River Estuary. CREST's involvement is a logical extension of the work done to date on projects where CREST was the Non-Federal Cost Sharing partner with The US Army Corps of Engineers (Miller Sands and Trestle Bay). We believe that this project supports CREST's mission to work with communities to improve the ecology of the Columbia River Estuary.

The proposed project is located on the Columbia River (on the Washington side) between River Mile 84 and 86. The project would utilize dredge material to create intertidal and subtidal habitat for the benefit of rearing juvenile salmonids. CREST intends to serve as the Section 204 project sponsor in partnership with the U.S. Fish and Wildlife Service, Portland District Army Corps and the Bonneville Power Administration. Sponsorship may include assistance with environmental compliance, cost coverage for the potential placement of fine materials on the proposed project site as well as implementation of the planting plan, pending further investigation and feasibility analysis. CREST would like to begin negotiating provisions of the Project Partnership Agreement (PPA) with the Corps to develop an agreement that can be approved and executed.

Thank you for the consideration of this request to sponsor this important project. CREST is clearly committed to implementing ecosystem restoration in the Columbia River Estuary and looks forward to working with the Portland District Army Corps moving forward on Section 204 restoration actions within the St. Helens Reach.

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US Army Corps
of Engineers ®
Portland District

Lower Columbia River Estuary
CAP Section 204 Studies

Woodland Islands
Appendix B: Hydrology and Hydraulics Analysis

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23 February 2018

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1 Introduction

1.1 Purpose

The purpose of this appendix is to present technical information and recommendations regarding hydrology, hydraulics, and fluvial morphology at Woodland Islands to the Product Delivery Team (PDT) in support of the integrated Feasibility Study and Environmental Assessment (FS/EA) report.

The analyses presented herein were performed to answer questions from the PDT regarding the following topics:

1. the hydrologic and hydraulic setting at the site
2. the fluvial morphologic characteristics at the site including site evolution, erosional and depositional patterns, and scour potential on the islands and nearby shoreline
3. assessment of with-project impacts including changes to channel velocity, water level, and expected fluvial morphologic patterns

Specific analyses include historic imagery assessment, shoreline migration assessment, and hydrodynamic modeling of existing and with project conditions using AdH. Major conclusion and recommendations of the analyses are presented in the following section and will be referenced in the main body of the FS/EA.

1.2 Summary of Results

Determining the potential adverse impacts of the project are a major driver of the H&H analyses. The AdH report attached at the end of the Appendix presents model results and detailed discussion supporting conclusions on with-project impacts. A summary of the anticipated impacts is presented below:

1. *Will the project impact local erosion and/or deposition patterns?*

Yes, although minimally. The specific changes in erosional/depositional pattern within the side channel resulting from recommended project are hard to quantify with precision; however, general patterns are inferred from hydraulic modeling. The existing side channel area is generally aggrading in response to the decades-long activities along the Woodland Island chain which concentrates flow the main channel. The overall impact of adding material into the side channel is to increase resistance, decrease energy, and increase total accretion. This is evident as a slight decrease in velocity at the side channel entrance during simulated high flow conditions.

Within the side channel, the placed material has a more pronounced effect on local hydrodynamics. The resulting topography will result in a concentration of flow into a new, narrower side channel and decreased energy in the sheltered embayment areas. The sediment dynamics resulting from these changes are slightly higher velocity and erosion potential in the side channel and a decrease in protected areas. Increased erosion potential may result in a decreased bed elevation in the side channel up to 2 feet, while increased aggradation of sand and fines is expected in the embayment areas.

The potential for erosion increase along the WA shore is minimal considering the low energy in the side channel generally. Model results indeed show the with-project increase in velocity decreases to zero with distance from the side-channel thalweg. No change is expected in near-shore topography and the ordinary high water boundary.

2. *Will the project increase water levels during flood events?*

No. An AdH simulation of the February 1996 flood with the extreme placement scenario (1.2 million CY including front-side protection) shows no increase in maximum water level. The physical conditions proposed by this project, 400 kcy on the backside of the islands would have less of an impact than the 1.2 million CY scenario. This is due to the relatively small fraction of the total cross-sectional area impacted by this project. Furthermore, local changes in roughness within the Columbia River system impact hydraulics which in turn impact fluvial morphology and roughness, and so system tends to absorb and spread out changes over a much larger area.

3. *How do you know the material is going to stay there?*

The placed dredged material is designed to be as stable as possible. Features are located and shaped to take advantage of existing sheltered areas created by the upstream high ground and pile dike system and are expected to remain largely intact, particularly after vegetation establishes from years 1 to 5. The low angle, vegetated slopes are set high enough to avoid sweeping velocities with common floods, yet low enough to produce the desired habitat. At the same time, the possibility of large floods moving the features around, to some degree, is completely acceptable and is anticipated.

4. *Will there be impacts to navigation?*

No. The main Columbia River federal navigation ship channel is located adjacent to the project area and there is a deep draft ship anchorage designated by the U.S. Coast Guard downstream of the project area. Due to the low energy in the side channel, transport potential out of the area is low suggesting most or all of the material mobilized into and from within the side channel will deposit further down the side channel in the lee of the larger island complex. The project will not increase sediment deposition in the FNC or the designated anchorage area. In the end, the proposed project is not expected to adversely affect O&M activities for the FNC and may likely be beneficial for sustaining the sediment budget of Woodland Islands and the LCR.

2 Background

2.1 Site Overview

The Woodland Islands site is a small island chain and side channel area located at river mile (RM) 84 to 86 of the Columbia River, near St Helens, Oregon. Situated east of the Federal Navigation Channel (FNC) adjacent to an extensive pile dike network dating back to as early as 1885, the island chain was created through the placement of dredged material. Most recently in the early 1970's, placed dredge material formed a continuous peninsula connecting to what is now Austin Point, creating a sheltered bay. By the end of the 1970's, material placement and apparent maintenance of the site ceased, and after almost 40 years of exposure to regular high water and periodic flood events, the peninsula has eroded into the small island chain there today.

The islands consists of densely vegetated in areas above 9 feet NAVD with several forested patches above 17 feet NAVD, approximately equal to the ordinary high water (OHW) level. There are numerous sand bars, cut banks, overwash areas situated between high points along the island chain. The total area of the islands (area above 7 feet NAVD or the mean September water level) is 112 acres, 16 of which is above OWH.

The side channel area between the islands and the WA shoreline consist of roughly 270 acres with bed elevations below the mean September water level. Water depths varies greatly based on location but the average depth below the mean September water level is 6 feet (1.2 feet NAVD) with maximum depths in excess of 20 feet.

Bed elevations are generally aggrading in the side channel but the area is considered to be generally too deep for valuable for salmonid, a species of interest in this effort. The proposed project involves placing several hundred thousand cubic yards of dredged material, creating peninsula-shaped bars extending from existing upland areas into the side channel. The placements have features with gentle slopes and top elevation a few feet above MHHW provide several functions that include expanded upland habitat, increased abundance of edge habitat, and increased shallow water habitat in sheltered embayment areas.

2.2 Hydrologic and Hydraulic Setting

2.2.1 Topography/Bathymetry

Broadly speaking, the Woodland Islands and side channel sits atop a shelf roughly 40 feet above the main channel. The pile-dike network and islands created from dredged material help keep the 43-foot navigation channel in place while providing relative shelter to the side channel. While most of the island chain is lower than the ordinary high water level (OHW), there are several upland areas above 20 feet NAVD with the tallest over 35 feet NAVD.

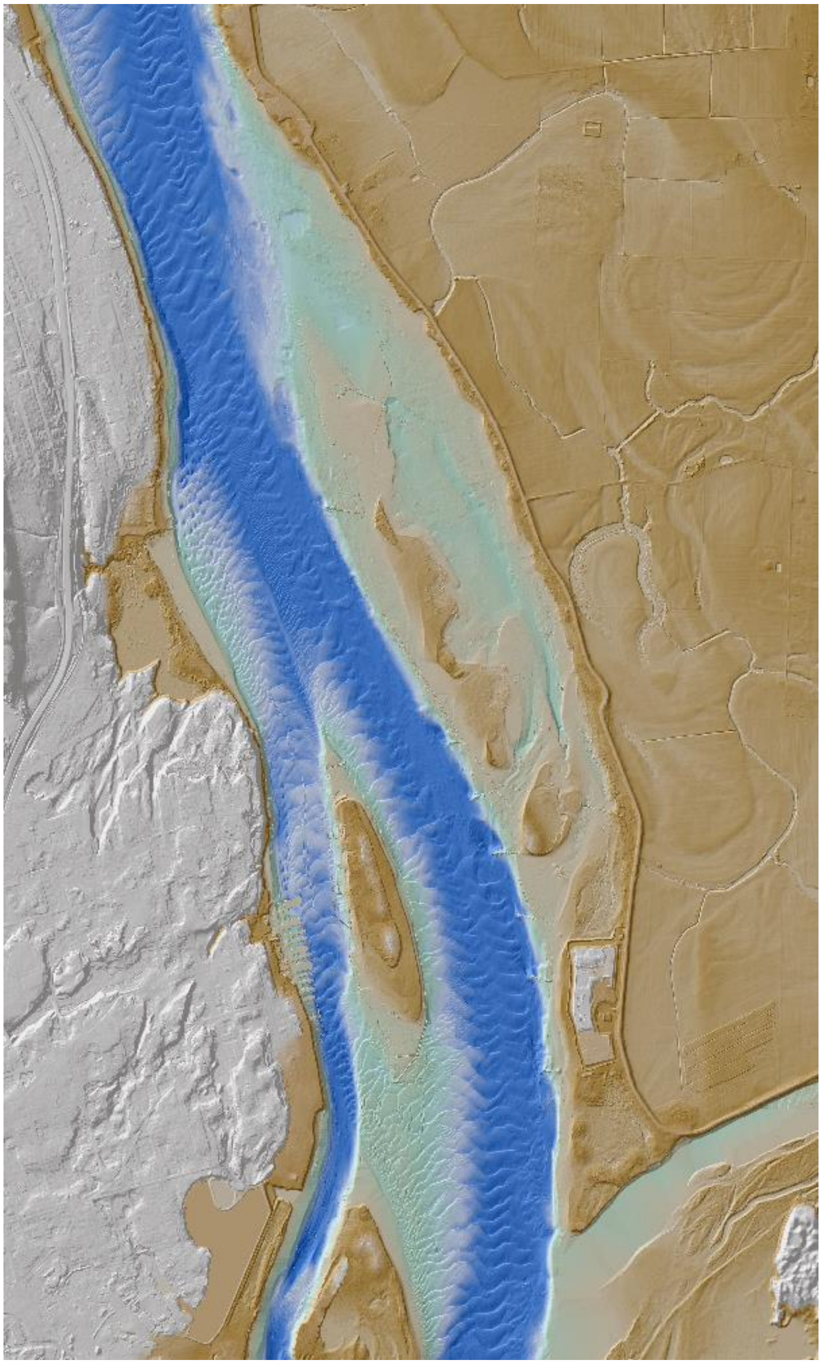

Figure 2.1. Terrain dataset created from LiDAR, Greenbeam imagery, and bathymetric surveys depicts existing topography and bathymetry of the Woodland Islands site and general vicinity.

Elevation ranges along the thalweg of the side channel are -10 to -5 feet NAVD88, or typical water depths of 10 to 15 feet below mean typical daily minimum water level during September when the lowest water levels of the year occur. Sand bars project downstream from the islands into the side channel, creating shallower areas from 0 to 10 feet NAVD88. Along the front side of the islands exposed to the main channel of the Columbia River, the terrain drops gradually toward the longitudinal pile dike around 0 feet NAVD88 and then more precipitously toward the navigation channel at approximately -40 feet NAVD88. Figure 2.2 shows a contour map of the site.

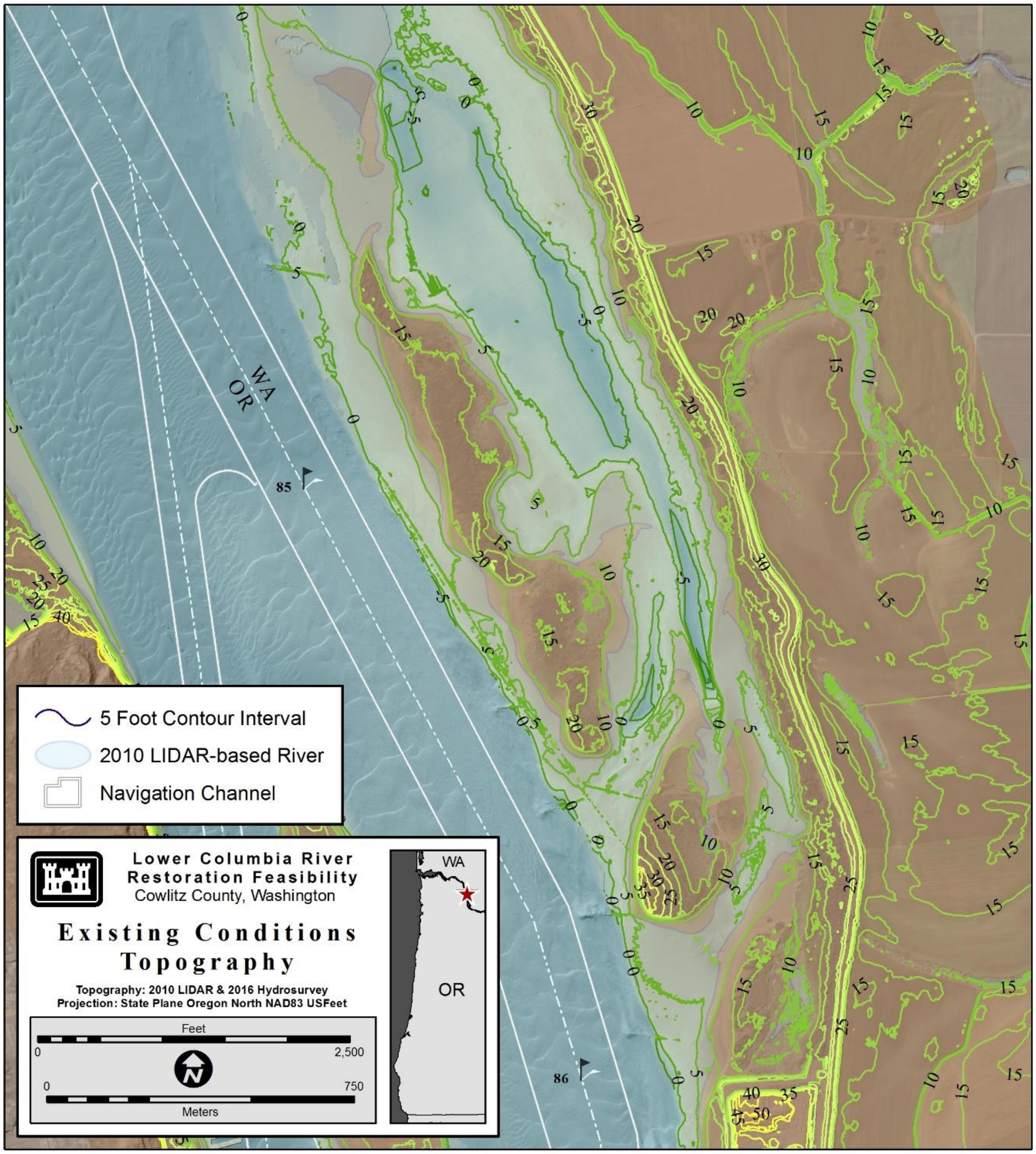

Figure 2.2. Contour map of the site showing typical ground surface and bed elevations (feet NAVD88).

Figure 2.3 shows typical cross-sections cut from the terrain dataset. From left to right, the cross-sections span from the deeper channel on the main-channel side of the islands, across the islands, into the relatively shallow cove, and up the Washington shore. Cross-sections cut from the terrain data show elevations through the sheltered cove on the backside of the north island.

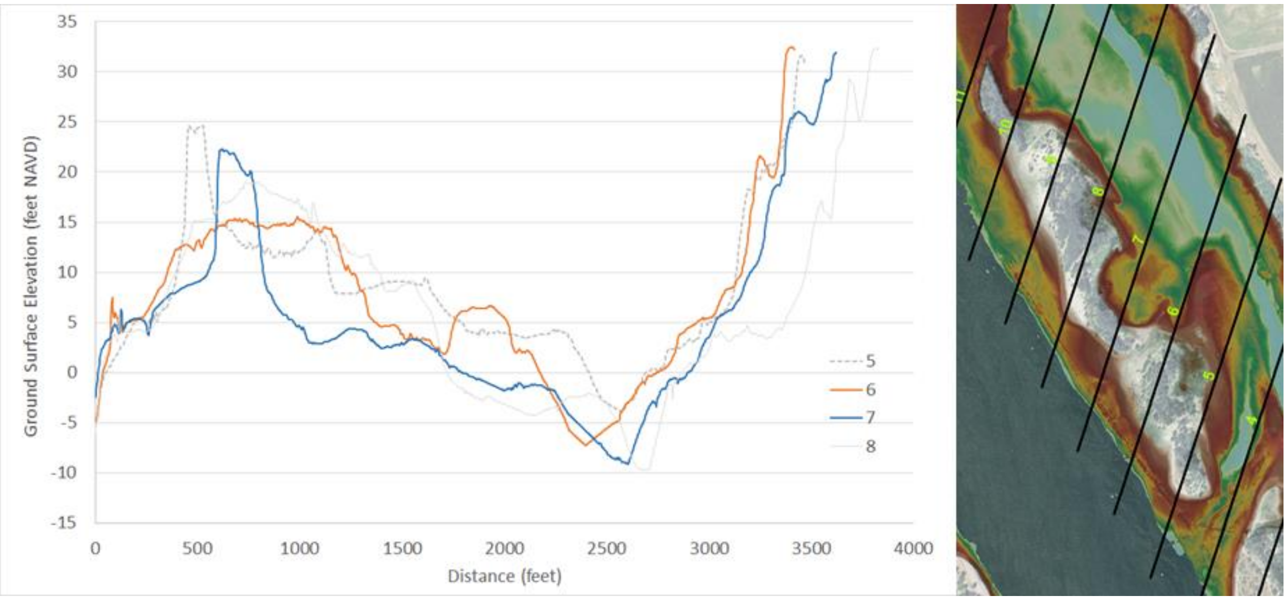

Figure 2.3. Cross-sections showing typical elevations across the islands and side channel.

2.2.2 Hydrology and Hydraulics

The Woodland Islands site is a small island chain and side channel area located at river mile (RM) 84 to 86 of the Columbia River, near St Helens, Oregon. For all practical purposes, water levels in the project area are the same as those in the main channel of the Columbia River.

The Columbia River drains over 259,000 square miles across most of the Northwestern US and some of Canada, and it has an average annual discharge of over 210,000 cfs. The river is highly controlled with dozens of flood control and water storage projects throughout the basin. The downstream-most project in the basin is Bonneville Dam at RM 146. Discharge from Bonneville and the upstream reservoirs is dominated by the annual spring freshet event, typically occurring from April to July. Below the dam, major tributaries including the Willamette River, Lewis River, and Cowlitz drain into the lower Columbia River reach and can add considerable volume to the Columbia River during winter flood events.

Tidal influences on the Columbia River occurs as far upstream the Bonneville Dam. At the Woodland Island sites, a strong tidal signal can be seen almost year-round with the most extreme effects including flow reversals occurring during the lower flow months of the summer and fall.

Tidal metrics and measured water level data from the NOAA gauge at St Helens, Oregon at RM 86, directly across from the Woodland Islands site are available the “Tides and Currents” website (http://tidesandcurrents.noaa.gov/waterlevels.html?id=9439201). **Error! Reference source not found.** lists NOAA’s tidal data and Figure 2.4. Summary or measured stage data at St Helens, Oregon along with NOAA tidal metrics and the 50% AEP flood elevation, equal to OHW at this site.

Table 1. Ordinary High Water (OHW) and tidal metrics for Woodland Islands at RM 86.

St Helens gage (NOAA 9439201) at RM 86.1 (feet NAVD88)	
OHW*	17.10
MHHW	9.24
MHW	8.74
MTL	7.45
MSL	7.44
MLW	6.15
MLLW	5.91
0 ft CRD	4.14
* calculated for RM 85.5	

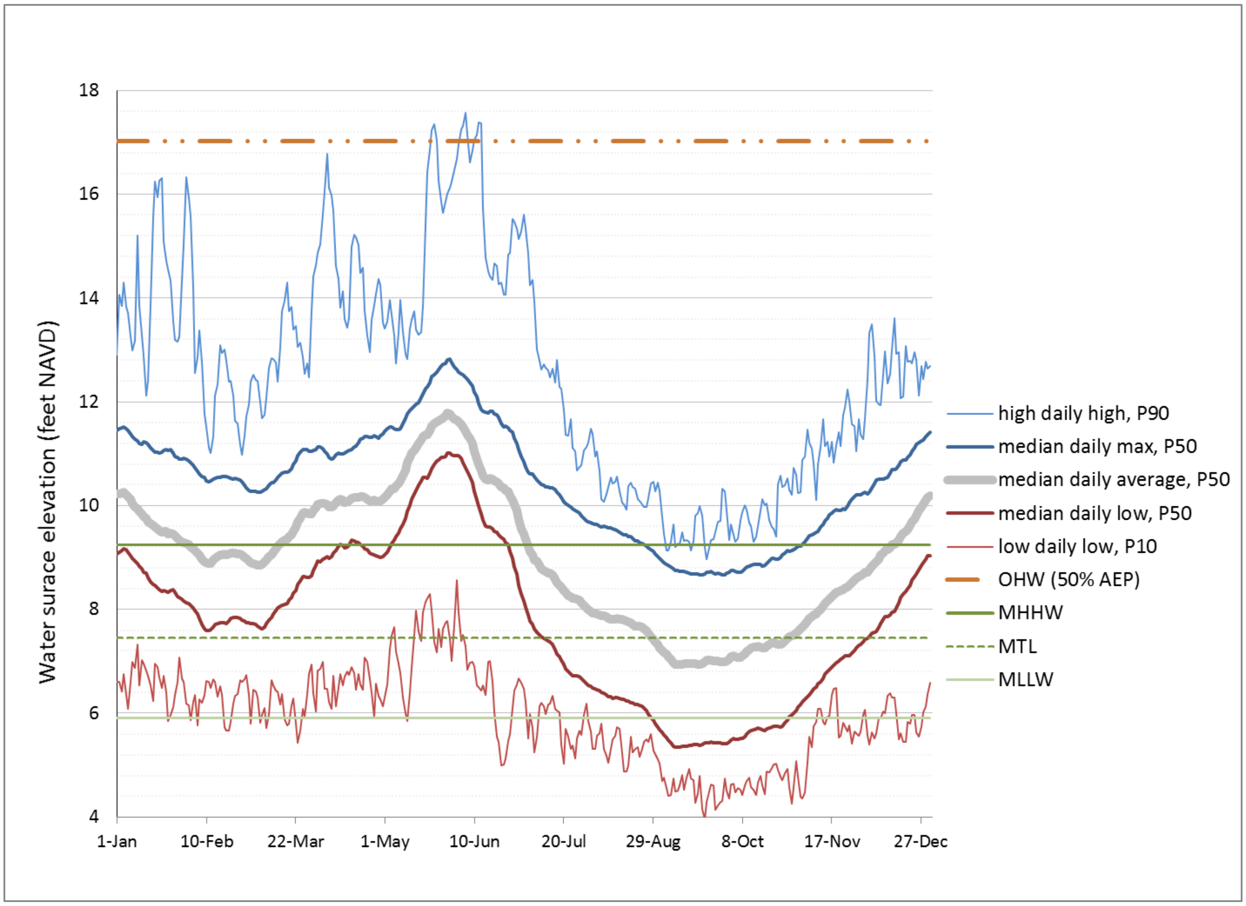

Figure 2.4. Summary or measured stage data at St Helens, Oregon along with NOAA tidal metrics and the 50% AEP flood elevation, equal to OHW at this site.

During the low water season, an average day flow of roundly 100,000 cfs is flowing by the Woodland Islands site. The island chain is generally out of the water and retards main channel flow from entering the side channel. Some flow passes through the inter-island channels, but velocity quickly dissipates once inside the side channel, due to relatively widening. Flow reversals are possible in low flow periods.

Much of islands are frequency inundated during seasonally high water levels including winter rain events, and most of the area is inundated during OHW. Figure 2.5 shows the islands inundated at four different water surface elevations. A stage hydrograph showing the available record of measured daily data at the NOAA gage at St. Helens just upstream of the Austin Point is also included in the figure.

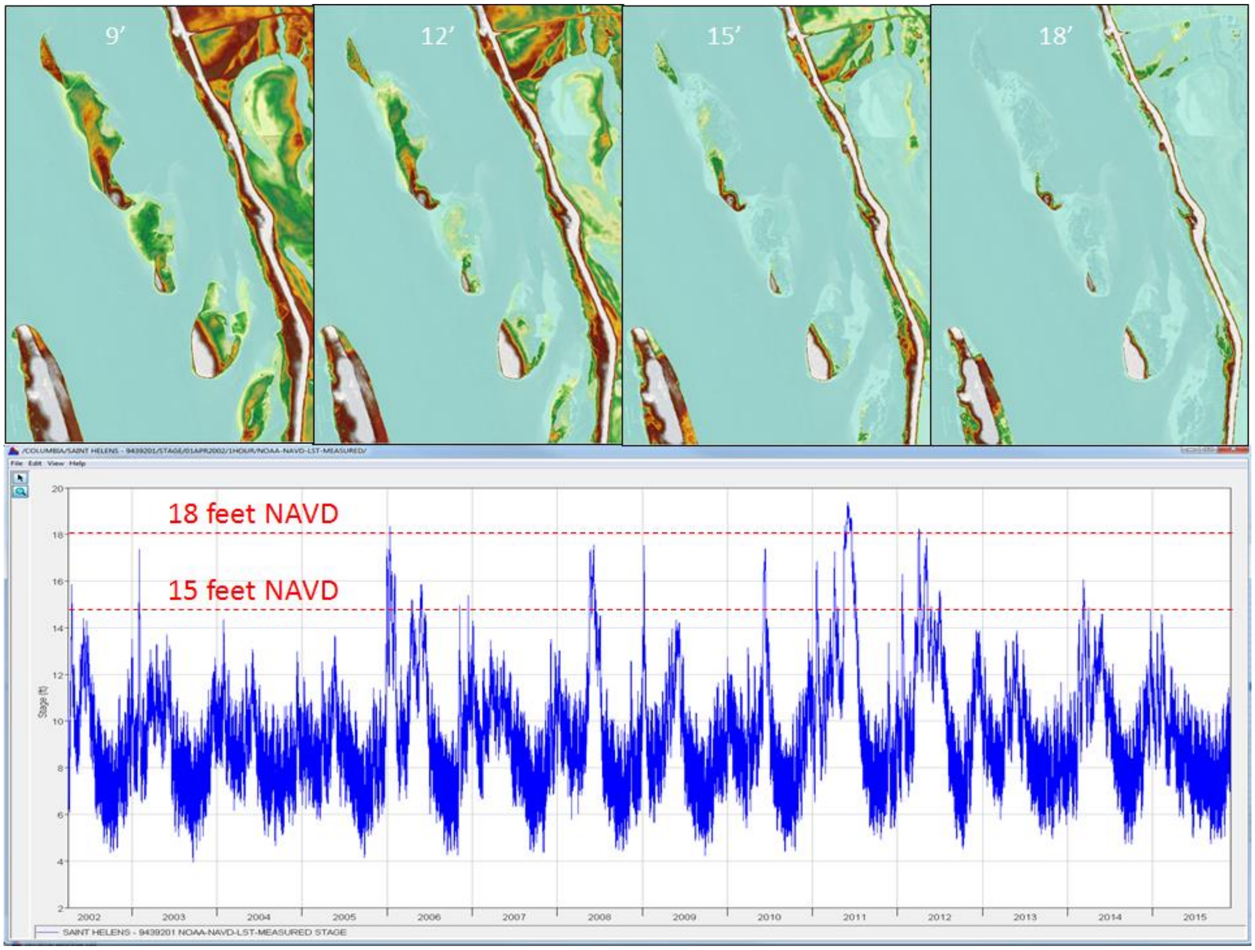

Figure 2.5. Existing terrain and inundated area graphics and measured water level data. All elevations in feet NAVD88.

Flooding typically occurs during the spring freshet but can occur as a result of winter rainfloods. The recent memorable flood in February 1996 crested at just over 27 feet NAVD, the fourth highest stage recorded at St Helens. The flood of record occurred in June 1948, which produced a stage of over 31 feet NAVD.

Combined probability flood profiles were produced from for the lower Columbia River based on one-dimensional, unsteady flow model results and statistical analysis. The profiles are indicators for expected probability of flooding and for defining critical flooding events. the upstream end of the site.

Table 2. Elevations of key annual maximum frequency discharges.

Event Frequency	Water Surface Elevation (feet NAVD88)
50% AEP (2-year)	17.0
10% AEP (10-year)	21.5
2% AEP (50-year)	24.9
1% AEP (100-year)	26.2
0.2% AEP (500-year)	29.3

summarizes the flood frequency elevations computed for St Helens at RM 86 at the upstream end of the site.

Table 2. Elevations of key annual maximum frequency discharges.

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1% AEP (100-year)	26.2
0.2% AEP (500-year)	29.3

A levee exists on the Washington bank that effectively separates the Columbia River from the historic floodplain situated on alluvial materials from the Lewis Rivers. The “Cowlitz 2 (Woodland)” levee located along the Washington bank has typical elevation from 30.5 to 32 feet NAVD88, which is well above the 500-year flood elevation. Due to the presence of low hills about St Helens on the Oregon side and the Cowlitz levee on the Washington side, flow is effectively confined to the main channel of the river for all but the rarest floods.

While much of the islands are submerged during high water, flow through the existing side channel is minimal compared to the main channel. The side channel is relatively shallow and much of the cross-sectional area is considered ineffective or not contributing to conveyance due to the presence of the islands and pile dike network.

2.3 Geomorphic Setting

2.3.1 Regional Setting

Over the last 150 years the natural landscape of the estuarine Lower Columbia River has been transformed by human activities. The hydrologic and geomorphic processes that sustained the river ecosystem have been altered by hydropower dam operation, channel confinement due to diking, and channel deepening; leading to changes in river circulation and sediment processes. Sand supply to the lower Columbia River has been reduced by ~70% over the last century, mostly due to a ~45% reduction in spring flows due to regulation and irrigation (Templeton and Jay 2013). In addition, dredging has removed ~620 – 900 megatons of sand over the same time period, and sand mining has removed an additional 18.6 ± 0.5 megatons since 1990 (Templeton and Jay 2013).

USACE is required to maintain a 43-foot navigation channel in the Columbia River and dredges 6 to 8 million cubic yards per year; mostly in June and July but with some “advance maintenance” in late fall. Dredged material placed at upland and deep-water sites results in a loss of this material from the river sediment budget. Based on USACE records, from 1971 to 1990 roughly 41% (±6.5%) of sediment dredged in the lower Columbia River was placed in locations that removed it from the system (Templeton and Jay 2013). This does not include dredging at the Columbia River mouth, which is comparable in the volume dredged. Additionally, dredging in the Columbia River has occurred since the 1860s by the City of Portland (later Port of Portland) and later also by the USACE (Templeton and Jay 2013), meaning sediment loss has been a sustained and ongoing process. Current channel maintenance practices are to place about 70% of dredged material back into the river system and about 30% along eroding shorelines and upland areas.

A matrix of wooden pile dikes provides shelter to the woodland islands complex and supports the federal navigation channel. This pile dike system is anticipated to be maintained such that the functionality it provides in the existing condition is maintained through the planning horizon.

There have been a number of instances where dredge material has been placed in large river systems over the past 50 years, including in the Columbia River. Many wetlands have formed as a result of the combined effect of dredged material placement and pile dikes, which help stabilize the dredged material and thereby provide adequate time for habitat to form. The fundamental concept is that dredged material must be placed such that semi-stable landforms remain in place long enough for plant communities to establish and intertidal channels to form.

2.3.2 Historic Imagery

The earliest available imagery from 1929 shows the major longitudinal pile dike, several smaller transverse pile dikes, and a single island supporting the most downstream pile dike. Also present at the time is a treeless Sand Island on the opposite side of the navigation channel. Figure 2.6 shows the 1929 imagery. The next available photo in 1939 (Figure 2.7) shows sparse vegetation on the created island, but no additional construction or apparent dredge material placement.

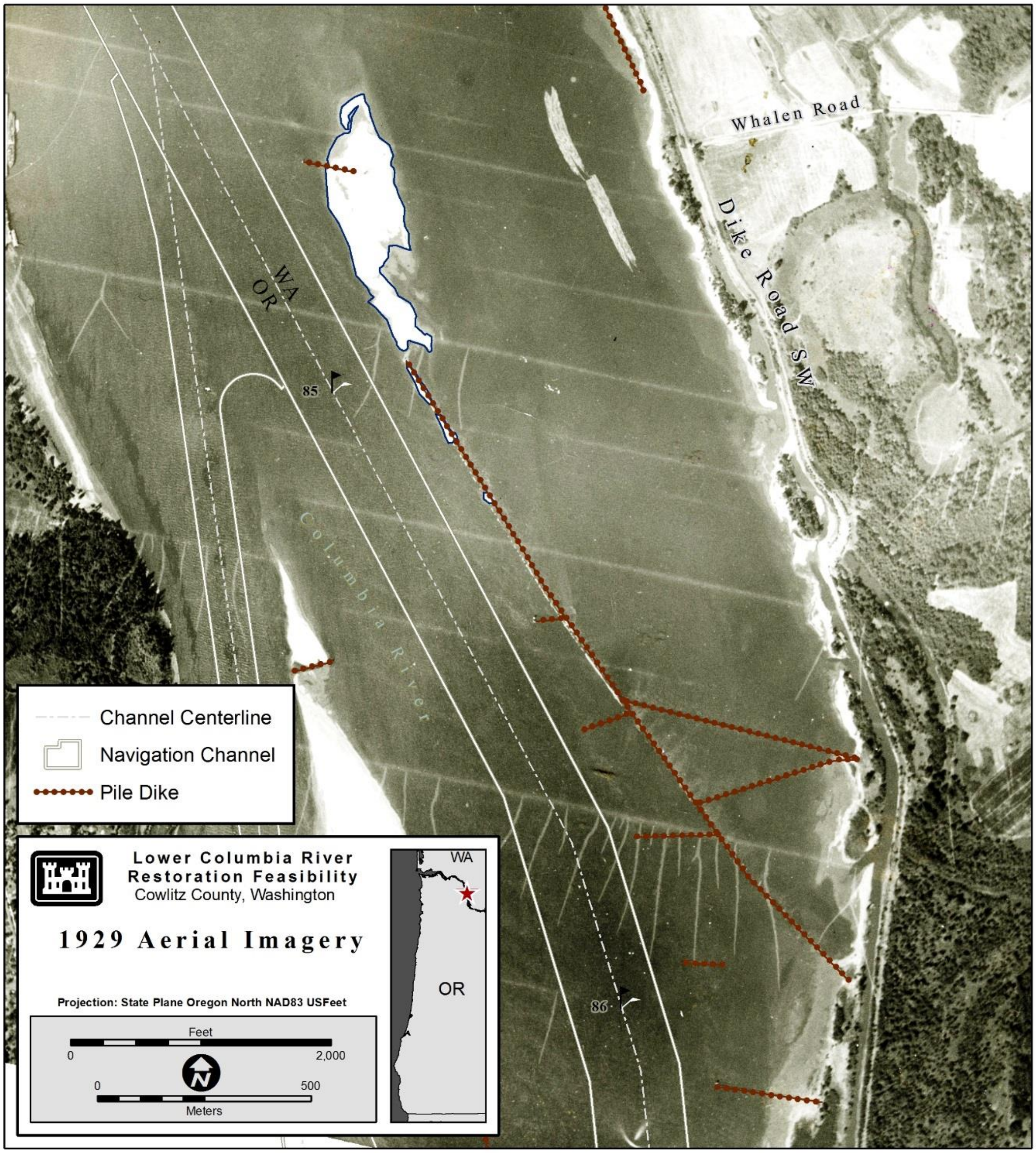


Figure 2.6: 1929 Aerial Imagery of Woodland Islands.

Figure 2.7. 1939 Aerial Imagery of Woodland Islands

Aerial imagery from 1957 (see Figure 2.8) show a larger island footprint suggesting that additional material was placed about the island and perhaps strategically along the pile dikes. The well-established vegetation on the island suggest that the series of very large floods in the 1940's and 1950's, including the largest recorded stage at St. Helens in 1948, were not large enough to scour the top of the island. Also in the image is a major store of timber rafts, suggesting this area was strategically created, at least in part, to support local industry.

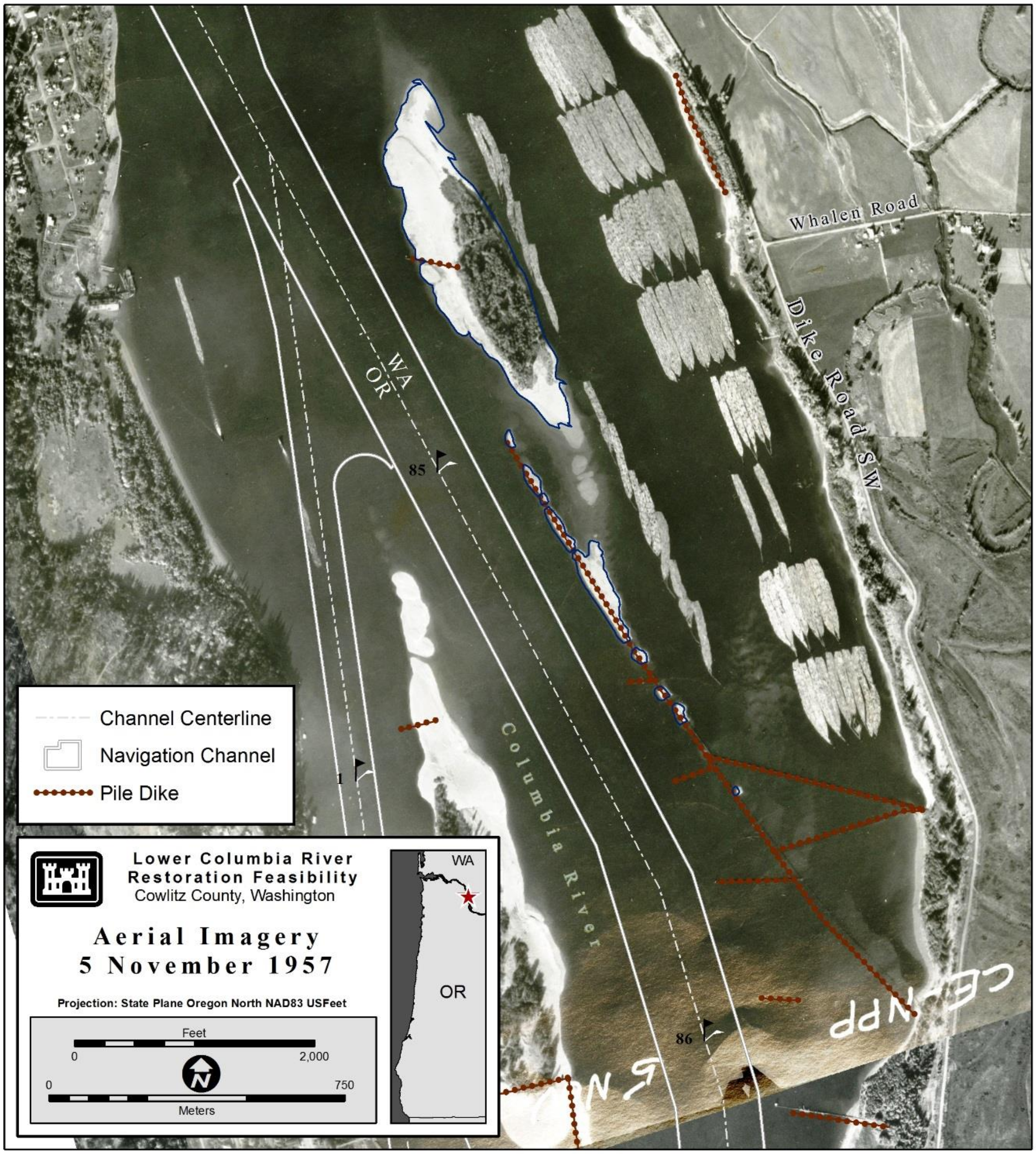


Figure 2.8: 1957 Aerial Imagery of Woodland Islands.

In 1968 the islands formed a chain resembling something similar to the existing condition and by 1973, the islands are completely joined, forming a long peninsula. This imagery, shown in Figure 2.9, depicts the largest footprint of the islands/peninsula. Apparent in this photo is an effort to establish vegetation on the islands being part of the project. The fingers on the sheltered side of the peninsula, also evident in the 1968 imagery, were likely caused by the December 1964 flood, the second highest recorded event at St. Helens in which the Willamette River discharged over six million tons of sediment into the Columbia River over a ten-day period. It is unclear how much of the fingers is material that was eroded from the peninsula itself

Figure 2.9: 1973 Aerial Imagery of Woodland Islands (peninsulas forming orange).

In 1977, the peninsula was still intact, however, there had obviously been some higher flow events resulting in overtopping at several locations and deposition of sand just downstream, creating several fingers that are still evident today. Between 1977 and 1980, there occurred what looks like at least one major flood that opened one major channel and several smaller openings between the large sand islands. By 1983, these channels have widened and it appears that no attempt to maintain the islands was performed (see Figure 2.10). It appears that one of the breach channels may have been excavated to support the reconnection with the main channel.

Figure 2.10: 1983 Aerial Imagery of Woodland Islands (breach locations blue).

Available photos from 1989, 1995, and 2011 show a more-or-less natural evolution of the site without new construction or dredge material placement. These imagery, particularly the 1989 imagery which was taken at a relatively low water level, are used to assess fluvial morphology and existing habitat. Figure 2.11 and Figure 2.12 show the 1989 imagery and the 2011 imagery, respectively.

Figure 2.11: 1989 Aerial Imagery of Woodland Islands.

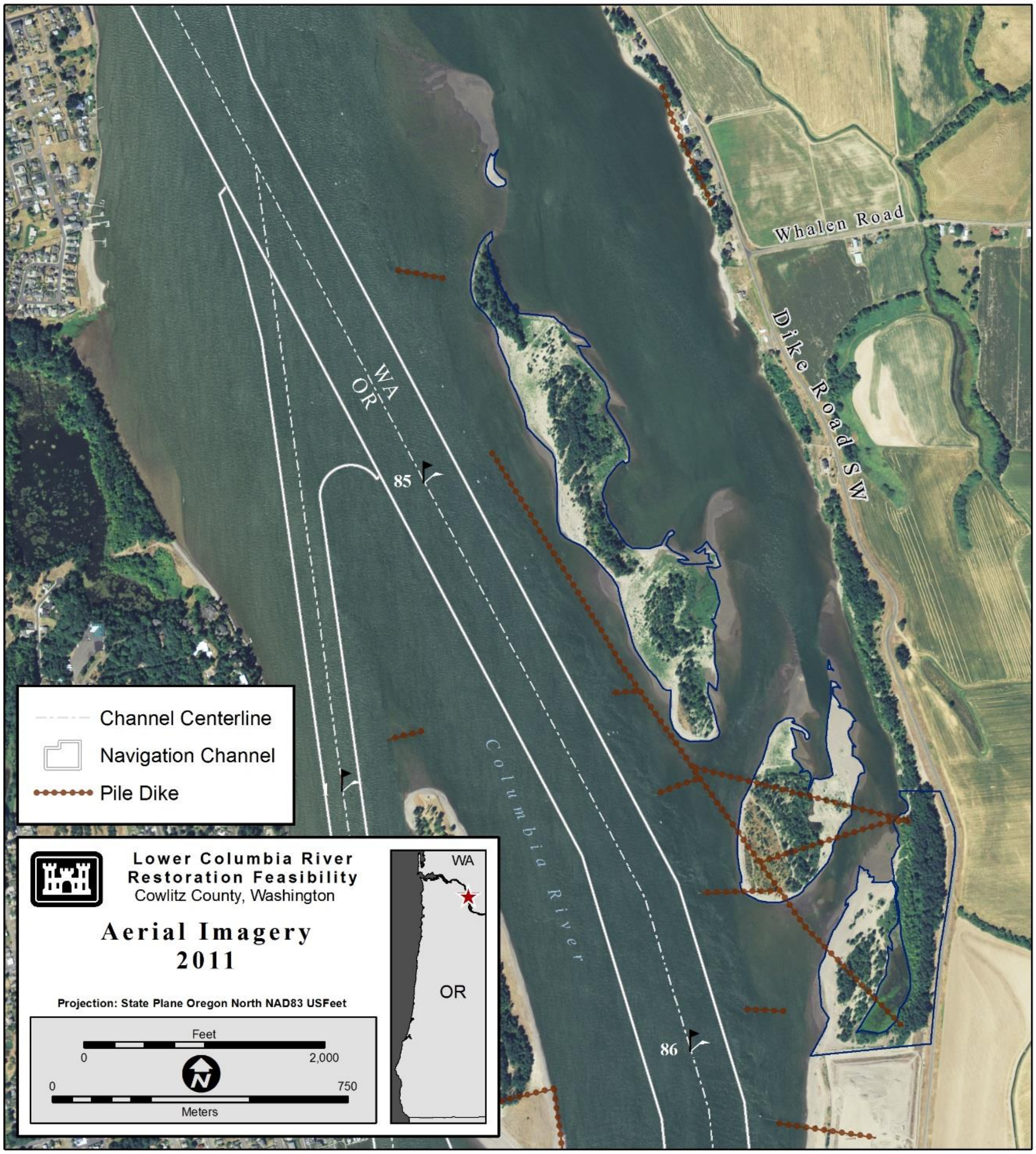


Figure 2.12: 2011 Aerial Imagery of Woodland Islands.

The island complex in the current configuration is almost completely different than what was present in 1929. By 1939, the extents of the downstream island expanded to the area that is currently occupied by the highest terrain containing the largest, oldest trees. This suggests that the oldest part of the existing island complex is roughly 80 years old, dating back to the 1930's. See Figure 2.13 for a side by side comparison of 1929 and 1939 aerial imagery overlaid with the 2011 island topography.

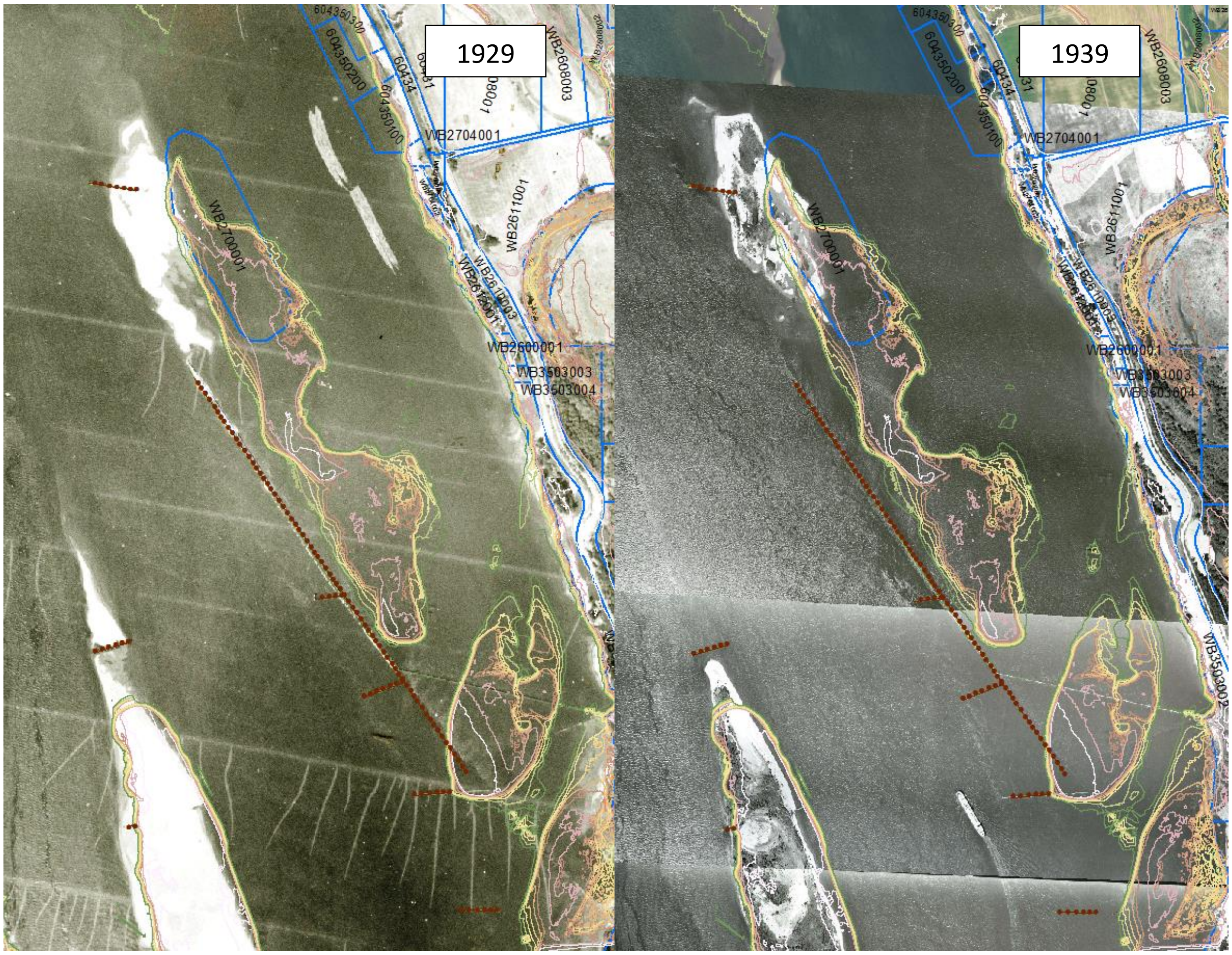


Figure 2.13: Comparison of 1929 to 1939 Aerial Imagery of Woodland Islands. Disregard tax lot information as this data layers contains known errors.

2.3.3 Erosion and Deposition

The site has been continuously changing since its creation prior to the 1920's. Dredge material has been placed along the longitudinal dike system from at least as early as the 1920's until the mid-1970's. The site has also been shaped by fluvial forces during regular high water and periodic floods.

Based on observations from island migration since the end of dredge placement at this site, island material has generally eroded and deposited in two distinct patterns. One occurs when river stages are below the island crown, material has eroded from the shoreline and swept downstream along to a depositional zone forming a scallop pattern in the shoreline. The other occurs when the river stage overtops the island saddles transporting material across the island and depositing on the leeward side to form a fan. Each pattern facilitates material deposition in the side channel embayment in between the islands and the Washington shore. Figure 2.14 compares 1977 imagery with topography from 2015.

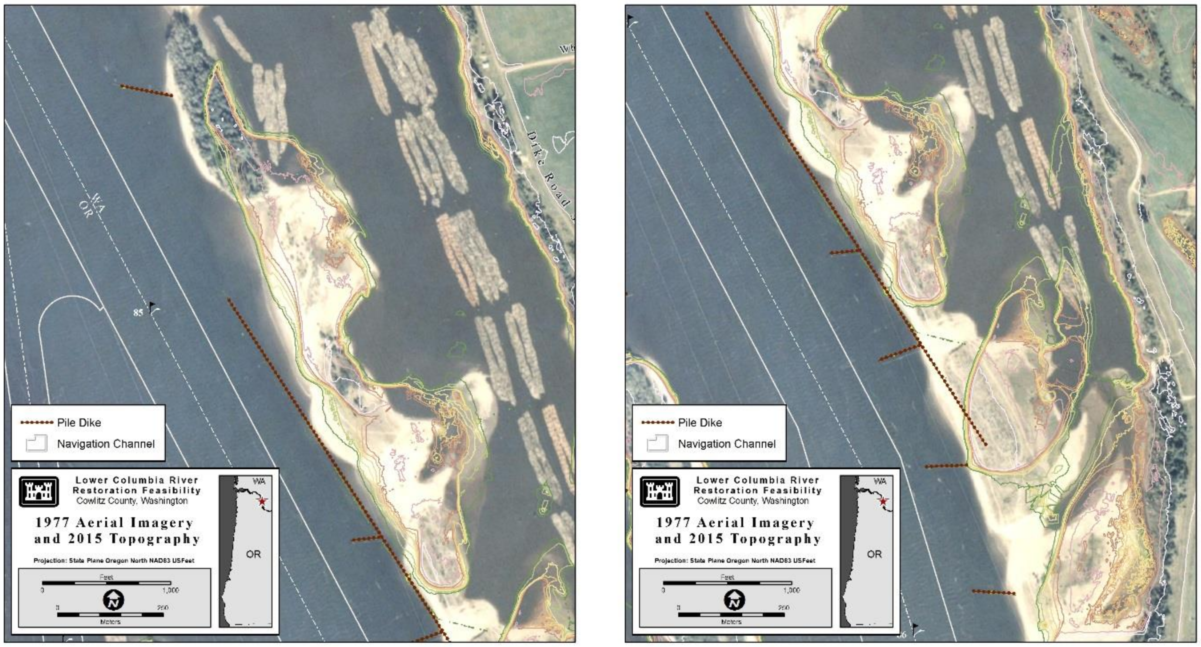


Figure 2.14. Changes due to erosion during the post-maintenance period from 1977 to 2015.

The scalloping pattern primarily occurs on the navigation side of the island complex and at the breaches in the island chain where the shoreline is subjected to higher velocities. Along this length the island complex is protected by a matrix of pile dikes oriented both longitudinally and transversely to the flow. These pile dike features add a significant level of protection against erosion deflecting and controlling direction of the flow energy approaching the islands when adequately spaced from or connected to the area of protection. However, when separation between the pile dike and shore is excessive, the pile dike can act as a training feature for erosive flow energy against the shore. This is occurring on the navigation side of the island and is most notably evident at Island D. As the shoreline erodes, which was once attached to the transverse pile dike adjacent to the island, the flow that was once trained toward the navigation channel now has opportunity to be entrained between the island and pile dike, increasing the erosive energy on Island D (see Figure 2.15 and Figure 2.16). Material is mobilized from the beach failure zone and deposited on the shoal downstream.

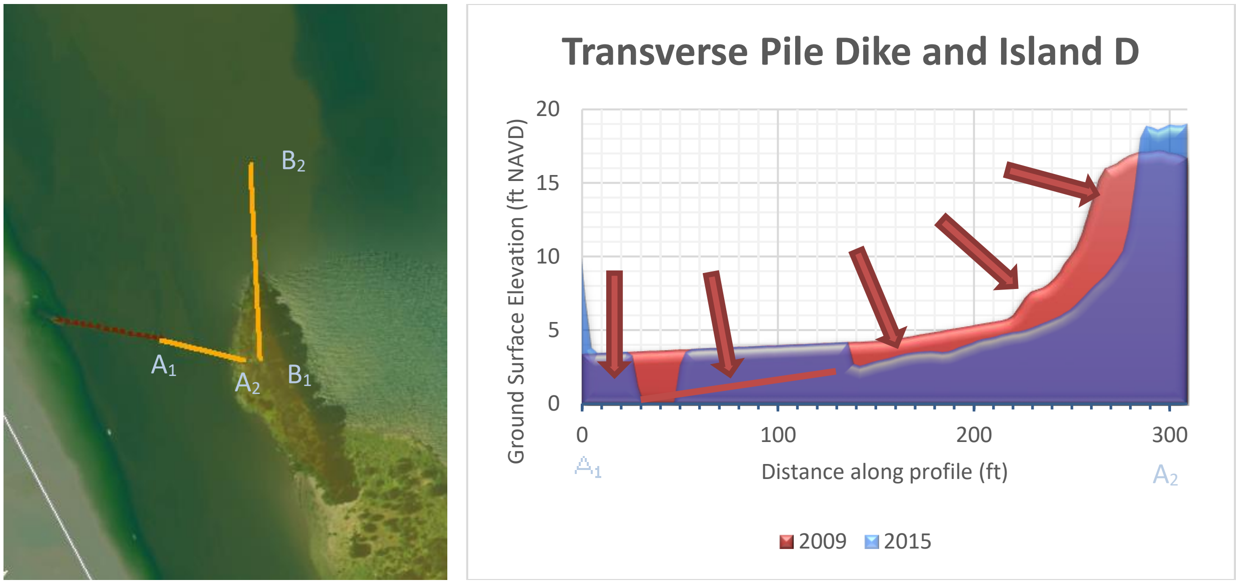


Figure 2.15: Profile Alignments of Island D and Profile between pile dike and Island D.

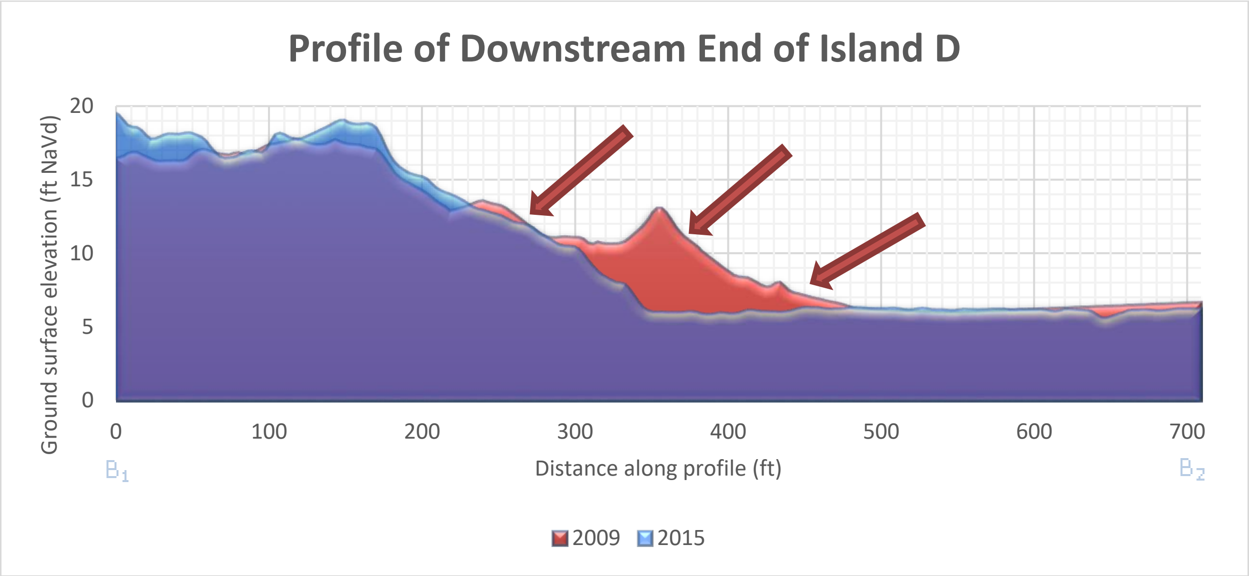


Figure 2.16: Profile of Downstream End of Island D.

Wind-wave effects can be observed in the topography and aerial imagery take at low water levels. The predominant wind direction during low-water periods is from the north-northwest, coming from down river. The fetch from this direction is roughly 2 miles, relatively long. The effect of wind-wave action is evident in the upstream migration and orientation of sand bars. The major downstream bar is an extreme example, but more subtle examples can be seen further up the side channel on both sides. Along with wake impacts from navigation traffic, the wind-wave effects contribute to beach failure destabilizing the exposed shoreline and promotes this scalloping erosive pattern.

The overtopping events of significant magnitude to cause significant erosion of the crown (often occurring at 14-15 ft NAVD) of the island chain has been relatively infrequent. The established vegetation on the crown of the island chain has provided some resistance to erosion and contributes to the roughness. On the leeward side of the islands the vegetation slows overtopping flow allowing for deposition to occur. This resulted minor to moderate accretion evident in aerial imagery and topography. With that being said there has been some significant reduction in upland terrain at elevation above 15 ft NAVD.

An effort to quantify the change in upland terrain was taken by calculating average rates of shoreline migration for the post-maintenance period over the past 40 years can be done using historic imagery. Variable river stage at the time of the photographs make it difficult for a direct comparison of island extents near the shoreline (because the aerial extent of the islands changes with stage); however, one can identify upland areas by consistent tree lines, stark transitions in vegetated to sandy areas indicating steep slopes, and cut banks approximate the change in total area above OHW due to the distinct change in vegetation from upland to below OHW. Figure 2.17 shows the aerial extent of the high ground with each island for available imagery from 1977 to 2016 overlaid on the 1977 imagery, and Figure 2.18 graphically shows the decline in acreages above OHW over time.

Figure 2.17. Estimated aerial extents of land above ordinary high water (OHW) overlaid on 1977 imagery.

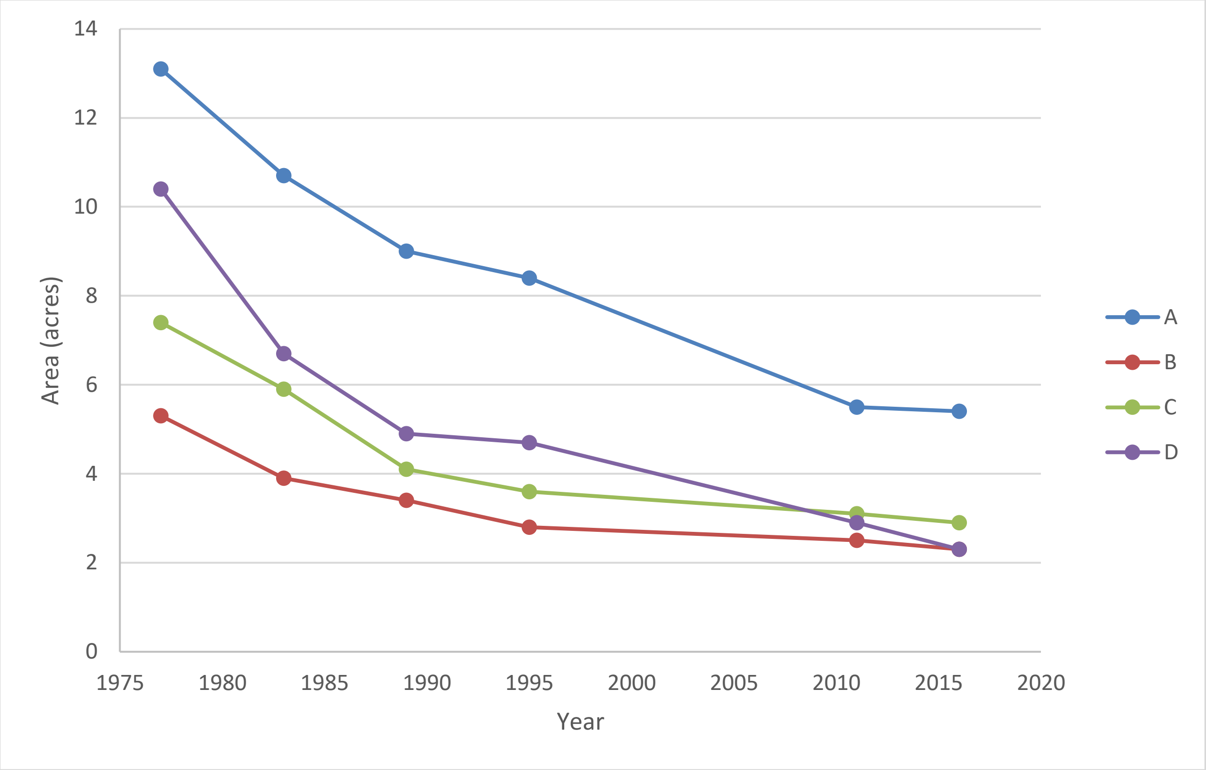


Figure 2.18. Decrease in acreage above ordinary high water (OHW) for the individual islands.

The total area above OHW has decreased by 64% from 36 acres to 13. The rate of decline was greatest in the 1970's and has slowed considerably since, despite one of the largest floods on record in February 1996 and large freshet events in 1997, 2011 and 2012. Upland areas on island D continue to be erode at a greater rate compared to the others. Most of the erosion is on the downstream end where flow accelerates as it wraps around the end of the island chain. Wind wave erosion is also a considerable factor at location, with the largest fetch of open water coming from downriver, which is the prevailing wind pattern during summer months.

Another way to look at the migration of the islands is to compare them with the pile dikes. The average distance from the pile dike to the islands has increased less than 100 feet on average from 1977 to 2016, but the losses on the downstream end are as much as 500 feet, which is more than 10 feet per year on average.

More accurately, shoreline migration can be calculated over the past 5 years by comparing topographic data from 2010 and 2015. Figure 2.19 shows that one major cutbank on island C eroded 35 feet horizontally between 2010 and 2015.

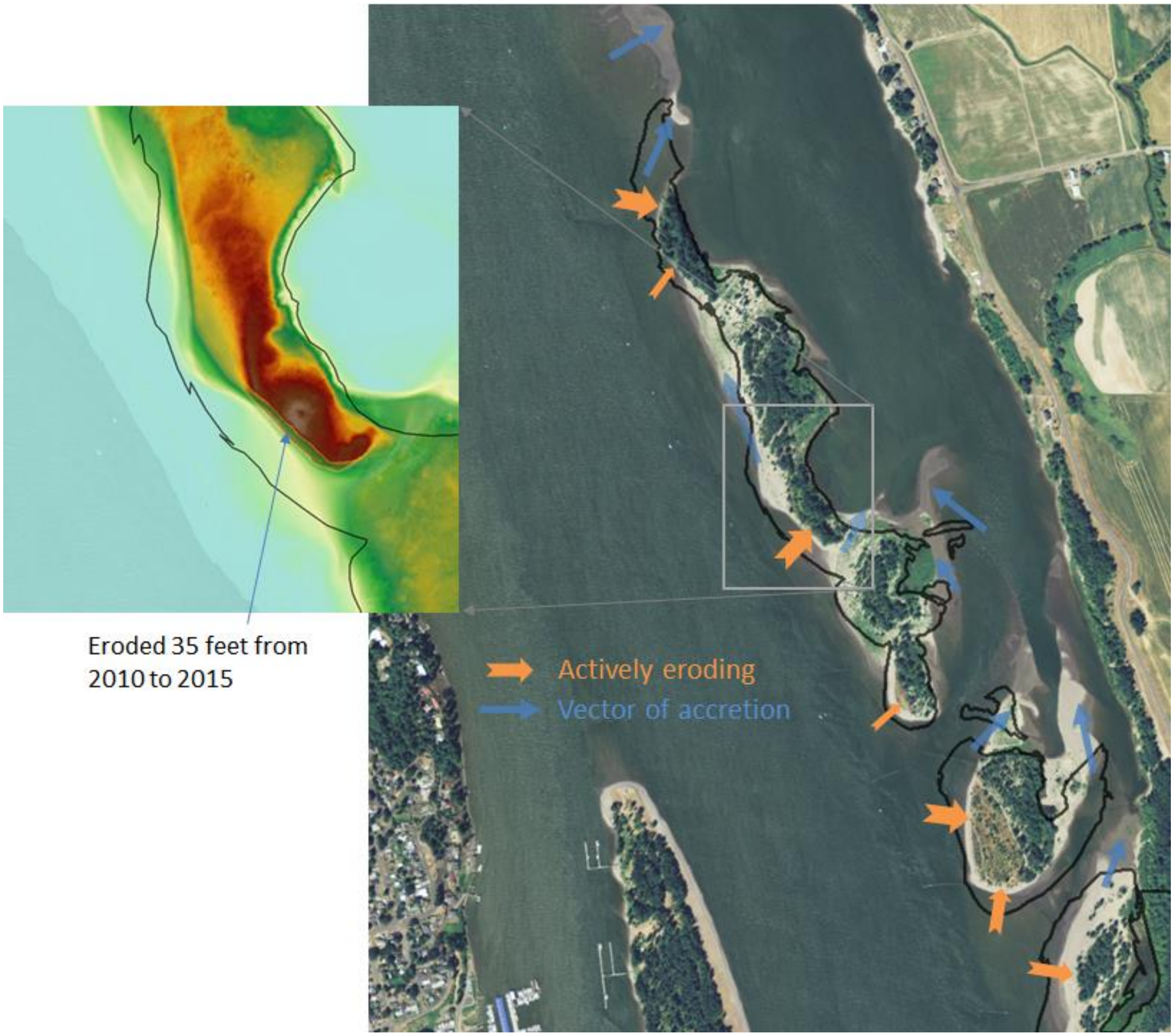


Figure 2.19. General morphology and detailed comparison of topography.

Additionally at the overtopping depositional zones between islands D and C and behind island B, cross sections compared from 2010 and 2015 terrain data sets show relative deposition given the 2011 flow event occurring in between data collections. Figure 2.20 shows the locations of sections A and B, which are shown in Figure 2.21 . Section A1-A2 indicate minor sloughing and bank failure around 13 to 14 ft NAVD. Section B1-B2 located on the land bridge near the downstream placement location indicates vegetative growth near shore line and minor changes below 10 ft NAVD.

Figure 2.20: Transects A and B, on the downstream, landward side of Island D.

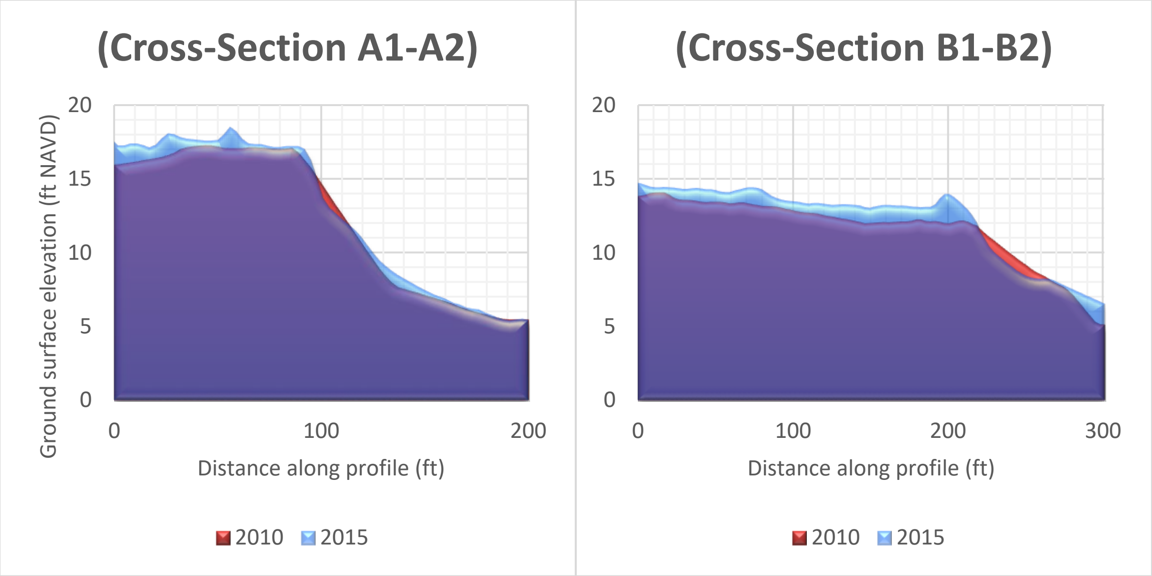


Figure 2.21: Section Views for A1-A2 and B1-B2 in 2010 (red) and 2015 (blue).

Cross sections compared from 2010 and 2015 terrain datasets at the proposed upstream placement attachment location show relative stability given the 2011 flow event occurring in between data collections. Figure 2.22 shows the locations of cross sections C, D and E on the landward side of Island B and shown in profile view in Figure 2.23.

Figure 2.22: Cross Sections C, D and E, on the landward side of Island A.

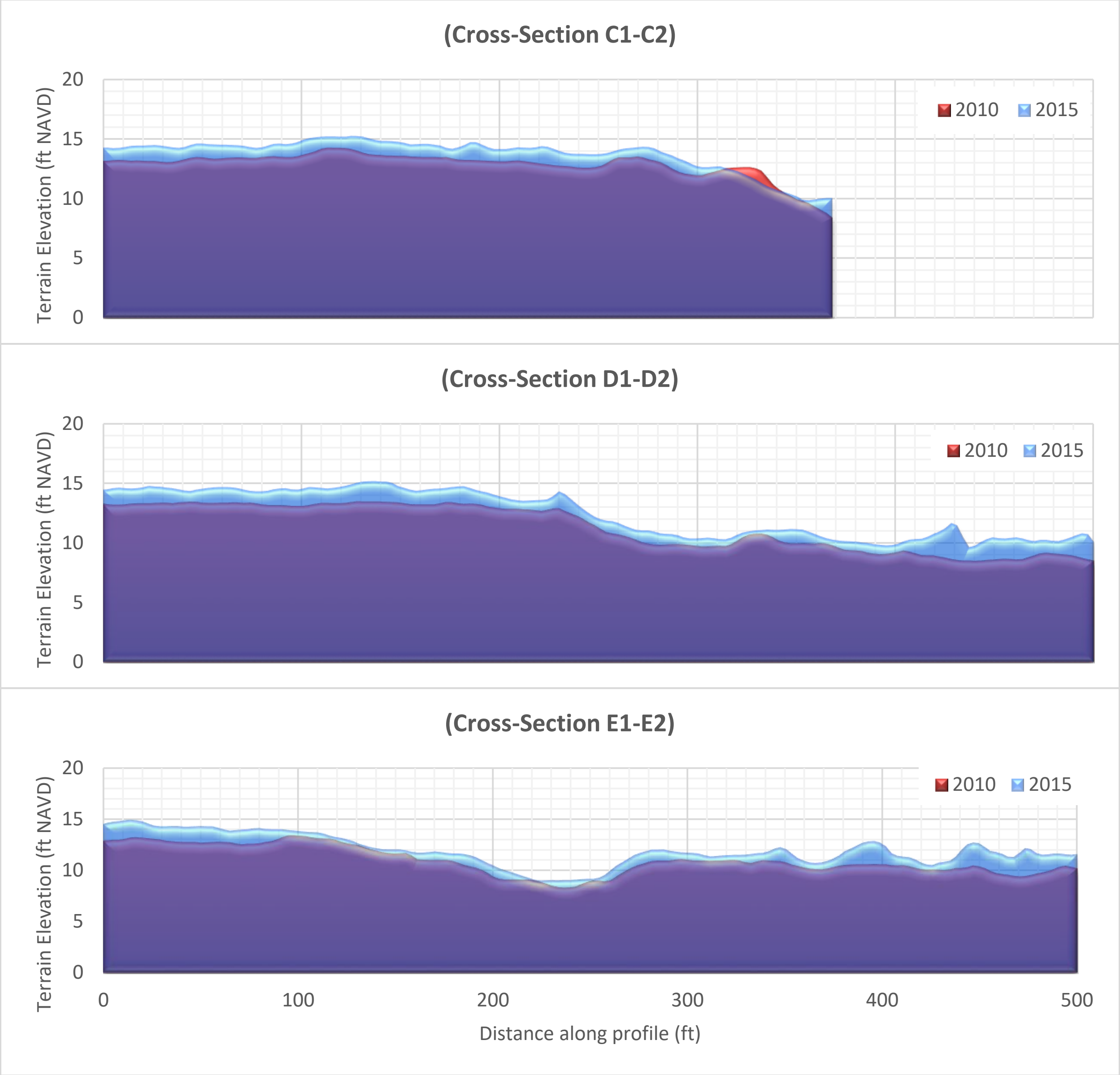


Figure 2.23: Profile View of Island A (Cross Sections C) in 2010 (red) and 2015 (blue).

2.3.4 Vegetation Response to Fluvial Morphology

General trends in morphology show active erosion on the upstream faces of the islands and deposition on the protected, downstream side. For material deposited behind the islands, either intentionally or via erosion and transport occurring with a flood event, the trend is away from active channels toward the sheltered areas, creating a wrap-around appearance.

As illustrated in the 1973 photo (Upper Right of Figure 2.24), amidst consecutive years of dredge material placement along the islands, a small sheltered cove was established. The lower elevation finger extending north was most likely created during the December 1964 flood, which would have overtopped nearly the entire island complex, scouring low spots on the island and depositing the eroded material immediately downstream. By 1995 this cove had mostly closed off, leaving a small pond sheltered by sand bars. A lone tidal channel is shown connecting the pond to the river. By 2011, the pond has completely filled in and a dense shrub/reed canary grass population has established itself in the area.

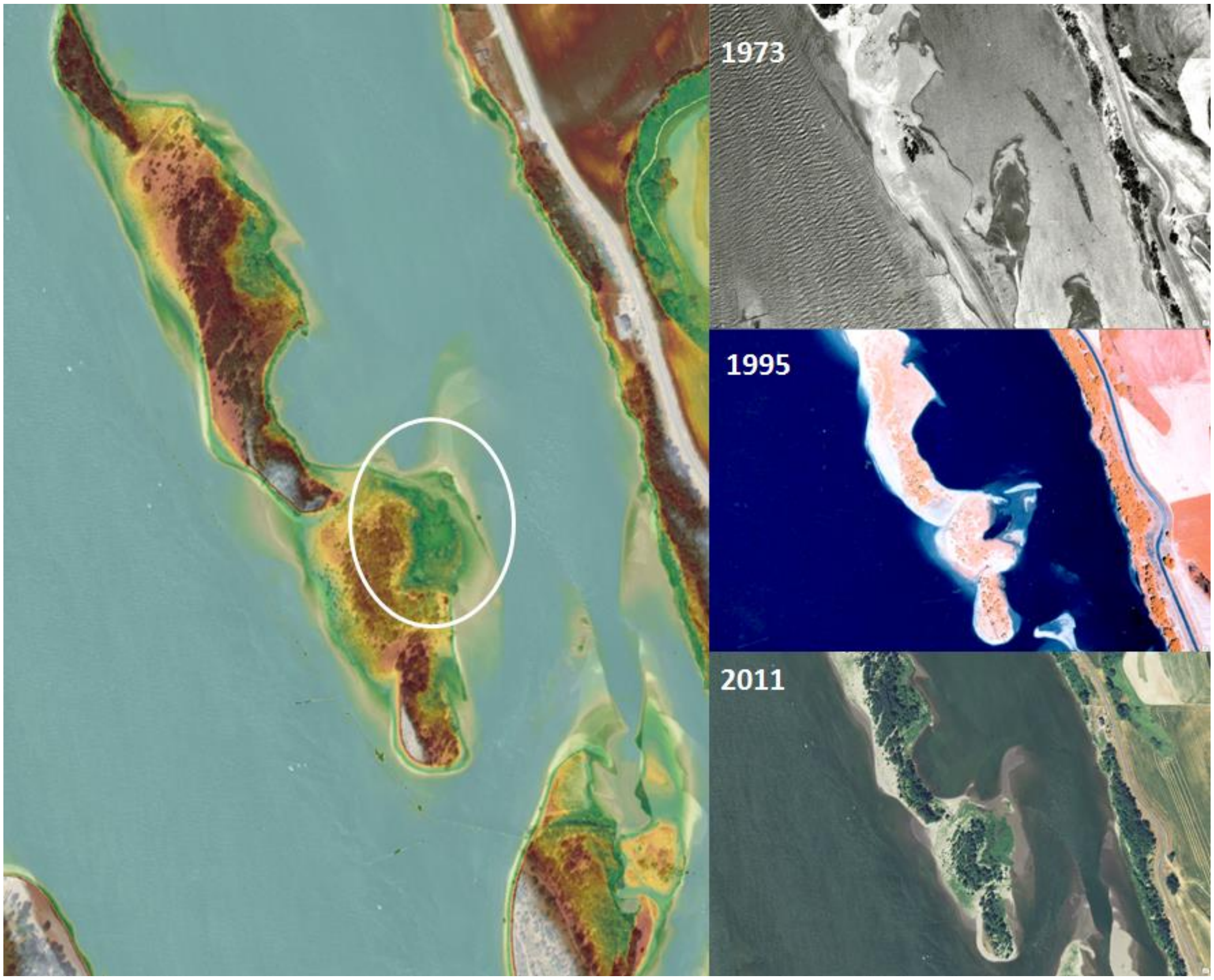


Figure 2.24. Evolution of existing wetland habitat on the backside of the islands.

The sheltered embayment that exists behind hills is accumulating fine grain material and supporting vegetative material at subtidal elevations. This material was discovered during a site visit on April 15th of

2016 and from aerial imagery on Google taken in the late summer of 2016 (see Figure 2.25). This is the only location in the area supporting vegetation at this elevation.

Figure 2.25: 2016 Aerial Imagery of Vegetative Material.

An evaluation of the elevation-vegetation relationship is presented in further detail in the following section including sheltering effects.

2.4 Elevation-Vegetation Relationships

A wetland survey of the site in 2016 identified the presence and extents of various vegetation and habitat types on the island. The survey was used in conjunction with aerial imagery to determine elevation zones for various habitat types in support of establishing habitat criteria.

Based on field observations from the wetland survey and an interrogation of the 2016 aerial photography, seven different habitat types were found on the island complex. These habitats were delineated by GIS shape files and overlaid on the existing bathymetric and topographic terrain sets to determine the relationship between plant community occurrence and the elevation.

While there was general correlation of habitat zone to elevation, it was found that the relationship identified on the navigation channel side of the island complex differed significantly and consistently with the relationships identified on the sheltered embayment side of the island complex. The navigation channel side of the island was made up fewer habitat zones in narrower bands while the sheltered side was composed of more complex distribution of plant communities of irregular banding widths. Several sections were taken of the shoreline to with the vegetation elevation banding applied, three were chosen for this document and can be seen in Figure 2.26, Figure 2.27, Figure 2.28, and Figure 2.29.

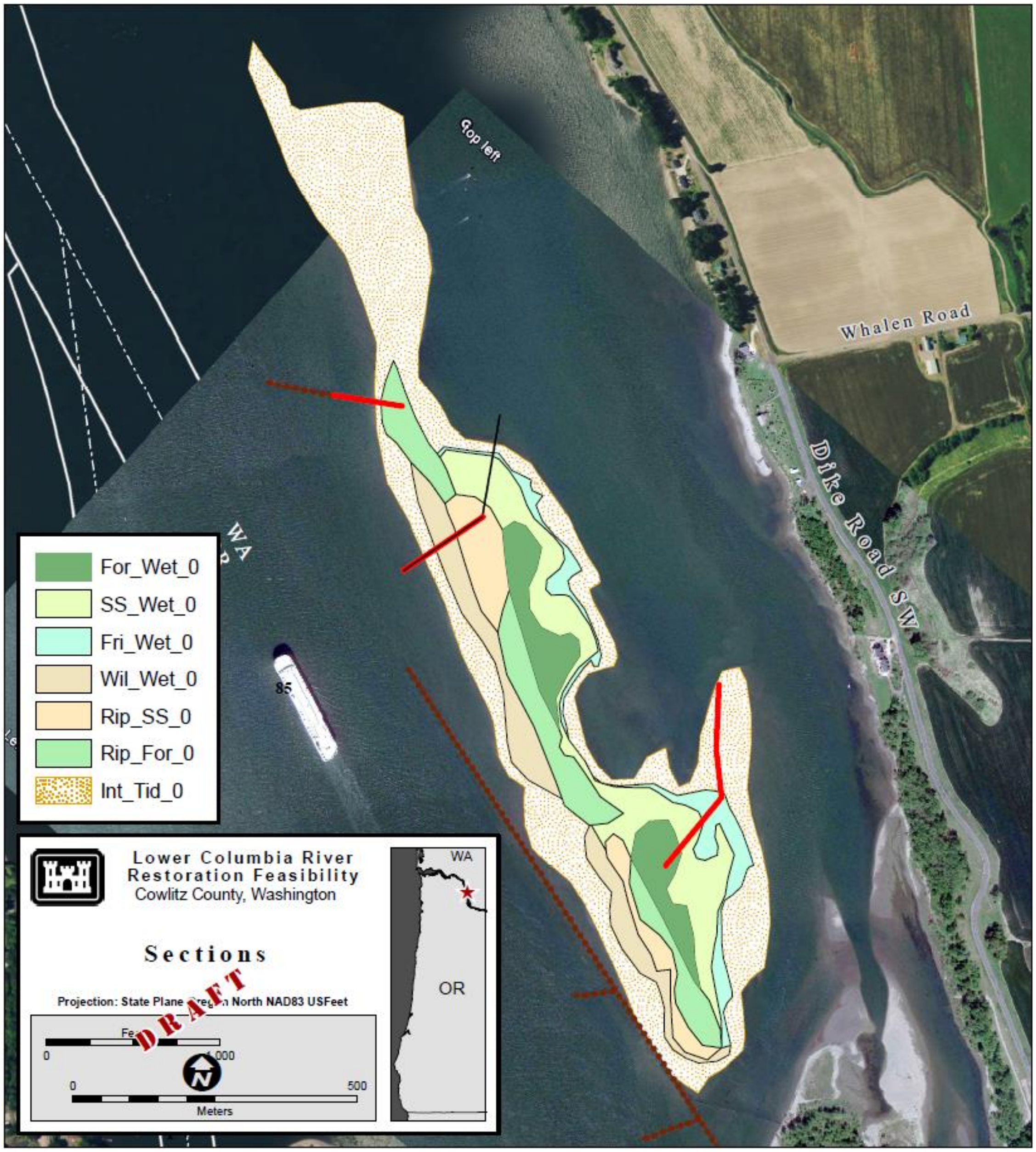


Figure 2.26. Vegetation Zones (2016 Conditions).

The habitat zonal coverage is delineated in Figure 2.26 below and plant community descriptions presented in the following paragraphs:

Forested wetland is dominated by an overstory cottonwood, red alder, and Oregon ash trees. The understory is sparse with few willows, red-osier dogwood, and slough sedge. This habitat is intermittently inundated by high tidal conditions and seasonal river flows. The soils are developed and have fine (silts/clays) particles repeatedly deposited by inundation over several years. (For_Wet_0 in map)

Scrub-shrub wetland is dominated by shrub-sized vegetation mixed with grasses and rushes. Shrubs include young cottonwood, alder, and willows. This habitat is regularly inundated and has a developing organic surface layer over a thin (<6 inches) loamy-sand soil over sand. (SS_Wet_0 in map)

Fringe wetland is dominated by young willow and alder shrubs, reed canary grass, and patches of dense sedges and sparse rushes. This habitat located in lowlands and on the sheltered perimeter of the islands. It is typically inundated daily with moderate seasonal high flows trapping suspended sediments, organics, and fine particles by the wetland vegetation. The soils have a thin (<3 inches) surface layer of fine-grained sediments and organics overlaying coarse to fine sands. (Fri_Wet_0 in map)

Intertidal zone is typically not vegetated and consists of the active beach zone that is gently sloping to open waters. The sediments are dominated by coarse to medium-sized sand grains and small gravels. (Int_Tid_0 in map)

Riparian forest is an upland community that is dominated by an overstory of deciduous trees, primarily cottonwood, with think understory of blackberry, Oregon ash, hawthorn, rose, horsetail, English ivy, scotch broom, and nettle. This area is a generally level to gently sloping landscape that is rarely flooded and has been established for several decades. This habitat has established soils with developed root zones and a surface organic layer. (Rip_For_0 in map)

Riparian scrub-shrub is dominated by young trees and multi-trunk shrubs of cottonwoods, alder, scotch broom, with few willows and several species of grasses and forbs. This habitat is rarely inundated. This habitat has established soils with developed root zones and a developing surface organic layer. (Rip_SS_0 in map)

Willow wetland is a tidally influenced community that is sparsely vegetated and only consists of young willows that are narrow (<2" diameter) and less than 8 feet tall. This is early successional community on recently (< 5 years) accumulated sandy sediments. (Wil_Wet_0 in map)

Beach failure zone is not vegetated and consisted of the actively eroding bank that underlies riparian vegetation. The upper portion of the zone consists of exposed roots and collapsing soils. (not shown in map due to scale and relative size of beach failure zones)

The tidal influence renders average high and low river stages of approximately 9 ft NAVD and 6 ft NAVD, respectively. Table 3, Table 4, and Table 5 were developed from onsite surveys at Woodland Islands, LiDAR and bathymetric data, and aerial photography. They show the elevations of the vegetation zones that were observed on and around the islands.

Table 3. Downstream tip of Island D, actively eroding edge (Figure 2.27).

Community Name	**Community Elevation**	**Abbreviation** (Figure 2.26)
Riparian forest	+12 ft. to +18 ft.	Rip_For_0
Beach/failure zone	+8 ft. to +13 ft.	N/A
Intertidal zone	+5 ft. to +9 ft.	Int_Tid_0

Table 4. Island C, accreting zone with thin willows, pile dike 84.99 downstream end (Figure 2.28).

Community Name	**Community Elevation**	**Abbreviation** (Figure 2.26)
Riparian scrub-shrub	+14 ft. to +16 ft.	Rip_SS_0
Willow (sparse) wetland	+10 ft. to +14 ft.	Wil_Wet_0
Intertidal zone	+3 ft. to +11 ft.	Int_Tid_0

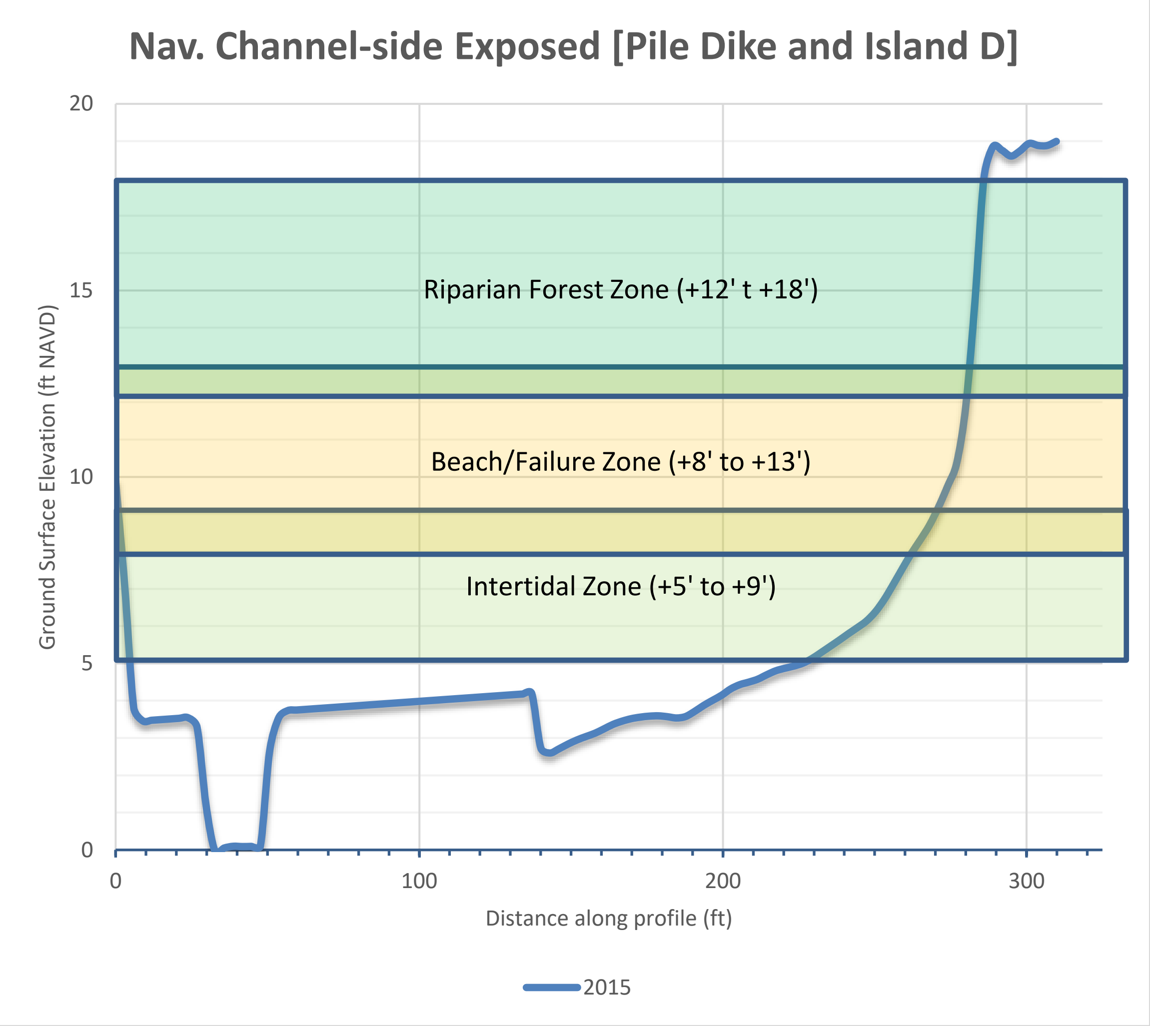
Table 5. Island B, sandbar to fringe wetland to forested wetland (Figure 2.29).

Community Name	**Community Elevation**	**Abbreviation** (Figure 2.26)
Forested wetland	+13 ft. to +15 ft.	For_Wet_0
Scrub-shrub wetland	+10 ft. to +14 ft.	SS_Wet_0
Fringe wetland	+9 ft. to +11 ft.	Fri_Wet_0
Intertidal zone	+6 ft. to +9 ft.	Int_Tid_0

An additional community of submerged aquatic vegetation (SAV) was further identified from subsequent aerial imagery (Google 2016 image). Given the river conditions of water clarity, wave action, and lack of reflection SAV was able to be delineated in sheltered zones of the side channel.

Based on the site specific plant community evaluation, the shoreline is delineated by 10 ft NAVD. This was selected as the interface of scrub-shrub wetland where vegetation cover is initially inundated. This elevation lies within mean low and high river stage during the assumed period of occupation by salmonids.

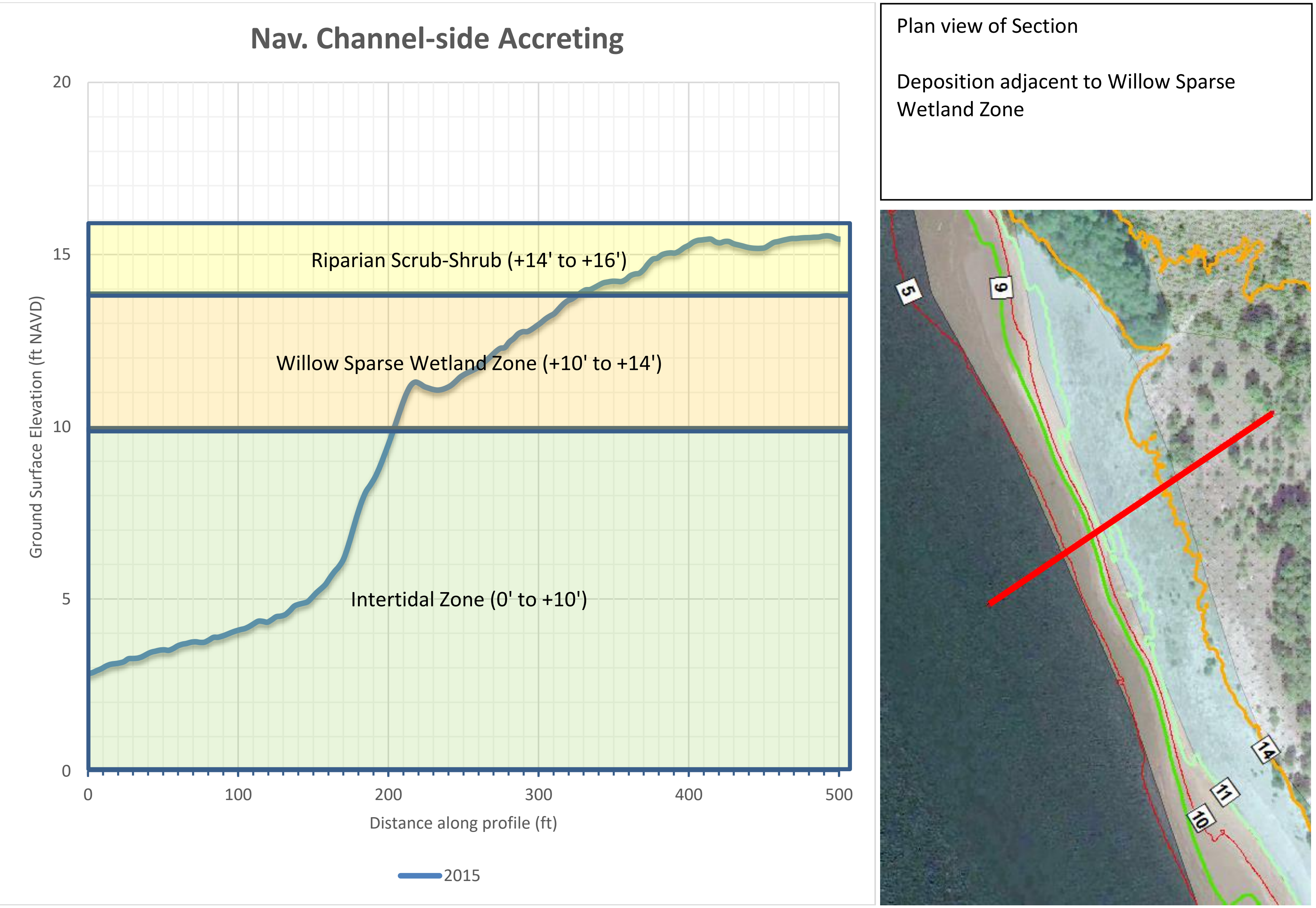
Figure 2.27, Figure 2.28, and Figure 2.29 show the ground surface elevation that corresponds to each red line cross section in the adjacent plan views and Figure 2.26. These Figures also relate to the zones of Table 3, Table 4, and Table 5, respectively. The figures provide profiles of the vegetation in different areas of the Islands; the channel and shoreward sides of the Islands have differences and there is also diverse vegetation when comparing profiles upstream and downstream.



Plan view of Section

Active erosion adjacent to Riparian Forest Zone

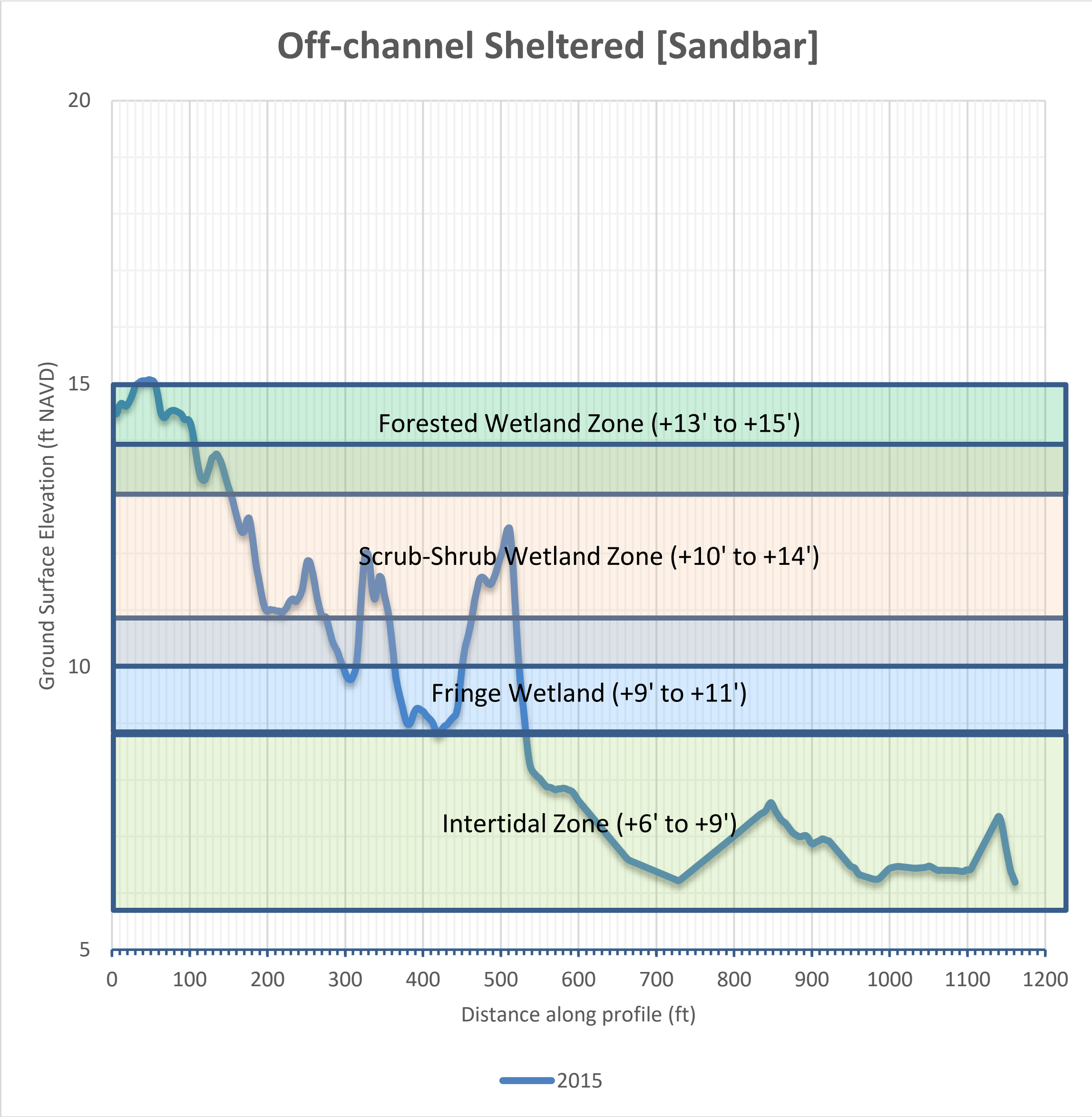
Figure 2.27. Nav. Channel-Side Exposed: At downstream tip of Island D, actively eroding edge (see Table 3).



Plan view of Section

Deposition adjacent to Willow Sparse Wetland Zone

Figure 2.28. Nav. Channel-Side Accreting: At Island C, accreting zone with thin willows at downstream end of pile dike 84.99 (see Table 4).



Plan view of Section

Sheltered wetlands transitioning to sand bar/ intertidal zone.

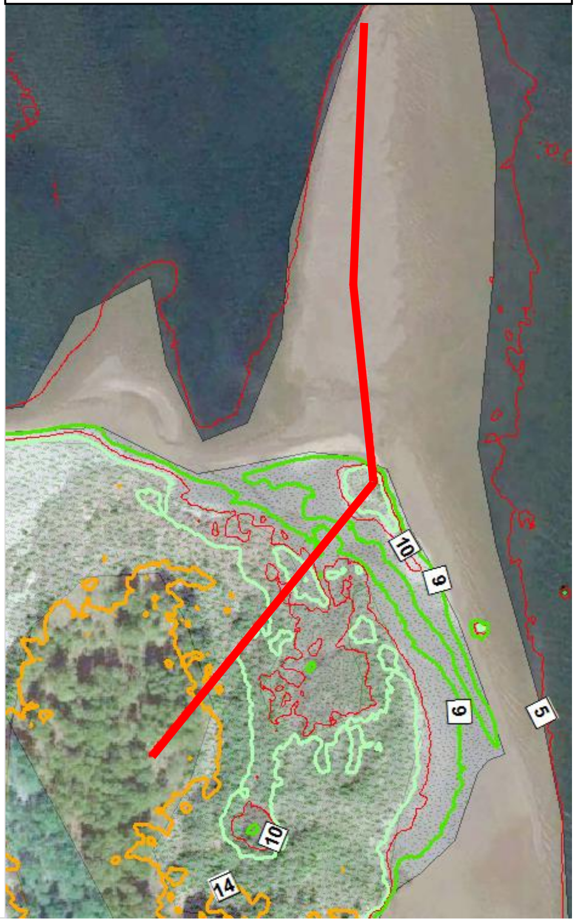


Figure 2.29. Off-channel Sheltered: At Island B, from sandbar to fringe wetland to forested wetland (see Table 5)

3 Project Design

3.1 Design Criteria

3.1.1 Target Elevations

The primary project objective is to use dredge material to create or improves a desired habitat, in this case shallow water and wetland habitat. The project placement features are intended to be stable where the desired habitat will be allowed to develop and mature overtime, and be able to be self-sustaining. Placements sites on the side-channel shoreline of Woodlands islands provide the most stability as described in the Geomorphic Setting section. The relationship derived from elevation and vegetation presence on the side-channel shoreline characterizes existing habitat as well as potential habitat creation. Juvenile salmonids and the Yellow Warbler were used as target species for habitat improvements. The specifics of the designated habitat for these species are described in greater detail in the Habitat Assessment Appendix but for the purposes of the Hydrology and Hydraulics Appendix it will be largely described by the elevation-vegetation relationship. The target habitat correlates to a desired increase in elevations ranging from 0 to 14 ft NAVD in relatively low velocity, sheltered zones.

Out-migrating or rearing juvenile salmonids are often shoreline orient and prefer shallow waters. While river stage varies greatly through the year dependent on river flow and tidal influence, the shoreline was identified at the 10 ft NAVD contour line based on the interface between Fringe Wetlands and Scrub-Shrub Wetlands consisting of large woody plant material. Shallow water below shoreline is considered to provide the most benefit. This correlates closely with the intertidal zones and the submerged aquatic vegetation zones which occur down to 0 ft NAVD.

Yellow Warbler habitat is closely tied to the presents of woody herbaceous plant life supporting nesting. This correlates with the Scrub-Shrub Wetland community which is present from 10 ft NAVD to 14 ft NAVD on the sheltered side of the island. This elevation zone also provides added stability to placement features as well as secondary benefits to aquatic species when inundated. Based on the present of invasive species above 14 ft, the upper bound of placed material was selected as 14 ft.

The following table was developed from onsite surveys at Woodland Islands, the terrain dataset and recent, aerial photography. This was cross-walked with the habitat suitability model criteria from the Habitat Modeling Appendix. The green highlighted habitat communities and associated elevation ranges were targeted in the project development.

Table 6. Habitat zones and associated elevation ranges based on observed conditions on site.

Community Name	Community Elevation
Forested wetland	+13 ft. to +15 ft.
Scrub-shrub wetland	+10 ft. to +14 ft.
Fringe wetland	+9 ft. to +11 ft.
Intertidal zone	+5 ft. to +9 ft.
Aquatic Vegetation (Velocity Sheltered Zones)	0 ft. to +5 ft.
Deep water (non-productive)	Below 0 ft.

3.1.2 Other Design Considerations

Slope

Dredge material placement often sets up on near 1:10 (V:H) slope and does not form a slope any steeper. Slopes exposed to wake action not to be shallower than 1:10 due to potential wake stranding of juvenile salmonids. For this reason slopes exposed to wake stranding are to be 1:10. Slopes approaching the existing island or in a sheltered plain may be lower to maximize creation of the habitat elevation range. All features will be positively graded to avoid ponding and stranding of aquatic species with lowering river stages.

Constructability

Additional discussion on construction of dredge material placement may be found in the Construction Appendix; however, it is pertinent to cover some general construction characteristics as they apply to placement design. Standard practice for dredge placement is to run to discharge pipes in parallel with an approximate 150-foot separation. One pipe discharges while the other pipe is being realigned to minimize downtime of the dredge. Material is placed high and then graded or “cast” down to the design elevation. This results in relatively broad features with fine terrain adjustments with mechanical means.

Topographic Complexity

There is variability in the elevation-vegetation relationship with the existing condition with some range be more productive that other. Placements should include enough topographic variability in a feature to cover the full range of elevation for which the target vegetation currently exists.

Impact to the Washington shoreline

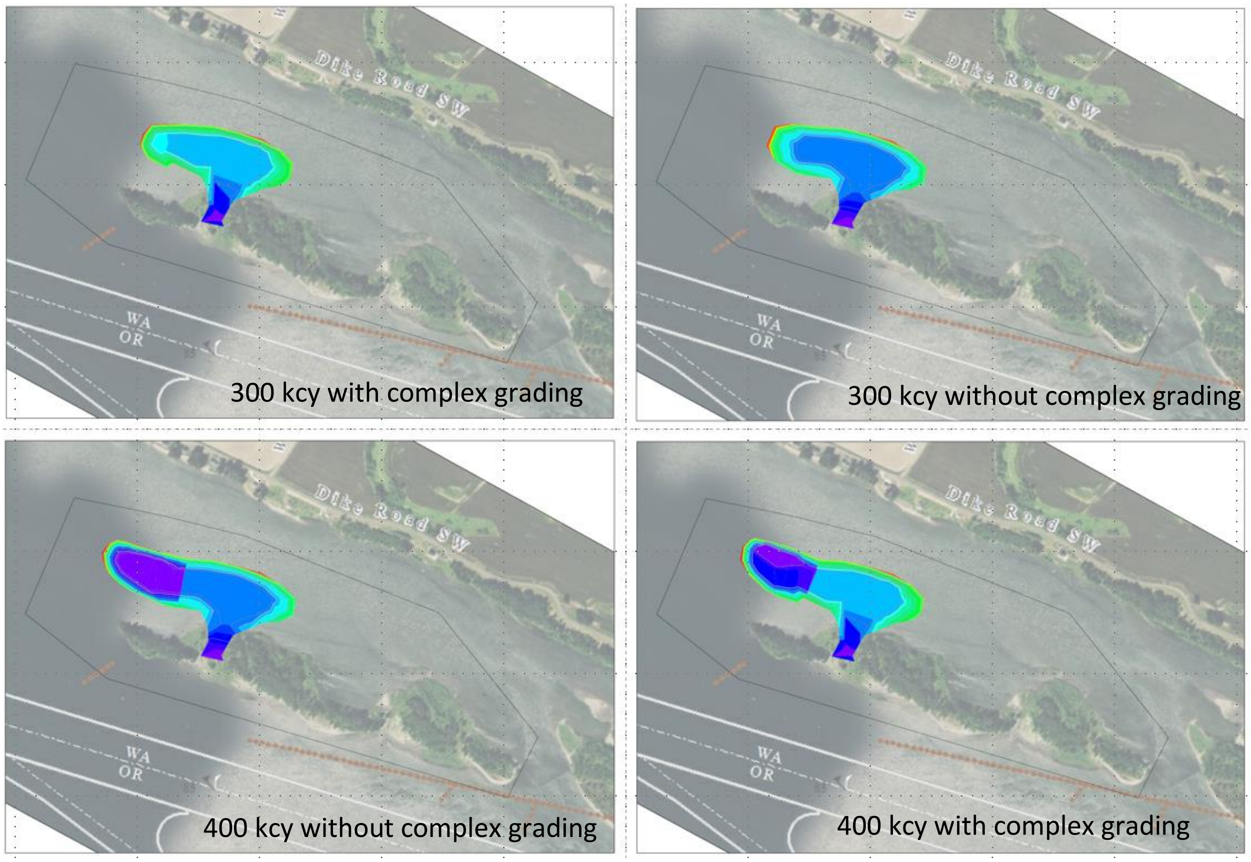
The Washington shoreline has several private properties. Placements should not incur any increase in erosive forces on the shoreline affecting those properties. Placements should not incur an increase in river stage. To achieve this, encroachment into the main side channel area is limited to minimum width upstream of placements.

3.2 Project Measures

The proposed project measures include placement of dredge material to increase existing elevations to that more suitable for the desired habitat, grading of the dredge material placement to affect greater and high quality habitat creation, and planting to increase habitat maturity. These measure are discussed in greater detail in the main report.

These measures were used in the development of several draft design placement configurations. Two locations on the side channel or landward shoreline of Woodlands islands were selected as stable attachment points for dredge material placements. Each site presented varying tradeoffs in converting existing habitat to more suitable habitat for the target species.

The downstream placement site consists largely of deep water with little habitat value for the target species. This presents an opportunity to convert relatively low quality habitat to high quality shallow water habitat and Scrub-Shrub Wetlands. The shoreline attachment for the placement is largely Scrub-Shrub Wetland offering some protection from overland flow erosion. Upstream of the proposed attachment location more a mix of Fringe Wetland and Scrub-Shrub Wetland. Enhancing or protecting this area is assumed beneficial. The figure below shows a serious of draft terrains for the planning purposes of varied topography and dredge placement volumes.


300 kcy with complex grading

300 kcy without complex grading

400 kcy without complex grading

400 kcy with complex grading

Figure 3.1. Preliminary design terrains for downstream placement.

The upstream placement site already consists of relatively shallow water suitable for aquatic species adjacent to a natural alcove but also lacks upland habitat and can be subject to higher velocities. This site presents an opportunity to convert shallow water to Scrub-Shrub Wetland and develop additional sheltered alcove/embayment areas with little volume of material placement. However, the further the placement extended downstream, the more placement material is required to develop more suitable habitat yielding diminished habitat returns. The following figure shows a serious of draft terrains for the planning purposes of varied topography and dredge placement volumes.

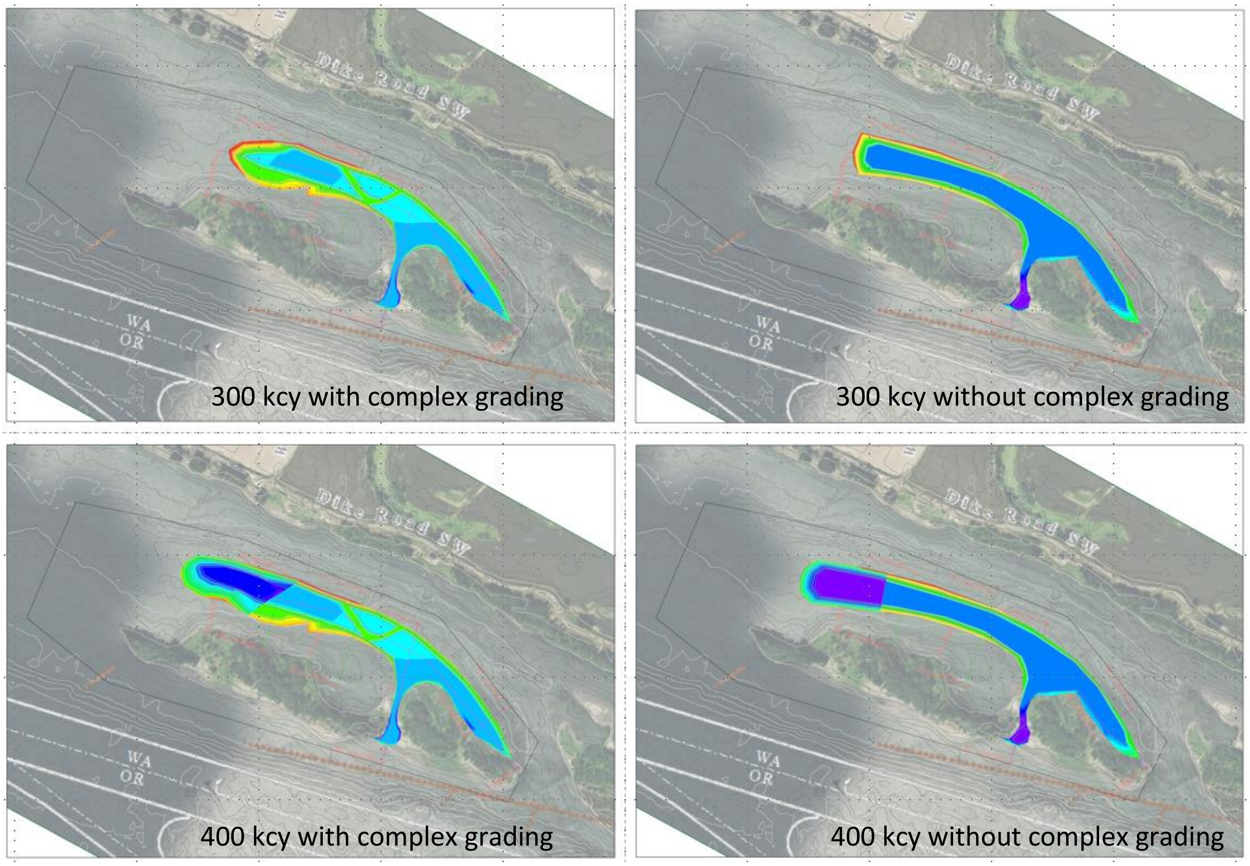


Figure 3.2. Preliminary design terrains for upstream placement.

These placement sites were also evaluated in pairs, distributing the allotted dredge material between the upstream placement site and downstream placement. This was deemed preferential as each placement compliments the other and will evolve and mature at different rates. Since the upstream placement requires less material to convert relatively the same amount of habitat as the downstream placement to suitable elevation, the split disbursement of material is 250 kcy for the downstream placement site and 150 kcy for the upstream placement site. This split placement is described in greater detail in the Recommended Plan section.

3.3 The Recommended Plan

Two locations on the landward side of Woodland islands were identified as viable locations for dredge placement. These locations demonstrate accretion of sand a fines under existing conditions suggesting sustainable placement options with minimal dynamic response to flood events less than the two year flood. These placement zones also present various benefits with regard to construction access and habitat development in elevation ranges below 14 ft NAVD which are discussed in the main report. Figure 3.3 shows potential dredged material placements. Terrains were created for environmental/economic analyses demonstrating potential habitat development with assumed dredging material volumes of 400 thousand cubic yard (kcy).

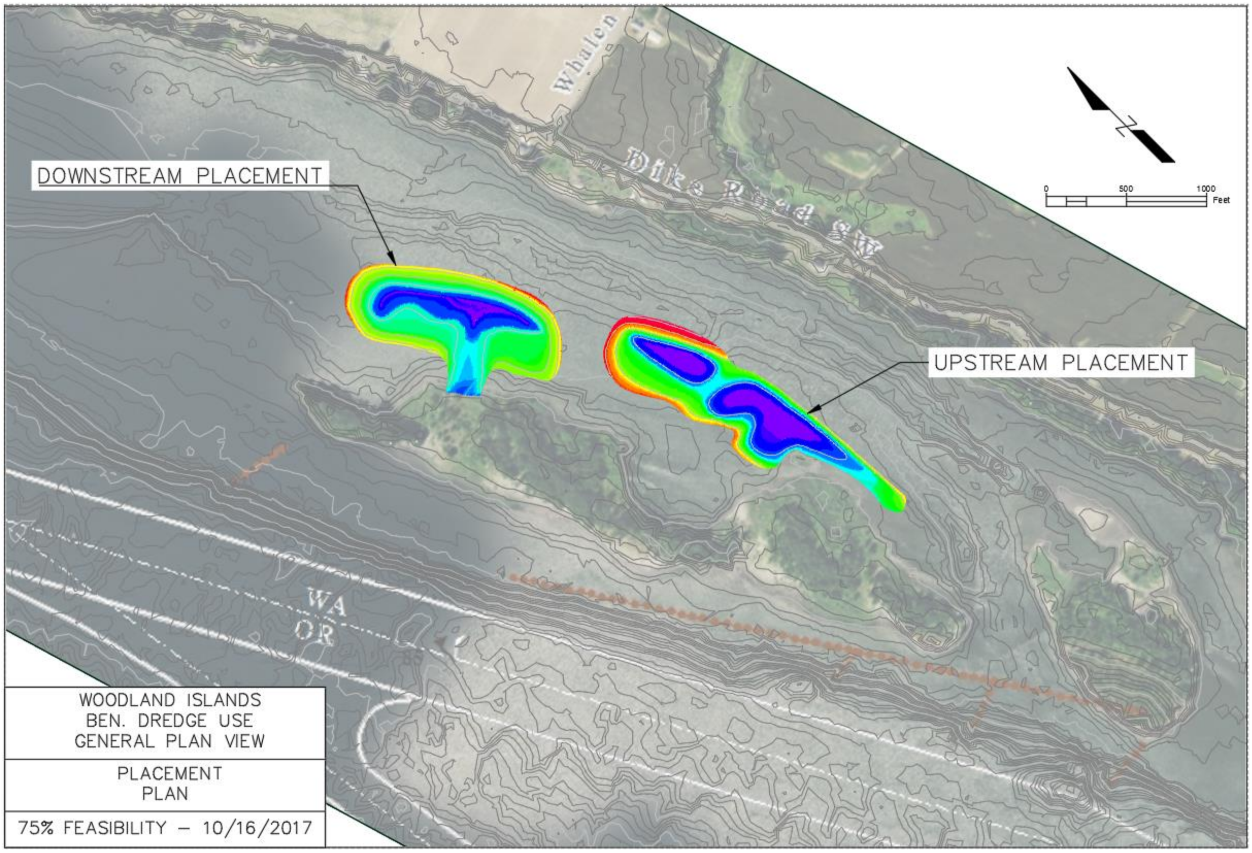


Figure 3.3. Potential Terrain Layout for Recommended Plan, 400 kcy, split placement with complex grading.

3.3.1 Downstream Placement

The selected Downstream Placement site lies on the landward side of island complex upstream Island D. The remnant of Island D is a relatively high shelf (around 20 ft NAVD) densely populated forested wetland. This is undergoing erosion on the navigation channel side of the island but provides an anchor to the downstream end of the island complex and a significant velocity shelter on the landward side of the island. The upstream connecting land bridge to Island C is lower in elevation with a crown of 13-14 ft and broader in width. When high flow events occur, this is one of the first places overland flow occurs. The crown is sparsely populated with scrub-shrub wetland providing some stabilization of the crown against erosion during overland flows. The landward side of the land bridge is demonstrating aggradation near shore with some vegetation recruitment. The side channel bathymetry drops off significantly to form deep water.

Due to the relative stability of the land bridge section of the island complex and the aggradation near the shoreline, this was selected a suitable location to build out the downstream placement.

Location specific objectives were identified in developing the placement features in coordination with the species of interest discussed in the main report and construction limitation. Objectives specific to implementing a complex grading plan and a planting plan with the placement are also listed below.

General Placement Objectives

- Create sheltering/alcoves adjacent to existing island.
- Increase shoreline length.
- Increase scrub shrub wetland habitat.

Complex Grading and Planting Objectives

- Added increase shoreline length
- Create broader distribution of habitat types (SAV, EAV or Fringe Wetland, Scrub-Shrub Wetland)
- Increased rate of vegetation establishment and feature maturation

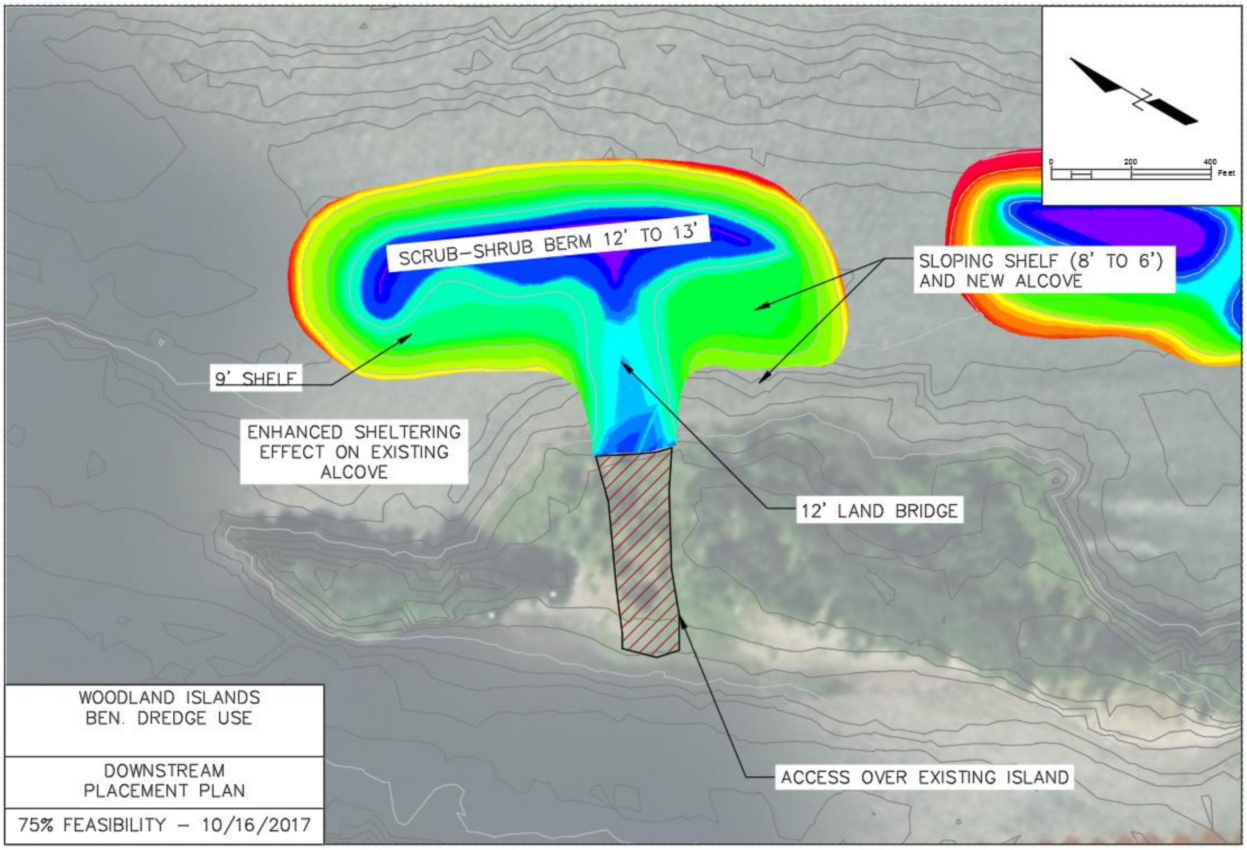


Figure 3.4. Downstream placement detail including topographic data and constructed features.

Generalized placement features include:

- Offset island berm with scrub-shrub wetland
- New alcove on upstream side of placement with adjacent low fringe wetland targeted shelf
- New/enhanced alcove on downstream side of placement with adjacent high fringe wetland targeted shelf
- Land bridge bisecting the upstream and downstream alcoves and connecting to bulk placement with scrub-shrub elevation targets to increase sheltering effects and stabilize the placement

This proposed placement extends from the existing shoreline on the landward side of the island complex out to into the deep water. The placement consists of a berm feature running parallel and offset 500 feet from the island complex shoreline. The berm feature target elevations are predominantly 13 feet to 14 feet with intent to support scrub-shrub wetlands with a broad crown width of approximately 150-200 feet. Once established, the scrub-shrub wetland vegetation will assist in resisting wind-wave and overland flow erosion. A connecting land bridge feature of from the berm feature to the existing shoreline of an elevation 1 to 2 feet lower than the berm bisects the open water between shorelines and develops two isolated alcove features. At river stages above 12 feet the land bridge will be overtopped and the alcoves will connect to form a channel between the berm and the existing island. The alcove features are partially filled in from the berm side to form sloping shelves of varied elevation from 6 feet to 9 feet. These shelves should develop to support fringe wetland communities. The alcove features or small embayment-like areas at the intersection of the placement and existing terrain are intended to accrete fines and develop submerged aquatic vegetation similar to what is noted in other areas along the landward side of the island complex. This placement is likely to increase the roughness of the island complex during overtopping flows thereby reducing velocities and cumulative erosion of the complex; however, the placement is not intended to affect the overall hydraulics within the side channel.

3.3.2 Upstream Placement

Upstream Placement Site lies on the landward side of Island B. Upstream of Island B, a connector-channel flanks the island. This channel actively transports fine material to the landward side of the island complex contributing to an existing sand bar. Downstream of Island B, a land bridge connects the island to Island C. This land bridge has a crown elevation of roughly 12 ft NAVD and experiences overland flow regularly. The land bridge sees minor erosion from the overland flow and is populated with scrub-shrub wetland which assists in stabilizing against erosion during these events. On the landward side of the bridge an alcove has formed with Island C providing confinement on the downstream side of the alcove and the sand bar in development on the upstream side. This alcove has shown accretion of fines, organics and submerged aquatic vegetation visible from aerial photographs and verified in site visits.

The terrain analysis and sand bar growth evident recent years indicate the attachment point for the proposed upstream placement to be relatively stable.

Location specific objectives were identified in developing the placement features in coordination with the species of interest discussed in the main report and construction limitation. Objectives specific to implementing a complex grading plan and a planting plan with the placement are also listed below.

General Placement Objectives

- Enhance sheltering/alcove effect of adjacent sand bar.
- Increase shoreline length.
- Increase scrub-shrub wetland habitat.

Complex Grading and Planting Objectives

- Added increase shoreline length
- Create broader distribution of habitat types (SAV, EAV, Scrub-Shrub)
- Increased rate of vegetation establishment and feature maturation

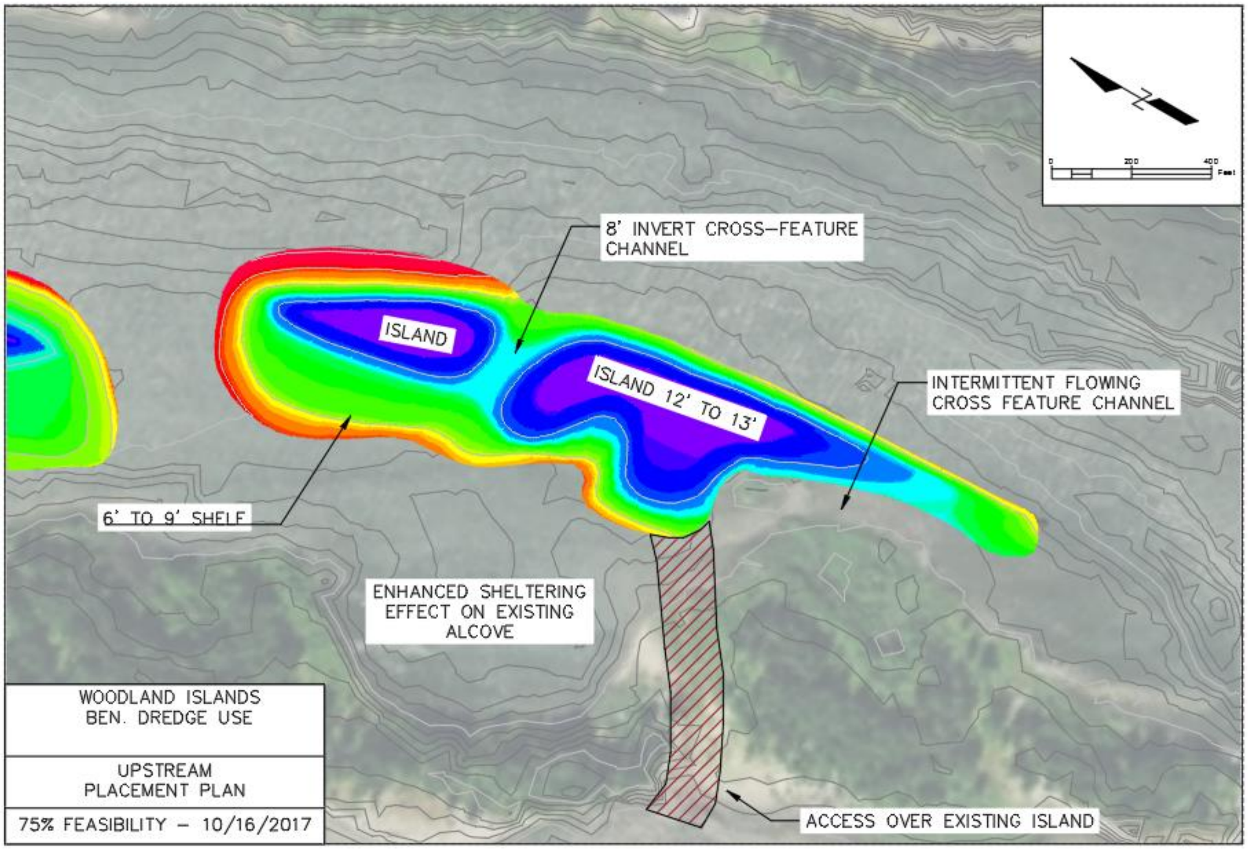


Figure 3.5. Upstream placement detail including topographic data and constructed features.

Generalized placement features include:

- Scrub-shrub habitat on new island/peninsula
- Pilot overflow channel at existing shoreline interface and mid length along the placement feature
- Low EAV target shelf on sheltered side of the feature placement

The placement site ties into the shoreline at the existing sand bar development and develop a peninsula its alignment. The sand bar existing elevation (7-8 ft NAVD) and orientation results in transverse water velocities and inundation recurrences which keep submerged or emergent vegetation from establishing. This placement will bring the crown up to an elevation that supports scrub-shrub wetland development and stabilize the feature against overland flows. The added height will reduce the occurrence of submerging the feature and provide enhanced sheltering effects for the alcove downstream. The material routed by the connector-channel depositing on the existing sand bar is expected to deposit at the end of the peninsula feature, elongating of over time. The landward side of the placement is expected to see minor erosion due to the adjacent connector-channel flow and is anticipated to be dominated by scallop formations and deposition at the downstream end of the peninsula during low flows. This is anticipated to equalize over time and unlikely to impact the overall feature stability. Overland flow erosion is not expected to be significant due to the backwater effects of the side channel system and the low hydraulic gradient formed across the peninsula.

Vegetation establishment on the crown of the feature would assist in resisting initial erosion along the landward shoreline. Without vegetation development, stability of the feature is subject to more dynamic processes and may not persist at design elevations long enough to establish plant communities through full natural recruitment. Adjacent to the feature placement, scrub-shrub wetland plant communities on the landward island of Island B densely populate elevation between 10 and 14 ft NAVD. It is expected that through planting or natural recruitment, this peninsula feature will support this wetland plant community well.

Increased confinement of the inlet/outlet to the alcove will increase the complexity of the internal hydraulics of the alcove associated with tidal fluctuations. Due to the nature of the placement materials being largely sand, it is unlikely that the peninsula will collapse on the alcove and plug the inlet. Tidal fluctuations will flush the inlet/outlet regularly and overland flow across the land bridge between Island B and C will be trained between the peninsula feature and Island C.

4. Impacts Analysis

4.1 Topographic and Habitat Changes

A hypsometric analysis of the existing terrain and with project terrain was completed to evaluate net increase in acres of targeted elevation ranges. The with-project increase in target elevation ranges and associated habitats within the placement boundaries are graphically depicted in **Error! Reference source not found.** and 4.2, respectively. The hypsometric curves Figure 4.1 show that nearly two-thirds of the area (20 of 32 acres) has bed elevations lower than the targeted shallow water depths, zero to 11 feet NAVD. With the use of dredged material, bed elevations are raised such that less than 10% of the area is below zero feet NAVD.

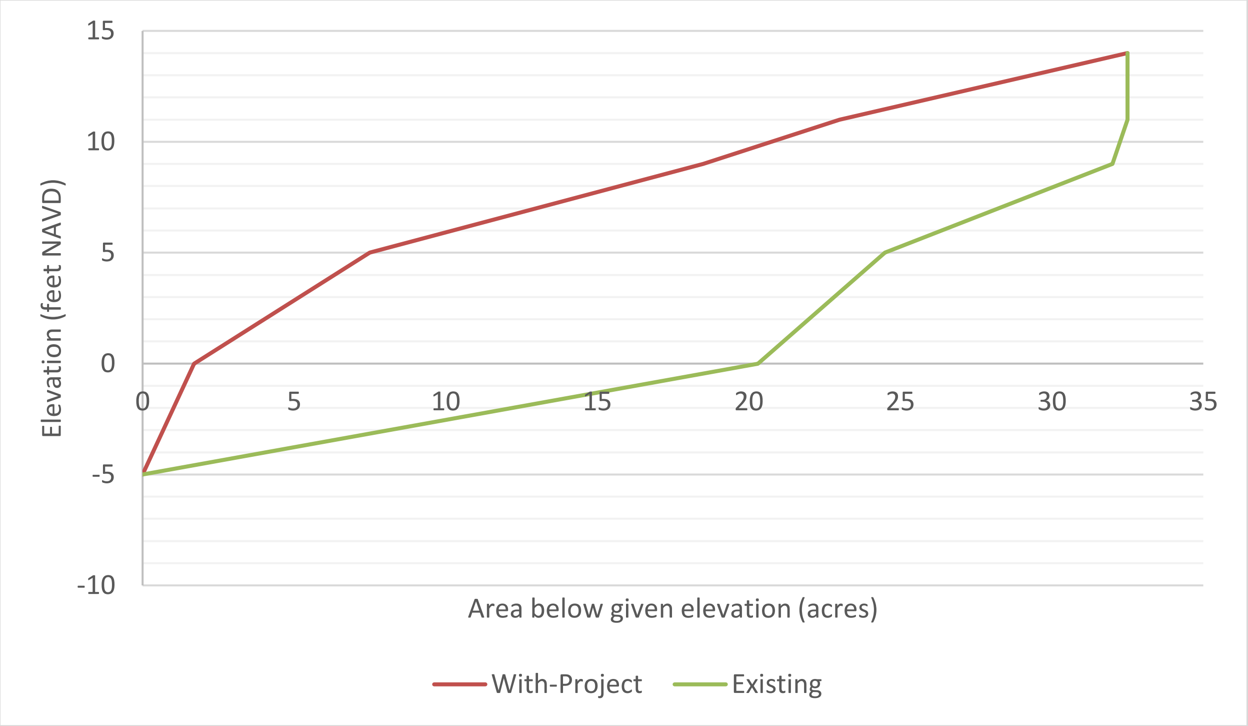


Figure 4.1. Hypsometric curve of the Existing terrain and the With-Project Terrain.

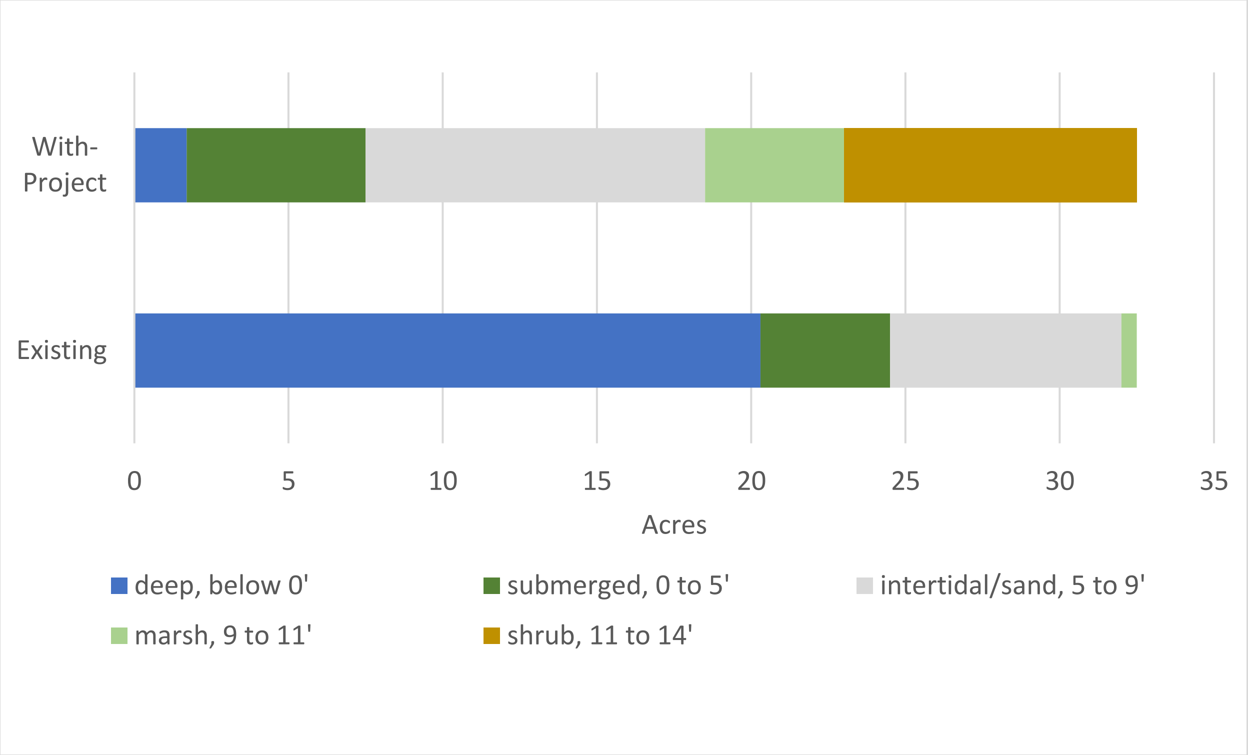


Figure 4.2. Acreage distribution by elevation range for with-project and existing terrain.

Error! Reference source not found. shows the comparison of the with-project and existing acreage distributions by range. The existing terrain was primarily dominated by elevations below 0 ft NAVD with little to no marsh or shrub habitats above 9 ft NAVD. The with-project distributions demonstrates that the proposed dredge material placements creates are greater diversity of habitat types as well as introduces a great band of habitat.

The existing terrain differs considerably between the two upstream and downstream placement locations. The upstream placement is situated on top of an existing sand bar, whereas the downstream placement extends from the shore into deeper water. Figure 4.3 shows the footprints of the upstream and downstream placements overlain on the existing terrain, here shown in three different depth ranges.

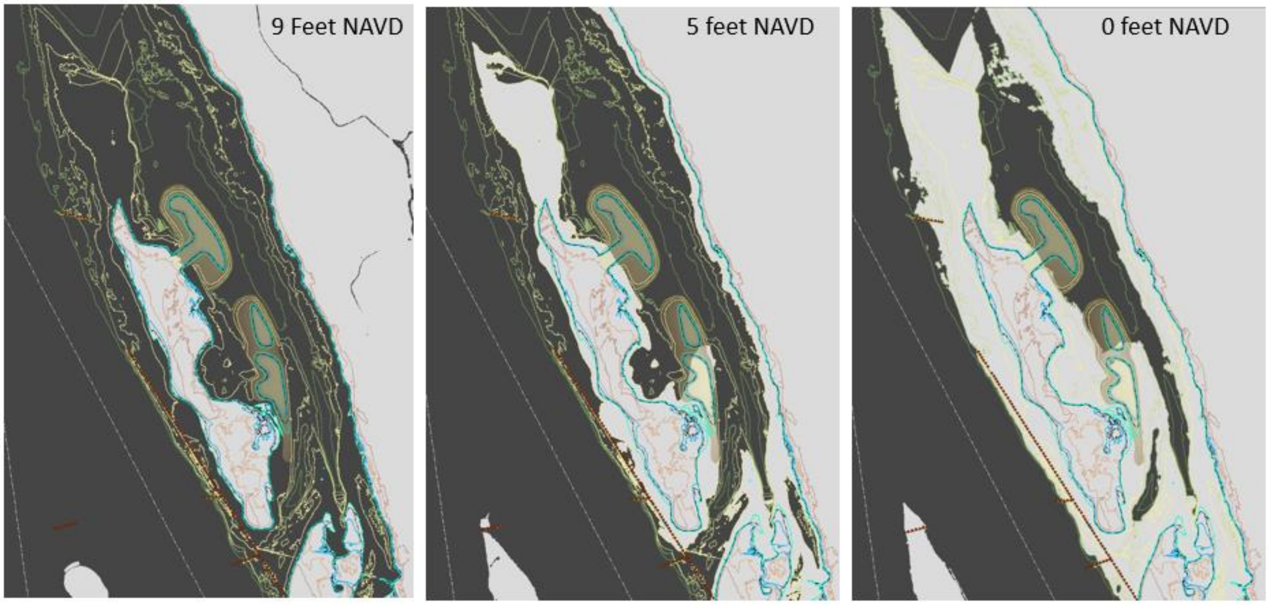


Figure 4.3. Maps indicating areas above 9 ft, 5 ft and 0 ft.

Figure 4.4 breaks out the existing elevation and habitat ranges covered up by the two placements individually. The downstream placement utilized approximately 250 kcy of material and converted elevations, primarily, below 0 ft NAVD to elevations that support shallow water habitats. The upstream placement utilized approximately 150 kcy of material and converted some deep water and some shallow water which was subjected to higher velocities to sheltered shallow water habitats. Each placement results in similar net acreage converted.

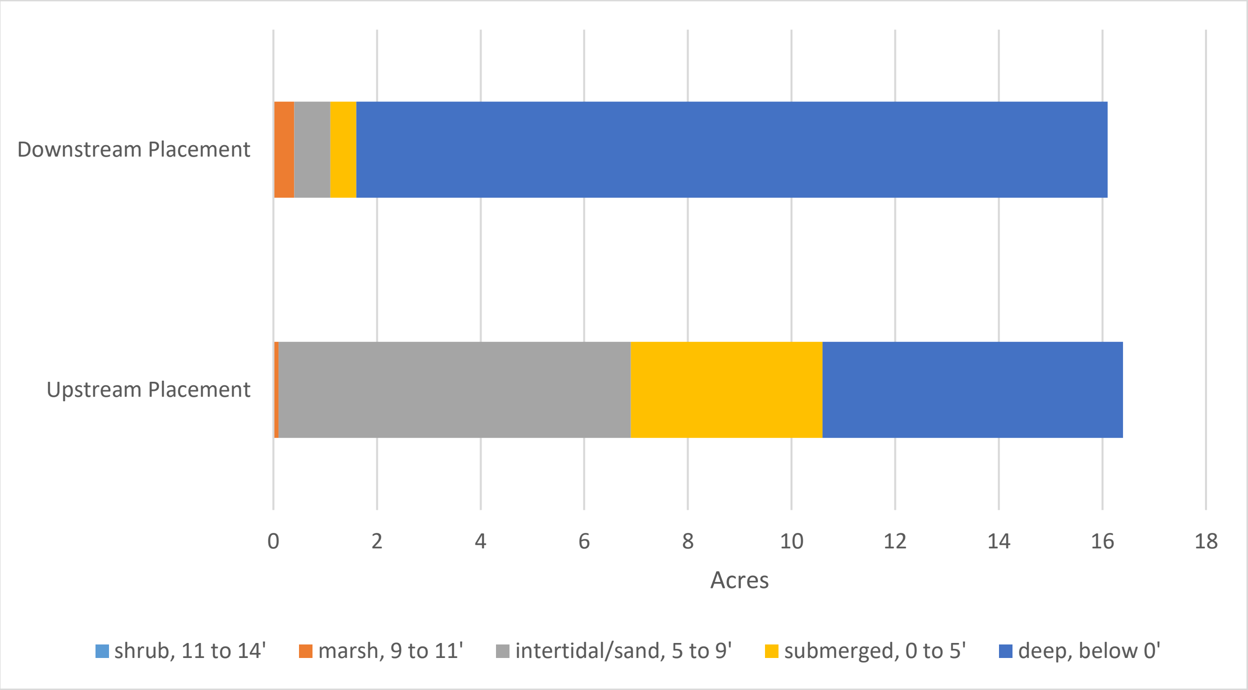


Figure 4.4. Distribution of existing habitat elevation ranges converted to new habit by each placement.

Error! Reference source not found. summarizes the net change in area for the different elevation ranges. There is net conversion of 19 acres of deep water areas to the targeted elevation ranges associated with shallow water and fringe habitat. Figure 4.5 also shows the relative change created from the two placements, with the downstream placement converting more of the total area below 0 ft NAVD.

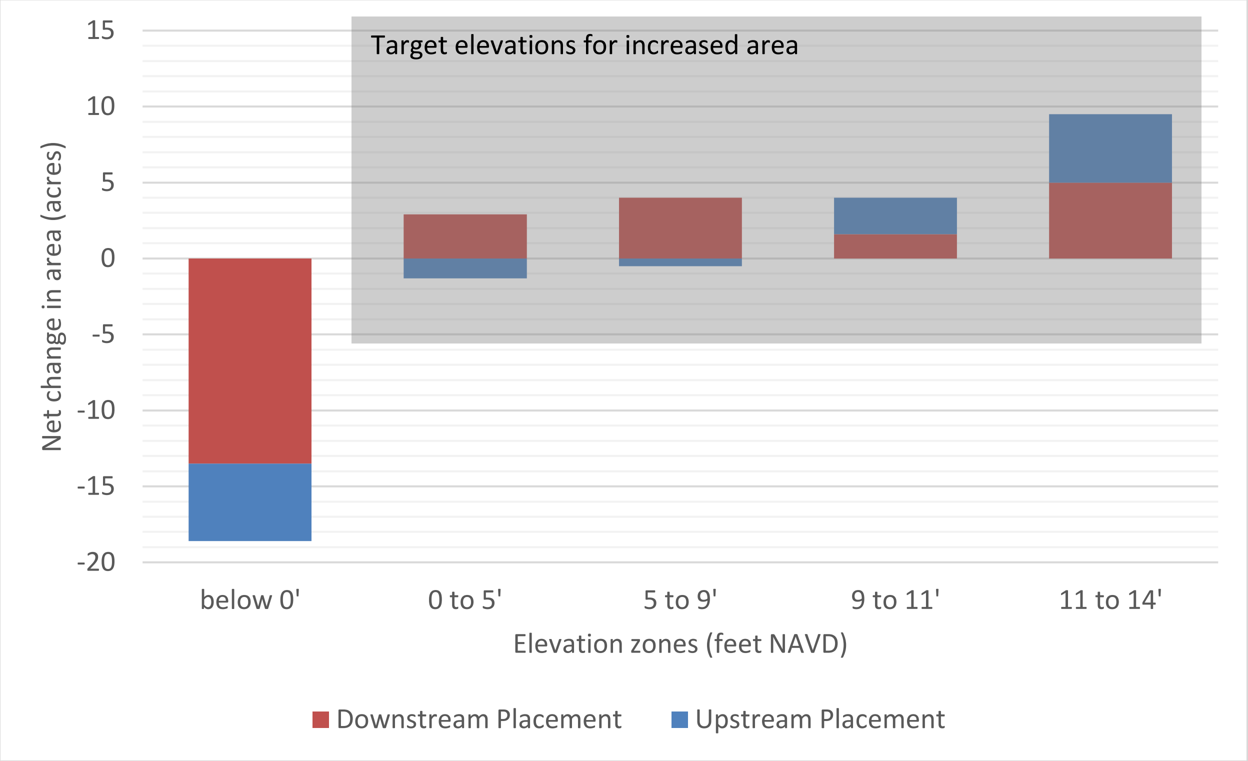


Figure 4.5. Change in area of identified elevation ranges.

4.2 Hydraulic and Fluvial Morphological Changes

With-project effects on hydraulics and fluvial morphology are discussed in the Adaptive Hydraulics (AdH) Hydrodynamic Modeling report, included as an attachment to this report. Impacts are summarized at the end of that attachment, at the beginning of this appendix, and in the main feasibility report.

5. References

United States Army Corps of Engineers (USACE), Portland. (2004) *Columbia River Combined Probability Flood Profiles, 21 May 2004*

United States Army Corps of Engineers (USACE), Portland District (2011). Unsteady Flow Hydraulic Model of the Lower Columbia River System from Bonneville Dam to the Pacific Ocean, Columbia River Treaty Review Studies.

Attachment: Adaptive Hydraulics (AdH) Hydrodynamic Modeling Report

Lower Columbia River Estuary Section 204 Studies - Woodland Islands
Adaptive Hydraulics (AdH) Hydrodynamic Modelling EC-HD, rev FEB 2018

Adaptive Hydraulics (AdH) Model – Lower Columbia River & Woodland Islands

Adaptive Hydraulics (AdH) is a finite element, numerical modeling package that can be used to simulate a wide-range of flow conditions. The AdH model capabilities include both saturated and unsaturated 3D groundwater flow, 2D overland flow, 3D Navier-Stokes flow, 3D shallow water flow, and 2D (depth averaged) shallow water flow. Application of AdH for the Lower Columbia River – Woodland Islands used the 2D shallow water flow module only; AdH simulated time-varying depth-averaged currents and time-varying river stage in a horizontally (XY) variable framework. The adaptive feature of AdH consists of its ability to dynamically refine and relax the mesh and temporal resolution such that both model accuracy and model performance are optimized. The ability of AdH to allow the domain to wet and dry as flow conditions or tides change is suitable for shallow marsh environments, beach slopes, floodplains, and other terrain features of interest. AdH can simulate subcritical and supercritical flow conditions within the same domain. Boundary conditions can be specified for a variety of different flow and stage scenarios. AdH was developed and actively maintained at the US Army Corps of Engineers Coastal and Hydraulics Laboratory (CHL).

The AdH model for the Lower Columbia River was initially developed in 2012 under a collaborative framework between Portland District and ERDC-CHL. The LCR ADH model extends inland from the mouth of the Columbia River (Pacific Ocean) to Bonneville Dam spanning 147 miles. Approximately 518,000 elements (268,000 node) are used to represent the LCR terrain within AdH. The LCR AdH model has been calibrated for a variety of flow and stage conditions [Pevey et al 2012, Sevant and McAlpin 2014, and USGS 2017], and the model is continually being evolved as it is used to for different projects through time. For the Woodland Islands application, the LCR AdH model was forced by ocean tides at the MCR (8 ft astronomical tidal variation) and fluvial input from 5 rivers (Columbia River at Bonneville Dam, Sandy River, Washougal River, Willamette River, Lewis River, and Cowlitz River). Time-varying fluvial input was imposed as a daily-average flow time-series (1 day time step). Ocean tides were imposed using an hourly time-step. Within the AdH model, all input and output is in SI units (MKS). Horizontal datum was state plane coordinate system (OR-north NAD83, meters). Vertical datum was NAVD (meters). At river mile-RM 86, 0 ft CRD = 4.14 ft NAVD (0 m CRD = 1.26 m NAVD).

Within this document, several of the AdH input and output metrics are expressed in terms of US customary units or as CGS units to enable portrayal of values in familiar or more compact context. River flow is expressed in terms of cubic feet per second (cfs, instead of cubic meters per second-cms). Where river current becomes very low (< 0.1 m/sec), current speed is expressed as cm/sec instead of m/sec. Elevations are expressed in terms of SI (meters) and US units (feet) throughout this document. Conversions between SI and US customary units are given within relevant figures.

The AdH model was run for the time period of 1 APR – 14 JUL 1997, to simulate the hydraulic effects of a high-flow freshet event having an annual expected probability of 0.03 (30-35 year return interval for Columbia River flow passing BON). Observed fluvial flow data was used for the AdH model boundary condition, with the last 2 weeks of the river-flow boundary conditions (1-14 JUL 1997) reduced to emulate “late summer” low flow season. This modified flow boundary condition provided for the evaluation of the future with project in terms for a high river flow (freshet) and low river flow (later summer) period, as compared to the Existing Condition.

Figure H1 shows the project area as expressed within the LCR AdH model. The finite element mesh is used to express the spatially variable terrain of the “real world” within “model world” of the AdH model, and is also used to express the AdH numerical solutions for time-spatially variable river stage and velocity. Existing Woodland Islands are shown as areas A-D. Future with project (FWP) features are also shown, for upstream (US) and downstream (DS) features. There are approximately 15,000 elements representing the Woodland Islands project area having mesh resolution (XY) varying from 6 – 30 meters (20-100 ft). Material properties affecting fluid flow due to local friction and eddy-viscosity were assigned for each element based on location-specific nature of morphology, and vegetation, and presence of pile dikes. The AdH model was used to simulate river hydraulics for both the Existing Condition terrain and the Future With Project (FWP) terrain.

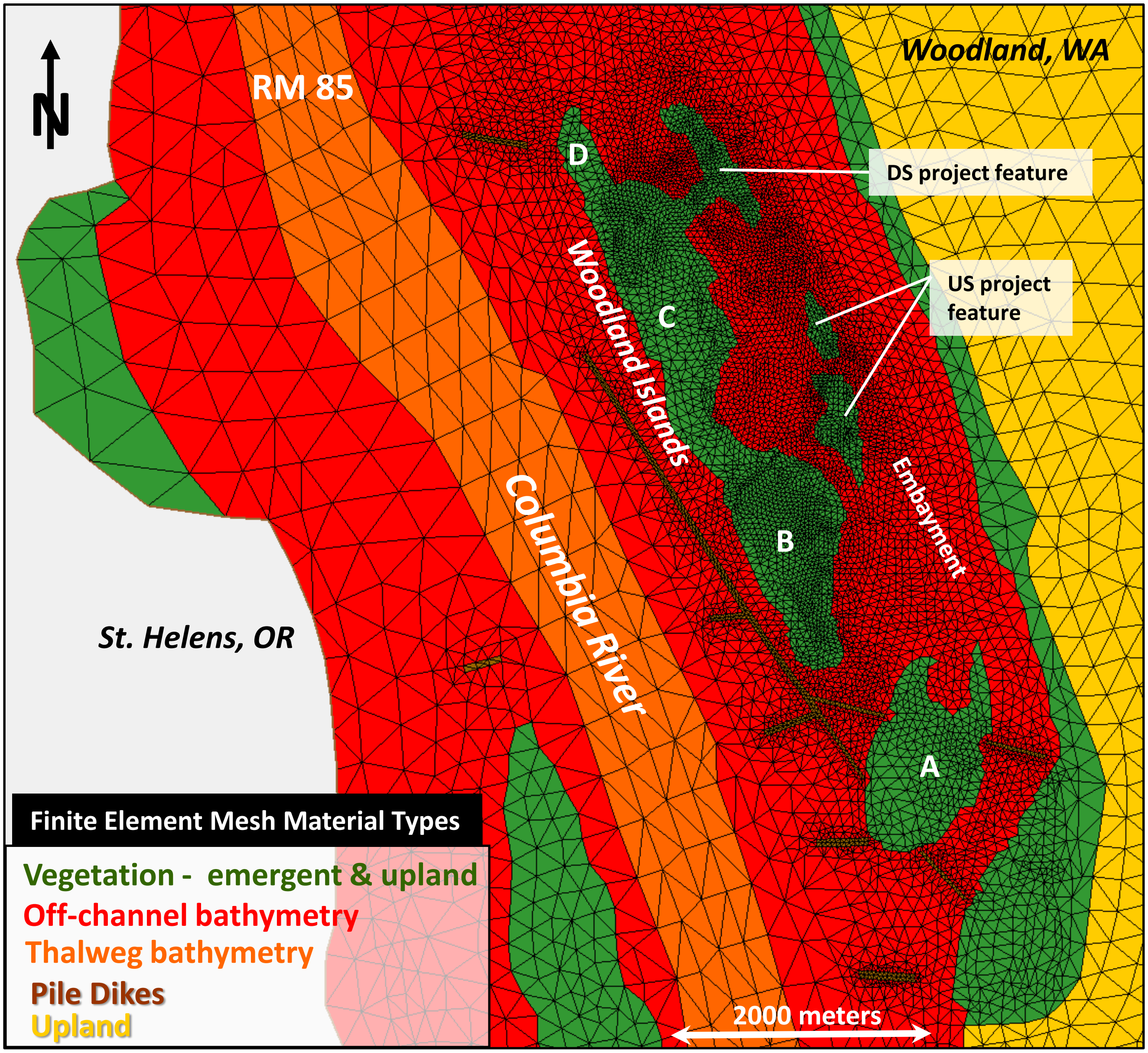


Figure H1. Woodland Island project site as represented within the AdH hydrodynamic model using a finite element mesh. Mesh resolution within project area varies from 6 to 30 meters.

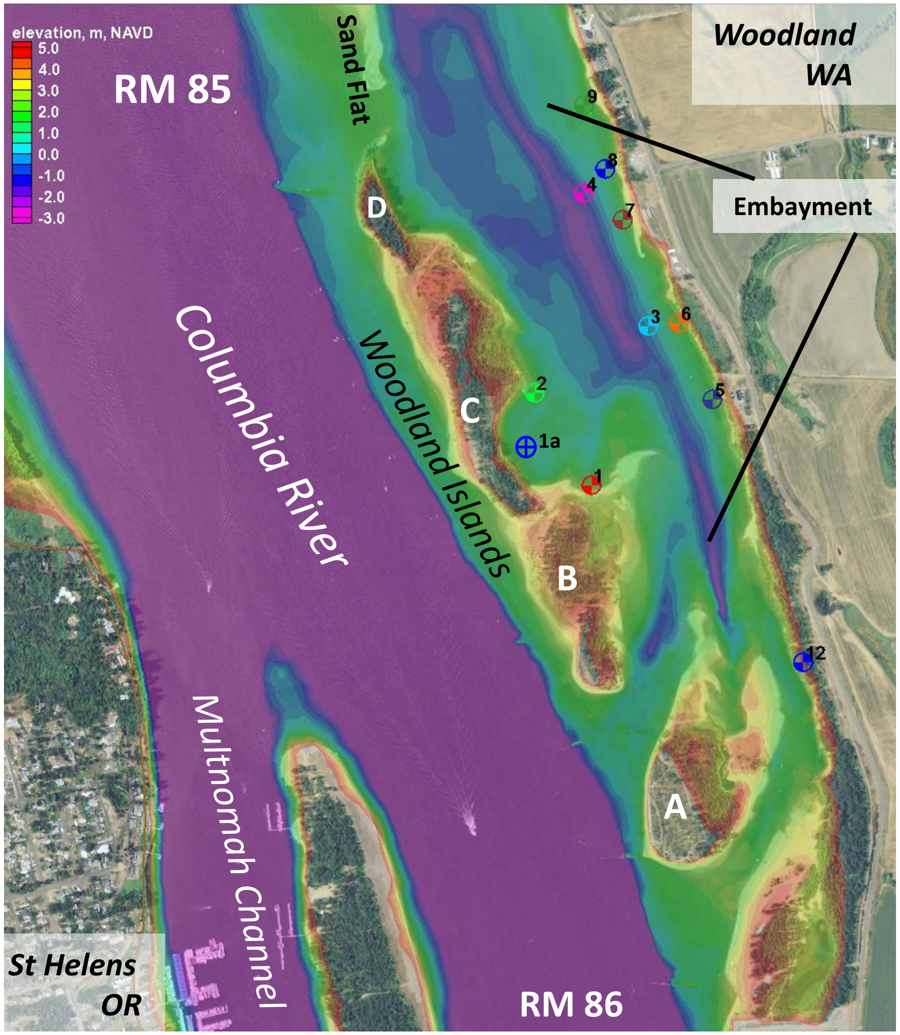


Figure H2a. Existing Condition Terrain elevation, with background photo image obtained with river stage at 3.4 m NAVD (11 ft NAVD or 7 ft CRD). Islands are individual denoted as A to D. 1 ft = 0.3048 meter. River bed elevations < -3 m (-9.8 ft) NAVD are shown as “purple”.

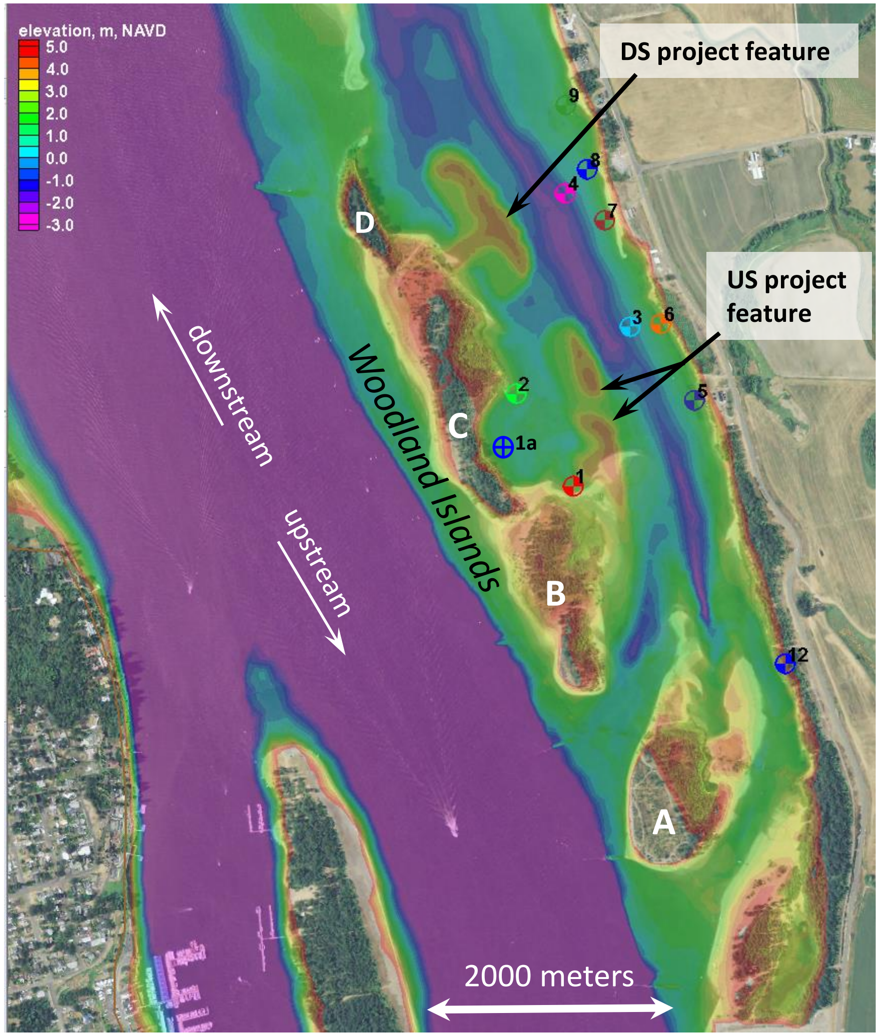


Figure H2b. Proposed With-Project Terrain Modification, spanning -1.8 to 4.1 m NAVD (-5.9 to +13.5 ft NAVD). Project features shown as upstream (US) and downstream (DS), to be created using controlled placement of sand dredged from the FNC near RM 86.5.

AdH model results for the Woodland Islands evaluation were developed as a series of "Existing Condition versus Alternative Plan implementation" comparisons, to identify potential changes in river stage and river current that could be realized in response to the Future With Project (alternative plan). The potential for river current alteration within the project area (in response to FWP) was used as a surrogate to evaluate possible sediment transport effects associated with FWP implementation, based on exceedance of threshold river current magnitude for sand transport. Bedload transport of very fine to fine sand (0.07 to 0.18 mm diameter) can initiate when free-stream current > 15 sm/sec. Medium-sized (0.18 to 0.35 mm) sand can be transported when current > 20 cm/sec. Course sand (0.35 to 1 mm) can experience bedlaod transport when current > 30 cm/sec.

Two types of visual products were generated to enable interpretation of AdH results: 1) Plan-view of maximum & minimum change in depth-averaged river current to shore the spatial extent in current changes, and 2) time-series plots of river current magnitude (for Existing and TWP conditions) at specific location of maximum change. Time-series portrayal for the changes is rive stage due to FWP is also shown for the project area. Each visual product has an associated narrative interpretation. Tables H1 and H2 summarize the time series evaluations for river current changes (at end of this document).

Woodland Islands - Existing Condition and Future With-Project (FWP) Terrain

Figure H2a shows the Existing Condition for the Woodland Islands project site, located cross-river from St. Helens OR along RM 85-87. Woodland Islands are individually designated as A-D. Appended to the end of this document are two field reports that describe: Field Report A) Existing conditions for each of the islands in terms of general aspects of surface soil/sediments, morphology, and vegetation; and Field Report B) Physical characteristics of existing embayment sediment where the proposed project is to be constructed, and physical characteristics of the dredged sediment that is to be used for constructing the proposed FWP.

Field Report "A" summarizes a Woodland Islands field visit during 15 APR16 part of which was used to inform the AdH model for emulating the material parameters and riparian/intertidal terrain for Woodland Islands. The Islands are composed of dredged material (fine-course sand) placed during 1930s to 1970s. The island surface has been reworked by flood events, with lower elevations (<7 ft NAVD) being composed mostly of bare sand flats with some ephemeral vegetation and progressively higher elevations (> 11 ft NAVD) having sustained woody vegetation with sand soils supplemented by detritus deposits. Along the riverside (west side) for some of the islands, there is active re-working of the island terrain (from 5 to 13 ft NAVD) by river currents during annual high water events. Along the shallow water embayment (east) side of the islands, the terrain is meta-stable due to protection from swift river currents. Several sub-embayments are located along the west shore of the islands where flow is further reduced and a backwater ecology has developed. The sediment on the embayment bed ranges from silt to coarse sand based on the locally-prevailing currents affecting erosion and deposition. Within tidal flow channels of the embayment, where currents often exceed 0.3 m/s the bottom sediment is dominated by sand. Within sheltered backwater areas of the embayment, where currents seldom exceed 0.1 m/s the bottom sediment composed mostly of silt. Field Report "B" shows where several sediment samples were collected in the project area and test results documenting physical aspects of sampled bottom sediment. Results indicate the bottom sediment within the embayment varies from grey silt to medium-course brown sand; having 1-5 percent gravel, 1-9 percent medium-course sand (0.18 – 1 mm), 55-68 percent very fine to fine sand, 30-35 percent fines (<0.068 mm), with 1-2 percent TOC. Bulk density = 1.69 to 1.84 gram/cm3.

The AdH model was used to evaluate the potential change in hydrodynamics associated with project implementation. Positive change (PC) observations from points 1-9 used to show areas where there was an estimated increase in current due to project Implementation, as compared to present condition. The topo-bathy data used to express the existing condition terrain within the AdH model was based on an ensemble collected during 2010-2015. Figure H2b show the FWP condition for Woodland Islands where 400,000 cubic yards of dredged sand is to be placed at two locations along the embayment side of Woodland Islands. The source for the dredged sand is to be from the St Helens bar along the Oregon side of the FNC, within RM 86 to 85. Based on lab testing results shown in Filed Report “B”, the dredged sand is characterized as medium-course grey sand; having 0.5 to 2 percent gravel, 90-98 percent medium-course sand (0.18 – 1 mm), 1-6 percent very fine-fine sand (0.07-0.18 mm), less than 0.1 percent fines (<0.068 mm), with 0.1 percent TOC. Bulk density = 1.90 to 2.03 gram/cm3. The sand is to be placed using a large hydraulic dredge (Oregon). The downstream (DS) feature is composed 250 KCY of dredged sand; the upstream (US) feature is composed of 150 KCY of dredged sand. The US and DS project features span an elevation range of -1.8 to +4.1 meters (-5.9 to 13.5 ft) NAVD. Habitat zones to be supported by the proposed FWP terrain include: intertidal sand flats (-5 to 0 ft NAVD), intertidal aquatic vegetation, (0 to 6 ft NAVD), emergent marsh or wetland fringe (6 to 10 ft NAVD), and scrub-shrub (10-14 ft NAVD). Both the DS and US FWP features are to be planted with willow.

Rather than waiting for vegetation to naturally establish by natural seed source and dispersal, a targeted planting plan would be conducted as part of the FWP condition to expedite formation of favorable terrestrial and aquatic habitat. The planting objective is to produce even distribution of willow shrubs across elevations 10 to 14 ft NAVD to provide scrub-shrub habitat, and to stabilize equilibrated placed dredged material. Plantings would likely consist of native willow stakes that are 3 ft in length, planted on a 5 ft increment. Plantings would help stabilize the FWP terrain features, encourage rapid development of scrub-shrub and emergent wetland habitat, and have minimal adverse impacts on the terrestrial and aquatic environments during installation. A successful planting plan is expected to achieve 80 percent survival of willow plantings one year after planting, with riparian habitat coverage along 80% of the west (protected) side of new sub-embayment areas, and is expected to provide moderate benefits for species that utilize shoreline and submerged habitats. To improve likelihood for planting survival within a hydraulically active riparian area, willow planting would be initiated approximately 1 year after construction of the FWP terrain, following a freshet (high-flow) season, to allow equilibration the newly-formed FWP terrain features with the hydraulic forcing environment. The AdH model expressed the FWP planting areas as ”emergent and upland vegetation” having higher frictional aspects on river hydraulics than off-channel bathymetry or sand flats.

In summary, each FWP terrain feature was imposed within the AdH model using CAD generated terrain surfaces. Both project features were emulated to include post-placement grading to create a mosaic of elevations that will encourage development of varying types of habitat to support fish (salmonids), amphibians, and land-species (ie yellow warblers). Additionally, each feature (DS and US) would include post placement planting of willows to encourage rapid development of a riparian shrub community to provide ecological benefits. These added effects were included within the AdH model framework as spatially variable-complex terrain and spatially variable frictional elements associated with FWP grading and vegetation.

HIGH River Flow Interaction with Woodland Islands Existing Condition and FWP – Hydraulic Changes

Figure H3a is a snapshot of river current vectors simulated by AdH model for 1200 on 15 JUN 1997 (model TS=1812 hrs), when river hydraulics was dominated by a high fluvial flow event with combined discharge = 610 Kcfs (17.3 Kcms). During this time, river stage was at the Woodland Island project site was 20.3 ft (6.2 m) NAVD inundating proposed FWP features by 6 ft (1.8 m). Flow was exclusively downstream; with no flow reversal due to tide. Depth-averaged current vectors shown for current magnitude > 0.03 m/s and < 0.9 m/s. Note the extent of “red” current vectors (mag > 0.7 m/s) extending into embayment east of Woodland Islands and the lack of circulation with the cove in central area of Woodland Islands.

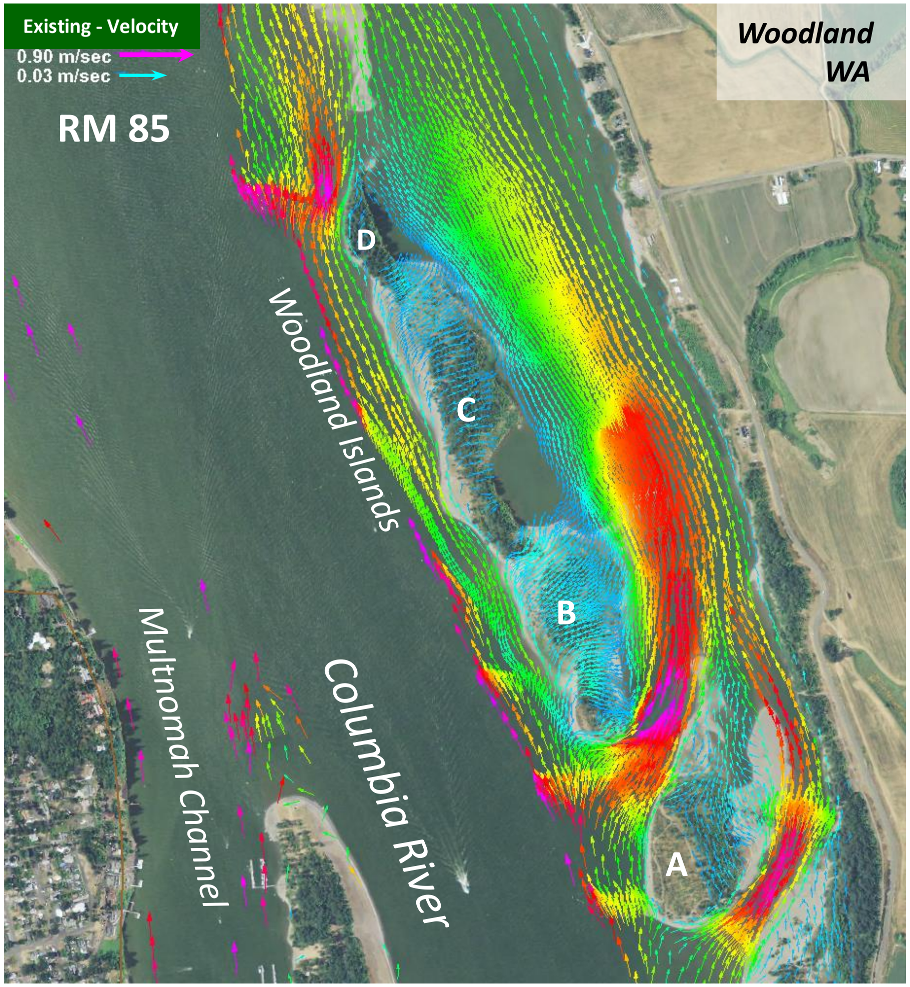


Figure H3a. Existing Condition Currents – HIGH River Flow Event, with Columbia River flow at RM 85 reaching 610 kcfs (17.3 kcms). Current speed within the mainstem Columbia River > 0.90 m/sec.

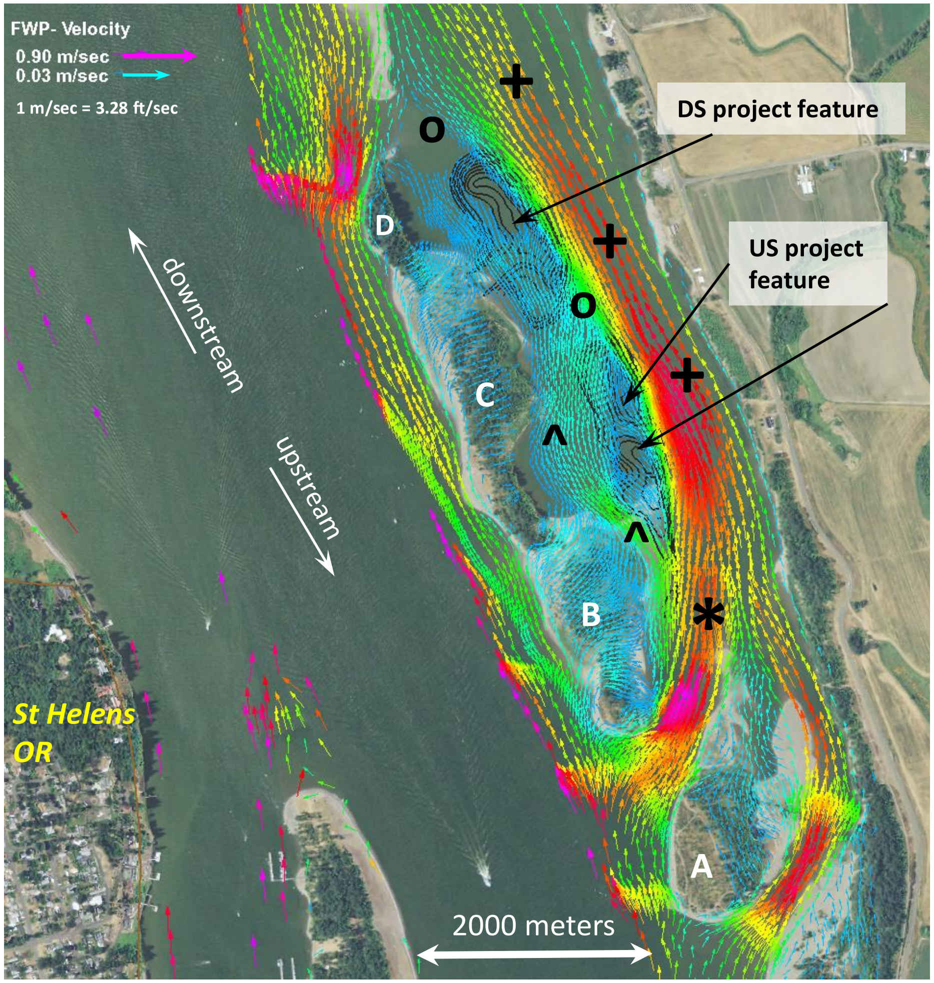


Figure H3b. FWP River Currents – HIGH River Flow Event Symbols indicate areas where aspects of current velocity are discussed. Both figure H3a and H3b are a “snapshot” of river current vectors simulated by AdH model for 1200 on 15 JUN 1997 (model TS=1812 hrs). River stage was at the Woodland Island project site was 20.3 ft (6.2 m) NAVD inundating proposed FWP features by 6 ft (1.8 m).

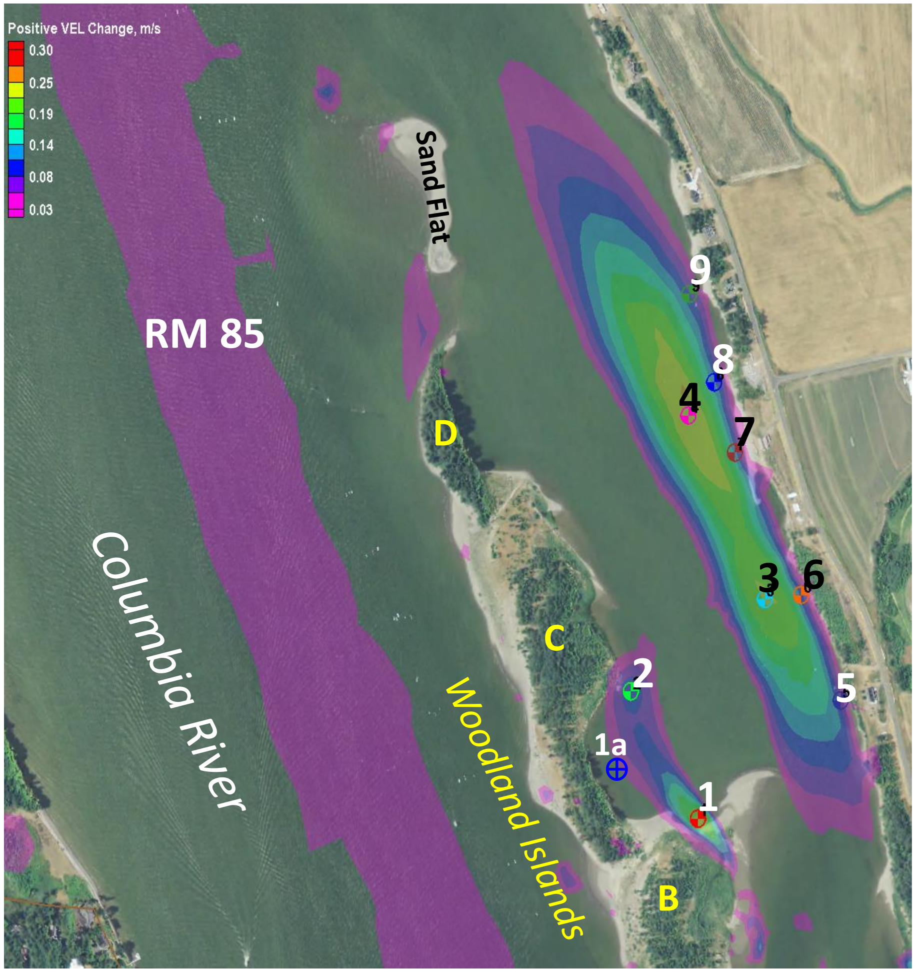


Figure H4a. Areas affected by an <u>INCREASE</u> in river current magnitude due to project implementation, as compared to existing condition. 1 m/s = 3.28 ft/s. This graphic shows the maximum increase in current between existing condition and FWP. The time series for currents observed at positive change (PC) points 1-9 are shown in figures H9-H19.

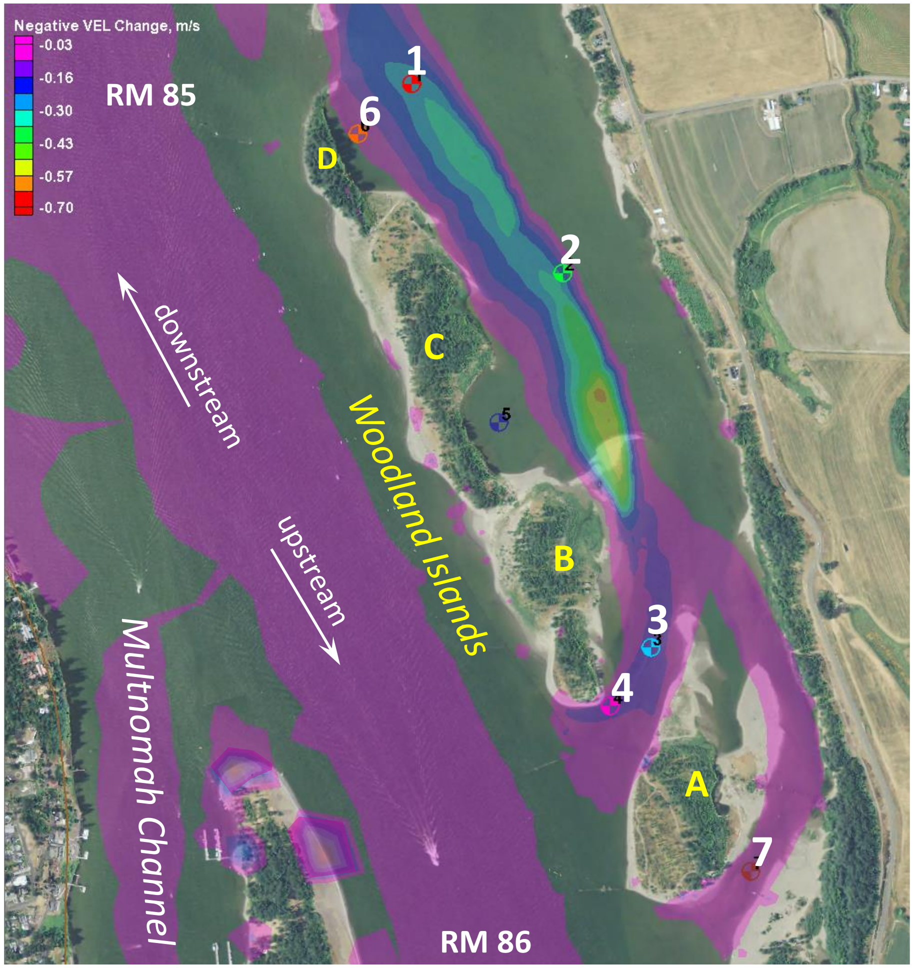


Figure H4b. Areas affected by <u>REDUCTION</u> in river current magnitude due to project implementation, as compared to present condition. This graphic shows the maximum decrease in current between existing condition and FWP. The time series for currents observed at negative change (NC) points 1-4, 6,7 are shown in figures H20-H26.

Figure H3b is the same timeframe as the "Exiting Condition" image shown in left graphic, but for TWP condition. Differences in currents within the off-channel embayment between this image and one to left are due to terrain medication under the FWP condition (DS and US project features). Areas that experienced a current speed reduction (at 1200 pm on 15 JUN 1997) are denoted by ***** and "**o**". Areas that experienced current speed increase are denoted by "**+**" and **^**.

Figure H4a shows areas affected by an <u>INCREASE</u> in river current magnitude due to project implementation, as compared to existing condition. Color scale indicates maximum INCREASE in river current during the simulation period for APR-JUN 1997. Results are based on AdH Model. Positive Change (PC) points 1-9 are used to show time-series details for how the With-Project condition <u>increases</u> the river current as compared to the existing condition. The terrain (bed elevation) at PC observation points is not affected by the FWP: Changes in river current at PC points are due to terrain changes from other areas. The background photo image shows 2011 configuration of Woodland Islands B-D. Refer to **Figures H19 and H10-H19** for AdH model results relating to the above "increased current" observation points.

Figure H4b show areas affected by <u>REDUCTION</u> in river current magnitude due to project implementation, as compared to present condition. Color scale indicates maximum DECREASE in river current during the simulation period for APR-JUN 1997. Results are based on AdH model. Negative Change (NC) points 1-7 are used to show time-series details for how the With-Project condition <u>decreases</u> the river current as compared to the existing condition. The terrain (bed elevation) at PC observation points is not affected by the FWP: Changes in river current at PC points are due to terrain changes from other areas. Photo image shows 2011 configuration of Woodland Islands A-D. Refer to **Figures H20 and H21-H26** for AdH model results relating to the above "decreased current" observation points.

Figure H5a is a snapshot of river current vectors simulated by AdH model for 1400 on 13 JUL 1997 (model TS=2486 hrs), when river hydraulics was dominated by (ebbing) tidal action during low fluvial flow 100 Kcfs (2.8 kcms). At this time, the tidal sequence was ebbing with predominate flow in downstream direction. River stage was at 6.7 ft and falling to 6.0 ft NAVD. Depth-averaged current vectors are shown in terms of current magnitude > 0.003 m/s and < 0.3 m/s. Currents during low flow & ebb tide have significantly less magnitude than high river flow conditions and are directed downstream, except near pile dikes and at areas of rapid morphology change where eddies and other local flow variation can occur. During ebb tide, flow enters the Woodland Island embayment mostly though the flow-way between Island A and B identified by "**+**". Figure H5a is a snapshot of the same timeframe as the "Exiting Condition" image shown in left graphic, but for TWP condition. Differences in currents within the off-channel embayment between this image and one to left are due to terrain medication under the FWP condition (DS and US project features). The US and DS project features span an elevation range of -1.8 to +4.1 meters NAVD and are each approximately 1,000 meters long. During low river flow conditions, the FWP features act to redirect currents and have much have less effect on current magnitude than during high river flow conditions. Areas that experienced a current speed reduction (at 1400 pm on 13 JUL 1997) are denoted by "**o**". Terrain areas that were filled by the FWP features had Existing Condition currents reduced to zero.

LOW River Flow Interaction with Woodland Islands Existing Condition and FWP

Figure H6a is a snapshot of river current vectors simulated by AdH model for 2000 on 12 JUL 1997 (model TS=2468 hrs), when river hydraulics was dominated by (flooding) tidal action during low fluvial flow 100 Kcfs (2.8 Kcms). At this time, the tidal sequence was flooding with predominate flow in upstream direction. River stage was at 8.1 ft and rising to 8.7 ft NAVD. Depth-averaged current vectors are shown in terms of current magnitude > 0.003 m/s and < 0.15 m/s. Currents during flood tide have significantly less magnitude than ebb tide conditions.

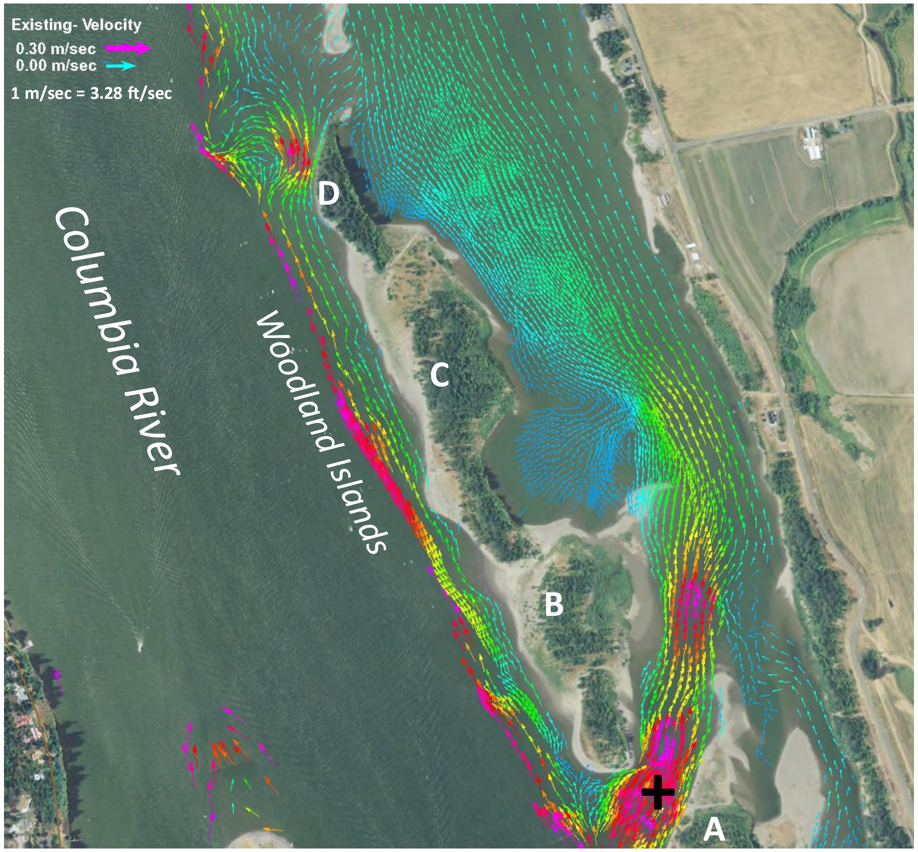


Figure H5a. Existing Condition Currents – HIGH River Flow Event, with Columbia River flow at RM 85 reaching 610 kcfs (17.3 kcms). Current speed within the mainstem Columbia River > 0.90 m/sec. River stage was at 6.7 ft and falling to 6.0 ft NAVD

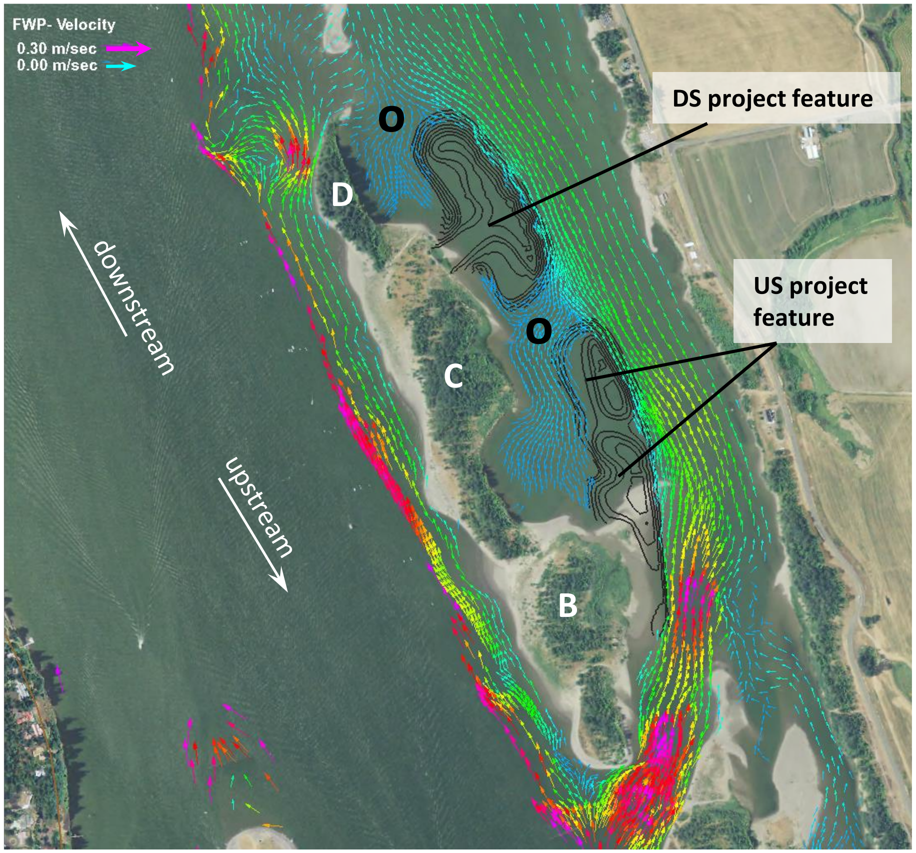


Figure H5b. FWP River Currents – HIGH River Flow Event. Symbols indicate areas where aspects of current velocity are discussed. Both figure H3a and H3b are a "snapshot" of river current vectors simulated by AdH model for 1200 on 15 JUN 1997 (model TS=1812 hrs)

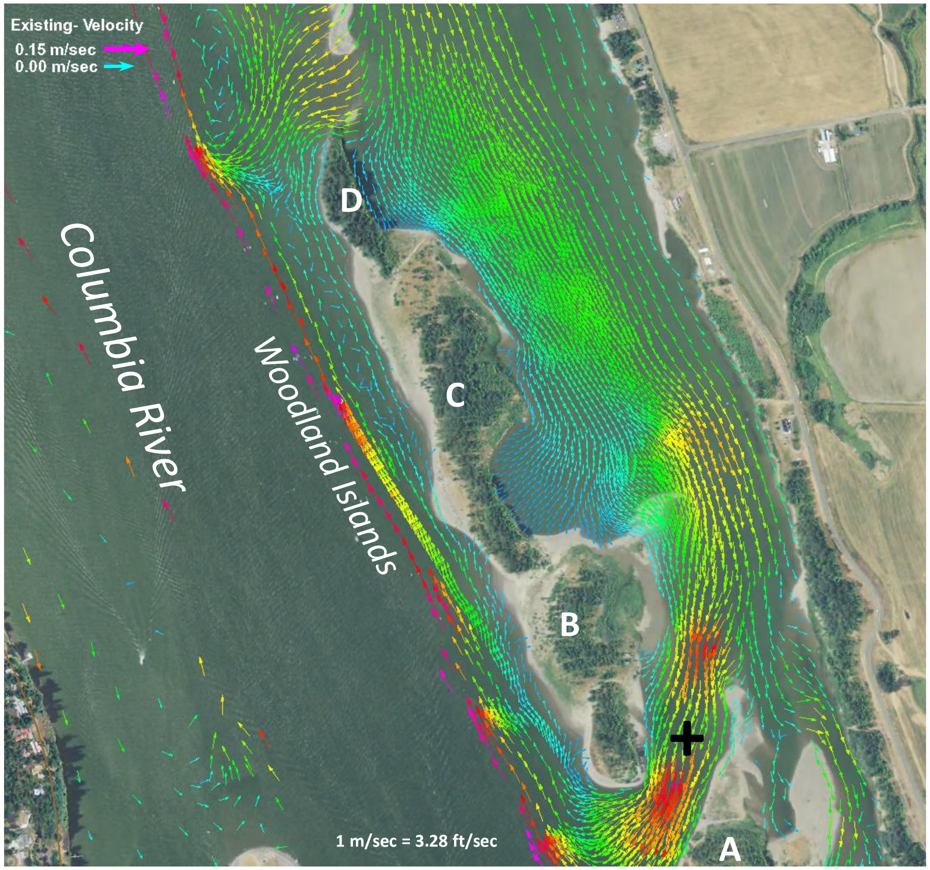


Figure H6a. Existing Condition Currents – Flood Tide Flood Tide during LOW riverine flow. Columbia River flow at RM 85 was about 100 Kcfs (2.8 kcms). Current speed within the mainstem Columbia River > 0.15 m/sec. River stage was at 8.1 ft and rising to 8.7 ft NAVD.

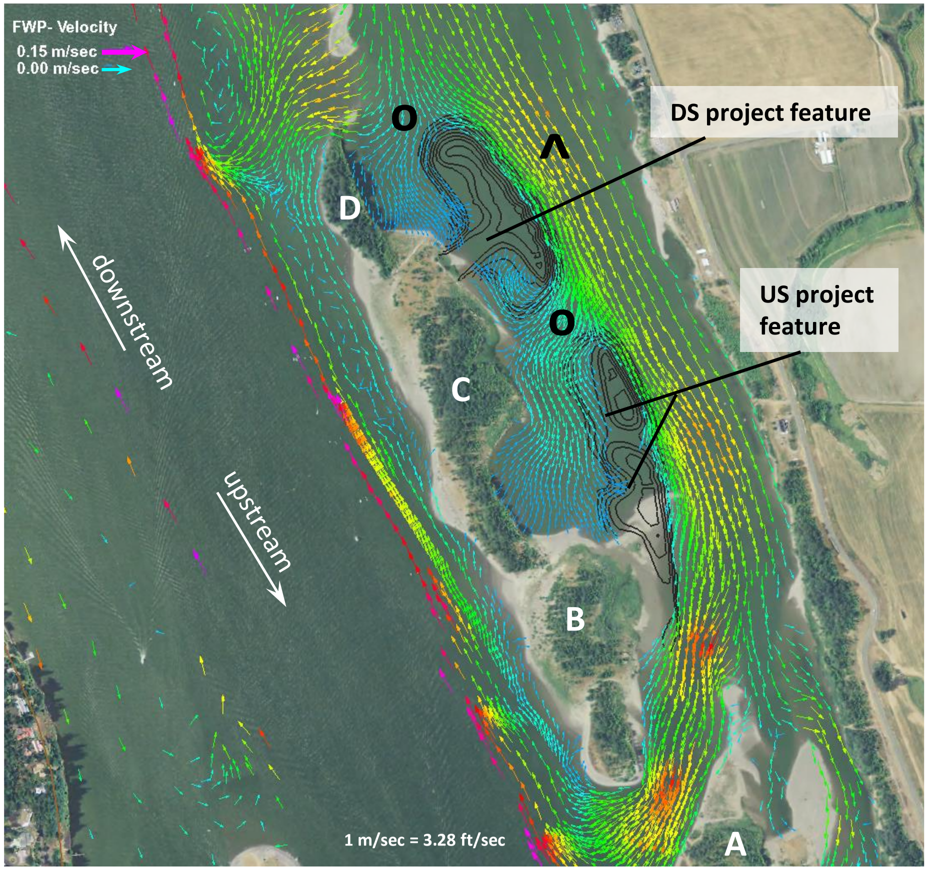


Figure H6b. FWP River Currents – Flood Tide during LOW riverine flow. Both figure H3a and H3b are “snapshots” of river current vectors simulated by AdH model for 2000 on 12 JUL 1997 (model TS=2468 hrs).

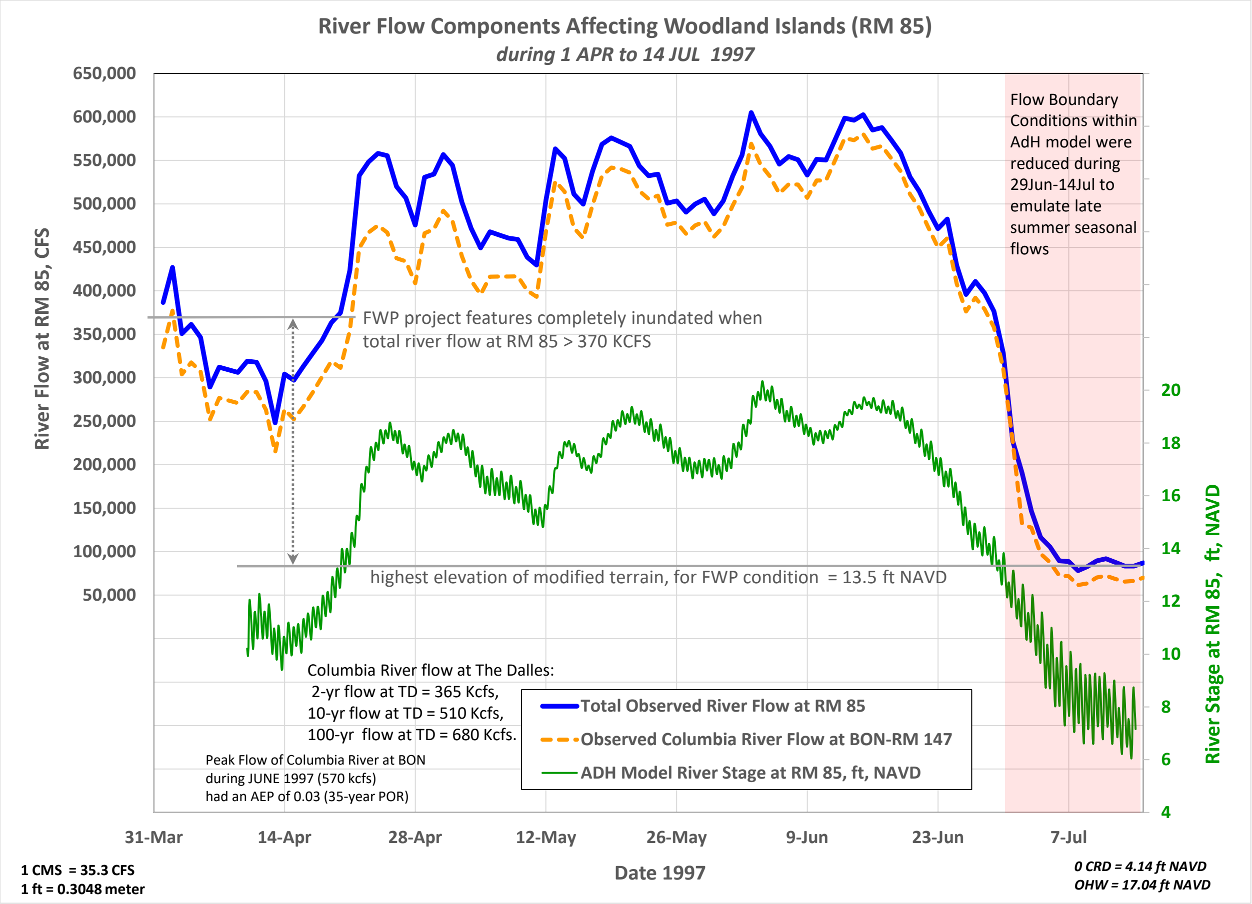


Figure H7. River flow and stage at Woodland Islands during the AdH model run, from APR –JUL 1997.

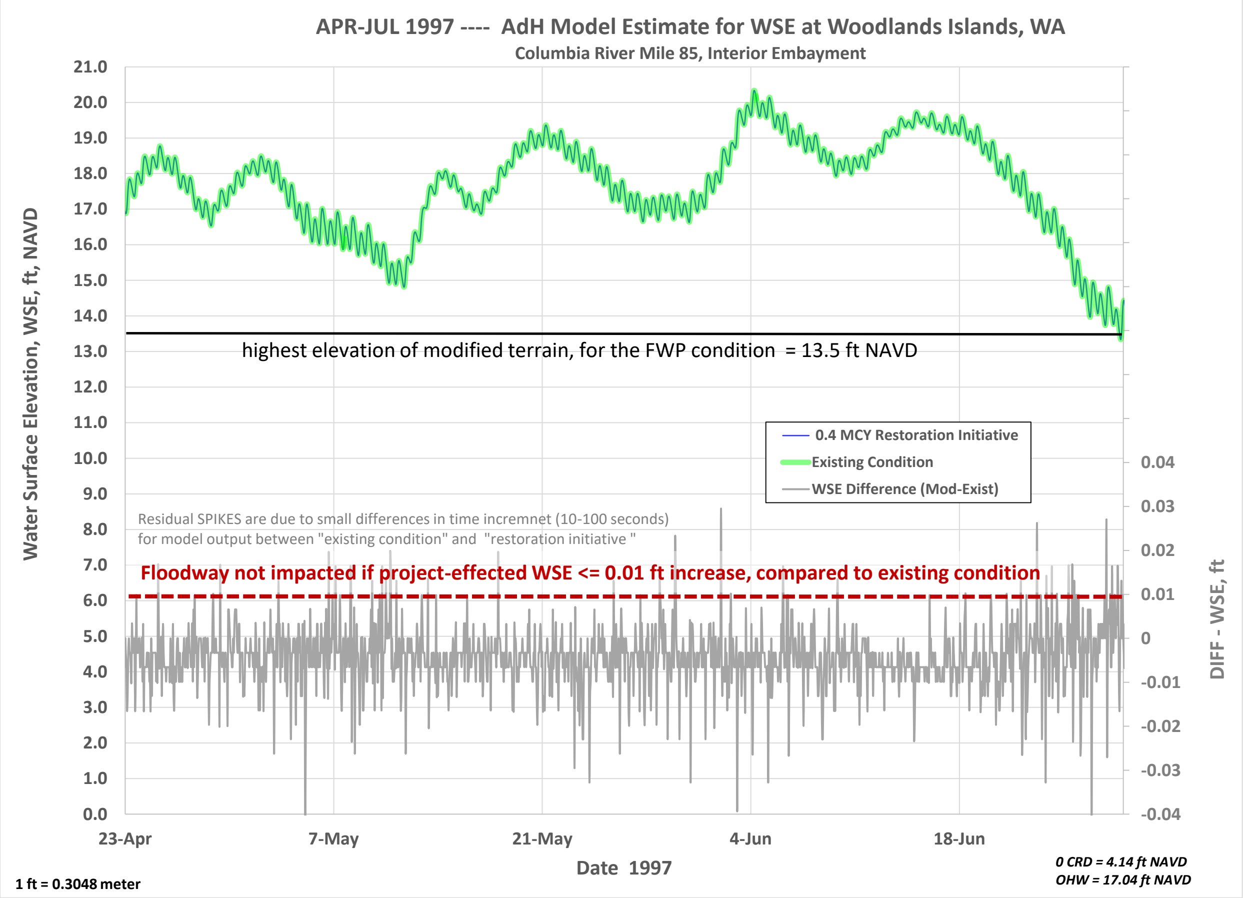


Figure H8. Comparison of river stage within the Woodland Island embayment for the existing vs. FWP.

At this time increment (Figure H6a and H6b), flow is directed upstream, except near pile dikes and at areas of rapid morphology change where eddies and other local flow variation can occur. Flow enters the Woodland Island embayment from downstream and exits the embayment flow-way identified by "**+**". Figure H6b is the same timeframe as the "Exiting Condition" image shown in left graphic, but for TWP condition. Differences in currents within the off-channel embayment between this image and one to left are due to terrain medication under the FWP condition (DS and US project features). The US and DS project features span an elevation range of -1.8 to +4.0 meters NAVD and are each approximately 1,000 meters long. During low river flow conditions, the FWP features act to redirect currents and have much less effect on current magnitude than during high river flow conditions. Areas that experienced a current speed reduction (at 2000 pm on 12 JUL 1997) are denoted by **^**, and include direct effect of the feature footprint. Areas that experienced increased current speed are denoted by **^**. Terrain areas that were filled by the FWP features had Existing Condition currents reduced to zero.

Figure H7 shows the fiver flow and stage at the Woodland Islands project area during the AdH model run period from APR-JUL 1997. Top two time series show river discharge passing RM 85 based on fluvial input from Bonneville Dam, Sandy River, Washougal River, Willamette River, and Lewis River. Values are expressed in terms of daily-averaged flow. Peak flow for the Columbia River at BON reach 570 Kcfs and total river flow passing RM 85 reached 610 Kcfs. The **red zone** identifies when the river flow boundary conditions for the AdH model were "reduced" from observed conditions to emulate a late summer low flow scenario (29 June – 14 July). This flow reduction was to emulate the late summer season, when tidal action would have a pronounced effect on river hydraulics at RM 85. Bottom time series shows the WSE at RM 85 responding to the variation in fluvial flow conditions and tidal forcing from the ocean. The highest point of the FWP modified terrain is 13.5 ft (4.1 m) NAVD , which would be submerged when total Columbia River flow at RM 85 exceeds 370 Kcfs (10.5 kcms). When Columbia River flow falls below 150 Kcfs (4.25 kcms), the WSE at RM 85 becomes dominated by tidal action.

Figure H8 shows the comparison of river stage (WSE) within the Woodland Island embayment for the existing vs. FWP condition, at a location where the increase in river current for the two conditions is maximum (refer to PC #4, in Figure H4a). At the peak of the 1997 freshet event (4 June), the WSE for the existing condition is estimated to have been at the 20.3 ft NAVD, submerging the FWP features by > 6 ft. The FWP modified terrain would be submerged during the entire high-flow time period shown here. The two WSE time series appear identical (FWP vs. Existing). The difference between WSE (at point #4) for the existing vs. FWP condition is shown by the grey time series on the bottom of the graph. *Implications:* The FWP WSE was estimated to be equal to or slightly lower than the existing condition. Based on these results, the FWP condition is not expected to affect the Columbia River floodway or increase WSE at the project site.

Positive Change (Increase) in currents at Woodland Islands due to FWP

Figure H9 shows existing condition time series of depth-averaged current magnitude at 9 different observation points within the Woodland Island project site. Refer to Figure H4a for location of **Positive Change** (PC) observation points. The terrain at these locations will not be changed by FWP sediment placement, as these areas are not within the FWP foot-print. These points are expected to be affected by an increase is current as a result of FWP. The current magnitude time series were produced by the AdH hydrodynamic model and show how current within different locations of the project site respond to changes in river flow. The 9 locations featured in this plot experienced various degrees of INCREASED current magnitude for the WFP condition as compared to the existing condition. Initiation of transport for sand-sized bottom sediment can range from 0.15 to 0.35 ft/sec, depending on bottom roughness and free-stream turbulence. As river flow falls below 150 Kcfs (shown here for 29 June), currents within the project site begin to fall below the threshold needed to mobilize active transport of sand-sized

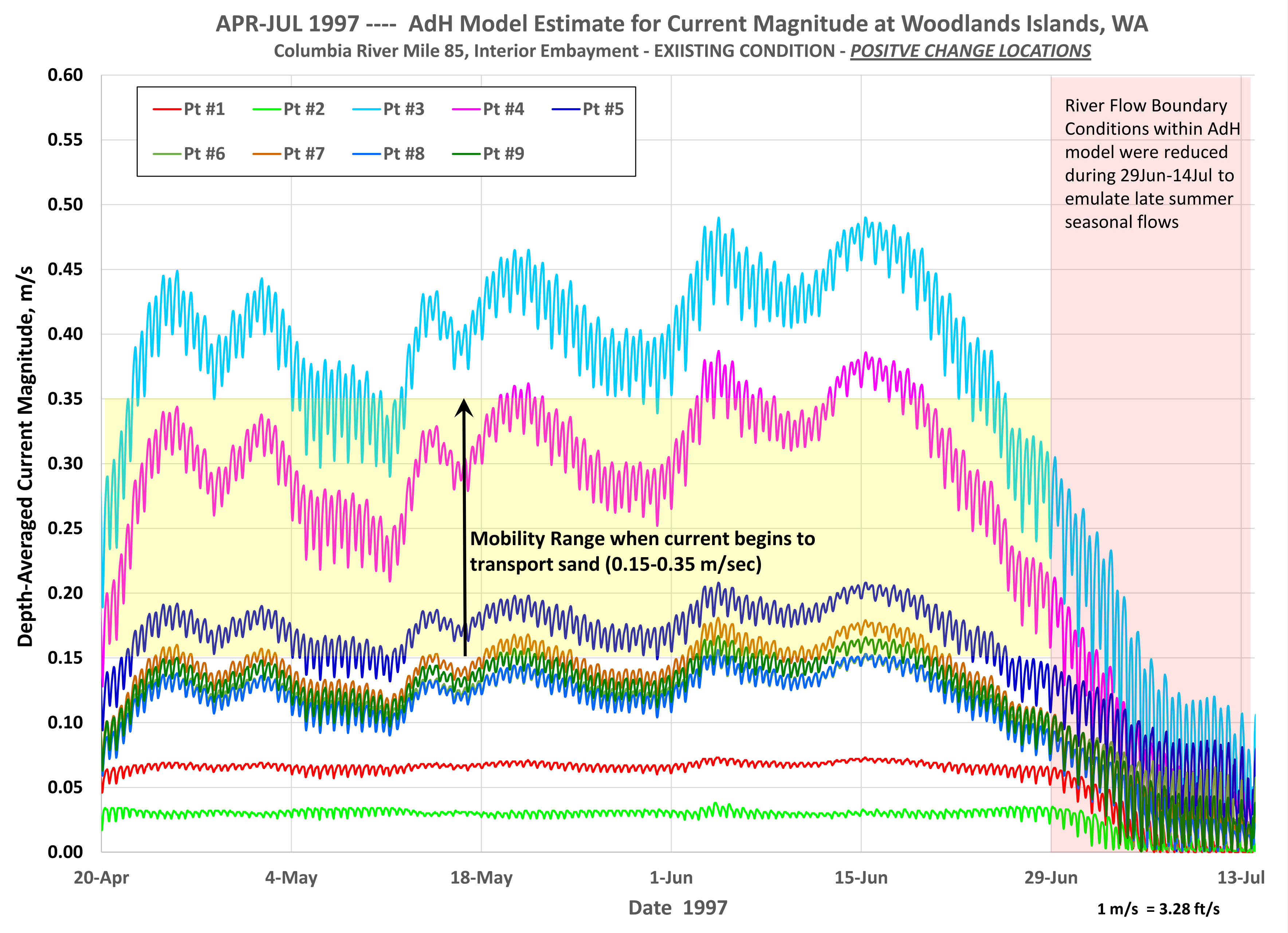


Figure H9. Existing condition time series of depth-averaged current magnitude at 9 different observation points within the Woodland Island project site. Refer to Figure H4a for location of Positive Change (PC) observation points.

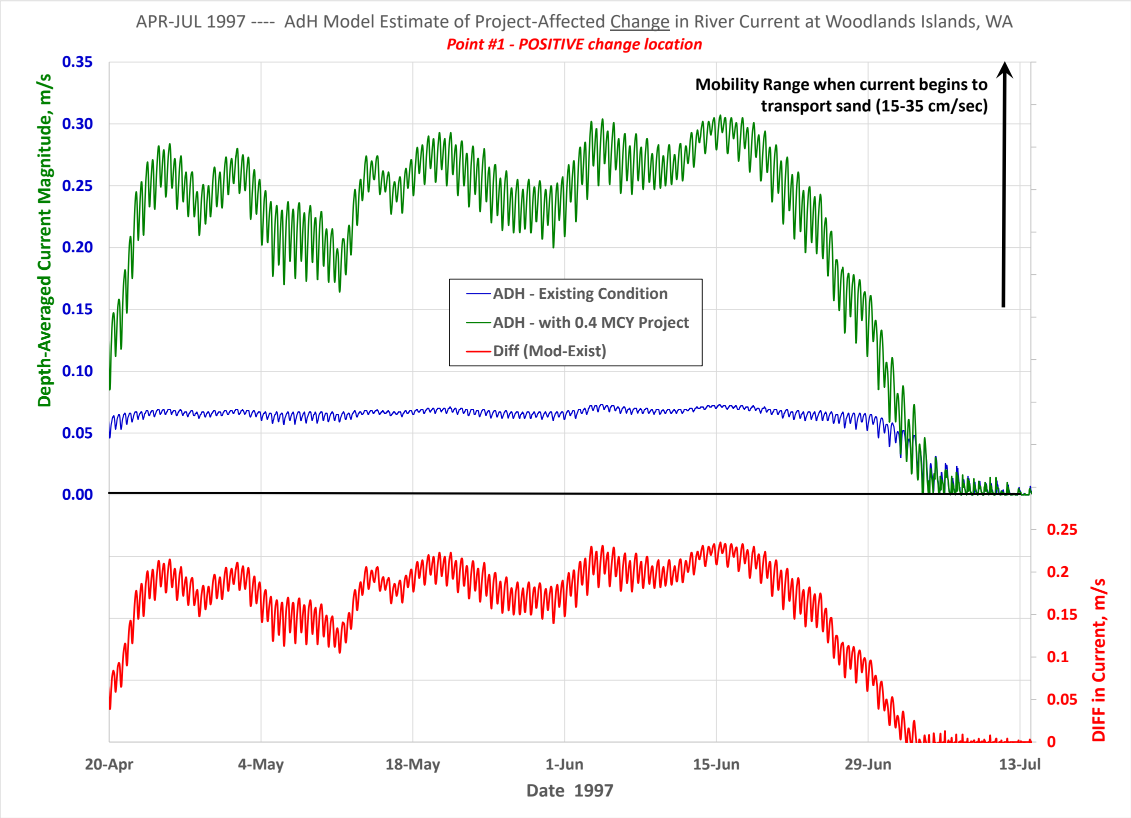


Figure H10. Comparison of AdH results at Positive Change observation point #1.

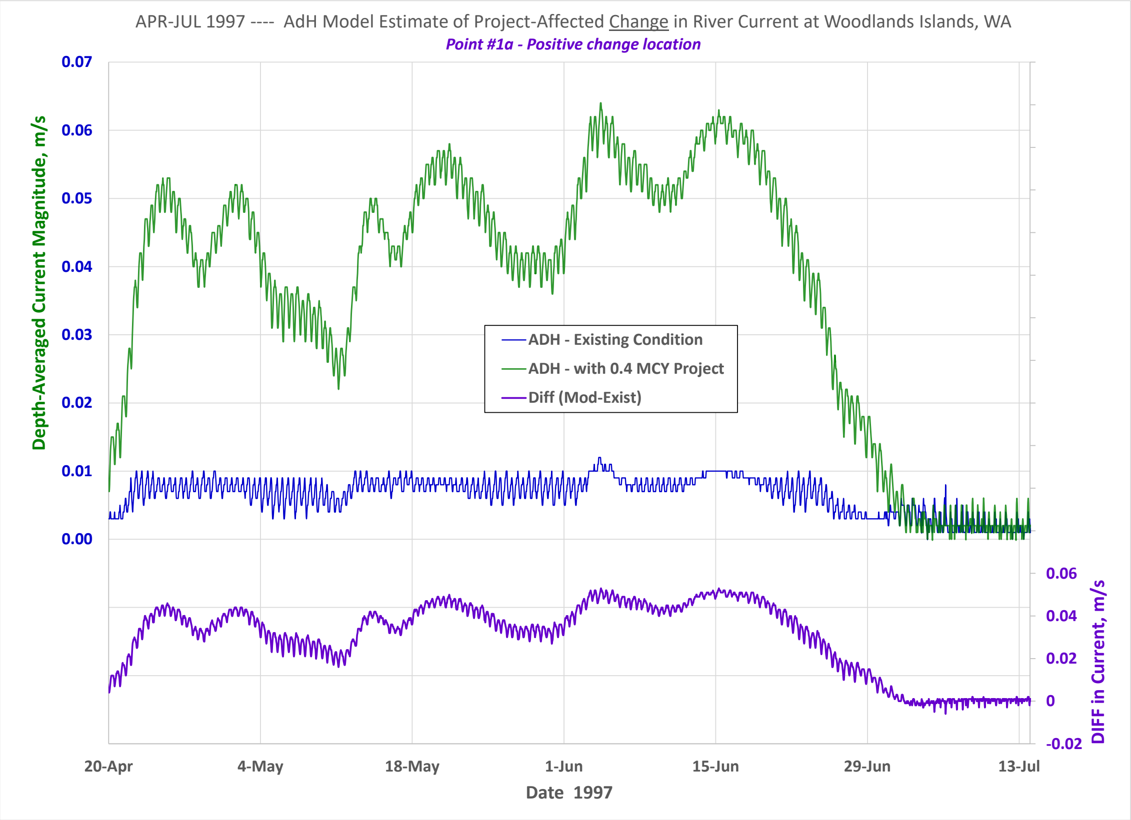


Figure H11. Comparison of AdH results at Positive Change observation point #1a.

sediment. Figures H10 to H19 show detailed comparison between Existing Condition and FWP time-series for current magnitude.

Woodland Island B-East Side: Figure H10 shows the comparison of AdH results at Positive Change observation point #1. Top two time series are depth-averaged current magnitude for Positive Change (PC) observation point #1, comparing AdH model results for the existing condition and FWP. PC point #1 is located on the shore attachment area (at 7.2 ft NAVD) of a sand flat which extends into the open water area along the east side of Woodland Island B. Existing condition currents are weak (<0.1 m/sec) at this location as water movement is arrested by the sand flat, and re-directed NE toward the openwater area. FWP currents at PC #4 are estimated to increase significantly during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.25-0.3 m/sec. Under the FWP, the increase in currents at this location will likely increase sediment transport along the shore connection of the sand flat, as the FWP current will be greater than the 0.15 m/sec threshold for sediment transport during periods of high river flow.

The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude at PC #4 by up to 0.2 m/sec. At this location, FWP currents increase because the US project feature is not fully connected to upland terrain of Island B, leaving a 50-m wide saddle zone (at 2.2 m NAVD elevation) between Island B and the FWP-modified terrain. During higher flow conditions (>250 Kcfs), this "saddle zone" provides a slot for flow to pass though, as the FWP US feature acts to increase river current within this area of the project and re-directs increased flow though the "saddle zone" During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition diminishes to zero. ***Implications:*** The FWP is expected to produce some localized enhancement of sediment transport (terrain lowering of 0.25 to 1 ft) along the shore connection area of the US project feature with Island B. The mobilized sediment is expected to be transported 50-200 meters northward and deposited along the margin of the cove that is to be partially enclosed by the US project feature and Island C. The FWP terrain (in this area of the project) is expected to equilibrate after some degree of natural sediment "re-working", as described above.

Woodland Island C-East Side Cove: Figure H11 show the comparison of AdH results at Positive Change observation point #1a. Top two time series are depth-averaged current magnitude for Positive Change (PC) observation point #1a, comparing AdH model results for the existing condition and FWP. PC point #1a is located within a sheltered cove (at 3.3 ft NAVD) along the east side of Woodland Island "C". Existing condition currents are very weak (<0.02 m/sec) at this location as water movement is muted within the protected cove. This cove is likely a deposition environment for fine grain sediment, as the currents here are very low during high flow conditions. FWP currents at PC #1a are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.04-0.06 m/sec. Under the FWP, the increase in currents at this location is not expected to increase sand sediment transport, as currents for both the Existing and FWP condition will be less than the 0.15 m/sec threshold for sediment transport. However, the FWP condition currents may mobilize some fine grain material that had previously deposited within the cove. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by 0.02-0.04 m/sec. At this location, FWP currents increase because the US project feature is not fully connected to Island B, leaving a 50-m wide saddle zone that acts a slot for flow to pass into the cove during high flow conditions. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition diminishes to zero. ***Implications:*** The FWP is expected to increase in currents with the sheltered 'cove area' along the east side of Island C, as compared to the existing condition. The FWP increased current is not expected to mobilize any sand, but could mobilize some of the fine-grained material that had previously deposited within this area of the cove.

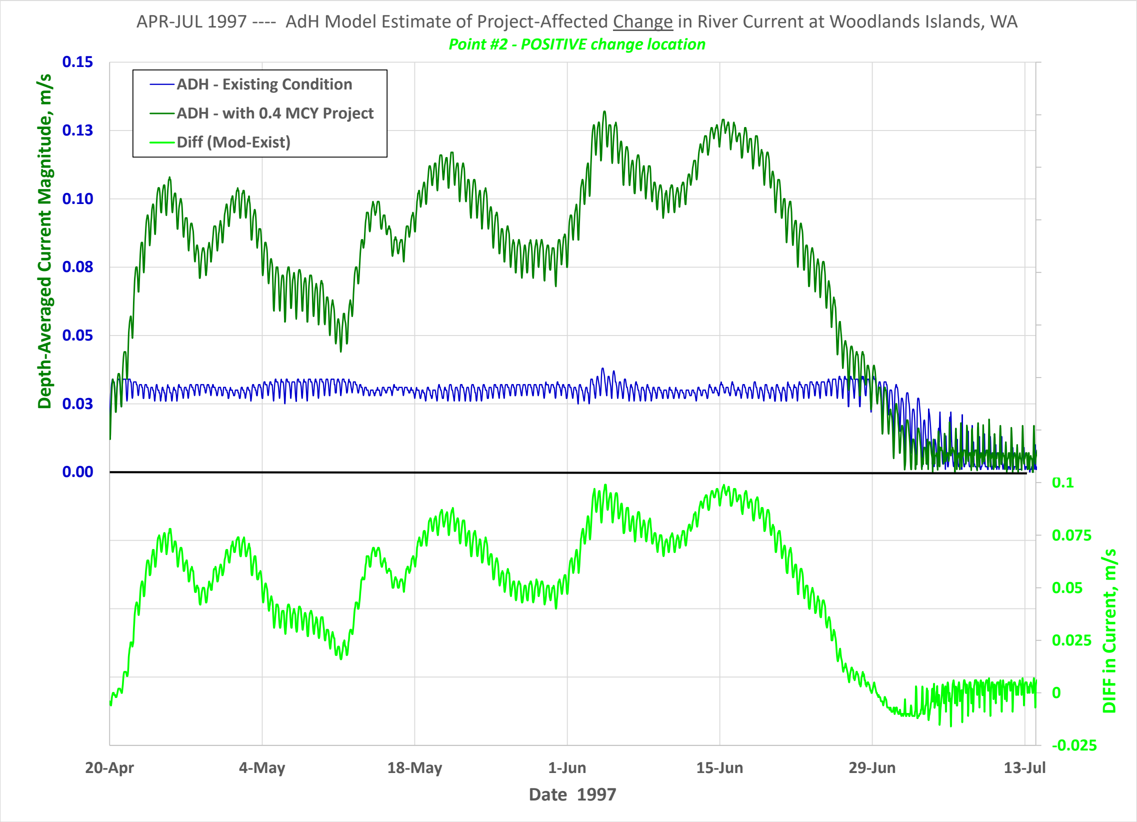


Figure H12. Comparison of AdH results at Positive Change observation point #2.

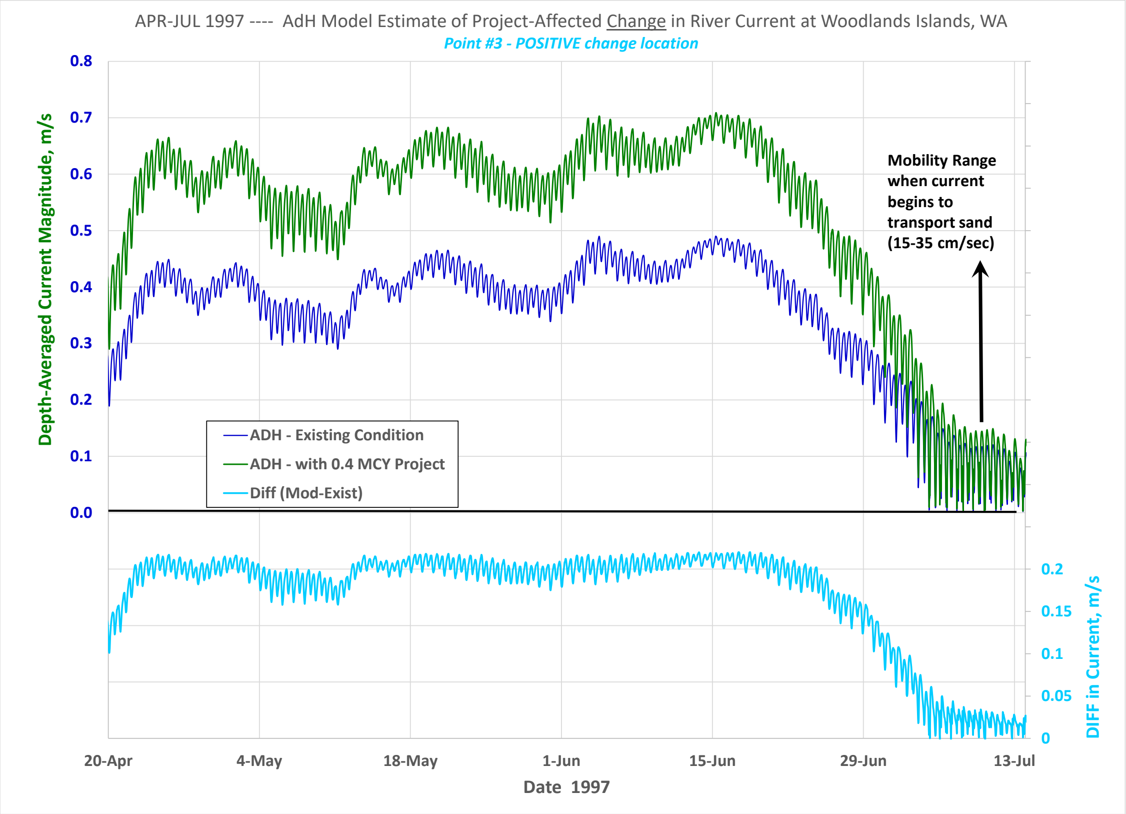


Figure H13. Comparison of AdH results at Positive Change observation point #3.

<u>Woodland Island C-East Side Inter-tidal</u>: Figure H12 show the comparison of AdH results at Positive Change observation point #2. Top two time series are depth-averaged current magnitude for <u>Positive Change (PC) observation point #2</u>, comparing AdH model results for the existing condition and FWP. PC point #2 is at 5.9 ft NAVD elevation and located on the northern shore edge of small cove near Island C, which would be partially enclosed by the FWP US project feature. Existing condition currents are weak yet persistent (<0.05 m/sec) at this location as water movement is indicative of a sheltered backwater cove, protected from ravages of the mainstem Columbia River. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.10-0.13 m/sec. The increase in currents at this location, under the FWP, is not expected to affect increased transport of sand sediment, even during higher river flow conditions as the maximum currents for both he Existing and FWP conditions are estimated to be < the 0.15 m/sec threshold needed to initiate sand transport.

The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase currents at this location by 0.02-0.08 m/sec. Although the difference between the FWP and Existing Condition is large on a relative basis, the magnitude of the change is small, and the resulting current magnitude under the FWP remains low. Under the FWP, currents at PC #2 are expected to increase because of the FWP effects associated with increased flow over the “saddle zone“ previously described at PC #1. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition rapidly diminish to zero. ***Implications***: The FWP is expected to produce localized increases in currents along the northern margin of the sheltered ‘cove area’ located immediately west of the US project feature and along Island C. The increased current is not expected to mobilize any sand, but could mobilize some of the fine-grained material that has previously deposited within this area of the cove.

<u>Woodland Island Embayment Tidal Channel</u>: Figure H13 show the comparison of AdH results at Positive Change observation point #3. Top two time series are depth-averaged current magnitude for <u>Positive Change (PC) observation point #3</u>, comparing AdH model results for the existing condition and FWP. PC point #3 is located 130 meters east of the US project feature at -1.3 ft NAVD, within the main tidal channel that conveys most of the flow within the large embayment east of Woodland Islands. Existing condition currents are moderate (0.3-0.5 m/sec) at this location as water movement is enhanced by converging flow within embayment’s main tidal channel. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.5-0.7 m/sec. Under the FWP, the increase in current magnitude at this location will likely enhance sediment transport within the embayment’s main tidal channel, as the FWP current will be greater than the 0.35 m/sec threshold for sediment transport during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by up to 0.2 m/sec. At this location, FWP currents increase because the US project feature reduces the width the Woodland Island embayment and re-directs more flow toward the remaining embayment area and the main tidal channel. The change in current magnitude (for the FWP) is uniform due to the uniform alignment of currents within the existing tidal channel and spatially uniform infringement of the US project feature. The “zone of effect” for increased currents for the FWP may extend 50-70 meters laterally beyond the tidal channel. This effect will quickly diminish within increased distance (> 70 meters) from the tidal channel. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition rapidly diminishes to < 0.03 m/sec. ***Implications:*** The FWP is expected to increase sediment transport within the main tidal channel of the Woodland Island embayment, as the tidal channel passes along the US project feature. Areas along the tidal channel margin may also experience some increased sediment transport. The existing substrate of the tidal channel and its immediate margins may experience some terrain lowering (0.25 to 2 ft of bed erosion) due to the FWP. The largest erosional effects induced by the FWP will be confined to the central axis/invert of the existing tidal channel, with diminishing erosion effects extending to the channel margins.

Bottom sediment at this location is mostly medium-course sand (0.18-0.35 mm). The mobilized sediment is expected to be transported downstream, and could re-deposit within the embayment between the US and DS project features or deposit along existing sand shoals immediately downstream of Woodland Islands. Existing embayment substrate along the tidal channel margins (and the US project feature) affected by the changes in FWP currents are expected to equilibrate after some degree of natural sediment "re-working".

Woodland Island Embayment Tidal Channel: Figure H14 show the comparison of AdH results at Positive Change observation point #4. Top two time series are depth-averaged current magnitude for Positive Change (PC) observation point #4, comparing AdH model results for the existing condition and FWP. PC point #4 is located 170 meters east of the DS project feature at -3.6 ft NAVD), within the main tidal channel that conveys most of the flow within the large embayment east of Woodland Islands. Existing condition currents are 0.2-0.4 m/sec at this location as water movement is enhanced by converging flow within embayment's main tidal channel. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.4-0.6 m/sec. Under the FWP, the increase in current magnitude at this location will likely enhance sediment transport within the embayment's main tidal channel, as the FWP current will be greater than the 0.35 m/sec threshold for sediment transport during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by up to 0.25 m/sec. At this location, FWP currents increase because the DS project feature reduces the width the Woodland Island embayment and re-directs more flow toward the remaining embayment area and the main tidal channel. The "zone of effect" for increased currents for the FWP may extend 70-90 meters laterally beyond the tidal channel. This effect will quickly diminish with within increased distance (> 90 meters) from the tidal channel. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition rapidly diminishes to less than 0.05 m/sec. ***Implications:*** The FWP is expected to increase sediment transport within the main tidal channel of the Woodland Island embayment, as the tidal channel passes along the DS project feature. Areas along the tidal channel margin may also experience some increased sediment transport. Bottom sediment at this location is mostly medium-course sand (0.18-0.35 mm). The existing substrate of the tidal channel and its immediate margins may experience some terrain lowering (0.25 to 2 ft of bed erosion) due to the FWP. The largest erosional effects induced by the FWP will be confined to the central axis of the existing tidal channel, with diminishing erosion effects extending to the channel margins. The mobilized sediment is expected to be transported downstream, and could re-deposit within the embayment immediately downstream of the DS project features or deposit along existing sand shoals immediately downstream of Woodland Islands. Existing embayment substrate along the tidal channel margins (and the DS project feature) affected by the changes in FWP currents are expected to equilibrate after natural sediment "re-working".

WA Shore – East of Island B: Figure H15 shows the comparison of AdH results at Positive Change observation point #5. Top two time series are depth-averaged current magnitude for Positive Change (PC) observation point #5, comparing AdH model results for the existing condition and FWP. PC point #5 is located along the foreshore of the WA riverbank at 5.6 ft NAVD, 200 meters east of the US project feature. Existing condition currents are low (0.15-0.2 m/sec) at this location as water movement is reduced along the shallows of the WA riverbank. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.2-0.3 m/sec. Under the FWP, the increase in current magnitude at this location may increase the potential for sediment transport, as the FWP current will be greater than the 0.15 m/sec threshold for sediment transport during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by 0.07 m/sec. At this location, FWP currents increase because the US project feature reduces the width the Woodland Island embayment and re-directs more flow toward the remaining embayment

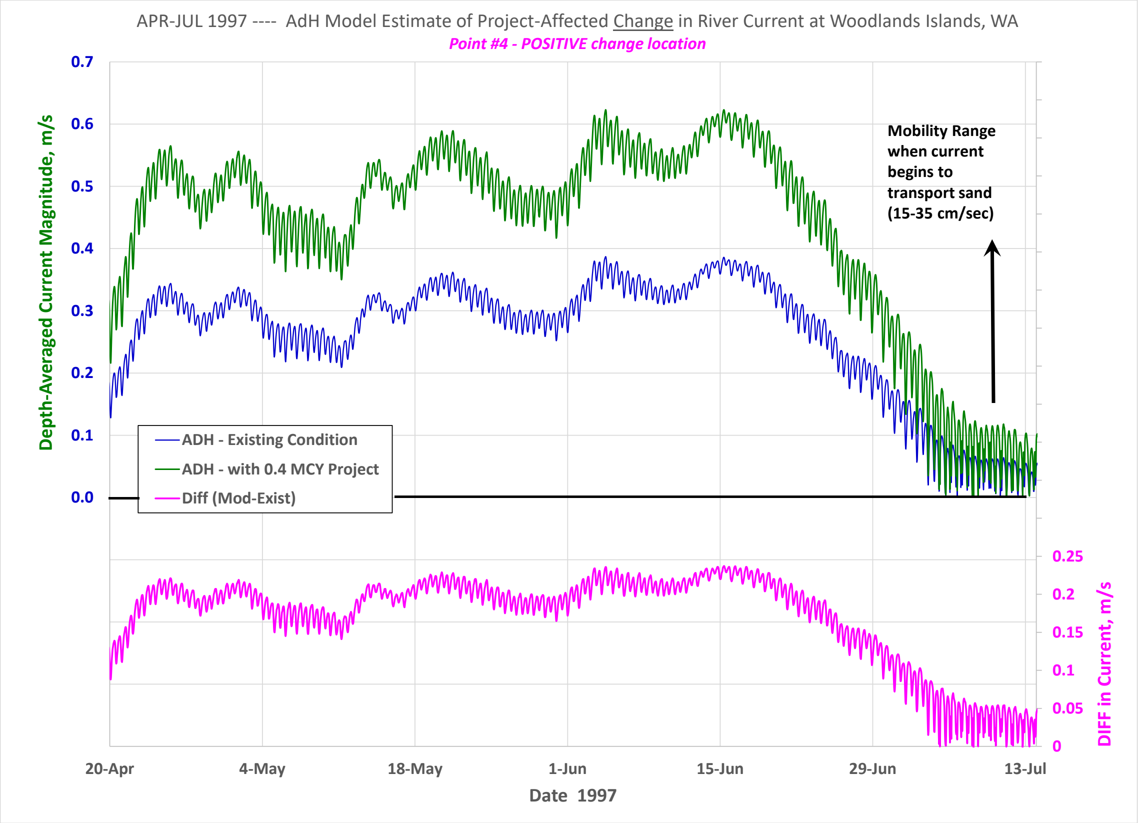


Figure H14. Comparison of AdH results at Positive Change observation point #4.

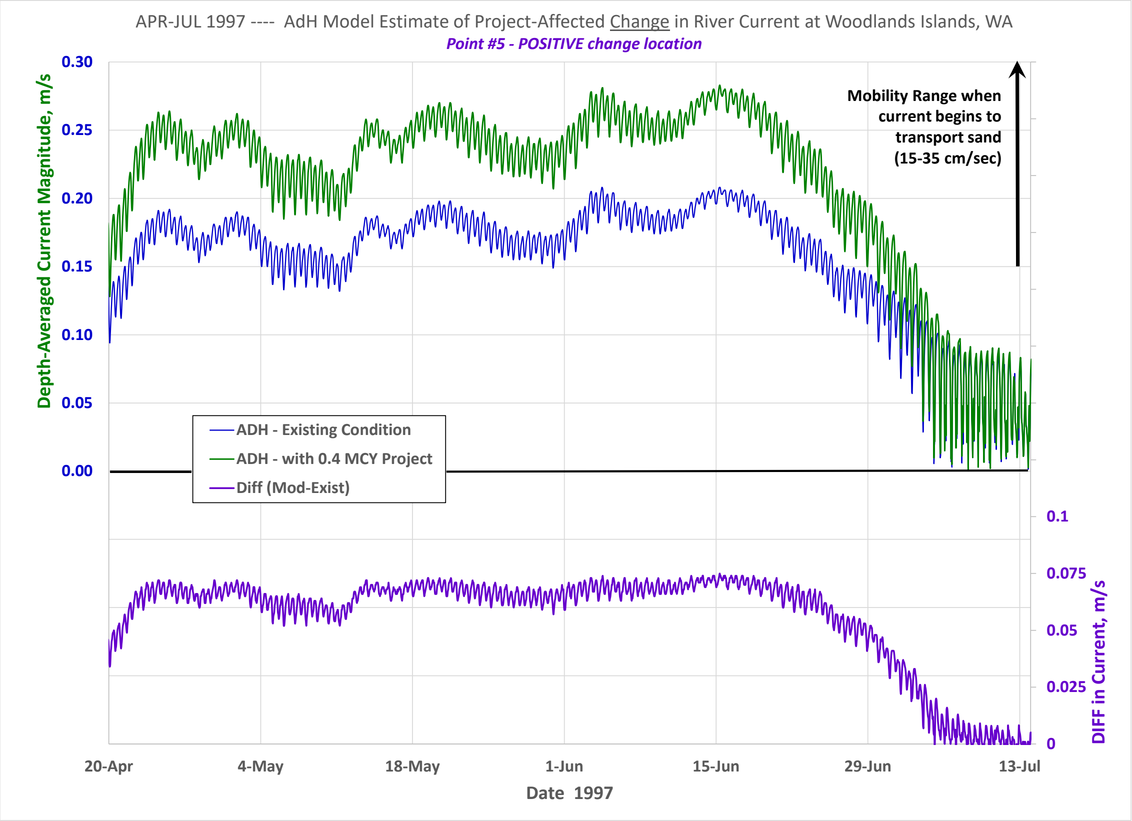


Figure H15. Comparison of AdH results at Positive Change observation point #5.

area and the main tidal channel. The change in current magnitude (due to the FWP) is uniform due to the uniform alignment of currents within the existing tidal channel and spatially uniform infringement of the US project feature. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition rapidly diminishes to zero. ***Implications:*** Although the difference between the FWP and Existing Condition is large on a relative basis, the magnitude of the change is small, and the resulting current magnitude under the FWP remains low. However, the FWP may increase the potential for sediment transport along the foreshore area of the WA riverbank, for areas due east of the FWP. The potential for increased sediment transport, due to the FWP, decreases as one moves further up the river bank foreshore (further away from the FWP features).

The existing substrate in the area of PC #5 may experience some terrain lowering (0.1 to 1 ft of bed erosion) due to the FWP. If sediment is mobilized in this area, it would likely be transported downstream, and re-deposit along the WA river bank. If the existing riverbank, in proximity of PC #5, is affected by changes in FWP currents the substrate is expected to equilibrate after minor natural sediment “re-working”.

WA Shore – East of Island C: Figure H16 shows the comparison of AdH results at Positive Change observation point #6. Top two time series are depth-averaged current magnitude for Positive Change (PC) observation point #6, comparing AdH model results for the existing condition and FWP. PC point #6 is located along the foreshore of the WA riverbank at 6.5 ft NAVD, 230 meters east of the US project feature and 75 meters east of PC #3. Existing condition currents are low (0.1-0.15 m/sec) at this location as water movement is reduced along the shallows of the WA riverbank. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.15-0.23 m/sec. Under the FWP, the increase in current magnitude at this location may increase the potential for sediment transport, as the FWP current will be greater than the 0.15 m/sec threshold for sediment transport during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by 0.08 m/sec. At this location, FWP currents increase because the US project feature reduces the width the Woodland Island embayment and re-directs more flow toward the remaining embayment area and the main tidal channel. The change in current magnitude (due to the FWP) is uniform due to the uniform alignment of currents within the existing tidal channel and spatially uniform infringement of the US project feature. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition rapidly diminishes to zero. ***Implications:*** Although the difference between the FWP and Existing Condition is large on a relative basis, the magnitude of the change is small, and the resulting current magnitude under the FWP remains low. However, the FWP may increase the potential for sediment transport along the foreshore area of the WA riverbank, for areas due east of the FWP. The potential for increased sediment transport, due to the FWP, decreases as one moves further up the river bank foreshore (further away from the FWP features). The diminishing effect of the FWP as one moves further up river bank foreshore is exemplified by comparing the AdH time series results for PCs #3 and #6. The existing substrate in the area of PC #6 may experience some terrain lowering (0.1 to 1 ft of bed erosion) due to the FWP. If sediment is mobilized in this area, it would likely be transported downstream, and re-deposit along the WA river bank. If the existing riverbank, in proximity of PC #6, is affected by changes in FWP currents the substrate is expected to equilibrate after minor natural sediment “re-working”.

WA Shore – East of Island C: Figure H17 shows the comparison of AdH results at Positive Change observation point #7. Top two time series are depth-averaged current magnitude for Positive Change (PC) observation point #7, comparing AdH model results for the existing condition and FWP. PC point #7 is located along the foreshore of the WA riverbank at 4.6 ft NAVD, 250 meters east of the DS project feature. Existing condition currents are low (0.1-0.18 m/sec) at this location as water movement is reduced along the shallows of the WA riverbank. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition,

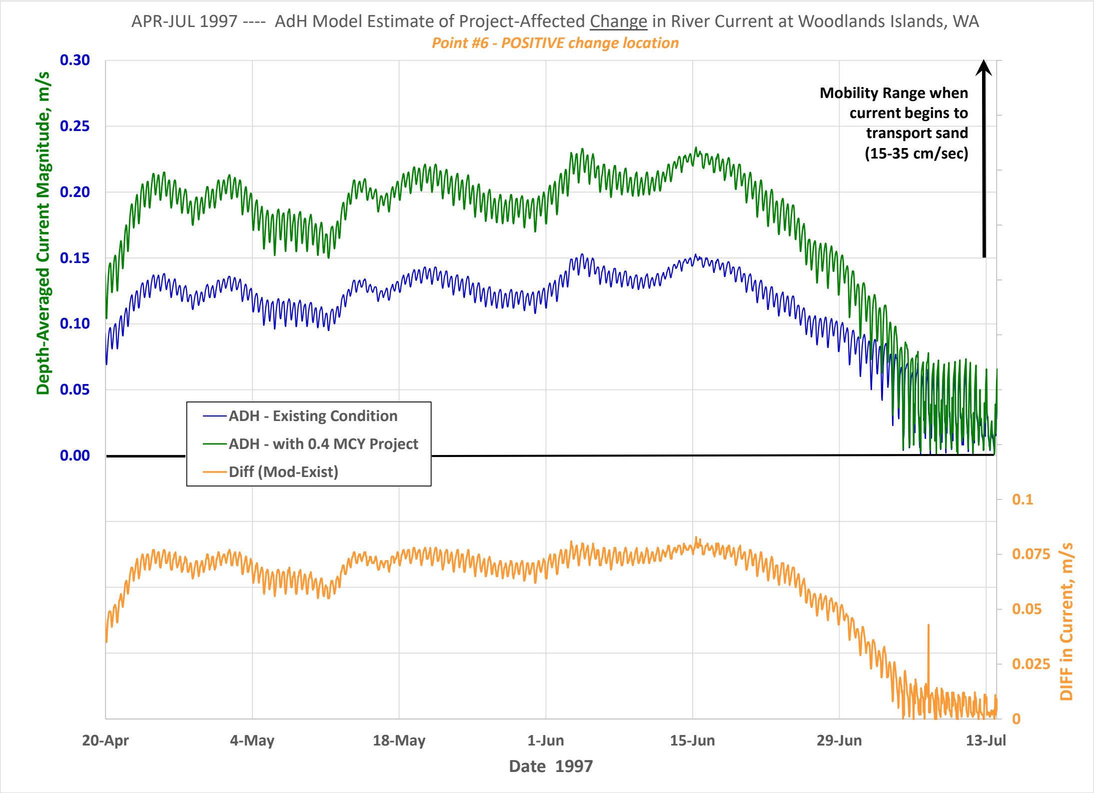


Figure H16. Comparison of AdH results at Positive Change observation point #6.

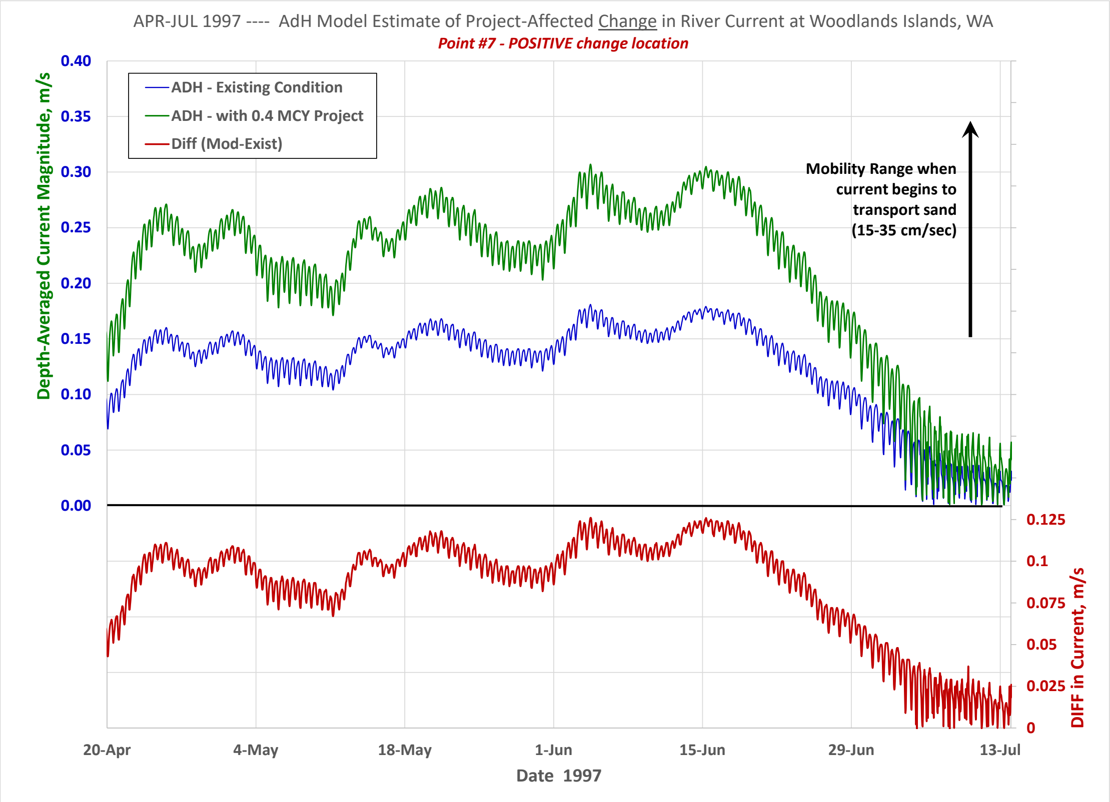


Figure H17. Comparison of AdH results at Positive Change observation point

with FWP current magnitudes reaching 0.18-0.3 m/sec. Under the FWP, the increase in current magnitude at this location may increase the potential for sediment transport, as the FWP current will be greater than the 0.15 m/sec threshold for sediment transport during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by 0.12 m/sec. At this location, FWP currents increase because the DS project feature reduces the width the Woodland Island embayment and re-directs more flow toward the remaining embayment area and the main tidal channel.

During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition rapidly diminishes to 0.01 m/sec. ***Implications:*** Although the difference between the FWP and Existing Condition is large on a relative basis, the magnitude of the change is small, and the resulting current magnitude under the FWP remains low. However, the FWP may increase the potential for sediment transport along the foreshore area of the WA riverbank, for areas due east of the FWP. The potential for increased sediment transport, due to the FWP, decreases as one moves further up the river bank foreshore (further away from the FWP features). The existing substrate in the area of PC #7 may experience some terrain lowering (0.1 to 1 ft of bed erosion) due to the FWP. If sediment is mobilized in this area, it would likely be transported downstream, and re-deposit along the WA river bank. If the existing riverbank, in proximity of PC #7, is affected by changes in FWP currents the substrate is expected to equilibrate after minor natural sediment “re-working”.

WA Shore – East of Island D: Figure H18 shows the comparison of AdH results at Positive Change observation point #8. Top two time series are depth-averaged current magnitude for Positive Change (PC) observation point #8, comparing AdH model results for the existing condition and FWP. PC point #8 is located along the foreshore of the WA riverbank at 3.3 ft NAVD, 270 meters east of the DS project feature and 50 meters east of PC #4. Existing condition currents are low (0.1-0.15 m/sec) at this location as water movement is reduced along the shallows of the WA riverbank. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.15-0.27 m/sec. Under the FWP, the increase in current magnitude at this location may increase the potential for sediment transport, as the FWP current will be greater than the 0.15 m/sec threshold for sediment transport during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by 0.12 m/sec. At this location, FWP currents increase because the DS project feature reduces the width the Woodland Island embayment and re-directs more flow toward the remaining embayment area and the main tidal channel. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition rapidly diminishes to 0.01 m/sec. ***Implications:*** Although the difference between the FWP and Existing Condition is large on a relative basis, the magnitude of the change is small, and the resulting current magnitude under the FWP remains low. However, the FWP may increase the potential for sediment transport along the foreshore area of the WA riverbank, for areas due east of the FWP. The potential for increased sediment transport, due to the FWP, decreases as one moves further up the river bank foreshore (further away from the FWP features). The diminishing effect of the FWP as one moves further up river bank foreshore is exemplified by comparing the AdH time series results for PCs #4 and #8. The existing substrate in the area of PC #8 may experience some terrain lowering (0.1 to 1 ft of bed erosion) due to the FWP. If sediment is mobilized in this area, it would likely be transported downstream, and re-deposit along the WA river bank. If the existing riverbank, in proximity of PC #8, is affected by changes in FWP currents the substrate is expected to equilibrate after minor natural sediment “re-working”.

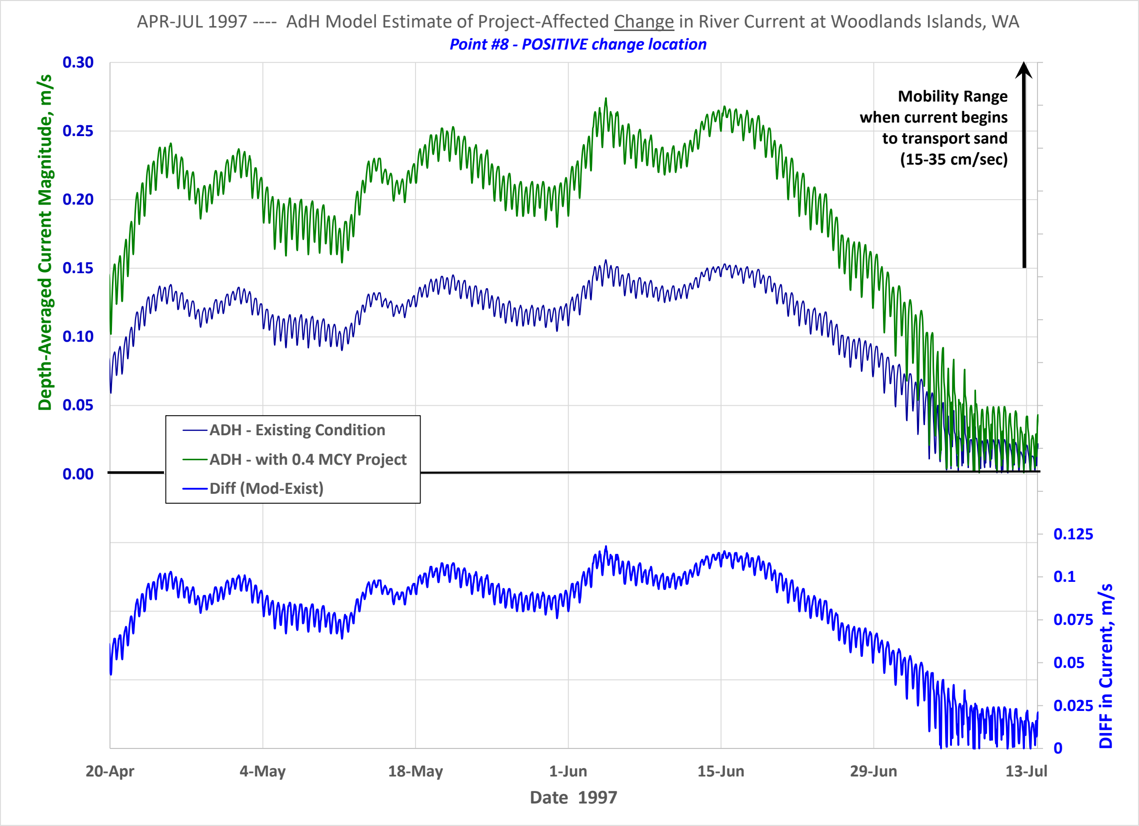


Figure H18. Comparison of AdH results at Positive Change observation point #8.

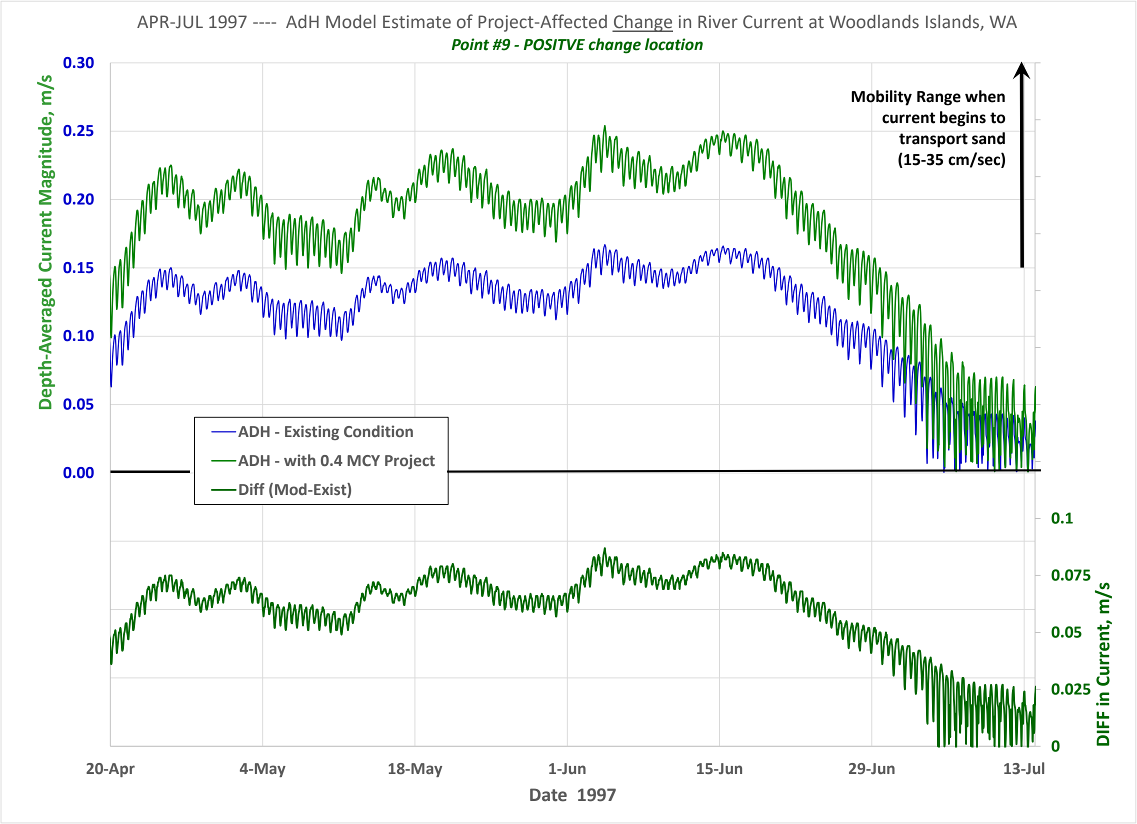


Figure H19. Comparison of AdH results at Positive Change observation point #9.

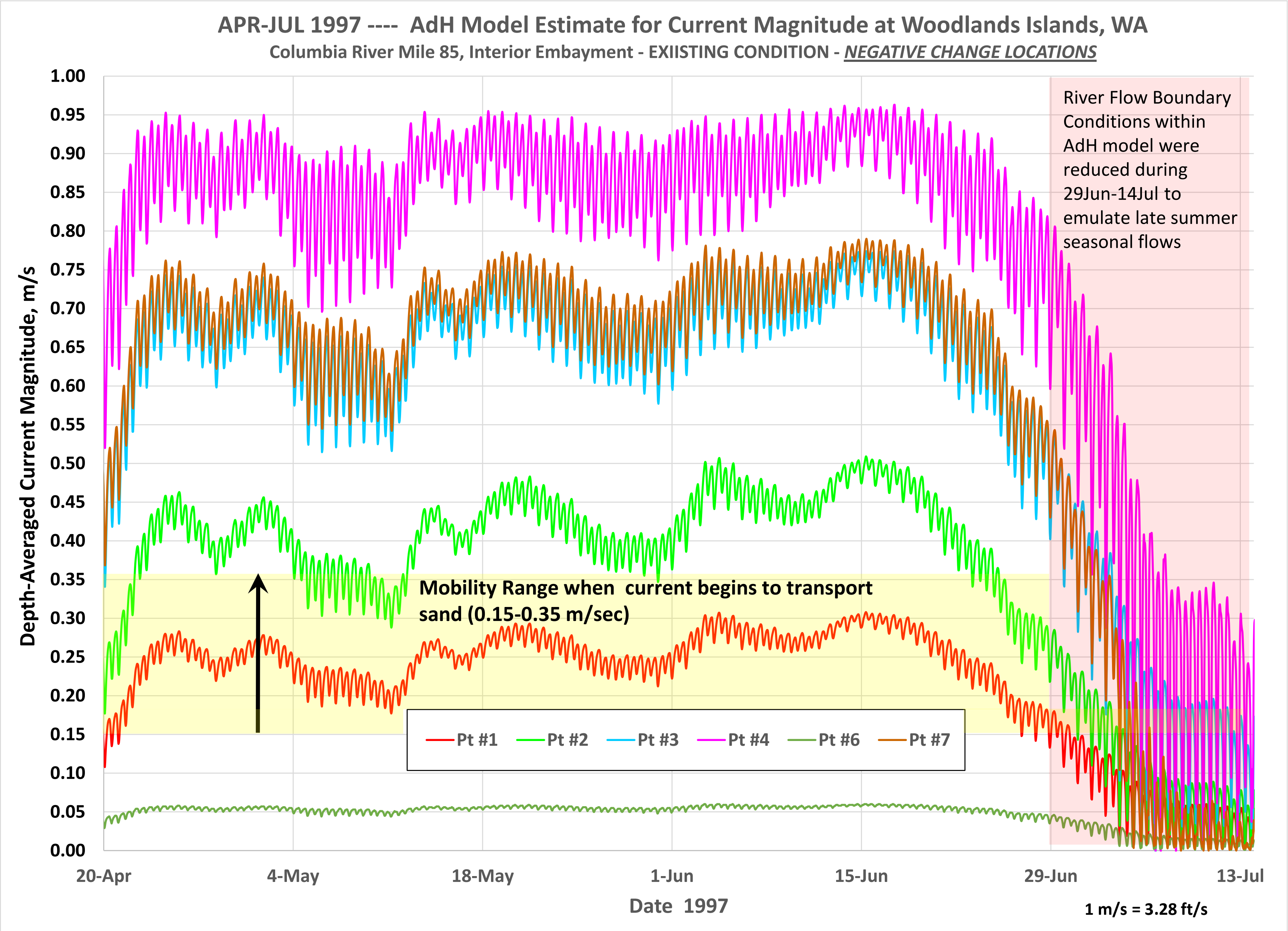


Figure H20. Existing condition time series of depth-averaged current magnitude at 6 different observation points within the Woodland Island project site. Refer to Figure H4b for location of Negative Change (PC) observation points.

<u>WA Shore – East of Island D:</u> Figure H19 shows the comparison of AdH results at Positive Change observation point #9. Top two time series are depth-averaged current magnitude for <u>Positive Change (PC) observation point #9</u>, comparing AdH model results for the existing condition and FWP. PC point #8 is located along the foreshore of the WA riverbank at 5.2 ft NAVD, 310 meters east of the DS project feature. Existing condition currents are low (0.1-0.16 m/sec) at this location as water movement is reduced along the shallows of the WA riverbank. FWP currents at this location are estimated to increase during high river flow periods compared to Existing Condition, with FWP current magnitudes reaching 0.15-0.25 m/sec. Under the FWP, the increase in current magnitude at this location may increase the potential for sediment transport, as the FWP current will be greater than the 0.15 m/sec threshold for sediment transport during periods of high river flow.

The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to increase current magnitude for this location by 0.08 m/sec. At this location, FWP currents increase because the DS project feature reduces the width the Woodland Island embayment and re-directs more flow toward the remaining embayment area and the main tidal channel. During lower river flow conditions (<250 Kcfs), the difference between FWP and Existing Condition currents rapidly diminishes to 0.01 m/sec. ***Implications:*** Although the difference between the FWP and Existing Condition is large on a relative basis, the magnitude of the change is small, and the resulting current magnitude under the FWP remains low. However, the FWP may increase the potential for sediment transport along the foreshore area of the WA riverbank, for areas due east of the FWP. The potential for increased sediment transport, due to the FWP, decreases as one moves further up the river bank foreshore (further away from the FWP features). The existing substrate in the area of PC #9 may experience some terrain lowering (0.1 to 1 ft of bed erosion) due to the FWP. If sediment is mobilized in this area, it would likely be transported downstream, and re-deposit along the WA river bank. If the existing riverbank, in proximity of PC #9, is affected by changes in FWP currents the substrate is expected to equilibrate after minor natural sediment "re-working".

Negative Change (Decrease) in currents at Woodland Islands due to FWP

Figure H20 shows the Existing condition time series of depth-averaged current magnitude at 6 different observation points within the Woodland Island project site. Refer to Figure H4b for location of **<u>Negative Change</u>** (PC) observation points. The terrain at these locations will not be changed by FWP sediment placement, as these areas are not within the FWP foot-print. These points are expected to be affected by an increase is current as a result of FWP. The current magnitude time series were produced by the AdH hydrodynamic model and show how current within different locations of the project site respond to changes in river flow. The locations featured in this plot experienced various degrees of DECREASED current magnitude for the WFP condition as compared to the existing condition. Initiation of transport for sand-sized bottom sediment can range from 0.15 to 0.35 ft/sec, depending on bottom roughness and free-stream turbulence. As river flow falls below 150 Kcfs (shown here for 29 June), currents within the project site begin to fall below the threshold needed to mobilize active transport of sand-sized sediment. Figures H21 to H26 show detailed comparison between Existing Condition and FWP time-series for current magnitude.

<u>Woodland Island D-Embayment:</u> Figure H21 shows the comparison of AdH results at Negative Change observation point #1. Top two time series are depth-averaged current magnitude for <u>Negative Change (PC) observation point #1</u>, comparing AdH model results for the existing condition and FWP. NC point #1 is located at the downstream extent of the embayment at -2.6 ft NAVD, immediately downstream of the DS project feature and east of Woodland Island "D" (Fig H4b). Existing condition currents are moderate (0.2-0.3 m/sec) at this off-channel location, as flow from the Woodland Islands embayment sweeps along a large underwater shoal extending downstream from Woodland Islands. FWP currents at NC #1 are estimated to decrease significantly

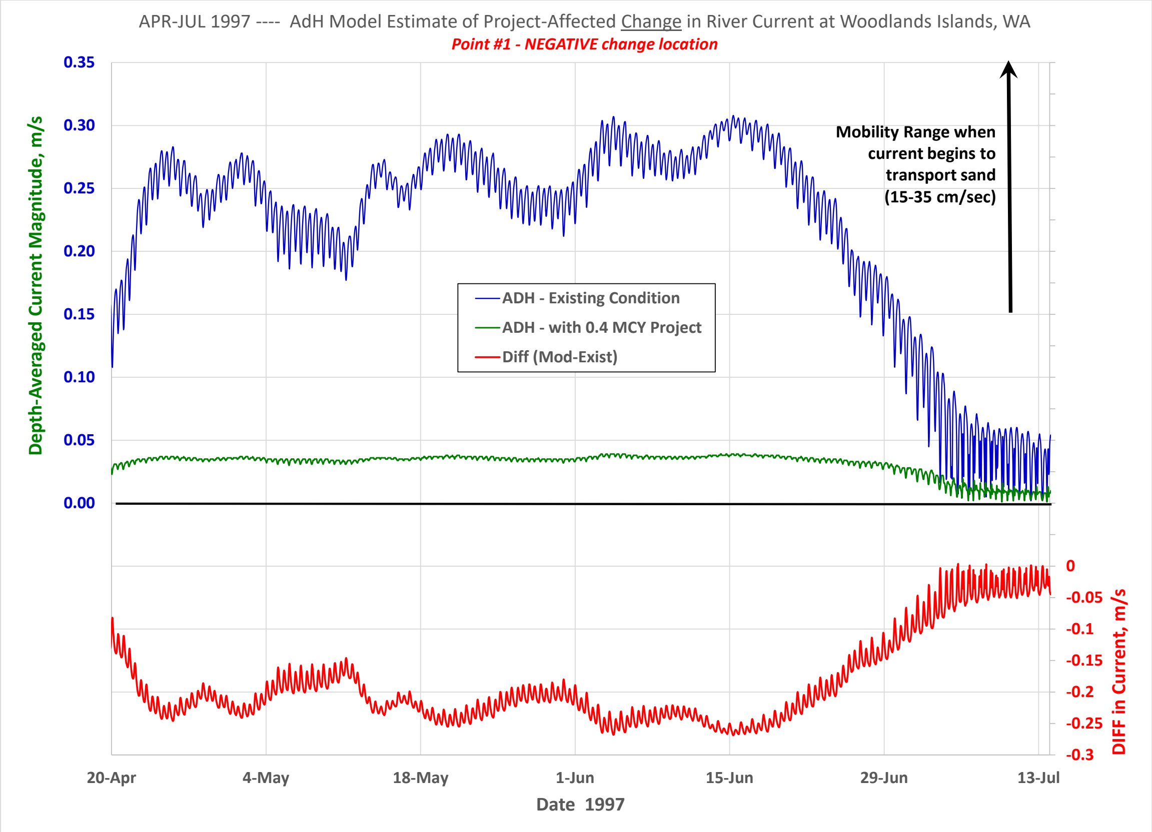


Figure H21. Comparison of AdH results at Negative Change observation point #1.

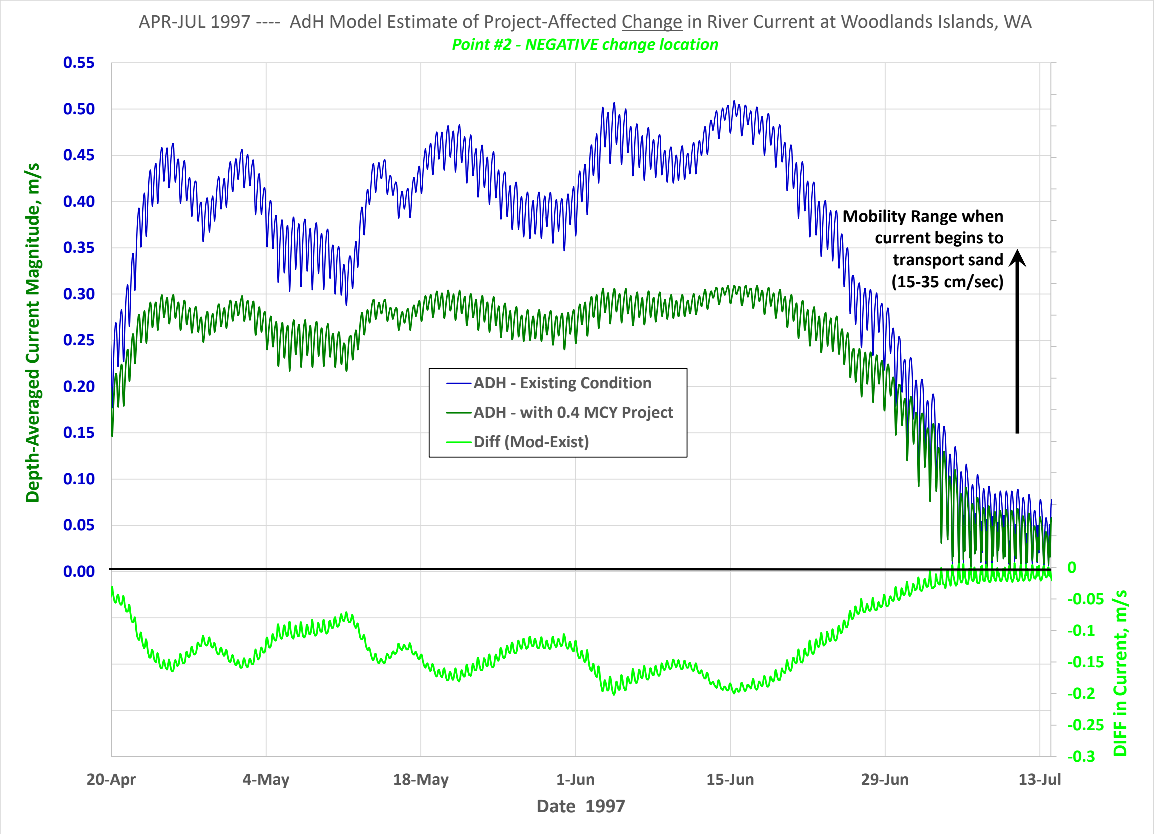


Figure H22. Comparison of AdH results at Negative Change observation point #2.

during high river flow periods compared to Existing Condition, with FWP current magnitudes being reduced to <0.05 m/sec. Under the FWP, the decrease in currents at this location will increase the potential for sediment deposition along the eastern flank of the submerged shoal, as the FWP current will be much less than the 0.15 m/sec threshold for sediment transport during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to decrease current magnitude for this location by 0.25 m/sec. During lower river flow conditions (<250 Kcfs), the difference between FWP vs. Existing Condition currents rapidly diminishes to zero. ***Implications:*** The FWP is expected to increase potential for sediment deposition downstream of the DS project feature, along the eastern flank of the large intertidal shoal extending downstream from Woodland Island "D". Sand-sized sediment may deposit in this area, if sediment load (within the water column) is sufficient for deposition. If sediment deposition does occur for the FWP terrain (in vicinity of NC #1), it is expected to equilibrate as the terrain aggregates and begins to be re-worked by high river flow conditions during the freshet season. This location is at the trailing edge of a long island chain within a rather dynamic area of the Columbia River, making this location (NC #1 and downstream) susceptible to rapid morphological change (erosion). Measures to slow this erosional trend would bring a positive benefit for stabilizing this area of the Woodland Islands; notably Island D, which has been eroding along its riverward and downstream perimeter for several decades. Should sediment accumulate immediately downstream of the DS project feature during several successive years of diminished freshets, the sheltering effect within the sub-embayment between Island D and the DS project feature could be enhanced improving habitat opportunity within the sub-embayment. As accumulated sediment (in vicinity of NC #1) becomes re-mobilized during return of high-flow freshets, the accumulated material would likely be re-mobilized downstream supplanting the sediment deficit along the trailing edge of Island D and reduce the erosional trend affecting that area. If sediment accumulates within vicinity of NC#1 (or immediately down) and persistently remains, it is estimated that a high flow event exceeding 700 kcfs (total flow at RM 85, having an estimated AEP of 0.02) would remobilize the accumulated material.

Woodland Island C-Embayment: Figure H22 shows the comparison of AdH results at Negative Change observation point #2. Top two time series are depth-averaged current magnitude for Negative Change (PC) observation point #2, comparing AdH model results for the existing condition and FWP. NC point #2 is located between the DS and US project features at -3.3 ft NAVD, within the embayment east side of Woodland Island "C" (fFg H4b). Existing condition currents are moderate (0.3-0.5 m/sec), as this area is affected by currents that sweep along the margins of the main tidal channel within the Woodland Island embayment. FWP currents at NC #2 are estimated to decrease during high river flow periods compared to Existing Condition, with FWP current magnitudes being reduced to <0.2 m/sec. Under the FWP, the decrease in currents at this location may increase the potential for sand deposition along the base of the DS project feature, during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to decrease current magnitude for this location by 0.1-0.2 m/sec. During lower river flow conditions (<250 Kcfs), the difference between FWP vs. Existing Condition rapidly diminishes to zero. ***Implications:*** The FWP is expected to increase potential for sediment deposition along the east side base of the DS project feature. Sand-sized sediment may deposit in this area, if sediment load (within the water column) is sufficient for deposition. If sediment deposition does occur for the FWP terrain (in vicinity of NC #2), it is expected to equilibrate as the terrain aggregates and begins to be re-worked by high river flow conditions.

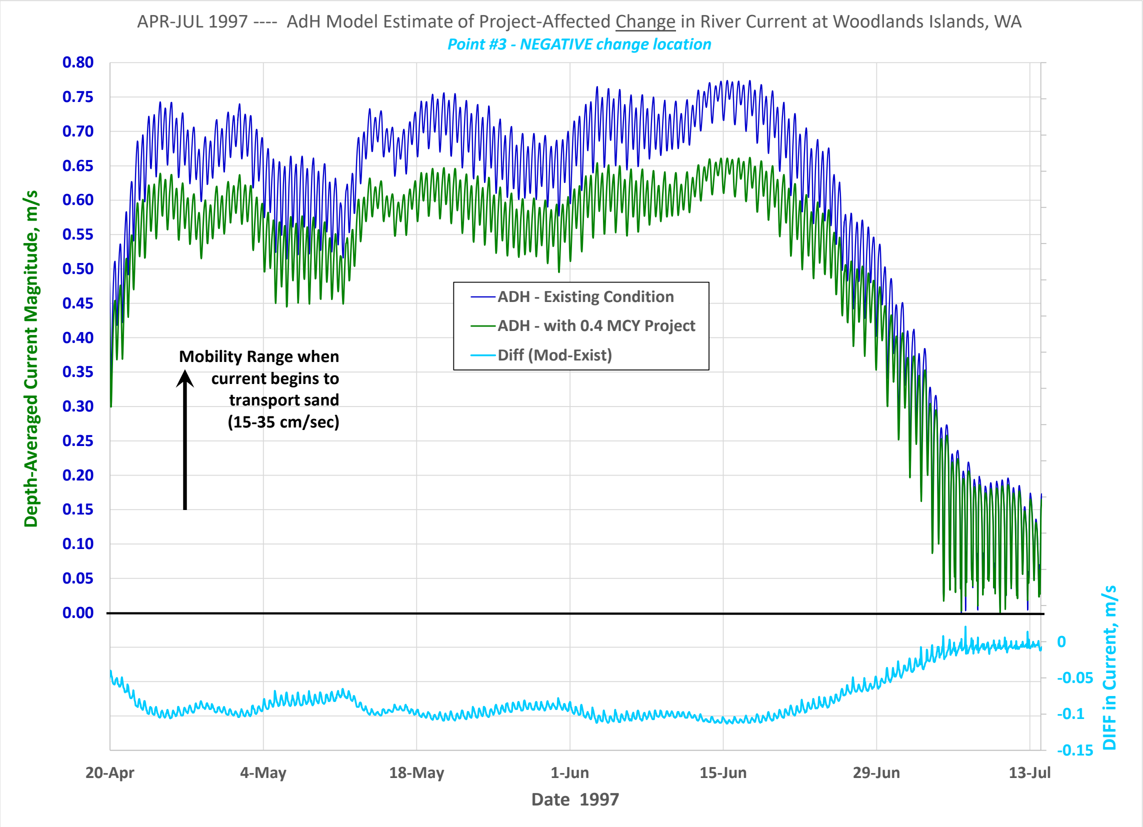


Figure H23. Comparison of AdH results at Negative Change observation point #3.

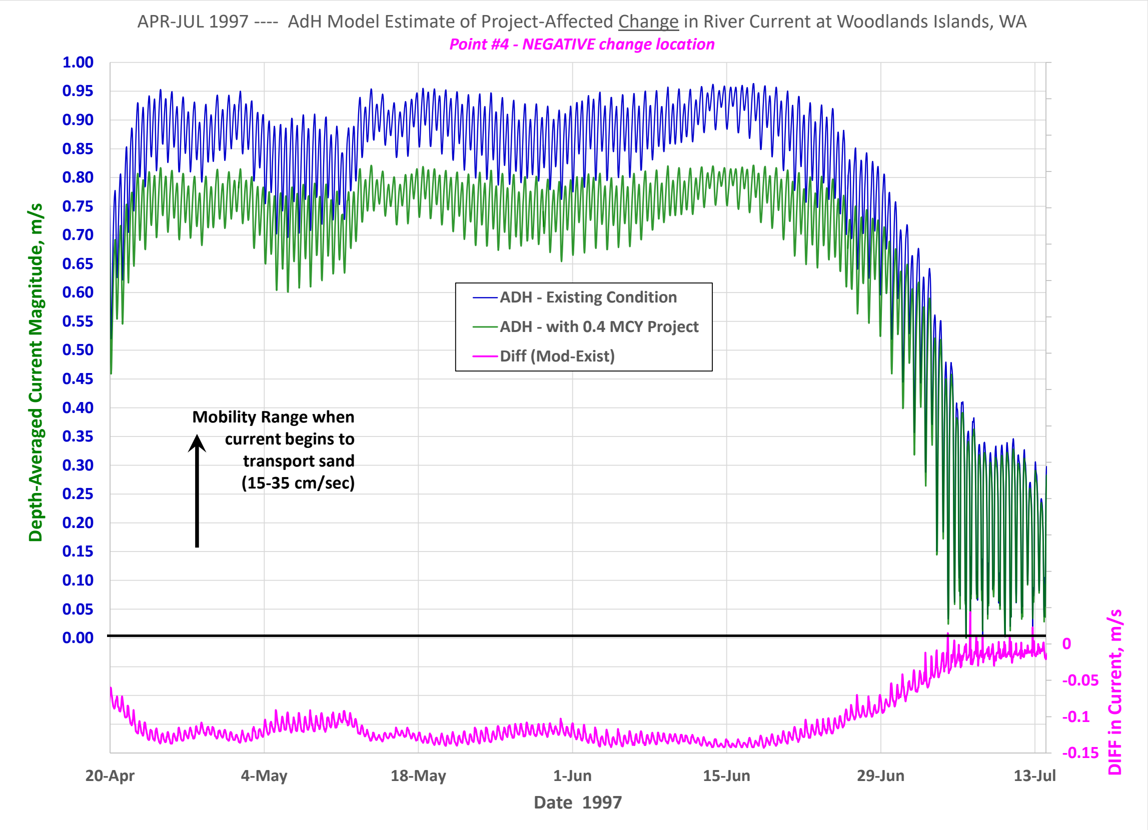


Figure H24. Comparison of AdH results at Negative Change observation point #4.

Woodland Island A&B – Flow-way: Figure H23 shows the comparison of AdH results at Negative Change observation point #3. Top two time series are depth-averaged current magnitude for Negative Change (PC) observation point #3, comparing AdH model results for the existing condition and FWP. NC point #3 is located at the upstream extent of the embayment at -1.6 ft NAVD, between Islands A and B, within the flow-way that provides most of the flow conveyance into the upstream reach of the embayment (Fig H4b). Existing condition currents are moderate to high (0.5-0.77 m/sec) at NC #3, as this location is within a principal flow-way channel for the Woodland Islands embayment. FWP currents at NC #3 are estimated to decrease during high river flow periods compared to Existing Condition, with FWP current magnitudes being reduced to <0.65 m/sec. Under the FWP, the decrease in currents at this location may increase the potential for sediment deposition within the flow-way, during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to decrease current magnitude for this location by 0.1 m/sec. During lower river flow conditions (<250 Kcfs), the difference between FWP vs. Existing Condition rapidly diminishes to zero. ***Implications:*** The FWP may increase potential for sediment deposition within the embayment's upstream flow-way. Sand-sized sediment may deposit in this area, if sediment load (within the water column) is sufficient for deposition. If sediment deposition does occur for the FWP terrain (in vicinity of NC #3), it is expected to equilibrate as the terrain aggregates and begins to be re-worked by high river flow conditions. If deposition is realized within this area of the flow-way under the FWP, flow through this area (into or out of the Embayment) could be reduced as compared to the Existing Condition. The net effect may reduce erosion for adjacent areas of the Woodland Islands A and B.

Woodland Island A & B – Flow-way: Figure H24 shows the comparison of AdH results at Negative Change observation point #4. Top two time series are depth-averaged current magnitude for Negative Change (PC) observation point #4, comparing AdH model results for the existing condition and FWP. NC point #4 is located at the upstream extent of the embayment at 2.6 ft NAVD, between Islands A and B, within the river-side entry point to the low-way that provides most of the flow conveyance into the upstream reach of the embayment (Fig H4b). Existing condition currents are moderate to high (0.7-0.95 m/sec) at NC #4, as this location is within a principal flow-way channel for the Woodland Islands embayment. FWP currents at NC #4 are estimated to decrease during high river flow periods compared to Existing Condition, with FWP current magnitudes being reduced to <0.8 m/sec. Under the FWP, the decrease in currents at this location may increase the potential for sediment deposition within the flow-way, during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to decrease current magnitude for this location by 0.15 m/sec. During lower river flow conditions (<250 Kcfs), the difference between FWP vs. Existing Condition rapidly diminishes to zero. ***Implications:*** The FWP may increase potential for sediment deposition within the embayment's upstream flow-way. Sand-sized sediment may deposit in this area, if sediment load (within the water column) is sufficient for deposition. If sediment deposition does occur for the FWP terrain (in vicinity of NC #4), it is expected to equilibrate as the terrain aggregates and begins to be re-worked by high river flow conditions. If deposition is realized within this area of the flow-way under the FWP, flow through this area (into or out of the Embayment) could be reduced as compared to the Existing Condition. The net effect may reduce erosion for adjacent riverside areas of the Woodland Islands A and B.

Woodland Island D - Cove: Figure H25 shows the comparison of AdH results at Negative Change observation point #6. Top two time series are depth-averaged current magnitude for Negative Change (NC) observation point #6, comparing AdH model results for the existing condition and FWP. NC point #6 is located at the downstream extent of the embayment at 2.0 ft NAVD along the east side of Woodland Island "D" (Fig H4b). Existing condition currents are weak (0.05-0.06 m/sec) at this off-channel location, as is it located within a protected area immediately adjacent to Island "D". FWP currents at NC #6 are estimated to decrease during high river flow periods compared to Existing Condition, with FWP current magnitudes being reduced to <=0.04 m/sec.

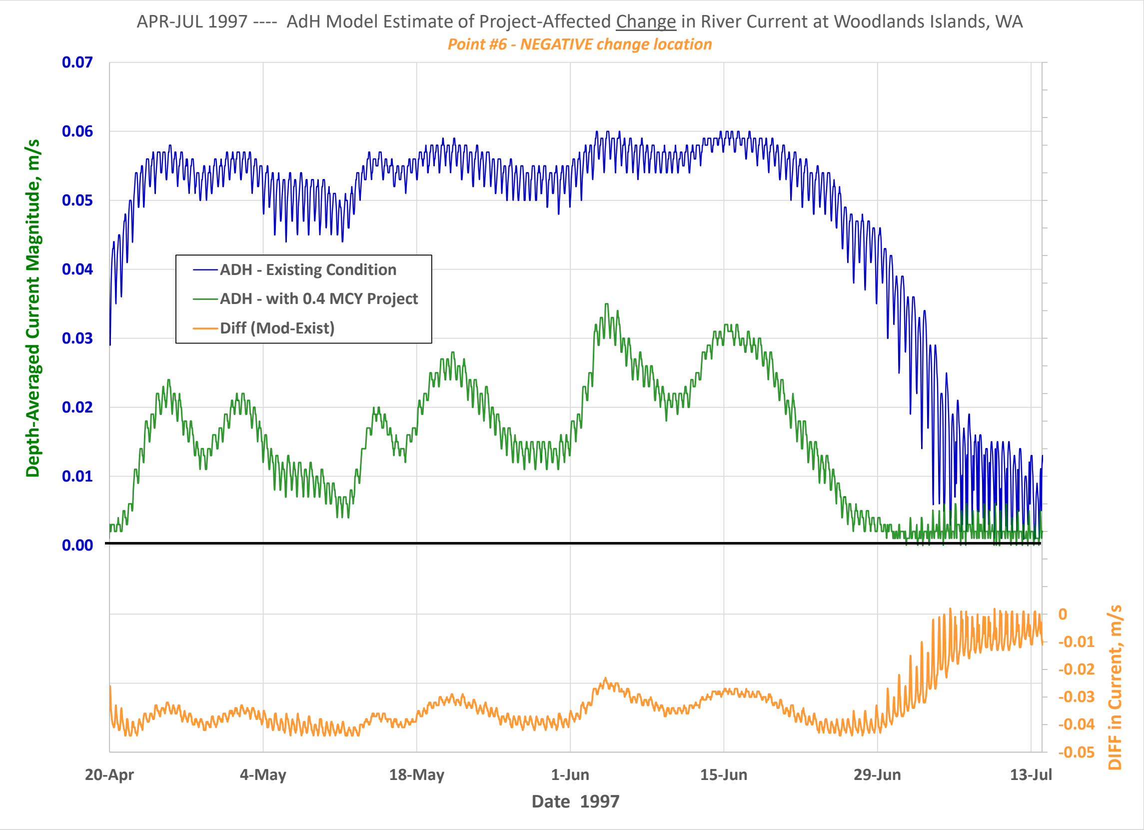


Figure H25. Comparison of AdH results at Negative Change observation point #6.

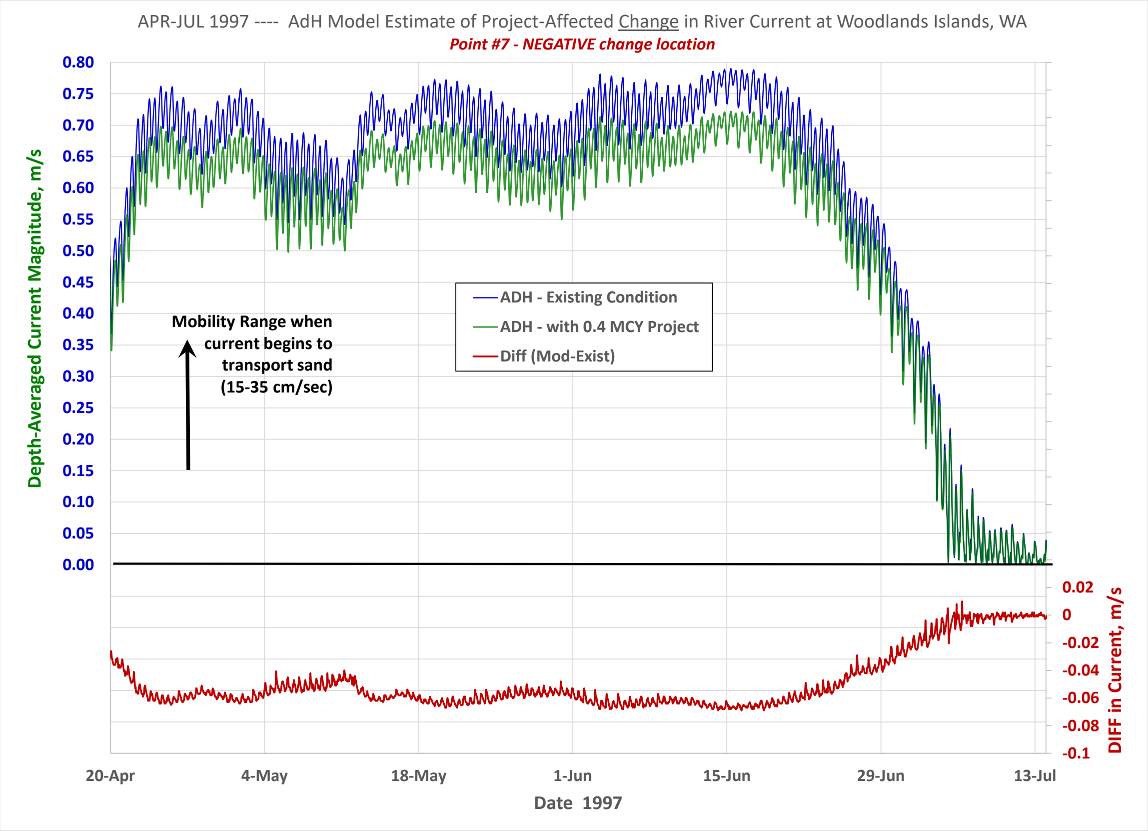


Figure H26. Comparison of AdH results at Negative Change observation point #7.

Under the FWP, the decrease in currents at this location is not expected to affect transport of sand-sized sediment deposition along the eastern flank of the submerged shoal, as both Existing and FWP current are estimated to be much less than the 0.25 m/sec threshold for sand sediment transport. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to decrease current magnitude for this location by 0.04 m/sec. During lower river flow conditions (<250 Kcfs), the difference between FWP vs. Existing Condition rapidly diminishes to -0.05 m/sec. ***Implications:*** The FWP is expected to increase potential for silt and fine-grained sediment deposition downstream of the DS project feature, along the eastern flank of the submerged shoal extending downstream from Island "D". Sediment may deposit in this area for material smaller than sand, if sediment load (within the water column) is sufficient for deposition. If sediment deposition does occur for the FWP terrain (in vicinity of NC #6), it is expected to equilibrate as the terrain aggregates and begins to be re-worked by high river flow conditions.

Woodland Island A & Shore – Flow-way: Figure H26 shows the comparison of AdH results at Negative Change observation point #7. Top two time series are depth-averaged current magnitude for Negative Change (PC) observation point #7, comparing AdH model results for the existing condition and FWP. NC point #7 is located at the upstream extent of the embayment at 5.5 ft NAVD, between Island A and shore, within upstream-most flow-way of the Woodland Islands embayment (Fig H4b). Existing condition currents are moderate to high (0.6-0.75 m/sec) at NC #7, as this location lies within a flow-way channel for the Woodland Islands embayment. FWP currents at NC #7 are estimated to decrease during high river flow periods compared to Existing Condition, with FWP current magnitudes being reduced to <0.70 m/sec. Under the FWP, the decrease in currents at this location may increase the potential for sediment deposition within the flow-way, during periods of high river flow. The bottom time-series is the difference in current magnitude (FWP-Existing), illustrating how the FWP is expected to decrease current magnitude for this location by 0.08 m/sec. During lower river flow conditions (<250 Kcfs), the difference between FWP vs. Existing Condition diminishes to zero. ***Implications:*** The FWP may increase potential for sediment deposition within the embayment's upstream flow-way. Sand-sized sediment may deposit in this area, if sediment load (within the water column) is sufficient for deposition. If sediment deposition does occur for the FWP terrain (in vicinity of NC #7), it is expected to equilibrate as the terrain aggregates and begins to be re-worked by high river flow conditions. If deposition is realized within this area of the flow-way under the FWP, flow through this area (into or out of the Embayment) could be reduced as compared to the Existing Condition. The net effect may reduce erosion for adjacent areas of the Woodland Islands A and Shore areas.

Summary of Results

The AdH model was used to simulate river hydraulics for both the Existing Condition terrain and the Future With Project terrain, during the time period of 1 APR – 14 JUL 1997. River hydraulics within the off-channel embayment east of Woodland Islands can exhibit spatially variable currents and circulation during all levels of river flow. There are areas that have "quiet" water (low velocity), such as the cove adjacent to Island D, and there are areas where river current can be moderately strong, such as the flow-way between Island A and B and the tidal channel within the embayment. The FWP had the effect of both increasing current magnitude and decreasing current magnitude at several different localized zone within the Woodland Islands project area. Refer to Tables H1 and H2 for summary compilation of results.

For areas adjacent to Woodland Islands (B and C) where the FWP ***increased*** current magnitude, there is low likelihood for increased sand sediment transport or erosion. Although the relative change in current magnitude at these locations is 50-150% (due to FWP), the FWP currents remain less than the threshold for sand transport. However, some fine grained material may be transported out from these localized areas under the FWP condition. At areas within the Woodland Island embayment tidal channel, there were meaningful changes in current magnitude (due to FWP) that will likely increase sediment transport within the channel with the potential to erode the channel bed by 0.5 to 2 ft at localized areas. The FWP has the potential to increase river currents along localized areas of the WA riverbank foreshore, across the embayment (east) from Woodland Islands. Attendant increase in sand sediment transport potential could lower the foreshore by 0.25 to 1 ft in localized areas. All of these effects on currents rapidly diminish to zero as river flow at RM 85 falls below 250 Kcfs.

For localized areas adjacent to Woodland Islands (C and D) where the FWP ***decreased*** current magnitude, there is meaningful reduction in current magnitude that has a high likelihood for motivating increased sand sediment deposition within affected areas (see figure H4b). At flow-way areas between Woodland Islands A and B (and between Island A and shore) there were meaningful changes in current magnitude (due to FWP) that will likely increase sediment deposition within localized areas of these flow-ways. These terrain changes (affected by FWP) could act to reduce conveyance of flow into/out of the Woodland embayment. All of these effects on currents rapidly diminish to zero as river flow at RM 85 falls below 250 Kcfs. The FWP did not increase the water surface elevation within the project area, for either high river flow (total DA-Q at RM 85 > 600 Kcfs) or low river flow periods (DA-Q < 150Kcfs).

As the newly formed FWP terrain (both DS and US features) equilibrates with the longterm forcing environment affecting all of the Woodland Islands, material that is transported off of the FWP features by currents will be deposited onto adjacent areas within the embayment and likely augment the terrain of existing islands. Due to the sheltering effect of the embayment (protection from energetic river currents), the proportion of placed sand that is expected to be eroded off of the FWP terrain is expected to be small (< 20% of initial placement) during the 50 years following project implementation. Some of this eroded material maybe be carried further upstream into the embayment during late summer when flood-tide currents are strong, and some eroded material will be carried downstream and leave the protective confines of embayment during high flow freshets. The longterm fate for sediment eroded from the FWP terrain would be no different than for material eroded from the existing Woodland Islands. Ultimately, material eroded from Woodland Islands would be transported downstream onto a large sand flat that currently extends 3,000 ft downstream from Island D (Figure H2a and Figure H4a). Material deposited onto this feature is eventually re-transported toward the thalweg of the LCR and enters the FNC. Although some of this sediment will be dredged as part of the LCR FNC O&M activity, it is necessary to provide (re-introduce) sediment to the LCR sediment budget to sustain the river's morphology, which is essential for maintaining a stable thalweg (and FNC channel). In the end, the FWP terrain is not expected to adversely affect O&M activities for the LCR FNC and may likely be beneficial for sustaining the sediment budget of Woodland Islands and the LCR.

Table H1. Summary of effects at areas that are expected to experience INCREASED current magnitude (positive change) in response to the FWP.

POSITIVE Change	**Project**	**Bed EL**	**Current Magnitude,** m/sec			**General impacts Affeccting Sediment Transport**
Observation Point	**Location**	ft, NAVD	**Existing**	**FWP**	**Difference**	**for FWP vs. Existing Condition when River Flow > 250 Kcfs**
1	Island B - east side intertidal	7.2	0.07	0.25 - 0.30	0.15 - 0.20	May locally increase transport potential, local bed eosion of 0.25 to 1 ft
1a	Island C - east side cove	3.3	0.02	0.04 - 0.06	0.02 - 0.04	May locally increase fine-grain transport potential within cove
2	Island C - east side intertidal	5.9	0.03	0.10 - 0.13	0.02 - 0.08	May locally increase fine-grain transport potential within cove
3	Embayment - tidal channel	-1.3	0.2 - 0.5	0.5 - 0.7	0.2	Likely to Increase transport potential within tidal channel, local bed eosion of 0.5 to 2 ft
4	Embayment - tidal channel	-3.6	0.2 - 0.4	0.4 - 0.6	0.2	Likely to Increase transport potential within tidal channel, local bed eosion of 0.5 to 2 ft
5	WA shore - east of Island B	5.6	0.15 - 0.2	0.2 - 0.3	0.1	May locally increase transport potential, local bed eosion of 0.25 to 1 ft
6	WA shore - east of Island C	6.5	0.1 - 0.15	0.15 - 0.23	0.08	May locally increase transport potential, local bed eosion of 0.25 to 1 ft
7	WA shore - east of Island C	4.6	0.1 -0.18	0.18 - 0.23	0.12	Likely to increase local transport potential, local bed eosion of 0.25 to 1 ft
8	WA shore - east of Island D	3.3	0.1 - 0.15	0.15 - 0.27	0.12	Likely to increase local transport potential, local bed eosion of 0.25 to 1 ft
9	WA shore - east of Island D	5.2	0.1 -0.16	0.15 - 0.25	0.08	May locally increase transport potential, local bed eosion of 0.25 to 1 ft

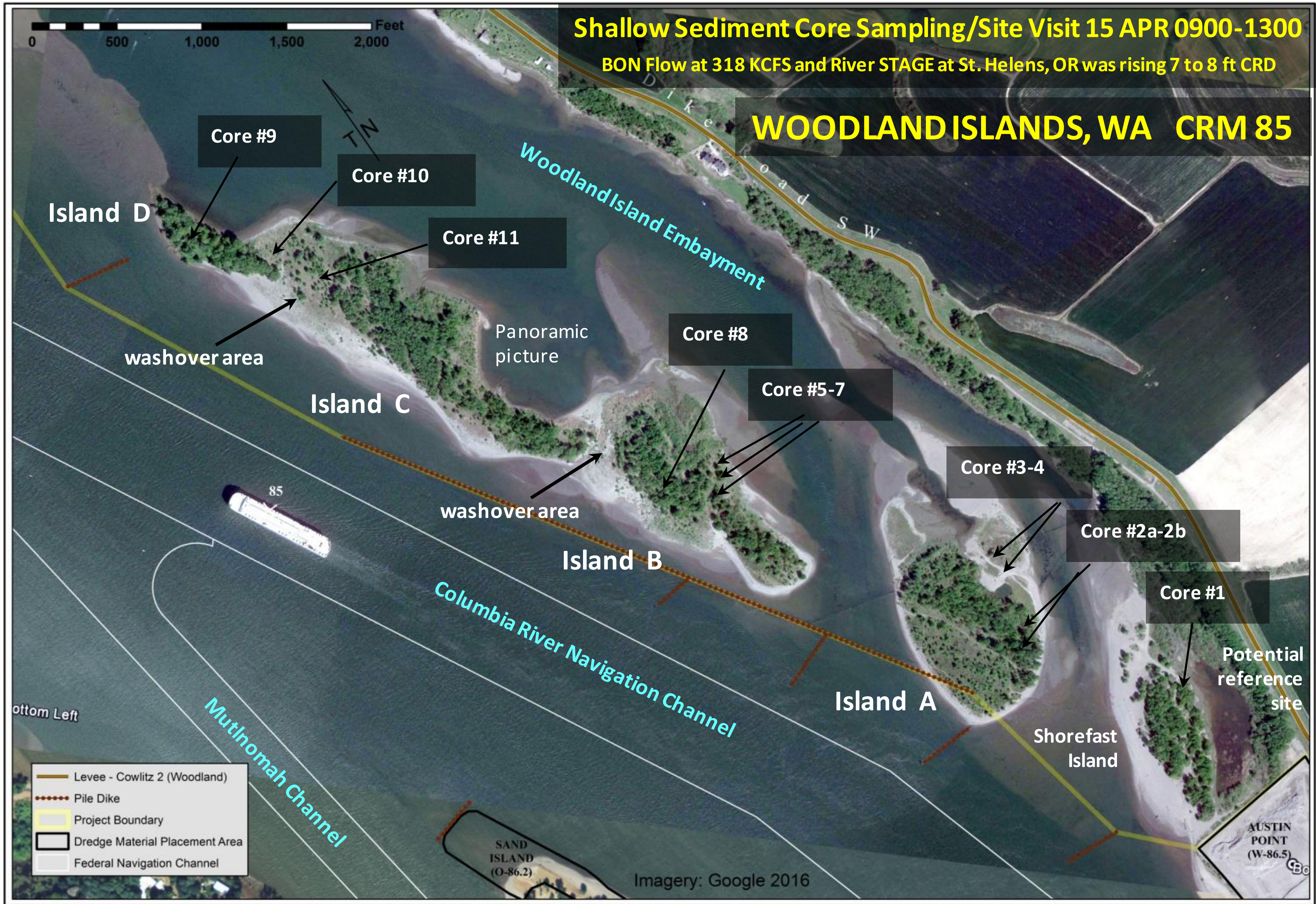
Table H2. Summary of effects at areas that are expected to experience DECREASED current magnitude (negative change) in response to the FWP.

NEGATIVE Change	**Project**	**Bed EL**	**Current Magnitude,** m/sec			**General impacts Affeccting Sediment Transport**
Observation Point	**Location**	ft, NAVD	**Existing**	**FWP**	**Difference**	**for FWP vs. Existing Condition when River Flow > 250 Kcfs**
1	Island D - embayment	-2.6	0.2 - 0.3	0.04	- (0.15 - 0.25)	Likley to locally increase deposiiton potential downstream of DS project feature
2	Island C - embayment	-3.3	0.3 - 0.5	0.25 - 0.3	-(0.1 - 0.2)	Likley to locally increase deposiiton potential downstream of US project feature
3	Island A & B - flow-way	-1.6	0.5 - 0.77	0.6	-0.15	Likely increase depostion with flow-way between Island A &B
4	Island A & B - flow-way	2.6	0.7 - 0.95	0.6- 0.8	-0.15	Likely increase depostion with flow-way between Island A &B
6	Island D - cove	2	0.05- 0.06	0.01 - 0.03	-0.04	May locally increase fine-grain transport potential within cove east of Island D
7	Island A & shore - flow-way	5.5	0.6 - 0.75	0.55 - 0.7	-0.07	May increase depostion with flow-way between Island A &.shore

Shallow Sediment Core Sampling/Site Visit 15 APR 0900-1300

BON Flow at 318 KCFS and River STAGE at St. Helens, OR was rising 7 to 8 ft CRD

WOODLAND ISLANDS, WA CRM 85



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Portland, OR

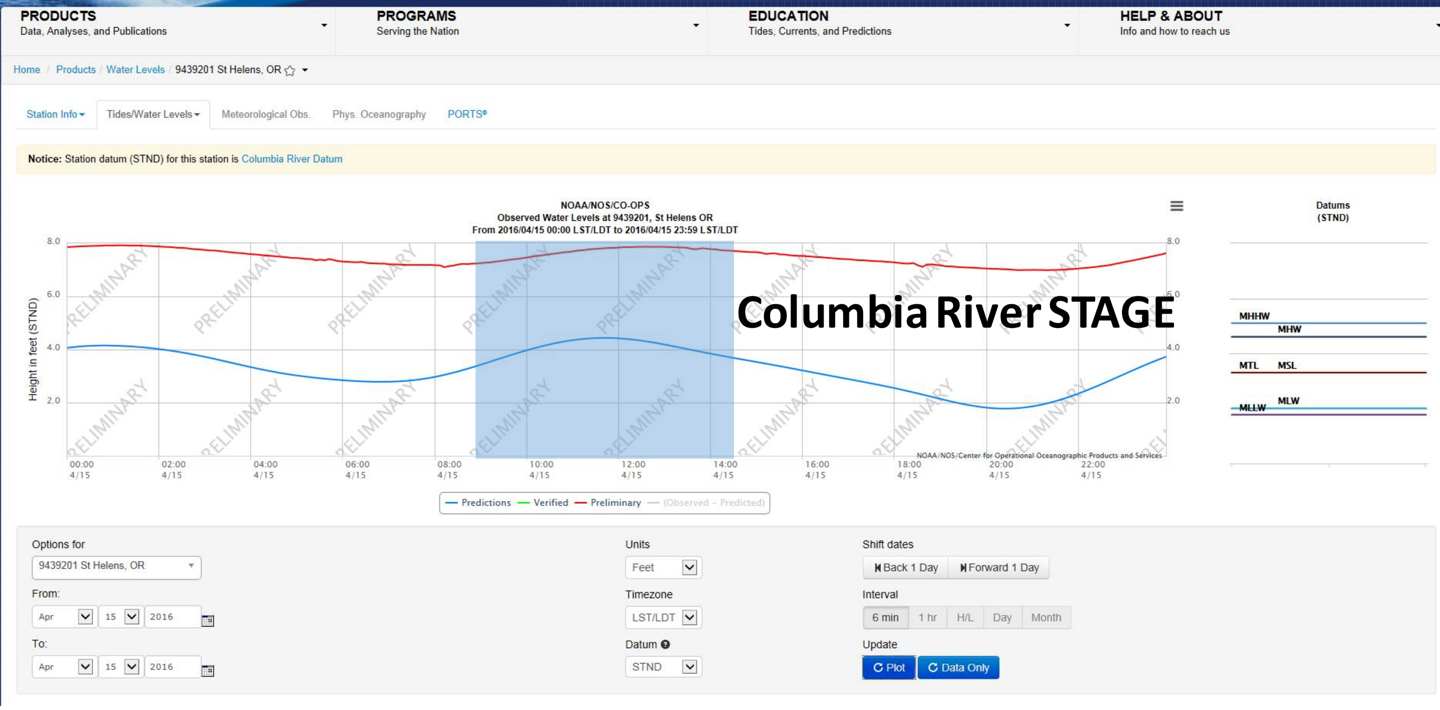
DESIGNED BY:		DATE: 4/14/2016	
DRAWN BY: G2ECCDCS	CHECKED BY:	SOLICITATION NO.:	
SUBMITTED BY:		CONTRACT NO.:	
PLOT SCALE: 1" = 400'	PLOT DATE: 4/14/2016	DRAWING NUMBER:	
SIZE: ANSI D	FILE NAME: Field Map		

Existing Conditions - Site RM85

Columbia City Area - River Mile 84-86

SHEET IDENTIFICATION

SHEET OF



Notice: Station datum (STND) for this station is Columbia River Datum

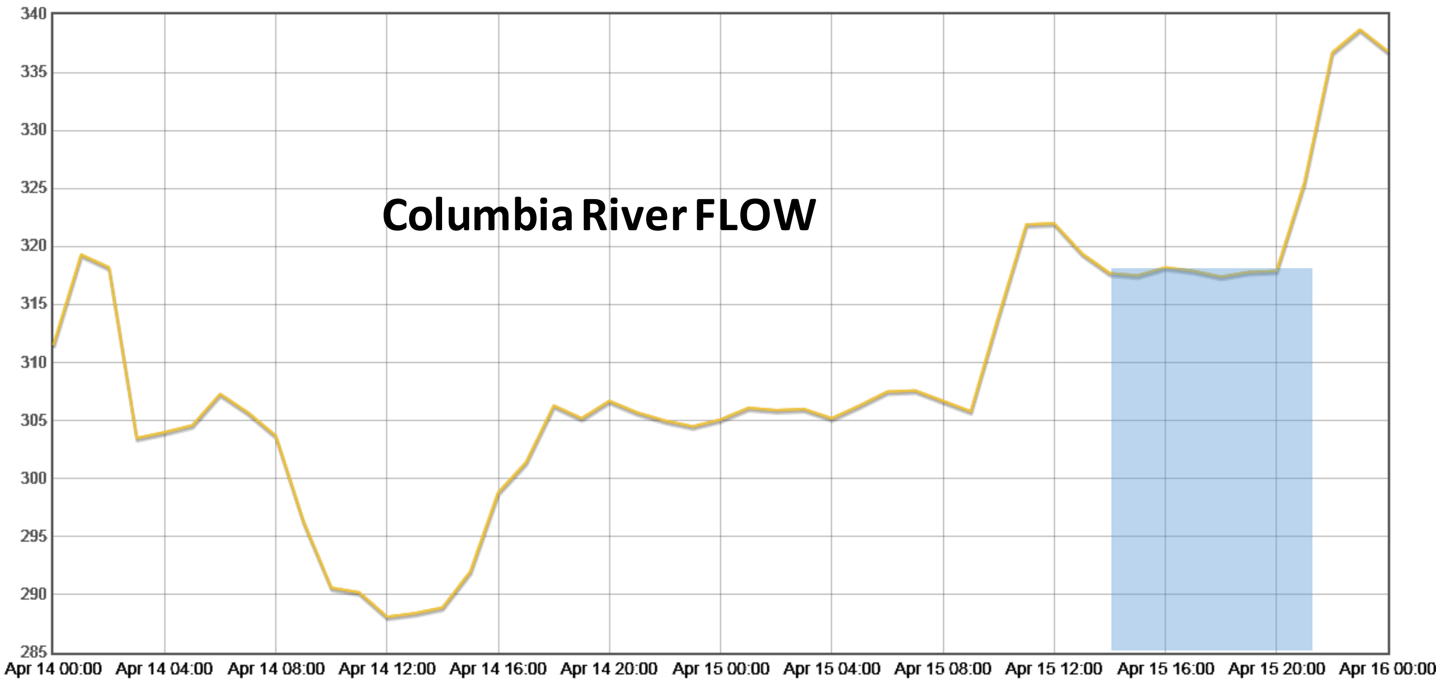
NOAA/NOS/CO-OPS
Observed Water Levels at 9439201, St Helens OR
From 2016/04/15 00:00 LST/LDT to 2016/04/15 23:59 LST/LDT

Columbia River STAGE

Options for: 9439201 St Helens, OR
From: Apr 15 2016
To: Apr 15 2016
Units: Feet
Timezone: LST/LDT
Datum: STND
Shift dates
Interval: 6 min
Update

During 0900-1400 local, 15 APR16, CR FLOW (BON) was 318 KCFS and River STAGE at St. Helens, OR was 8 ft CRD (12.1 NAVD)

2-year flow at BON = 363 Kcfs
2–year stage at St. Helens = 12.9 ft CRD (17.04 ft NAVD)



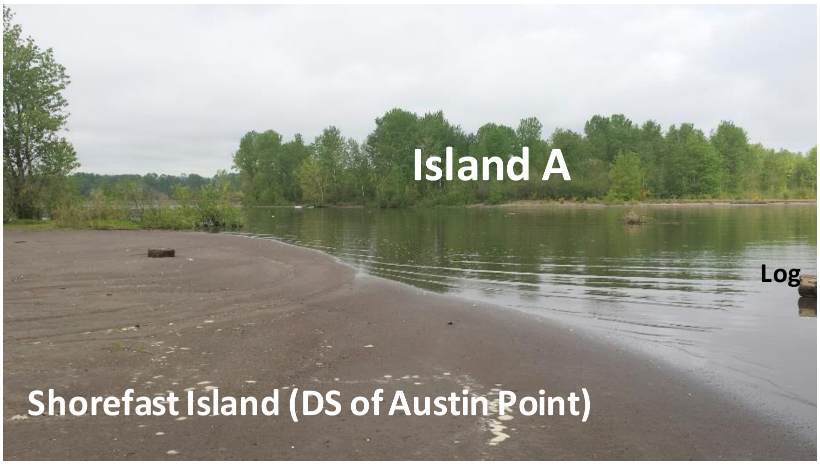
Columbia River FLOW

Woodland Islands

Shorefast Island at Austin Point

Potential reference site for emulating emergent marsh and wetlands connected to Columbia River, created using dredged material placement.

Shorefast Island (just DS of Austin Point)



Core #1 taken 100 ft from slough/swamp area adjacent to "shorefast island". Top 12 inches of core was silty-organic material. Below 12 inches, sand become more predominate, with grey sand at 16-18 inches below surface.

Core #2a taken on "Island A", located in woodland. Top 2 inches of core was sandy-loam material; composed of vegetation organics mixed with fine sand (likely transported overland during high water events). Below 2 inches from surface, loamy material transitions to brown-sand, and becomes sand-dominated at 5 inches. By 12 inches below surface; material is grey coarse sand (dredged material).

Core #2b at "Island A", located in a woodland topographic depression. Top 12 inches of core was fine-grained material (silt) with loam and some sand. Below 18 inches, silty material transitions to brown-sand. At 28 inches below surface; grey coarse sand is abruptly encountered (dredged material).

View to North

Rising river stage (7 to 8 ft CRD) was producing inbound flow to island interior.


Core #3 – Island A

Core #3 taken on "Island A", near tidal slough. Top 1 inch of core was fines-sandy material mix. Below first inch, material becomes progressively more brown sand-based. At 24 inches below surface; material is grey coarse sand (dredged material).

Core #4 taken on "Island A", on "button-topography" near Big Cottonwood tree. Top 6 inches of core was brown loose river overwash sand. Below 6 inches, material becomes progressively more grey coarse sand (dredged material).


Core #3 – Island A


Core #4 – Island A

Core #5 – Island B

Core #5 taken on "Island B", on east side near Legacy Bay. Top 18 inches of core is silty fine-grained material with some sand. After 18 inches, material transitions to mostly sand and water table is encountered.

Core #6 – Island B

Core #6 taken on "Island B", on east side on ledge inshore from Legacy Bay. Top 6 inches of core is silty fined-grained material mixed with some fine sand. After 6 inches material transitions to brown sand. After 12 inches from surface, material abruptly changes to gray course sand (dredged material) and water table is encountered.

Core #7 – Island B

Core #7 taken on "Island B", inshore of core #6. Top 6 inches of core is silty fined-grained material. Material becomes mixed with fine brown sand at 6-16 inches. After 16 inches from surface, material changes to gray course sand (dredged material).

Woodland in center of Island B

Core #8

Core #8 – Island B

Core #8 – Island B

Woodland in center of Island B

Core #8 taken on "Island B", at woodland in center of island. Top 3 inches is silt, transitioning to silty sand by 6 inches. After 12 inches, core becomes brown sand, transitioning to gray sand at 12 inches. After 16 inches from surface, material changes to gray fine sand sand (dredged material); at 24 inches course gray sand and water table

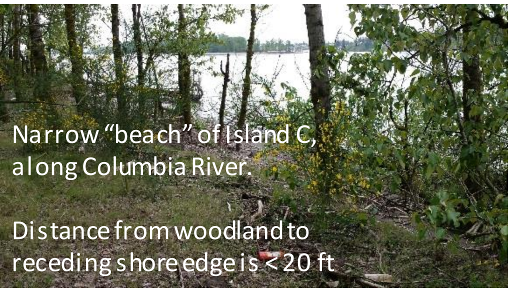
Transiting from Island B to Island C along high river stage over-wash area between islands

photos progress from South to North

Over-wash area between Island B and C – View to WEST toward Columbia River

1 inch Layer of recent Fines Deposition at overwash area – During last high water event (between island B and C)

Over-wash area between Island B and C – View from Island C to SOUTH toward Island B



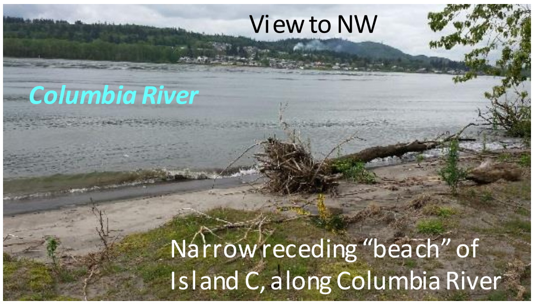
Narrow "beach" of Island C, along Columbia River.

Distance from woodland to receding shore edge is < 20 ft

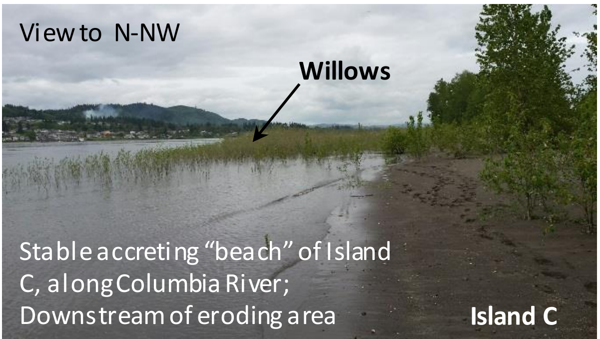
View to South with Sauvie Island in background

Recent scarping/erosion of Island C shoreface along Columbia River; receding shore edge
View to SOUTH

Rack-line on River side of Island C

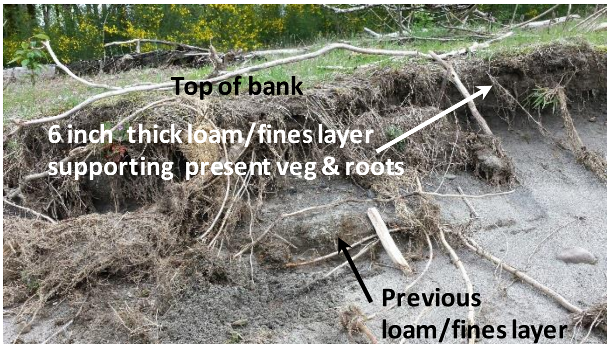


Narrow receding "beach" of Island C, along Columbia River



Stable accreting "beach" of Island C, along Columbia River; Downstream of eroding area

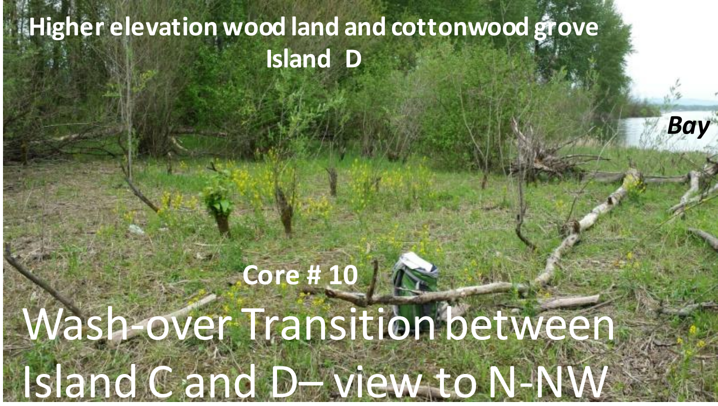
Active erosion of Island C, along Columbia River



Upland grove of
Cottonwoods
At interior of
Island D

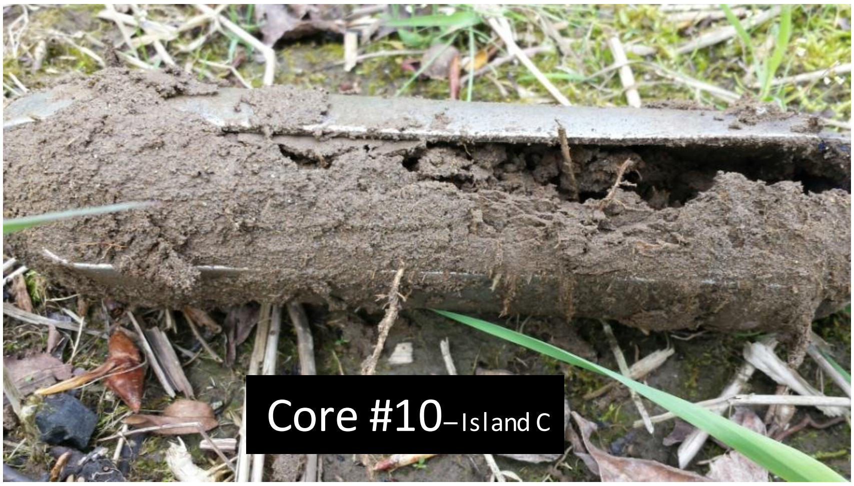
Core #9 taken on “Island D”, at established woodland in center of island. Topography seemed higher than all other locations visited. Grove of cottonwood trees > 40 years old. Top 3 inches is loamy organic material, transitioning to fine light color sand by after 3 inches. Light fine sand for 3-18 inches from top of core. After 18 inches, core abruptly becomes firm brown colored clayey-silt and remains as such > 24 inches. (bottom photo)

Wash-over Transition between Island C and D – view to SE



Wash-over Transition between Island C and D– view to N-NW

Core #10 taken on backside of washover area separating "Island D" and "Island C", near Legacy Bay. Top 4 inches is fines mixed with sand. At 6 inches from surface, transition predominant sand (some fines). At 16 inches, course sand becomes dominant. Water table encountered at 18 inches.



Core #10–Island C

Core #11–Washover zone for Island C and D

Core #11 taken on at transition (overwash) area between "Island C" and "Island D". Top 4 inches is fines mixed with sand. Below 4 inches, brown sand extends to 13 inches from surface. Below 13 inches, course gray sand becomes dominant.

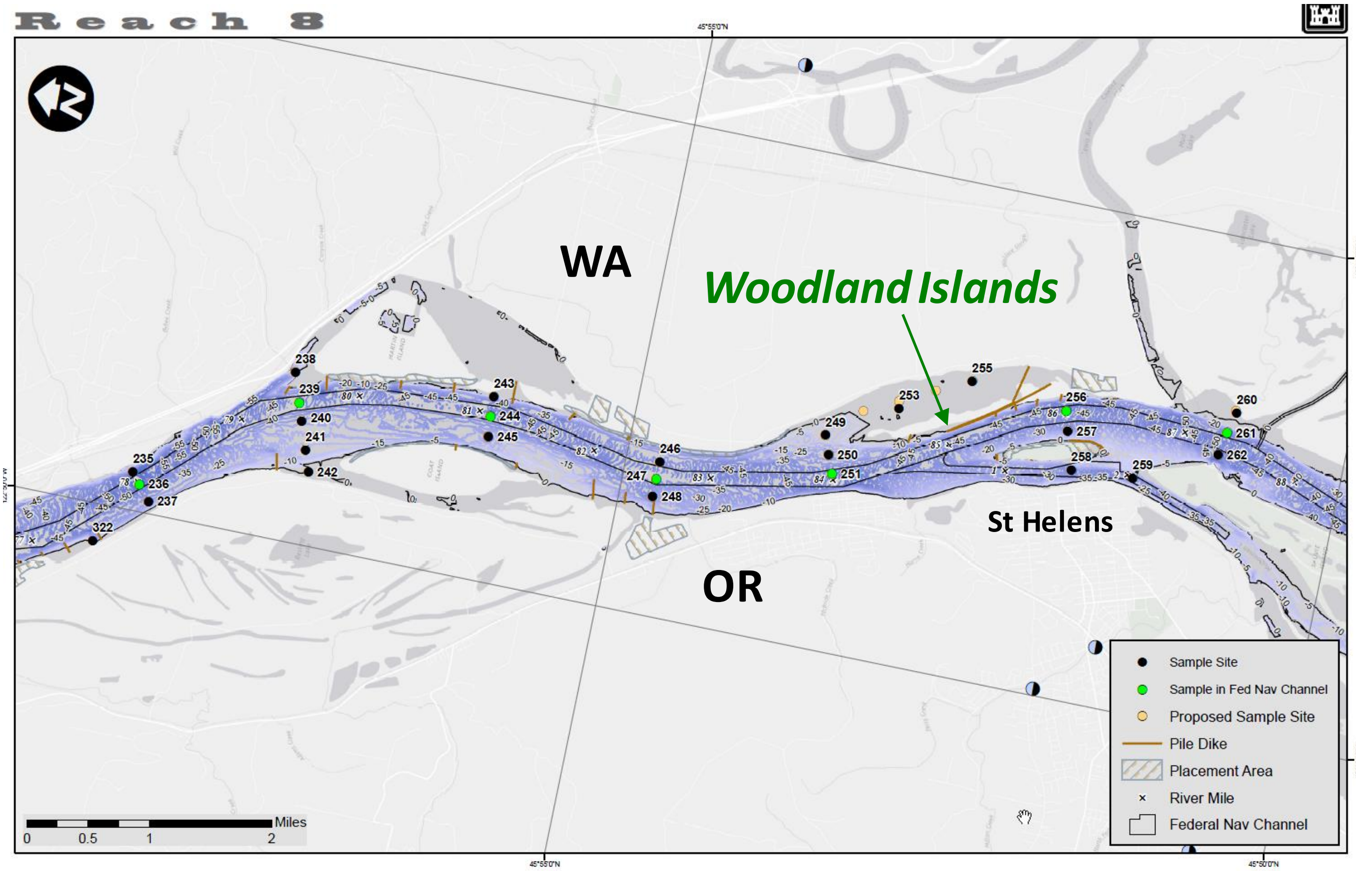
Panoramic View to NW to SW

View to EAST
Opposite from Panoramic

WOODLAND ISLANDS, WA - CRM 85, In-River Sediment Sampling

<u>**Sediment Samples related to Project Collected on 23 MAR 2016**</u>

249 - Woodland Island embayment – Low Flow / protected area
250 - Riverside of Woodland Islands – Moderate Flow Columbia River
251 – FNC – High Flow Columbia River
253 - Woodland Island embayment – Low Flow / protected area
255 - Woodland Island embayment – Moderate Flow / embayment channel
256 - FNC near area for dredged material source – High Flow Columbia River
257 - Near area for dredged material source – High Flow Columbia River



ALS Group USA, Corp.
dba ALS Environmental
Analytical Report

Client: NewFields Environmental
Project: LCR RSM
Sample Matrix: Soil

Service Request: K1602981
Date Collected: 3/23/2016
Date Received: 3/24/2016
Date Analyzed: 4/14/2016

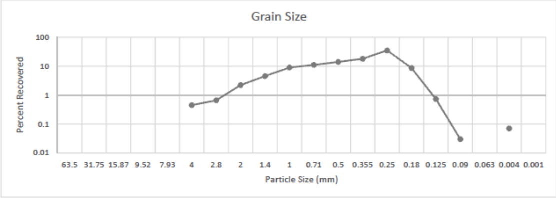
Particle Size Determination
ASTM D422M

Sample Name: CR 251
Lab Code: K1602981-022

Sand Fraction: Weight (Grams)	68.6053
Sand Fraction: Weight Recovered (Grams)	68.3770
Sand Fraction: Percent Recovery	99.67

Weight as received (Grams)	86.4148
Percent Solids	75.9
Weight Oven-Dried (Grams)	65.5888

Description	Sieve Size	Sieve Number	Dry Weight (Grams)	Percent of Total Weight Recovered
Cobbles (g)	63.5 mm	2 1/2"	0.0000	0.00
Pebbles (g)	31.75 mm	1 1/4 "	0.0000	0.00
Pebbles (g)	15.87 mm	5/8"	0.0000	0.00
Pebbles (g)	9.525 mm	3/8"	0.0000	0.00
Pebbles (g)	7.9375 mm	5/16"	0.0000	0.00
Pebbles 4.00 mm (g)	4.00 mm	5	0.2959	0.45
Pebbles 2.80 mm (g)	2.80 mm	7	0.4298	0.66
Pebbles 2.00 mm (g)	2.00 mm	10	1.4539	2.22
Sand 1.40 mm (g)	1.40 mm	14	2.9803	4.54
Sand 1.00 mm (g)	1.00 mm	18	5.8627	8.94
Sand 0.710 mm (g)	0.710 mm	25	7.2449	11.05
Sand 0.500 mm (g)	0.500 mm	35	9.2090	14.04
Sand 0.355 mm (g)	0.355 mm	45	11.8283	18.03
Sand 0.250 mm (g)	0.250 mm	60	22.9050	34.92
Sand 0.180 mm (g)	0.180 mm	80	5.6636	8.64
Sand 0.125 mm (g)	0.125 mm	120	0.4819	0.73
Sand 0.090 mm (g)	0.090 mm	170	0.0183	0.03
Sand 0.063 mm (g)	0.063 mm	230	0.0023	0.00
Silt	0.004 mm		0.0450	0.07
Clay	0.001 mm		0.0000	0.00
		Total	68.4209	104.32



ALS Group USA, Corp.
dba ALS Environmental
Analytical Report

Client: NewFields Environmental
Project: LCR RSM
Sample Matrix: Soil

Service Request: K1602981
Date Collected: 3/23/2016
Date Received: 3/24/2016
Date Analyzed: 4/14/2016

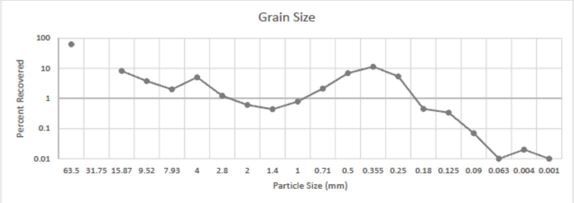
Particle Size Determination
ASTM D422M

Sample Name: CR 250
Lab Code: K1602981-023

Sand Fraction: Weight (Grams)	457.6200
Sand Fraction: Weight Recovered (Grams)	454.4000
Sand Fraction: Percent Recovery	99.30

Weight as received (Grams)	515.68
Percent Solids	79.0
Weight Oven-Dried (Grams)	407.3872

Description	Sieve Size	Sieve Number	Dry Weight (Grams)	Percent of Total Weight Recovered
Cobbles (g)	63.5 mm	2 1/2"	255.7200	62.77
Pebbles (g)	31.75 mm	1 1/4 "	0.0000	0.00
Pebbles (g)	15.87 mm	5/8"	33.3800	8.19
Pebbles (g)	9.525 mm	3/8"	15.3500	3.77
Pebbles (g)	7.9375 mm	5/16"	8.1900	2.01
Pebbles 4.00 mm (g)	4.00 mm	5	20.5900	5.05
Pebbles 2.80 mm (g)	2.80 mm	7	5.0100	1.23
Pebbles 2.00 mm (g)	2.00 mm	10	2.4900	0.61
Sand 1.40 mm (g)	1.40 mm	14	1.8100	0.44
Sand 1.00 mm (g)	1.00 mm	18	3.2100	0.79
Sand 0.710 mm (g)	0.710 mm	25	8.6800	2.13
Sand 0.500 mm (g)	0.500 mm	35	28.2400	6.93
Sand 0.355 mm (g)	0.355 mm	45	46.1300	11.32
Sand 0.250 mm (g)	0.250 mm	60	22.0200	5.41
Sand 0.180 mm (g)	0.180 mm	80	1.8400	0.45
Sand 0.125 mm (g)	0.125 mm	120	1.3900	0.34
Sand 0.090 mm (g)	0.090 mm	170	0.2900	0.07
Sand 0.063 mm (g)	0.063 mm	230	0.0600	0.01
Silt	0.004 mm		0.0650	0.02
Clay	0.001 mm		0.0500	0.01
		Total	454.5150	111.55



ALS Group USA, Corp.
dba ALS Environmental
Analytical Report

Client: NewFields Environmental
Project: LCR RSM
Sample Matrix: Soil

Service Request: K1602981
Date Collected: 3/23/2016
Date Received: 3/24/2016
Date Analyzed: 4/14/2016

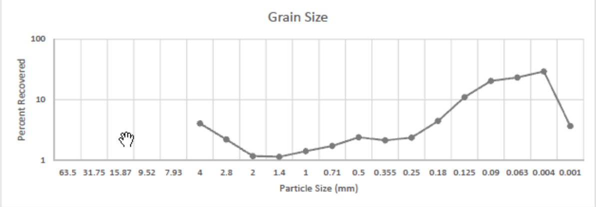
Particle Size Determination
ASTM D422M

Sample Name: CR 249
Lab Code: K1602981-024

Sand Fraction: Weight (Grams)	24.3326
Sand Fraction: Weight Recovered (Grams)	24.0740
Sand Fraction: Percent Recovery	98.94

Weight as received (Grams)	42.8327
Percent Solids	62.3
Weight Oven-Dried (Grams)	26.6848

Description	Sieve Size	Sieve Number	Dry Weight (Grams)	Percent of Total Weight Recovered
Cobbles (g)	63.5 mm	2 1/2"	0.0000	0.00
Pebbles (g)	31.75 mm	1 1/4 "	0.0000	0.00
Pebbles (g)	15.87 mm	5/8"	0.0000	0.00
Pebbles (g)	9.525 mm	3/8"	0.0000	0.00
Pebbles (g)	7.9375 mm	5/16"	0.0000	0.00
Pebbles 4.00 mm (g)	4.00 mm	5	1.0811	4.05
Pebbles 2.80 mm (g)	2.80 mm	7	0.5866	2.20
Pebbles 2.00 mm (g)	2.00 mm	10	0.3109	1.17
Sand 1.40 mm (g)	1.40 mm	14	0.3040	1.14
Sand 1.00 mm (g)	1.00 mm	18	0.3757	1.41
Sand 0.710 mm (g)	0.710 mm	25	0.4596	1.72
Sand 0.500 mm (g)	0.500 mm	35	0.6391	2.39
Sand 0.355 mm (g)	0.355 mm	45	0.5679	2.13
Sand 0.250 mm (g)	0.250 mm	60	0.6291	2.36
Sand 0.180 mm (g)	0.180 mm	80	1.1867	4.45
Sand 0.125 mm (g)	0.125 mm	120	2.9345	11.00
Sand 0.090 mm (g)	0.090 mm	170	5.4477	20.42
Sand 0.063 mm (g)	0.063 mm	230	6.2143	23.29
Silt	0.004 mm		7.8150	29.29
Clay	0.001 mm		0.9800	3.67
		Total	29.5322	110.69



ALS Group USA, Corp.
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Analytical Report

Client: NewFields Environmental
Project: LCR RSM
Sample Matrix: Soil

Service Request: K1602981
Date Collected: 3/23/2016
Date Received: 3/24/2016
Date Analyzed: 4/14/2016

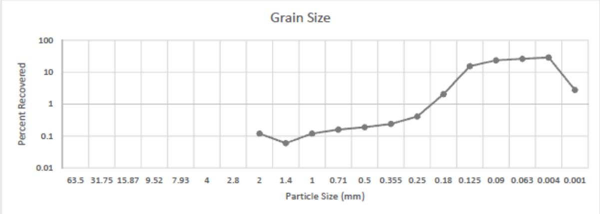
Particle Size Determination
ASTM D422M

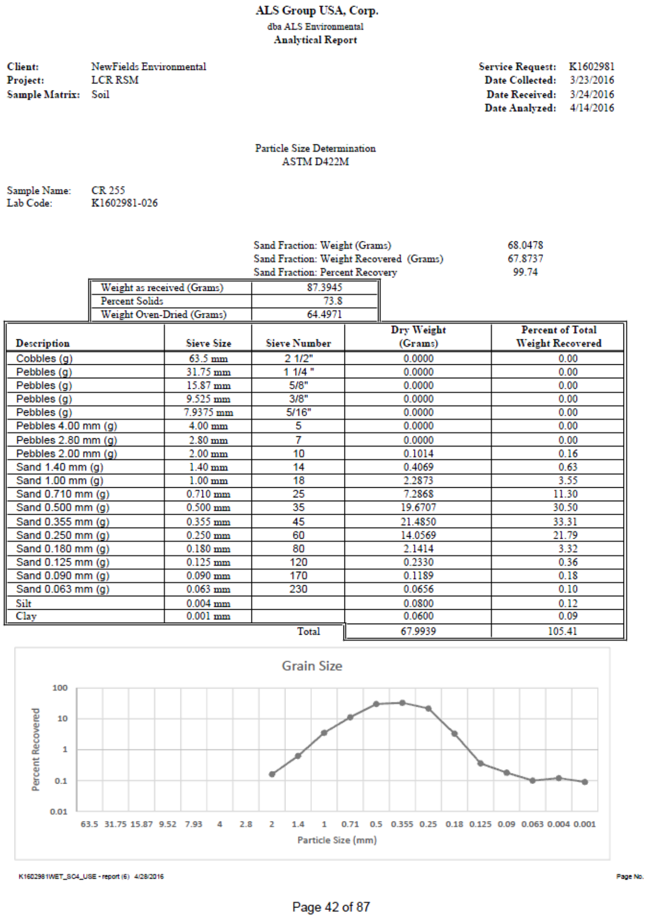
Sample Name: CR 253
Lab Code: K1602981-025

Sand Fraction: Weight (Grams)	28.6577
Sand Fraction: Weight Recovered (Grams)	28.5066
Sand Fraction: Percent Recovery	99.47

Weight as received (Grams)	55.4475
Percent Solids	62.9
Weight Oven-Dried (Grams)	34.8765

Description	Sieve Size	Sieve Number	Dry Weight (Grams)	Percent of Total Weight Recovered
Cobbles (g)	63.5 mm	2 1/2"	0.0000	0.00
Pebbles (g)	31.75 mm	1 1/4 "	0.0000	0.00
Pebbles (g)	15.87 mm	5/8"	0.0000	0.00
Pebbles (g)	9.525 mm	3/8"	0.0000	0.00
Pebbles (g)	7.9375 mm	5/16"	0.0000	0.00
Pebbles 4.00 mm (g)	4.00 mm	5	0.0000	0.00
Pebbles 2.80 mm (g)	2.80 mm	7	0.0000	0.00
Pebbles 2.00 mm (g)	2.00 mm	10	0.0430	0.12
Sand 1.40 mm (g)	1.40 mm	14	0.0215	0.06
Sand 1.00 mm (g)	1.00 mm	18	0.0412	0.12
Sand 0.710 mm (g)	0.710 mm	25	0.0545	0.16
Sand 0.500 mm (g)	0.500 mm	35	0.0651	0.19
Sand 0.355 mm (g)	0.355 mm	45	0.0843	0.24
Sand 0.250 mm (g)	0.250 mm	60	0.1432	0.41
Sand 0.180 mm (g)	0.180 mm	80	0.7169	2.06
Sand 0.125 mm (g)	0.125 mm	120	5.3958	15.47
Sand 0.090 mm (g)	0.090 mm	170	8.1876	23.48
Sand 0.063 mm (g)	0.063 mm	230	9.1568	26.25
Silt	0.004 mm		10.1200	29.02
Clay	0.001 mm		0.9750	2.80
		Total	35.0049	100.38





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Analytical Report

Client:	NewFields Environmental	Service Request:	K1602981
Project:	LCR RSM	Date Collected:	3/23/2016
Sample Matrix:	Soil	Date Received:	3/24/2016
		Date Analyzed:	4/14/2016

Particle Size Determination
ASTM D422M

Sample Name: CR 255
Lab Code: K1602981-026

Sand Fraction: Weight (Grams)	68.0478
Sand Fraction: Weight Recovered (Grams)	67.8737
Sand Fraction: Percent Recovery	99.74

Weight as received (Grams)	87.3945
Percent Solids	73.8
Weight Oven-Dried (Grams)	64.4971

Description	Sieve Size	Sieve Number	Dry Weight (Grams)	Percent of Total Weight Recovered
Cobbles (g)	63.5 mm	2 1/2"	0.0000	0.00
Pebbles (g)	31.75 mm	1 1/4 "	0.0000	0.00
Pebbles (g)	15.87 mm	5/8"	0.0000	0.00
Pebbles (g)	9.525 mm	3/8"	0.0000	0.00
Pebbles (g)	7.9375 mm	5/16"	0.0000	0.00
Pebbles 4.00 mm (g)	4.00 mm	5	0.0000	0.00
Pebbles 2.80 mm (g)	2.80 mm	7	0.0000	0.00
Pebbles 2.00 mm (g)	2.00 mm	10	0.1014	0.16
Sand 1.40 mm (g)	1.40 mm	14	0.4069	0.63
Sand 1.00 mm (g)	1.00 mm	18	2.2873	3.55
Sand 0.710 mm (g)	0.710 mm	25	7.2868	11.30
Sand 0.500 mm (g)	0.500 mm	35	19.6707	30.50
Sand 0.355 mm (g)	0.355 mm	45	21.4850	33.31
Sand 0.250 mm (g)	0.250 mm	60	14.0569	21.79
Sand 0.180 mm (g)	0.180 mm	80	2.1414	3.32
Sand 0.125 mm (g)	0.125 mm	120	0.2330	0.36
Sand 0.090 mm (g)	0.090 mm	170	0.1189	0.18
Sand 0.063 mm (g)	0.063 mm	230	0.0656	0.10
Silt	0.004 mm		0.0800	0.12
Clay	0.001 mm		0.0600	0.09
		Total	67.9939	105.41

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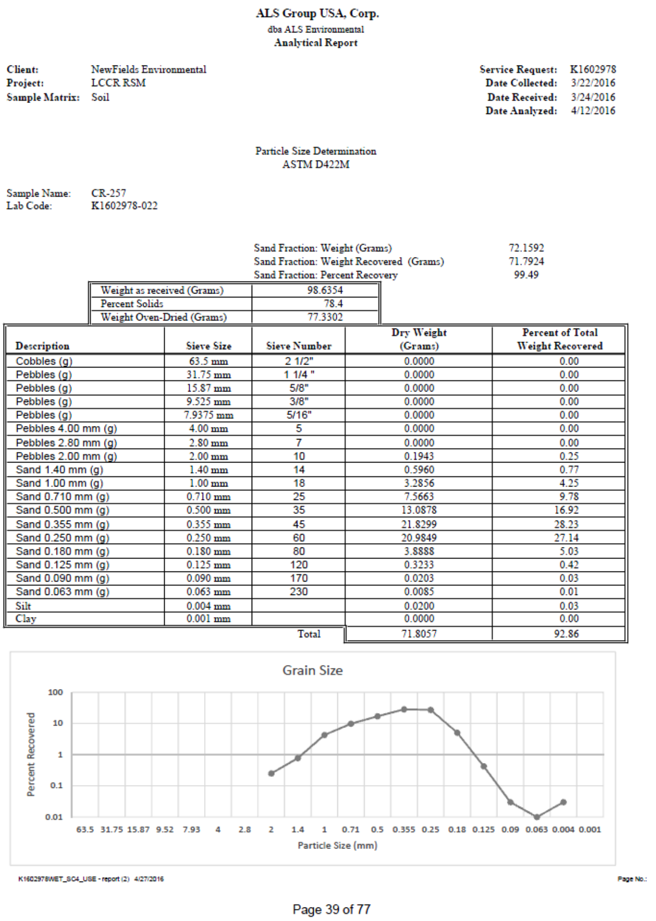

ALS Group USA, Corp.
dba ALS Environmental
Analytical Report

Client:	NewFields Environmental	Service Request:	K1602978
Project:	LCCR RSM	Date Collected:	3/22/2016
Sample Matrix:	Soil	Date Received:	3/24/2016
		Date Analyzed:	4/12/2016

Particle Size Determination
ASTM D422M

Sample Name: CR-257
Lab Code: K1602978-022

Sand Fraction: Weight (Grams)	72.1592
Sand Fraction: Weight Recovered (Grams)	71.7924
Sand Fraction: Percent Recovery	99.49

Weight as received (Grams)	98.6354
Percent Solids	78.4
Weight Oven-Dried (Grams)	77.3302

Description	Sieve Size	Sieve Number	Dry Weight (Grams)	Percent of Total Weight Recovered
Cobbles (g)	63.5 mm	2 1/2"	0.0000	0.00
Pebbles (g)	31.75 mm	1 1/4 "	0.0000	0.00
Pebbles (g)	15.87 mm	5/8"	0.0000	0.00
Pebbles (g)	9.525 mm	3/8"	0.0000	0.00
Pebbles (g)	7.9375 mm	5/16"	0.0000	0.00
Pebbles 4.00 mm (g)	4.00 mm	5	0.0000	0.00
Pebbles 2.80 mm (g)	2.80 mm	7	0.0000	0.00
Pebbles 2.00 mm (g)	2.00 mm	10	0.1943	0.25
Sand 1.40 mm (g)	1.40 mm	14	0.5960	0.77
Sand 1.00 mm (g)	1.00 mm	18	3.2856	4.25
Sand 0.710 mm (g)	0.710 mm	25	7.5663	9.78
Sand 0.500 mm (g)	0.500 mm	35	13.0878	16.92
Sand 0.355 mm (g)	0.355 mm	45	21.8299	28.23
Sand 0.250 mm (g)	0.250 mm	60	20.9849	27.14
Sand 0.180 mm (g)	0.180 mm	80	3.8888	5.03
Sand 0.125 mm (g)	0.125 mm	120	0.3233	0.42
Sand 0.090 mm (g)	0.090 mm	170	0.0203	0.03
Sand 0.063 mm (g)	0.063 mm	230	0.0085	0.01
Silt	0.004 mm		0.0200	0.03
Clay	0.001 mm		0.0000	0.00
		Total	71.8057	92.86

K1602978WET_SC4_USE - report (2) 4/27/2016 Page No.:

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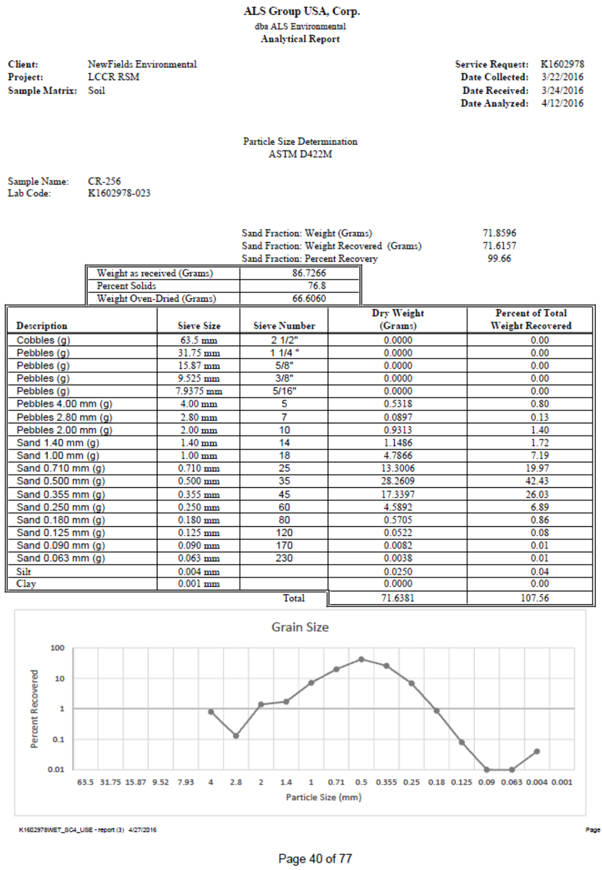
Source location of dredged material to be used for placement at Woodland Islands project site: 0.5 to 2 percent gravel, 90-98 percent medium-course sand (0.18 – 1 mm), less than 0.1 percent fines (<0.068 mm), with 0.1 percent TOC. Bulk density = 1.90 to 2.03 gram/cm3.

Bottom Sediment within moderate flow/channelized areas at Woodland Islands project site: 0.3 percent gravel, 96 percent medium-course sand (0.18 – 1 mm), 2.5 percent very fine-fine sand, 0.2 percent fines (<0.068 mm), with 0.1 percent TOC. Bulk density = 1.75 to 1.80 gram/cm3.

Bottom Sediment within sheltered areas at Woodland Islands project site: 1-5 percent gravel, 1-9 percent medium-course sand (0.18 – 1 mm), 55-68 percent very fine-fine sand, 30-35 percent fines (<0.068 mm), with 1-2 percent TOC. Bulk density = 1.69 to 1.84 gram/cm3.



ALS Group USA, Corp.
dba ALS Environmental
Analytical Report

Client:	NewFields Environmental	Service Request:	K1602978
Project:	LCCR RSM	Date Collected:	3/22/2016
Sample Matrix:	Soil	Date Received:	3/24/2016
		Date Analyzed:	4/12/2016

Particle Size Determination
ASTM D422M

Sample Name: CR-256
Lab Code: K1602978-023

Sand Fraction: Weight (Grams)	71.8596
Sand Fraction: Weight Recovered (Grams)	71.6157
Sand Fraction: Percent Recovery	99.66

Weight as received (Grams)	86.7266
Percent Solids	76.8
Weight Oven-Dried (Grams)	66.6060

Description	Sieve Size	Sieve Number	Dry Weight (Grams)	Percent of Total Weight Recovered
Cobbles (g)	63.5 mm	2 1/2"	0.0000	0.00
Pebbles (g)	31.75 mm	1 1/4 "	0.0000	0.00
Pebbles (g)	15.87 mm	5/8"	0.0000	0.00
Pebbles (g)	9.525 mm	3/8"	0.0000	0.00
Pebbles (g)	7.9375 mm	5/16"	0.0000	0.00
Pebbles 4.00 mm (g)	4.00 mm	5	0.5318	0.80
Pebbles 2.80 mm (g)	2.80 mm	7	0.0897	0.13
Pebbles 2.00 mm (g)	2.00 mm	10	0.9313	1.40
Sand 1.40 mm (g)	1.40 mm	14	1.1486	1.72
Sand 1.00 mm (g)	1.00 mm	18	4.7866	7.19
Sand 0.710 mm (g)	0.710 mm	25	13.3006	19.97
Sand 0.500 mm (g)	0.500 mm	35	28.2609	42.43
Sand 0.355 mm (g)	0.355 mm	45	17.3397	26.03
Sand 0.250 mm (g)	0.250 mm	60	4.5892	6.89
Sand 0.180 mm (g)	0.180 mm	80	0.5705	0.86
Sand 0.125 mm (g)	0.125 mm	120	0.0522	0.08
Sand 0.090 mm (g)	0.090 mm	170	0.0082	0.01
Sand 0.063 mm (g)	0.063 mm	230	0.0038	0.01
Silt	0.004 mm		0.0250	0.04
Clay	0.001 mm		0.0000	0.00
		Total	71.6381	107.56

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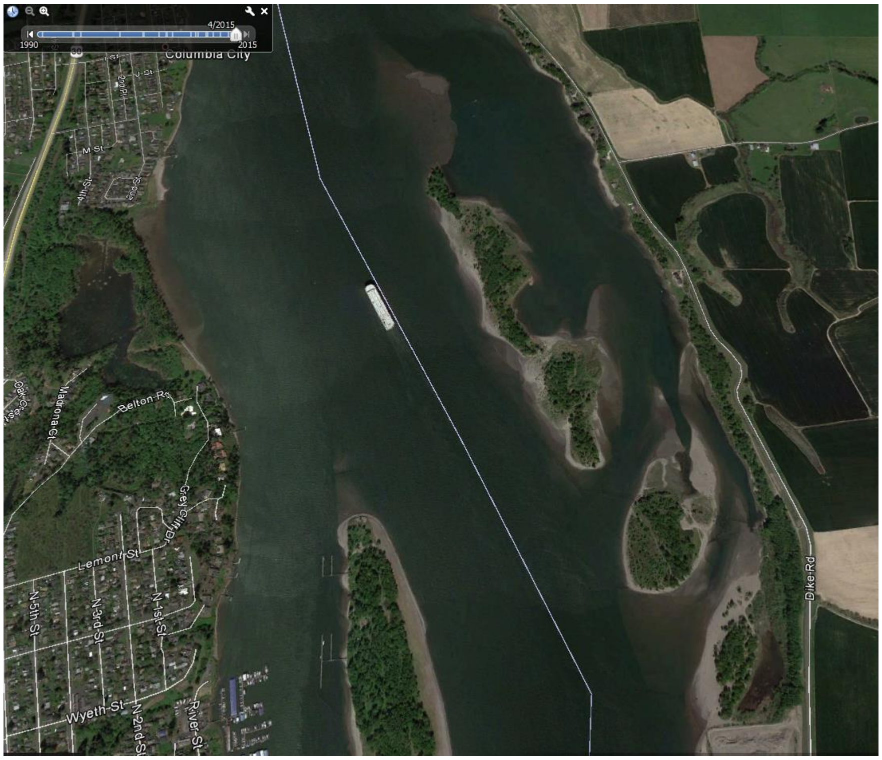
Portland District

Lower Columbia River Estuary
Section 204 Studies



Woodland Dike Islands

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I. Dredge Equipment

A. General

This section presents basic information about pipeline and hopper dredges, which are used for navigation channel maintenance in the Columbia River.

B. Pipeline dredge

Pipeline dredges are typically used for dredging cutline shoals and continuous sand wave shoals where there is a large quantity of material (200kcy to 400kcy) concentrated within a small area. A typical shoal for a pipeline dredge would include an area that is roughly 250 to 300 feet wide by 2,000 to 4,000 feet long, though shoals vary in length, width and depth depending on flow conditions. A pipeline dredge uses a "cutterhead" on the end of an arm that is buried three to six feet deep in the river bottom and swings in a 250- to 300-foot arc in front of the dredge. Spuds at the back of the dredge penetrate the river bottom to anchor the dredge in place while the cutterhead and suction arm are in operation. A slurry of dredged material is sucked up through a pipe behind the cutterhead, through the main pump and on through floating and shore pipe to discharge at low pressure. To create or widen a beach, discharge occurs at the shore-water interface. For confined upland placement, discharge occurs within the bermed upland area. In both cases, dozers and other equipment move the pipe and grade the sand as it is being placed. For in-water placement, it is possible to discharge at the water surface through a floating pipeline or through a downspout below -20 feet CRD. Material is dredged from the shoal and pumped to the placement site in one continuous action, so shoals are removed as quickly as possible. The contract pipeline Dredge OREGON, operated by the Port of Portland, is used for Columbia River navigation channel maintenance. Because of limited floating pipe length, the dredged material placement site must be located within 8,500 feet of the shoal area.

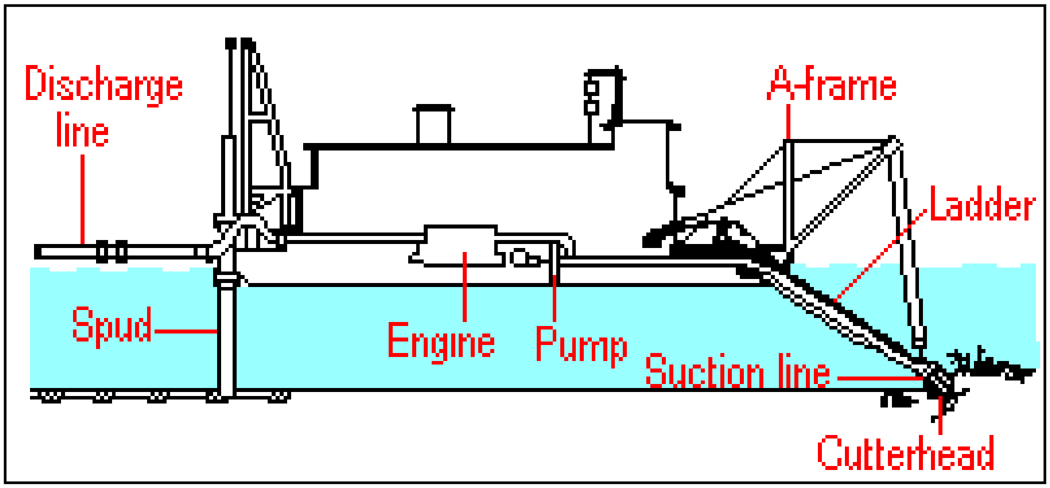

Figure 1 Typical pipeline dredge schematic

C. Hopper Dredge

Hopper dredges are mobile vessels (ships) and can move between shoals more efficiently than a pipeline dredge. Hopper dredges have two dragarms (one on each side of the dredge) that are lowered to the bottom of the river to suck a mixture (slurry) of dredged material and water into the hopper bin inside the dredge. Unlike a pipeline dredge, a hopper dredge cannot dredge material from the shoal and move it to a placement site in one continuous action. Once the hopper is full, the dredge stops dredging, sails to a deep area in the river, and places the material in-water by opening the bottom of the vessel to release the material using force of gravity. Hopper dredges that work in the Columbia River cannot place material in-water at depths shallower than -20 feet CRD to avoid grounding. Some contract hopper dredges have pump-out capability. They can either hook up to a pipe and pump a slurry of dredged material at low pressure to an upland site or beach, where dozers and other equipment move the pipe and grade the sand as it is being placed, or use a high pressure nozzle on the dredge to pump a rainbow spray discharge of dredged material-water mixture in an arc thru the air. However, it takes approximately twice as long to clear a shoal when material is pumped back out of a hopper dredge compared to in-water placement. For Columbia River navigation channel maintenance, hopper dredges are typically used to dredge scattered sand wave shoals and place material in-water in stable areas outside the channel. In some cases where a shoal is located too far from the preferred placement site for a pipeline dredge to reach, a hopper dredge may be used to dredge the shoal, bring the material closer, and place it temporarily in-water for a pipeline dredge to rehandle to the preferred placement site. To minimize sailing time (and therefore remove shoals more quickly), placement sites for hopper dredges are typically chosen within 5 miles of the shoal area.

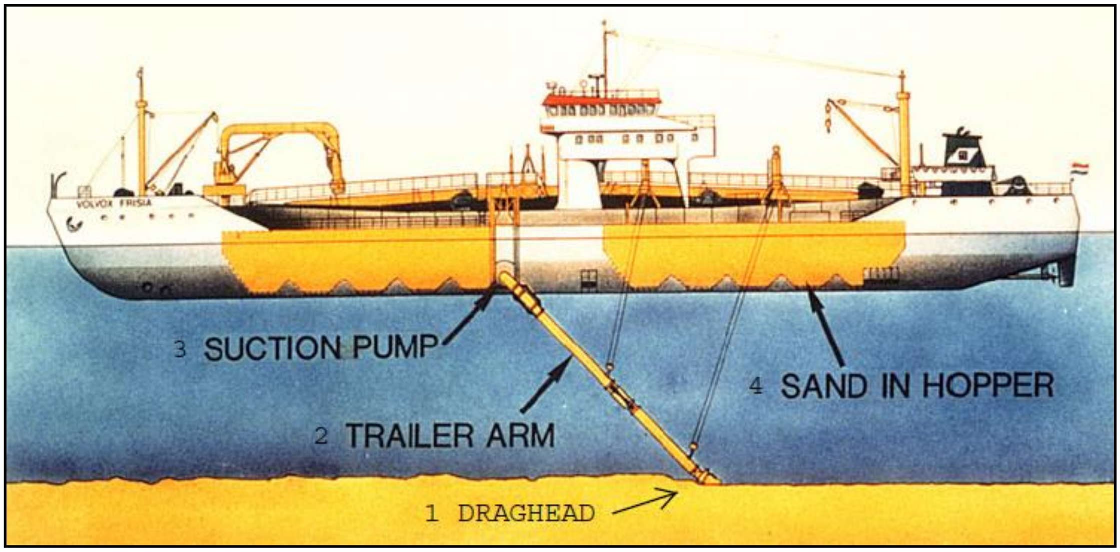

Figure 2 Typical hopper dredge schematic

D. Summary of Equipment Limitations

Dredge Type	Dredging	Max distance shoal to placement site	Placement
Pipeline	Plan 200kcy - 400kcy per event	8,500 feet	High pressure “rainbow spray” discharge not possible because of pressure loss thru pipe.
Hopper	-	5 miles	Cannot use in-water gravity placement in areas shallower than -20 feet CRD Pump-out takes twice as long to clear shoal

II. Sources of Dredged Material (Channel Shoaling)

A. General

This section presents potential sources of dredged material for beneficial use at the Woodland Dike Islands.

B. Constraint

Based on the dredge equipment limitations (distance between shoal and dredged material placement site) provided in the previous section, the project is limited to material dredged from shoals on St. Helens Bar (where the restoration site is located) and the neighboring channel reaches within 5 miles upstream and downstream (Warrior Rock Bar and Upper Martin Bar).

Figure 3: Map of Dredged Material Sources (shoaling)

C. Sources of Dredged Material

1. St. Helens Bar RM 84 to 87

Based on an evaluation of past dredging needs, the anticipated future dredging need at St. Helens Bar shoal is pipeline dredging of 300kcy every 2-3 years on average, although individual dredging events may range from 200kcy to 400kcy or more.

The history of dredging at St. Helens Bar from 1975 to 2016 is shown in Table 1, along with an evaluation of trends for different distinct periods. Shoaling volumes at this bar vary with river flow conditions, which cannot be predicted with certainty. Dredging frequency also varies depending on shoaling volumes and previous level of maintenance achieved (longer periods between advanced maintenance dredging events). The O&M dredging history after deepening the channel to 43-ft has been overshadowed by significant shoaling from a high, sustained freshet in 2011, which makes it difficult to estimate a 'typical' future dredging need. However, review of periods of time without unusually large freshets indicate that major dredging events suitable for a pipeline dredge (approximately 300kcy but may range from 200kcy to 400kcy or more) will be required every 2-3 years on average. There is a known risk that dredged material at St. Helens Bar may not be immediately available for the restoration project, however we can be reasonably certain that there will be need for a major dredging event within the first 3 years.

Table 1: History of Corps Dredging at St. Helens Bar

Year	*St. Helens Bar Dredging*	*Trend Evaluation*	*Year*	*St. Helens Bar Dredging*	*Trend Evaluation*
1975	0	**1975-1995 (40-ft channel): essentially 200kcy every 4 years with some minimal dredging in-between**	**1996**	**171,564**	**1996-2000 high, sustained freshet + following 4 years (40-ft channel): 1.1mcy total, 220kcy per year average**
1976	**193,279**		**1997**	**333,509**	
1977	0		**1998**	**273,878**	
1978	0		1999	31,118	
1979	0		**2000**	**294,344**	
1980	63,195		2001	0	**2001-2007 (40-ft channel): essentially 200-300kcy every 2 years with minimal dredging in-between; Corps channel condition surveys indicate advanced maint. not achieved - explains frequent dredging of smaller volumes**
1981	**146,880**		**2002**	**240,466**	
1982	0		2003	0	
1983	33,660		**2004**	**194,485**	
1984	0		2005	86,894	
1985	**177,301**		**2006**	**306,782**	
1986	0		2007	20,100	
1987	26,700		**2008**	**376,006**	2008 (channel deepening to 43 ft)
1988	65,000		2009		2009-2010 (just after deepening but before 43-ft channel O&M)
1989	89,000		2010		
1990	**194,000**		**2011**	**339,105**	**2011-2015 high, sustained freshet + following 4 years (43-ft channel): 1.3mcy total, 260kcy per year average; finally achieved full advanced maintenance in 2015**
1991	0		**2012**	147,361	
1992	0		**2013**	**324,762**	
1993	0		2014	86,760	
1994	**121,000**		**2015**	**416,656**	
1995	24,000		2016	33,112	2016 (43-ft channel): 30kcy

2. Upper Martin Bar RM 80 to 84 & Warrior Rock Bar RM 87 to 90

Based on an evaluation of past dredging needs, the anticipated future dredging need at Upper Martin Bar and Warrior Rock Bar shoals is annual hopper dredging of approximately 90kcy and 60kcy, respectively.

A select history of dredging at Upper Martin Bar and Warrior Rock Bar, with periods intended to be most representative of typical conditions, is shown in Table 2, along with an evaluation of trends for different distinct periods. Shoaling volumes at these bars also vary with river flow conditions, which cannot be predicted with certainty. Shoals are predominantly sand waves that form each year. Average dredging records for this select history indicate that hopper dredging will be required annually to remove approximately 90kcy from Upper Martin Bar and 60kcy from Warrior Rock Bar. We can be reasonably certain that there will be an annual need for dredging, although the exact volumes may differ from the average by 50kcy or more at each bar.

Table 2: History of Corps Dredging at Upper Martin Bar and Warrior Rock Bar

Year	*Upper Martin Bar Dredging*	*Trend Evaluation*	Year	*Warrior Rock Bar Dredging*	*Trend Evaluation*
2001	5,484	2001-2007 (40-ft channel): Average annual dredging need is 56kcy	2001	0	2001-2007 (40-ft channel): Average annual dredging need is 66kcy
2002	23,152		2002	11,576	
2003	0		2003	133,201	
2004	53,319		2004	17,874	
2005	145,909		2005	100,683	
2006	30,695		2006	81,551	
2007	131,092		2007	118,638	
2011	89,058	2011-2015 high, sustained freshet + following 4 years (43-ft channel): Average annual dredging need is 133kcy	2011	0	2011-2015 high, sustained freshet + following 4 years (43-ft channel): Average annual dredging need is 64kcy
2012	109,152		2012	77,483	
2013	63,469		2013	36,320	
2014	367,695		2014	170,030	
2015	36,901		2015	34,466	
2016	88,351	2016 (43-ft channel): 90kcy	2016	51,185	2016 (43-ft channel): 50kcy
Avg	**90kcy**	**Average of selected years**	**Avg**	**60kcy**	**Average of selected years**

D. Uncertainty

In addition to the uncertainty of annual river flows and resulting shoal development (volumes of dredging needed) at these bars, risk factors inherent to the Corps' routine channel maintenance project include dredge equipment reliability/availability, competing needs of higher priority shoals (including other projects) and uncertain O&M funding which may not meet all dredging needs. These risks are identified because they could also affect the timing (year) and actual volume of dredged material available to construct the restoration site. It is not possible to further reduce the uncertainties or level of risk discussed here.

Shoal	*Volume*	*Dredging method to get material to project site*	
		Pipeline dredge pumps material directly to site (shoal less than 8,500 ft from restoration site)	*Hopper dredge places material in-water and pipeline dredge rehandles to site (shoal greater than 8,500 ft but less than 5 miles from restoration site)*
Upper Martin Bar (RM 80 to 84)	90kcy (annual)		X
St. Helens Bar (RM 84 to 87)	300kcy (every 2-3 yrs)	X	
Warrior Rock Bar (RM 87 to 90)	60kcy (annual)		X

III. Baseline Channel Maintenance Plan

A. St. Helens Bar

Major dredging events will be accomplished using a pipeline dredge with placement on the shoreline of Sand Island in Oregon and/or upland at the Austin Point site in Washington. Hopper dredges will address sand waves as needed between major dredging events and place material at stable locations in-water within 5 miles of the shoal.

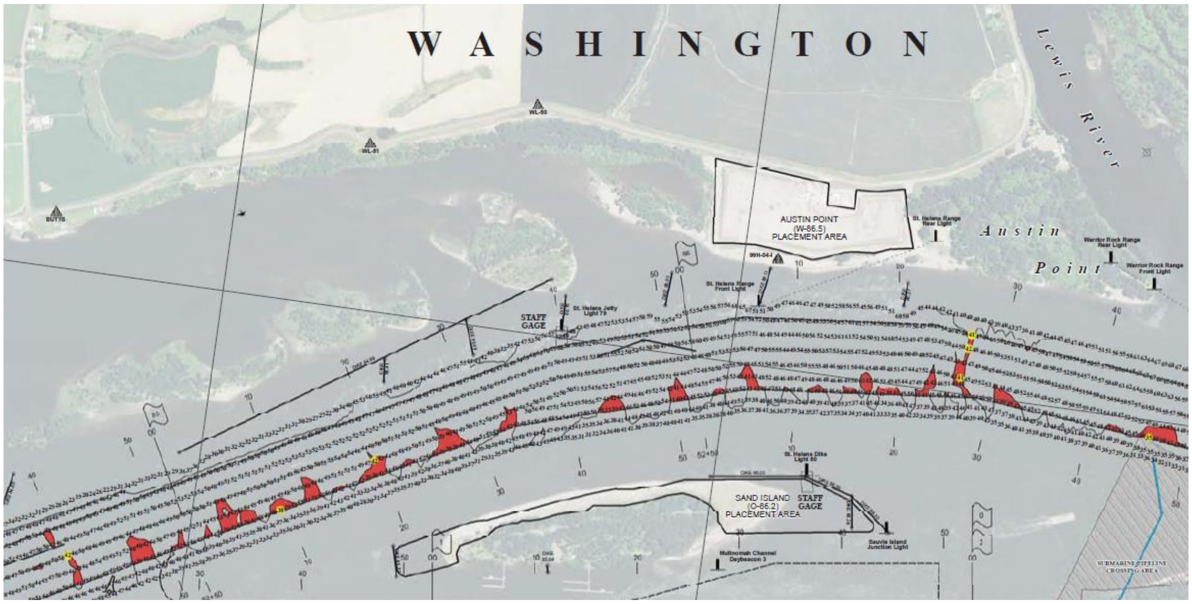

Figure 4: Baseline Plan (St. Helens Bar shoal shown in red; survey dated 28 May 2013)

B. Upper Martin Bar & Warrior Rock Bar

Hopper dredges will remove sand waves annually and place material either at stable locations in-water within 5 miles of the shoals or at St. Helens bar for rehandle as dredge timing/funds allow.

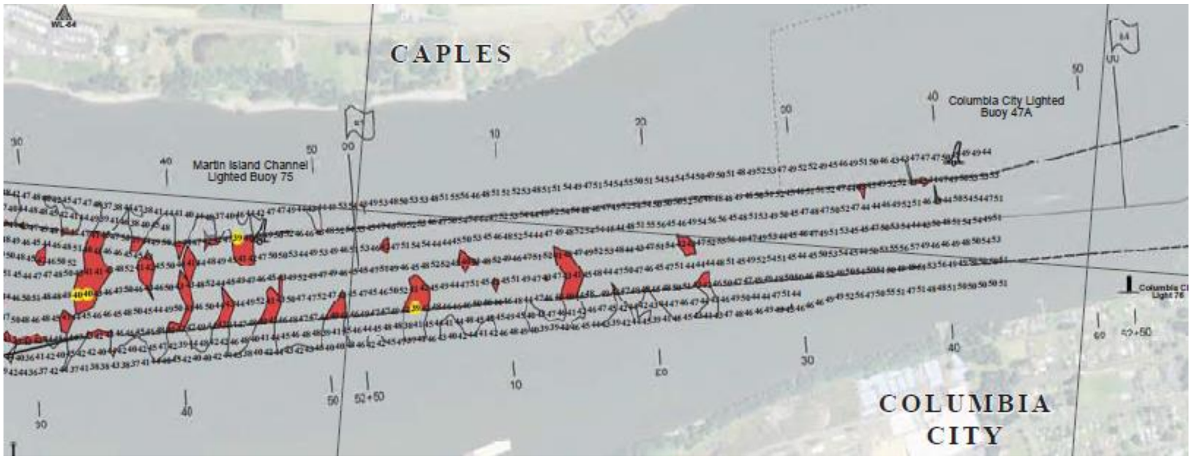

Figure 5: Baseline Plan (representative sand wave shoaling shown in red; survey dated 6 August 2012)

IV. Project Dredging Options

A. General

This section presents options for dredging volumes of material placed for beneficial use at the Woodland Dike Islands. Dredging operations employ all BMPs to reduce turbidity and impacts to other sensitive areas within the project site.

B. Constraints

- The project cannot increase risk of an adverse impact on the authorized navigation channel. Specifically, dredging measures must be compatible with the Corps' navigation channel maintenance plan for a given season, including the amount of material to be dredged and the type of dredge available.

  Consequently, a hopper dredge cannot be used to pump dredged material to the project site because it fundamentally conflicts with this project constraint. Pumping dredged material back out of a hopper dredge takes twice as much time to clear the shoaling compared with the base channel maintenance plan and that is an unacceptable increased risk of adverse impact on the authorized navigation channel.
- The project must be completed within one construction season.
- Sufficient dredged material must be available to initiate construction of the proposed project feature(s).

C. Engineering Consideration

Depths at the restoration site are too shallow (less than -20 feet CRD) for hopper dredges to place material in-water directly at the site.

D. Methods required to get shoal material to project restoration site

Given constraints and engineering considerations, the existing contract with the Port of Portland for channel maintenance using the pipeline dredge OREGON must be used to place dredged material at the restoration site. Where a shoal is not located within pipeline dredge reach of the restoration site, a hopper dredge may be used to dredge the shoal, bring the material closer, and place it temporarily in-water for the pipeline dredge to rehandle to the restoration site. Methods required to get potential dredged material sources (shoals) to the restoration site are as follows:

E. Project dredging options

Project dredging options use a single shoal method or combinations to provide different dredged material volumes for project restoration measures.

1. St. Helens Bar shoal

If sufficient material is available in the shoal on this bar, the dredge OREGON can pump to Woodland Island directly to create the project feature(s).

2. St. Helens Bar supplemented with material from neighboring shoals

If additional material is needed to supply sufficient material for initial construction of the project, hopper dredges could bring additional material (estimated at 100kcy) from adjacent bars to supplement the material on St. Helens Bar. A rehandle operation was conducted at St Helens bar (hopper dredge was dredging material from different part of St Helens bar) with 100kcy successfully in 2013. The amount of time between the placement of material by hoppers and rehandling by pipeline should be minimized, definitely within a single season when flows are low so the material doesn't move. The maximum amount of material we should risk placing along the channel edge for a rehandle is 100kcy; neighboring shoal volumes are greater, will support this option.

V. Project Dredged Material Discharge Options

A. General

This section presents options for dredged material discharge by the pipeline dredge OREGON to create project restoration measures at Woodland Dike Islands.

B. Dredged material discharge options

1. Low pressure discharge of dredged material-water mixture at water surface

Pumping a button – best for making deep water areas shallower; discharged sand builds up in a pile called a "button". Once enough material builds the button above the daily max water level, dozers can start moving the material around.

2. Low pressure discharge of dredged material-water mixture at shore interface

Traditional shoreline placement – best for making sand bars with high enough elevation that shore equipment can grade

C. Summary of Engineering Considerations & Limitations

Discharge Method	*Restrictions on use*	*Equipment*	*Time*	*Precision*
1) Water Surface	Use to create feature elevations below max daily water level (change deep to shallow water habitat)	Minimum	Minimum	Not precise; more natural
2) Shore Interface	Use to create feature elevations above max daily water level (sand bars)	Add dozers & grading equipment	Add time for final grading (will not unreasonably delay channel O&M)	Very precise; less natural

VI. Project Construction

A. General

This section presents the basic construction considerations, restrictions and coordination for major features of the Woodland Dike Islands.

- Primary assumption: construction will be accomplished using the pipeline Dredge Oregon under the current cost-reimbursable contract with the Port of Portland.

B. Schedule

1. In-water Work Period

There is no environmental in-water work restriction. However, maintenance dredging normally occurs from July through October in the Columbia River.

2. Construction Schedule

Approximately 300,000-400,000 CY of dredged material would be placed upland until one or both features has been constructed. It is assumed that the construction period for dredged material placement would be from September 1 to November 1. Based on average quantities dredged over the past 5 years there should be enough material available in 2018 to complete one or both features. Plantings would take place during the spring or fall of the following year.

C. Access

1. Engineering considerations

a) General

A landing ramp and access road must be constructed to provide sufficient water depth for the equipment barge to land at the shoreline to gain access to the site for equipment and pipe.

Figure 23. Typical build out of a barge landing (Rice Island).

b) Discussion

Once landed, equipment can be offloaded and an access road can be constructed along the channel side of the island with a width of 70-100'. This will allow the shore crew to bring equipment and shore pipe to the crossing area for access to the upstream feature to be created. If there is insufficient sand existing along the island face for an access road, the dredge may need to pump some material into the area as a supplement. Dozers would then work the material in creating the access road. See description of work below.

2. Build dredged material access landing on channel side of islands

The upland site crew will begin the site prep for material placement by first creating a suitable landing point and placing pipe across the island. In order to create an access landing, floating pipe will be brought into the shoreline and dredged material will be pumped into the sand/water interface through a 30" pipe until enough sand has accumulated to be able to push a landing barge into the shore to offload equipment. Once the barge is in place, dozers can be offloaded and used to spread the dredged material out along the beach to create an access road for additional equipment and shore pipe. This landing will occur on the shoreline of the island just downstream of the pile dike that parallels the Federal navigation channel. The access road along the front of the island will be created using existing sand and/or by pumping material until it reaches the location where pipe could more easily access the back side of the islands. The dozers will create a temporary berm to contain the material as it settles out from the discharge pipe, and pipe will be added as material is placed and worked with dozers. The minimum width of this access road will be 70-75 feet. This road is necessary for access of equipment and pipe to the location where the dredge pipe will need to cross the island to the lagoon on the back side, where the proposed features will be created.

Figure 6 Active shoreline placement at Sand Island (looking upstream)

3. Build access road across island to back side

Once the access road has reached the location where pipe can traverse the island to the back side, an access road for equipment and pipe will need to be created. Vegetation will need to be cleared to a width of approximately 150 feet to allow equipment to be able to work and place shore pipe to reach the back side of the island. After the vegetation has been cleared, the site will be graded for adequate placement of the pipe. The upland site crew will then use dozers and loaders to move the pipe and the material into the desired locations and elevations, as needed.

D. Stage shore work equipment

Shoreline placement requires staging shore equipment, vehicles and pipes above the ordinary high water line (on existing island and/or on newly placed access sand). These staging areas are typically 50 feet by 90 feet (~0.10 acre) and are located as close to the shoreline as safely feasible. During inspections prior to placement, the exact location of the 0.10-acre staging area can be located to avoid or minimize impacts.

Figure 7 Staging equipment on topo of the bank at Sand Island beach nourishment site

E. Construct Woodland Dike Islands features on the back side

The Dredge Oregon will obtain most of the material needed for creation of the habitat restoration features from maintenance dredging of St. Helens Bar. It is assumed that the construction period for this work would be from September 1 to November 1. Typical pumping production is around 15-20,000 cubic yards per day.

Standard practice for dredge placement is to run two discharge pipes in parallel to minimize downtime of the dredge. Using two discharge pipes allows the dredge to continue pumping, maintaining steady production, while the flow of slurry is switched from one pipe to the other. This is facilitated by using a “wye” with a valve. One pipe that exits the wye discharges while the other pipe is being lengthened (another section of pipe added) as material settles out and new upland is created. See figure 8 below. Placement material is diked along the outsides of the pipes to confine the discharge and promote aggradation in front of the discharge pipe. This placement typically occurs above high tide to maintain productivity throughout the period of work. During the assumed period of construction, average high stage of the river is approximately 9.5 feet NAVD. It is assumed that bulk placement would fill up to 12.0 feet NAVD to minimize wave impacts and coincidently meet the target elevation for scrub-shrub habitat.

Figure 8 Dredging elements (landing, access road, pipe, wye, etc.)

Placement of dredged material to create features below the water surface elevation is somewhat challenging for this particular site because it is not a routine placement operation. Two methods for this type of placement are commonly used: 1) pumping material using a "snorkel" and floating pipe in deep waters (>20 feet) to create shallow habitat, and 2) placing material above water and later contouring the material with an excavator resulting in a terrain 1-2 feet below the water surface. This is difficult when considering shallow water (5-15 feet deep) at Woodland Islands, but constructible.

"Snorkel" placements may be made at the downstream end of the island with modification to the down pipe but would require routing the floating pipe downstream past the sand shoal at the end of the island. The down pipe, a 90-degree elbow with a baffle on the end of the vertical section of pipe, would be on a shallow barge with winch anchors used to move the pipe around to avoid mounding in one location (see figure 9 below). As material is pumped into the river, the barge is winched back and forth to distribute the dredged material in a uniform manner. There is potential for high turbidity with shallow snorkel placement. The length of floating pipe needed is nearing the limits of available floating pipe. The alignment of the floating pipe and snorkel would be directed against the flow current rather than the more common practice of aligning the placement of the pipe with the flow current.

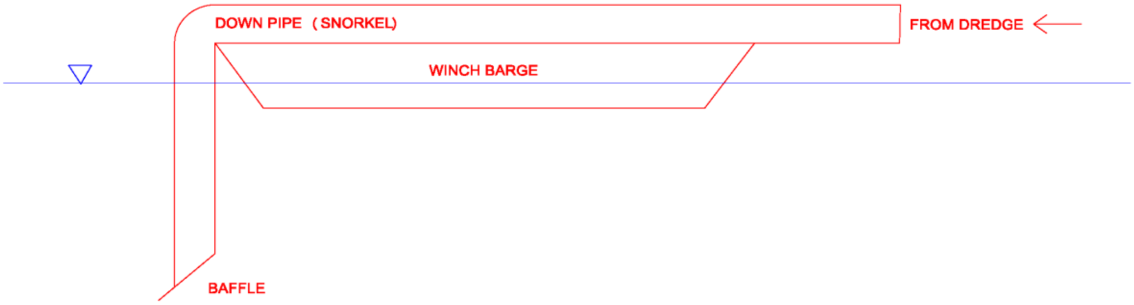

FIGURE 9 Cross-sectional schematic of the “snorkel” used by the Dredge OREGON for in-water placement >20ft.

Placing material to a grade above the water surface, which is a standard practice, then subsequently grading it down (by contouring with an excavator) would be more feasible; however, it will be time extensive and will be limited in elevation placement. An evaluation of the available river stage at St. Helens yields an average low tide of approximately 6 feet NAVD. This would indicate that the contractor could grade high placements down to 5 feet NAVD during the low tide. This would be a time sensitive effort as this target elevation would only be achievable during low tide rendering grading efforts potentially more expensive. The tidal influence renders average high and low river stages of approximately 9 feet NAVD and 6 feet NAVD, respectively. It is assumed that this zone would have greater productivity because it could be graded with various types of equipment, will be intermittently dry, and has greater accessibility. The river stage does not exceed the river stage of 9 feet NAVD and existing ground and placements above this area are continuously dry during the assumed construction period.

The various elevations will be graded flat and it is expected that the river will naturally slope the sand between each of the elevations over time through erosion.

Figure 8 Active shoreline placement at Sand Island (looking downstream)

F. Construction Logistical Limitations Summary

The following is a summary of logistical limitations to construction:

- Access point or landing required
- Ample working space required for equipment and pipeline
- Adequate soils required (to avoid sinking equipment)
- Limited precision

Woodland Islands Section 204 Beneficial Use of Dredged Material
Appendix D – Monitoring and Adaptive Management

Introduction

This monitoring and adaptive management plan has been developed to assess the success of the recommended restoration plan in meeting project objectives and provide a process to identify if any adaptive management actions are warranted. Topography and vegetation are the key elements that will be modified by the project and are the key indicators of project performance. The methods to be used to evaluate topography and vegetation performance are described in this section. Photo-monitoring will also be conducted to document site changes over time including vegetation establishment and physical habitat features.

Project Objectives:

1. Increase rearing/foraging habitat for juvenile salmonids at Woodland Island through year 2068
2. Increase flood refugia for juvenile and adult salmonids at Woodland Island through year 2068
3. Increase floodplain habitat complexity at Woodland Island through year 2068
4. Increase quality riparian habitat at Woodland Island through the year 2068
5. Limit the amount and extent of non-native vegetation at Woodland Island through the year 2068

The types and number of restoration activities to be carried out are described in Section 5.1.1 of the Feasibility Report.

The physical actions to be undertaken to achieve project objectives are described in Section 5.3.

The functions and values that will result from the restoration plan are described in Section 3.

The monitoring activities described below are proposed for monitoring the success in meeting each set of objectives.

Increase juvenile salmonid habitat (rearing/foraging, flood refugia, and floodplain), as well as the opportunity for flood refugia for adult salmonids (objectives 1-2).

<u>Target(s):</u>

1. Increase the amount of floodplain/subtidal habitat (elevation 0 to 9 NAVD88)
2. Retain the floodplain area with minimal sediment deposition in the embayment area and no significant sediment loss.

<u>Monitoring Protocol:</u>

1. Conduct a topographical survey of the area via aerial photography each year post-construction during a low water period (low flows, low tide). Surveys will occur at Time Zero (T0, immediately post-construction) and after 1, 2, 3, and 5 years post-construction and will be compared to those taken preceding construction to estimate any decrease or increase in embayment area.
2. Using the same pre- and post-construction surveys, determine whether sediment movement/deposition has changed the total area of the floodplain/subtidal (0 to 9 NAVD88) portion of the islands over the first two years. A total change of more than 15% will be considered significant.

<u>Adaptive Management Trigger(s):</u>

1. Any decrease in the embayment area, due to sedimentation, will be noted and causal mechanisms identified. Collected information will be utilized for future beneficial use projects.

2. Any decrease (or increase) in the area of floodplain/subtidal (area between 0 to 9 NAVD88) will be noted and causal mechanisms identified. Collected information will be utilized for future beneficial use projects.

Increase ecosystem function at Woodland Islands; including increased floodplain habitat complexity, increased availability of riparian habitat, and limiting the establishment of non-native vegetation (objectives 3-5).

Target(s):

1. Achieve 80% survival of original willow plantings after two years post-planting. Planting will occur one year after construction.
2. Document that natural reseeding and revegetation is occurring in newly formed embayment area below 9 NAVD (emergent marsh habitat (6 – 9 ft NAVD), determined by aerial surveys occurring during a low tide at T0, 1, 2, 3, and 5 years post-construction.
3. Riparian habitat, defined as scrub/shrub habitat occurring along the shoreline (elevation 9 NAVD), should cover 50% of the inward side of the new embayment area after 3 years and 75% in 5 years.

Monitoring Protocol:

1. Willow establishment and survival will be documented at 1, 2, 3 and 5 years post-construction (T0, 1, 2, and 4 years after initial planting) via either aerial photography and/or ground surveys.
2. Plant species composition will be evaluated by establishing five permanent vegetation plots, which will be 10 ft (3.05 m) by 10 ft (3.05 m) with the location documented via GPS coordinates (USACE Wetland Delineation Manual, 1987). Percent cover will be visually assessed and documented for each stratum (herbs, shrubs, trees, woody vines) and each species with more than 5 percent cover. Sampling will occur at 1, 2, and 5 years post-construction. Non-native vegetation in all locations will be documented, including the average percent cover by species across the site and the estimated total area of infestation.

Adaptive Management Trigger(s):

1. If willow survival is less than 80% after two years after initial planting (3 years post-construction), the Corps and non-Federal sponsor will plant new willows to replace those lost.
2. If riparian habitat is less than 75% after five years post-construction, the Corps and non-Federal sponsor will evaluate the trends of vegetation establishment and seek to determine the cause(s). If riparian habitat is not becoming established due to river flows and scour, no action will be taken. If riparian habitat is not becoming established because of the lack of shrub reproduction (e.g., a seed source), the Corps and non-Federal sponsor will replant and/or seed the inward side of the new embayment area with native shrub seeds.

References:

Richter, A. and S.A. Kolmes. 2005. Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. *Rev in Fish Sci.* **13**: 23-49.

Environmental Laboratory. 1987. "Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. [NTIS document number ADA 176734/2INE.]

U.S. Environmental Protection Agency (USEPA). 1986. Ambient Water Quality Criteria for Dissolved Oxygen. *Office of Water.* EPA document 440/5-86-003. 46 pp.

WOODLAND ISLANDS
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COWLITZ COUNTY, WASHINGTON

APPENDIX E

ECONOMICS

1. OVERVIEW OF COST EFFECTIVENESS AND INCREMENTAL COST ANALYSES

In the absence of a common measurement unit for comparing the non-monetary benefits with the monetary costs of ecosystem restoration projects, cost effectiveness and incremental cost analyses (CE / ICA) was conducted for this Woodland Islands, Beneficial Use of Dredge Material, Section 204 study to assist in decision making and to identify the National Ecosystem Restoration plan. The results of the analysis are displayed below as graphs, charts, and tables to permit the PDT to progressively compare alternative levels of environmental outputs and ask the questions: "Are the least cost alternatives being identified?", and "Is the next level of environmental outputs worth the investment?" The NER plan is the alternative plan that reasonably maximizes benefits over costs, and is considered as the base federal interest plan considered for cost sharing purposes.

The implementation of CE / ICA helps in the formulation of efficient and effective ecosystem restoration solutions for ecosystem restoration projects. Cost effectiveness is conducted to ensure that the least cost plan alternative is identified for each possible level of environmental output. The process filters out those plans that produce the same level as another plan, but cost more. In addition this process filters out plans cost more and produce less output. Incremental Cost Analysis is conducted to show changes in costs for increasing levels of environmental outputs. It provides data for decision-makers to address the question, "Is the next level worth it?" It measures the incremental or *additional cost* of the next additional level of environmental output. Once a least cost plan is identified that also produces greatest output for the least cost, it labeled as a "best buy" plan.

The non-monetary benefits are derived by calculating the habitat units (HU's) resulting from the Habitat Evaluation Procedure (HEP) conducted for this project on the environmental restoration measures and alternatives over a 50 year period of analysis. The output for the CE / ICA model is the average annual Habitat Units. They represent the net increase in output above and beyond the output calculated for without-project condition. The implementation costs for the project are the costs associated with the project (with-project condition), including outlays for construction, real estate costs, O&M costs, monitoring cost, and interest during construction. To compare costs with average annual environmental outputs, it is necessary to convert implementation costs to average annual costs. The stream of costs associated with the project occurs at various points in time. Therefore, to develop equivalent average annual costs, all costs were present-valued and amortized at the fiscal year 2018 federal discount rate of 2.75% over the project life of 50 years.

To determine the economic cost of capital during the construction period and to analyze the costs and benefits from a common point of time, interest during construction (IDC) was calculated. This calculation is added to the other costs of the project and is included as part of the average annual implementation cost. The IDC is calculated using the fiscal year 2018 discount rate of 2.75%, over a construction period projected to be 3 months in duration, and assumes middle of the month payments during the construction period. Consideration of operation and maintenance costs for the project included upkeep of plantings, waterfowl management and removal of invasive plant species. Since these management measures are currently being practiced by CREST and all project alternatives are not expected to add to or alter the current non-federal project partner's management measures in any significant way, the O&M costs were estimated to be zero dollars for each alternative. Real estate costs include the direct administrative costs of overseeing and implementing a temporary construction easement with a private land owner for purposes of access, along with any agreement required with Washington Department of Natural

Recourses for placement of material on their lands above and below the ordinary high water mark (OHWM).

Monitoring costs assume that the Corps will monitor changes in juvenile salmonid habitat for a 3-year period after construction. CREST will monitor the project for the remaining project life. Monitoring costs included the establishment of sampling points, the recording and collection of data, labor for drafting reports, and mileage to and from the project site and, for purposes of analysis, has been assumed to be 1% of the total construction costs.

All planning level cost estimates were expressed in terms of average annual dollars, combining all construction, monitoring, O&M, real estate, and IDC costs amortized at the fiscal year 2018 federal discount rate of 2.75% over the project life of 50 years.

After estimating the costs and outputs of each measure and combination of measures to derive the cost of the alternatives, the alternatives were sorted in terms of increasing output. This is done as a prelude to the cost effectiveness and incremental cost analysis to determine which alternative cost the least for each level of output and to determine when/if the law of diminishing returns will apply when analyzing the efficiency of each of the cost effective plans. The Corps' Institute for Water Resources Cost-Effectiveness and Incremental Cost Analysis software (IWR-PLAN version 2.0.9.1 10/30/2017) was used to analyze, tabulate, graph and chart the project alternatives.

While the CE / ICA analyses will usually not lead, and are not intended to lead, to a single best solution (as in economic benefit-cost analysis), it improves the quality of decision making by ensuring that a rational, supportable, focused and traceable approach is used for considering and selecting alternatives for ecosystem restoration.

This appendix briefly summarizes the plan formulation and modeling efforts for this ecosystem restoration project. The contents of this appendix are as follows:

- Section 1, Overview of Cost Effectiveness and Incremental Cost Analyses
- Section 2, Summary of Plan Formulation and Identification of Restoration Alternatives
- Section 3, Evaluation of Project Benefits
- Section 4, Evaluation of Project Costs
- Section 5, IWR Planning Suite Model Inputs
- Section 6, Cost Effectiveness and Incremental Cost Analysis (CE/ICA) Alternatives Evaluation
- Section 7, Final Array of Alternatives
- Section 8, Recommended Plan
- Section 9, References

2. SUMMARY OF PLAN FORMULATION AND IDENTIFICATION OF RESTORATION ALTERNATIVES

The planning process included the identification of problems, opportunities, objectives and constraints, as well as the identification of management measures, the establishment of screening criteria, and alternatives screening, all of which is documented in Chapters 2 and 3 of this integrated report.

The array of alternatives was formulated based on historical hydrographic surveys and technical constraints identified by the engineers discussed with the rest of the team. A review of prior shoaling activity indicates a minimum of 200,000 cubic yards accumulates annually at the confluence of the Columbia and Lewis River. This quantity was established as the minimum amount of dredge material necessary for a successful project. Constraints include the quantity of material that could be placed without adversely impacting the FEMA flood profile of adjoining properties. Best professional judgement to maximize ecosystem restoration benefits, such as certainty of success, was also used to formulate the array of alternatives considered in this CE / ICA analysis.

The alternatives were derived by identifying all possible combinations of a given set of management measures. The primary (base) measure for this project was the placement of dredged material. A base measure is a key measure for which all project alternatives are based (and improve the quantity or quality of the ecosystem). All additional measures depend upon implementation of the base measure.

Due to the quantity of aggradation expected at the confluence of the Lewis and Columbia Rivers, and the constraint of using the Dredge Oregon for a single season for this restoration effort, only three base measures were considered for this project: placement of either 200,000 (200K), 300,000 (300K), or 400,000 (400K) cubic yards of material placed within the Woodland Island complex. All of these base measures were considered mutually exclusive, as they represented the total quantity of a one-time placement of dredge material. Secondary measures included additional grading of the placed material (complex grading) to establish topographical features beneficial for creation of desired ecosystem restoration habitat. Complex grading (CG) could occur with any one of the base measures: Complex Grading with either the placement of 200K, 300K or 400K cubic yards of material (200K + CG or 300K + CG or 400K + CG). Planting of specific types of Willows for the promotion of both upland and aquatic habitat for this restoration effort was also considered. The planting of Willows could be combined with either the simple placement of material or the placement of material along with the complex grading. As a result, 13 combinations of measures were identified by the PDT:

<u>Plan</u>	<u>Plan Description</u>
No Action Plan	Default No Action Plan
A	200Kcyds of Dredge Material
B	300Kcyds of Dredge Material
C	400Kcyds of Dredge Material
D	200Kcyds of Dredge Material + Complex Grading
E	300Kcyds of Dredge Material + Complex Grading
F	400Kcyds of Dredge Material + Complex Grading
G	200Kcyds of Dredge Material + Willows
H	300Kcyds of Dredge Material + Willows
I	400Kcyds of Dredge Material + Willows
J	200Kcyds of Dredge Material + Complex Grading +Willows
K	300Kcyds of Dredge Material + Complex Grading +Willows
L	400Kcyds of Dredge Material + Complex Grading +Willows

A map of the study area and its vicinity is shown as Figure 1 in the main report. A map showing typical ground surface and bed elevations is shown as Figure 2 of the main report. A conceptual terrain depicting added topographic diversity possible with additional grading is provided as Figure 4 of the main report.

3. EVALUATION OF PROJECT BENEFITS

Habitat Evaluation Procedures (HEP) is an ecosystem restoration model used to evaluate and document expected habitat losses and habitat gains resulting from various project alternatives. HEP documents the change in habitat availability for selected species through the application of their respective habitat suitability indices (HSI). The HSI value, a proxy for habitat quality, is derived from an evaluation of key habitat components and the life requisites of selected wildlife and fish species. Total habitat is a product of habitat area and habitat quality. The habitat quality value for a given area is assigned values representative of the whole area of interest, which may include an area of decreased quality along exposed shorelines, for example.

Two species were selected for use in the Woodland Island HEP - yellow warbler and juvenile Chinook salmon in a mainstem river. The HSI variables for both species along with assumptions about project-related impacts to HSI variables as needed for CE / ICA analysis are described for both species in the following sections.

3.1. YELLOW WARBLER

Yellow Warbler habitat is defined as the acreage of nesting areas (a constant, non-overlapping circular area of 0.15 ha per territory) with suitable vegetation that falls within the elevation bands 10 to 14 feet NAVD. The total nesting area is approximately equal to 90% of the total area in this elevation band.

This HEP model includes three HSI variables for Yellow Warbler.

Variable	Metric	Description
V1	Percent deciduous shrub canopy cover	Percent cover in the elevation range from 10 to 14 is dependent on measures Habitat quality is less for existing conditions (V1 = 0.5) due to patchy willows along shoreline Habitat quality is slightly better for with-project conditions and natural planting (V1 = 0.6) Habitat quality is increased with the planting measure (V1 = 1.0) Habitat quality not sensitive to placement site (1 vs 2 vs combined)
V2	Average height of deciduous shrub canopy	Constant for all conditions - all willows are assumed to reach a height of 6’ or greater by year 5, regardless of planting or grading measures (V = 0.9)
V3	Percent shrub canopy composed of hydrophytic shrubs	Constant for all conditions - all shrubs that will naturally grow or be planted in this elevation range are hydrophytic shrubs (V3 = 1.0)

Table 3.1.1 HSI Variables for Yellow Warblers

3.2. JUVENILE CHINOOK SALMON

Juvenile Salmon habitat is defined as area within 20 meters from the average shoreline elevation, assumed to be at 10 feet NAVD. The three HSI variables in the table below describe the quality of the habitat in that area and/or along the shoreline.

Variable	Metric	Description
V1	Percent cover of bank vegetation	Percent shrub cover at shoreline is sensitive to planting measures - Existing conditions and measures without plantings have less than ideal cover (V1 = 0.3) Habitat quality increases with planting measures (V1 = 0.6)
V2	Availability (depth metric)	Depth metric varies depending on grading method - depth near shore is within target range but not optimal (V2 = 0.6)
V3	Substrate	Constant for all conditions - assumed substrate is sand, EAV, or SAV (V3 = 1.0) for all conditions, in all locations

Table 3.1.2 HSI Variables for Juvenile Chinook Salmon

3.3. HEP MODEL RESULTS

In the HEP model in the current design, areas further than 20m from the shoreline are not assigned any habitat value. This includes existing and created shallow water habitat areas and protected embayment areas.

The HEP model is not sensitive to habitat benefits created by sheltering effects or terrain variations created by complex grading, which could have subtle effects on rate of growth, vigor, etc. of planted willows and shoreline vegetation.

The HEP model does not account for any fluvial morphological functions including increased stability due to vegetation, relatively stability due to feature location, wind-wave sheltering effects, etc.

Habitat complexity and certainty of success are not evaluated in the HEP model.

The HEP model uses acreages from area-volume relationships developed from analysis of coarsely developed terrain models from earlier iterations of the project. The analysis included a number of simplifying assumptions of the relationship between habitat area and placement volume, and looked at effect of location and complex grading at various project sizes. The figure below shows the area-volume relationship used to calculate habitat areas used in the HEP analysis.

	Basic, Total			Complex Grading		
V, Kcy	Total	Basic Salmon	Basic, Warbler	Total	Complex Salmon	Complex, Warbler
200	18	3.6	14.4	18.6	4.7	14
300	21.6	4.3	17.3	22.5	5.6	16.9
400	27	5.4	21.6	28.2	7.1	21.2

Table 3.1.3.1 Area Volume Relationships for the Indicator Species

The table above indicates the habitat acres of dredged material available to juvenile salmon and yellow warbler at the Woodland Island Complex.

The table below summarizes the derivation of Habitat Units for Yellow Warblers, the indicator species for a number of terrestrial species, especially passerine avian species

	Yellow Warbler HSI					
Alternative	V1	V2	V3	Aggregate	Area (acres)	AAHU for Warblers
No Action	0.5	0.9	1.0	0.8	N/A	N/A
Place 200 Kcyds	0.5	1.0	1.0	0.8	14.4	11.60
Place 200 Kcyds, CG	0.5	1.0	1.0	0.8	14	11.28
Place 200 Kcyds, Plantings	1.0	1.0	1.0	1.0	14.4	14.28
Place 200 Kcyds, CG, PP	1.0	1.0	1.0	1.0	14	13.88
Place 300 Kcyds	0.5	1.0	1.0	0.8	17.3	13.94
Place 300 Kcyds, CG	0.5	1.0	1.0	0.8	16.9	13.61
Place 300 Kcyds, Plantings	1.0	1.0	1.0	1.0	17.3	17.16
Place 300 Kcyds, CG, Plantings	1.0	1.0	1.0	1.0	16.9	16.76
Place 400 Kcyds	0.5	1.0	1.0	0.8	21.6	17.40
Place 400 Kcyds, CG	0.5	1.0	1.0	0.8	21.2	17.08
Place 400 Kcyds, Plantings	1.0	1.0	1.0	1.0	21.6	21.42
Place 400 Kcyds, CG, Plantings	1.0	1.0	1.0	1.0	21.2	21.02

Table 3.1.3.2 Average Annual Habitat Units for Yellow Warblers

The table below summarizes the derivation of the Habitat Units for Chinook Salmon, the indicator species for aquatic anadromous fish.

	Chinook HSI					
Alternative	**V1**	**V2**	**V3**	**Aggregate**	**Area (acres)**	**AAHU for Juv-Chinook**
No Action	0.3	1	1.0	0.8	N/A	N/A
Place 200 Kcyds	1.0	1.0	1.0	1.0	3.6	3.6
Place 200 Kcyds, CG	1.0	1.0	1.0	1.0	4.7	4.7
Place 200 Kcyds, Planting	0.2	1.0	1.0	0.7	3.6	2.6
Place 200 Kcyds, CG, PP	0.2	1.0	1.0	0.7	4.7	3.4
Place 300 Kcyds	1.0	1.0	1.0	1.0	4.3	4.3
Place 300 Kcyds, CG	1.0	1.0	1.0	1.0	5.6	5.6
Place 300 Kcyds, Plantings	0.2	1.0	1.0	0.7	4.3	3.2
Place 300 Kcyds, CG, Plantings	0.2	1.0	1.0	0.7	5.6	4.1
Place 400 Kcyds	1.0	1.0	1.0	1.0	5.4	5.4
Place 400 Kcyds, CG	1.0	1.0	1.0	1.0	7.1	7.1
Place 400 Kcyds, Plantings	0.2	1.0	1.0	0.7	5.4	4.0
Place 400 Kcyds, CG, Plantings	0.2	1.0	1.0	0.7	7.1	5.2

Table 3.1.3.3 Average Annual Habitat Units for Juvenile Chinook Salmon

The table below is a sum of the Habitat Units for each species (Yellow Warblers and Chinook Salmon) and is used as the ecological lift (benefits or outputs) in the IWR Planning Suite Software.

Alternative	**Total AAHUs**
No Action	18.28
Place 200 Kcyds	15.20
Place 200 Kcyds, CG	15.98
Place 200 Kcyds, Planting	16.92
Place 200 Kcyds, CG, PP	17.33
Place 300 Kcyds	18.24
Place 300 Kcyds, CG	19.21
Place 300 Kcyds, Plantings	20.31
Place 300 Kcyds, CG, Plantings	20.87
Place 400 Kcyds	22.80
Place 400 Kcyds, CG	24.18
Place 400 Kcyds, Plantings	25.38
Place 400 Kcyds, CG, Plantings	26.23

Table 3.1.3.4 Total Average Annual Habitat Units for Juvenile Chinook Salmon and Yellow Warblers

4. EVALUATION OF PROJECT COSTS

Table 4-1 below shows the total investment cost along with the annualized investment cost and the economic components required to derive the estimated investment cost for each alternative.

The total investment cost for this Section 204 project considers all economic costs for the proposed alternatives. The economic costs include development costs (construction costs), monitoring costs (1% of construction costs), real estate costs, operation and maintenance (O&M) costs, and interest during construction (IDC). Because a cultural investigation revealed no cultural relics, artifacts, or other matters that would require potential mitigation, no cultural mitigation costs were deemed required for this economic analysis. In order to compare costs with average annual environmental outputs (HU's), it was necessary to convert the total investment costs to average annual costs. All economic costs formulating the total investment cost were based on November 2017 price levels, present-valued and amortized at the fiscal year 2018 federal discount rate of 2.75% over the 50 year project life. Additional cost information can be found in Appendix D, Cost Estimate.

Alternatives	Implementation Costs ($)	RE Costs ($)	O&M Costs ($)	Monitoring Costs ($)	IDC ($)	Total ($)	AVE Annual Costs ($)
No Action	-	-	-	-	-	-	-
Plan A - Place 200K cyds	$ 397,161	$ 25,000	$ -	$ 3,972	$ 10,511	$ 436,644	$ 16,174
Plan B - Place 200K cyds + Complex Grading	$ 434,949	$ 25,000	$ -	$ 4,349	$ 11,511	$ 475,809	$ 17,624
Plan C Place 200K cyds + Planting of Willows	$ 630,355	$ 25,000	$ -	$ 6,304	$ 16,682	$ 678,340	$ 25,126
Plan D - Place 200K cyds + Complex Grading + Planting of Willows	$ 661,665	$ 25,000	$ -	$ 6,617	$ 17,511	$ 710,793	$ 26,328
Plan E - Place 300K cyds	$ 449,938	$ 25,000	$ -	$ 4,499	$ 11,908	$ 491,345	$ 18,200
Plan F - Place 300K cyds + Complex Grading	$ 494,536	$ 25,000	$ -	$ 4,945	$ 13,088	$ 537,569	$ 19,912
Plan G - Place 300K cyds + Planting of Willows	$ 730,094	$ 25,000	$ -	$ 7,301	$ 19,322	$ 781,717	$ 28,956

Alternatives	Implementation Costs ($)	RE Costs ($)	O&M Costs ($)	Monitoring Costs ($)	IDC ($)	Total ($)	AVE Annual Costs ($)
Plan H - Place 300K cyds + Complex Grading + Planting of Willows	$ 768,215	$ 25,000	$ -	$ 7,682	$ 20,331	$ 821,228	$ 30,419
Plan I - Place 400K cyds	$ 502,715	$ 25,000	$ -	$ 5,027	$ 13,304	$ 546,046	$ 20,226
Plan J - Place 400K cyds + Complex Grading	$ 562,179	$ 25,000	$ -	$ 5,622	$ 14,878	$ 607,679	$ 22,509
Plan K - Place 400K cyds + Planting of Willows	$ 852,505	$ 25,000	$ -	$ 8,525	$ 22,561	$ 908,591	$ 33,655
Plan L - Place 400K cyds + Complex Grading + Planting of Willows	$ 905,492	$ 25,000	$ -	$ 9,055	$ 23,964	$ 963,511	$ 35,689

Table 4.1 Total Average Annual Costs for Each Alternative

4.1. Construction Costs

Preliminary planning level construction costs were provided by Cost Engineering. Although the costs included mobilization and demobilization, job office overhead, home office overhead, profit, and bond, the cost estimate does not include contingency, or construction management (S&A). These costs will be estimated during the development of the MII cost estimate after selection of the Tentatively Selected Plan. Please see Appendix D, the Cost Appendix, for additional details and a listing of the assumptions that were used during the development of the cost estimate. The following table arranges the alternatives by increasing levels of output, and then illustrates the Incremental Output, Total Construction Cost, Average Annual Construction Cost, Average Total Construction Cost, Marginal Construction Costs, the Incremental Cost per unit of incremental output, and Percent of Total Implementation Cost for each of the alternatives.

Plan	output	Incremental Output	Total Construction Cost	Average Annual Costs	Average Costs	Incremental (marginal) Costs	Incremental Cost per Incremental Output	% of Total Implementation Costs
A	15.2	15.2	$ 397,161	$ 14,711	$ 26,129	$ 397,161	$ 26,129	93%
D	15.98	0.78	$ 661,665	$ 24,509	$ 41,406	$ 264,504	$ 339,108	95%
G	16.92	0.94	$ 730,094	$ 27,043	$ 43,150	$ 14,989	$ 15,946	96%

J	17.33	0.41	$ 562,179	$ 20,824	$ 32,440	$ (167,915)	$ (409,549)	96%
B	18.24	0.91	$ 434,949	$ 16,111	$ 23,846	$ (127,230)	$ (139,813)	93%
E	19.21	0.97	$ 449,938	$ 16,666	$ 23,422	$ 14,989	$ 15,453	94%
H	20.31	1.1	$ 768,215	$ 28,455	$ 37,824	$ 318,277	$ 289,342	96%
K	20.87	0.56	$ 852,505	$ 31,578	$ 40,848	$ 84,291	$ 150,519	96%
C	22.8	1.93	$ 630,355	$ 23,349	$ 27,647	$ (222,151)	$ (115,104)	95%
F	24.18	1.38	$ 494,536	$ 18,318	$ 20,452	$ (135,819)	$ (98,419)	94%
I	25.38	1.2	$ 502,715	$ 18,621	$ 19,808	$ 8,179	$ 6,816	94%
L	26.23	0.85	$ 905,492	$ 33,540	$ 34,521	$ 402,777	$ 473,855	96%

Table 4.1.2 Construction Costs for Each Alternative

4.2. OPERATION AND MAINTENANCE COSTS

As mentioned above, all project alternatives are not expected to add to or alter the current non-federal project partner's management activities in any significant way and, therefore, the O&M costs were estimated to be zero dollars for each alternative.

4.3. MONITORING COSTS

Monitoring costs for CE / ICA are assumed to be 1% of the construction costs. Tasks are assumed to include the establishment of field sampling geo-referenced photo points, use of data logging instruments to collect data on water surface elevations and water temperatures, archaeological monitoring of all ground-disturbing activities during ground reconfigurations and construction to ensure that no subsurface or undetected cultural resources are disturbed or inadvertently discovered, review of high-resolution aerial photographs and use of field survey transects to identify, delineate and compare emergent marsh species and invasive plant species development, and the gathering and reporting of data on an annual basis. The following table arranges the alternatives by increasing levels of output, and then illustrates the Incremental Output, Total Monitoring Cost, Average Annual Monitoring Cost, Average Total Monitoring Cost, Marginal Monitoring Costs, the Incremental Cost per unit of Incremental Output, and Percent of Total Implementation Cost for each of the alternatives.

Plan	output	Incremental Output	Total Monitoring Cost	Average Annual Costs	Average Costs	Incremental (marginal) Costs	Incremental Cost per Incremental Output	% of Total Implementation Costs
A	15.2	15.2	$ 3,972	$ 147	$ 261	$ 3,972	$ 261	1%
D	15.98	0.78	$ 7,151	$ 265	$ 448	$ 3,179	$ 4,076	1%
G	16.92	0.94	$ 7,301	$ 270	$ 431	$ 150	$ 159	1%
J	17.33	0.41	$ 5,622	$ 208	$ 324	$ (1,679)	$ (4,095)	1%
B	18.24	0.91	$ 4,349	$ 161	$ 238	$ (1,272)	$ (1,398)	1%
E	19.21	0.97	$ 4,499	$ 167	$ 234	$ 150	$ 155	1%
H	20.31	1.1	$ 7,682	$ 285	$ 378	$ 3,183	$ 2,893	1%
K	20.87	0.56	$ 8,525	$ 316	$ 408	$ 843	$ 1,505	1%
C	22.8	1.93	$ 6,304	$ 233	$ 276	$ (2,222)	$ (1,151)	1%
F	24.18	1.38	$ 4,945	$ 183	$ 205	$ (1,358)	$ (984)	1%
I	25.38	1.2	$ 5,027	$ 186	$ 198	$ 82	$ 68	1%
L	26.23	0.85	$ 9,055	$ 335	$ 345	$ 4,028	$ 4,739	1%

Table 4.1.3 Monitoring Costs for Each Alternative

4.4. INTEREST DURING CONSTRUCTION

Interest during construction (IDC) is calculated as a pre-base year cost adjustment, where the base year is the year when the project is expected to be "operational." This calculation brings costs incurred before the base year equivalent in time value to other benefits and costs. This amount is added to the other costs of the project and is included as part of the average annual cost. The IDC is calculated using the fiscal year 2018 discount rate of 2.75%, with a construction period projected to be twenty-four months in duration, and assumes middle of the month payments during the construction period. The following table arranges the alternatives by increasing levels of output, and then illustrates the Incremental Output, Total IDC Cost, Average Annual IDC Cost, Average Total IDC Cost, Marginal IDC Costs, the Incremental Cost per unit of Incremental Output, and Percent of Total Implementation Cost for each of the alternatives.

Plan	output	Incremental Output	Total IDC Cost	Average Annual Costs	Average Costs	Incremental (marginal) Costs	Incremental Cost per Incremental Output	% of Total Implementation Costs
A	15.2	15.2	$ 10,511	$ 389	$ 692	$ 10,511	$ 692	2.41%
D	15.98	0.78	$ 17,511	$ 649	$ 1096	$ 7,000	$ 8,974	2.46%
G	16.92	0.94	$ 19,322	$ 716	$ 1,142	$ 1,811	$ 1,927	2.47%
J	17.33	0.41	$ 14,878	$ 551	$859	($4,444)	($10,839)	2.45%
B	18.24	0.91	$ 11,511	$426	$631	($3,367)	($3,700)	2.42%
E	19.21	0.97	$ 11,908	$441	$620	$397	$409	2.42%
H	20.31	1.1	$ 20,331	$753	$1,001	$8,423	$7,657	2.48%
K	20.87	0.56	$ 22,561	$836	$1,081	$2,230	$3,982	2.48%
C	22.8	1.93	$ 16,682	$618	$732	($5,879)	($3,046)	2.46%
F	24.18	1.38	$ 13,088	$485	$541	($3,594)	($2,604)	2.43%
I	25.38	1.2	$ 13,304	$493	$524	$216	$180	2.44%
L	26.23	0.85	$ 23,964	$888	$914	$10,660	$12,541	2.49%

Table 4.1.4 IDC Costs for Each Alternative

4.5. REAL ESTATE

As the exact location for placement of material has not been identified, the real estate costs are "worst case scenarios" whereby it is assumed the costs include the direct administrative costs of overseeing and implementing a temporary construction easement with a private land owner for purposes of access, along with any agreement required with Washington Department of Natural Recourses for placement of material on their lands above and below the Ordinary High Water mark. The following table arranges the alternatives by increasing levels of output, and then illustrates the Incremental Output, Total Real Estate Cost, Average Annual Real Estate Cost, Average Total Real Estate Cost, Marginal Real Estate Costs, the Incremental Cost per unit of Incremental Output, and Percent of Total Implementation Cost for each of the alternatives.

Plan	output	Incremental Output	Total Real Estate Cost	Average Annual Costs	Average Costs	Incremental (marginal) Costs	Incremental Cost per Incremental Output	% of Total Implementation Costs
A	15.2	15.2	$ 25,000	$ 926	$ 1,645	$ 25,000	$ 1,645	5.85%
D	15.98	0.78	$ 25,000	$ 926	$ 1,564	$ 0	$ 0	3.34%
G	16.92	0.94	$ 25,000	$ 926	$ 1,478	$ 0	$ 0	3.27%
J	17.33	0.41	$ 25,000	$ 926	$ 1,443	$ 0	$ 0	4.21%
B	18.24	0.91	$ 25,000	$ 926	$ 1,371	$ 0	$ 0	5.37%
E	19.21	0.97	$ 25,000	$ 926	$ 1,301	$ 0	$ 0	5.20%

H	20.31	1.1	$ 25,000	$ 926	$ 1,231	$ 0	$ 0	3.11%
K	20.87	0.56	$ 25,000	$ 926	$ 1,198	$ 0	$ 0	2.81%
C	22.8	1.93	$ 25,000	$ 926	$ 1,096	$ 0	$ 0	3.77%
F	24.18	1.38	$ 25,000	$ 926	$ 1,034	$ 0	$ 0	4.76%
I	25.38	1.2	$ 25,000	$ 926	$ 985	$ 0	$ 0	4.68%
L	26.23	0.85	$ 25,000	$ 926	$ 953	$ 0	$ 0	2.65%

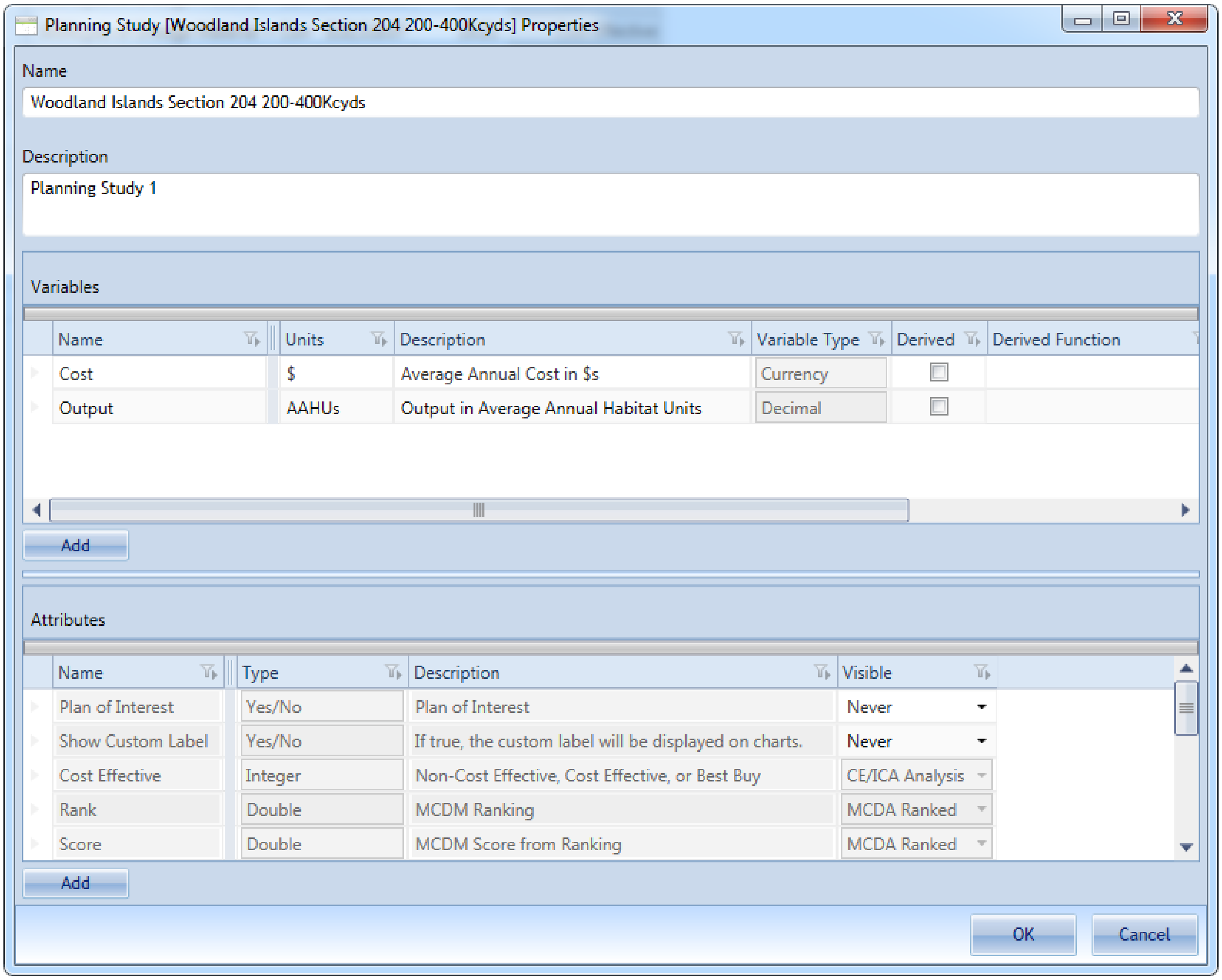
Table 4.1.5 Real Estate Costs for Each Alternative

5. IWR PLANNING SUITE MODEL INPUTS

This section describes the model inputs for performing the cost effectiveness and incremental cost analyses using the IWR Planning Suite, version 2.0.9.1. The USACE Institute for Water Resources (IWR) developed this software to assist with the formulation and comparison of alternative plans. The software can assist with plan formulation by combining solutions to planning problems and calculating the additive effect of each combination, or “plan”, by utilizing inputs on outputs (AAHU’s), costs, and rules (combinability and dependency relationships) for combining solutions into plans. Plans are then compared in IWR Planning Suite by conducting cost effectiveness and incremental cost analyses (CE/ICA), identifying the plans which are the best financial investments, and displaying the effects of each on a range of decision variables.

5.1. PLANNING STUDY PROPERTIES

Figure 5-1 below displays the variables used for the cost effectiveness and incremental cost analysis. Costs were input in terms of total average annual cost, where the values are displayed in $1s, while the output scores are input in terms of average annual habitat units (AAHU).



Planning Study [Woodland Islands Section 204 200-400Kcyds] Properties

Name: Woodland Islands Section 204 200-400Kcyds

Description: Planning Study 1

Variables

Name	Units	Description	Variable Type	Derived	Derived Function
Cost	$	Average Annual Cost in $s	Currency	☐	
Output	AAHUs	Output in Average Annual Habitat Units	Decimal	☐	

Attributes

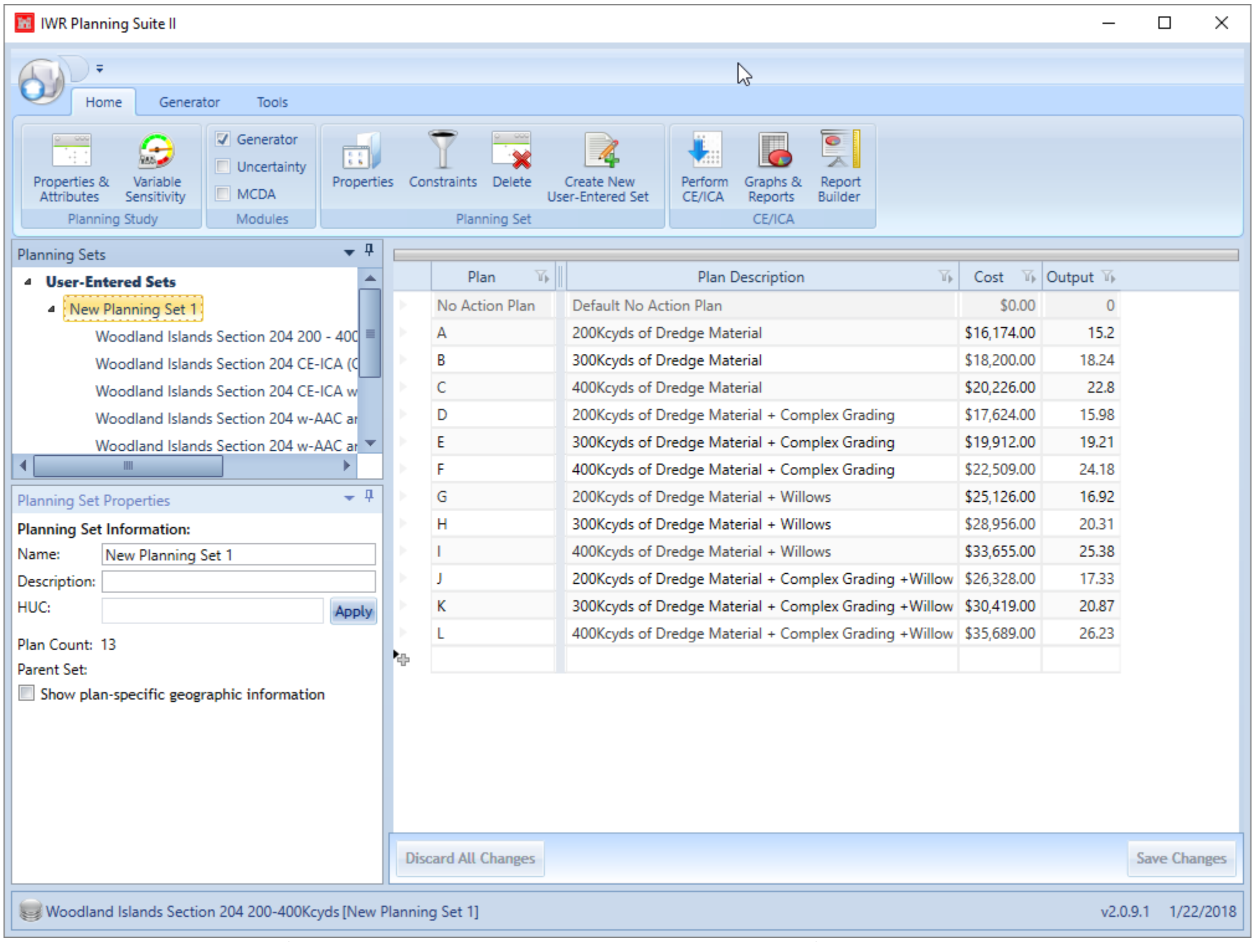
Name	Type	Description	Visible
Plan of Interest	Yes/No	Plan of Interest	Never
Show Custom Label	Yes/No	If true, the custom label will be displayed on charts.	Never
Cost Effective	Integer	Non-Cost Effective, Cost Effective, or Best Buy	CE/ICA Analysis
Rank	Double	MCDM Ranking	MCDA Ranked
Score	Double	MCDM Score from Ranking	MCDA Ranked

Figure 5.1 Planning Study Properties for Woodland Islands, Section 204

5.2. SOLUTIONS AND SCALES

Although the IWR Planning Suite (Version 2.0.9.1) has the capability to combine the project measures into the full range of alternatives through the use of solutions, scales, and by defining the appropriate relationships (dependencies and combinability's) through the use of the IWR generator, for this particular study the PDT established the full range of alternatives and then the total cost and benefit for each alternatives was entered into the IWR Planning Suite.

Figure 5.2 below displays the costs, benefits for each alternative, and serves as the planning set for performing CE / ICA.



User-Entered Sets
New Planning Set 1
Woodland Islands Section 204 200 - 400
Woodland Islands Section 204 CE-ICA (C
Woodland Islands Section 204 CE-ICA w
Woodland Islands Section 204 w-AAC ar
Woodland Islands Section 204 w-AAC ar

Planning Set Properties

Planning Set Information:
Name: New Planning Set 1
Description:
HUC:
Plan Count: 13
Parent Set:
☐ Show plan-specific geographic information

Plan	Plan Description	Cost	Output
No Action Plan	Default No Action Plan	$0.00	0
A	200Kcyds of Dredge Material	$16,174.00	15.2
B	300Kcyds of Dredge Material	$18,200.00	18.24
C	400Kcyds of Dredge Material	$20,226.00	22.8
D	200Kcyds of Dredge Material + Complex Grading	$17,624.00	15.98
E	300Kcyds of Dredge Material + Complex Grading	$19,912.00	19.21
F	400Kcyds of Dredge Material + Complex Grading	$22,509.00	24.18
G	200Kcyds of Dredge Material + Willows	$25,126.00	16.92
H	300Kcyds of Dredge Material + Willows	$28,956.00	20.31
I	400Kcyds of Dredge Material + Willows	$33,655.00	25.38
J	200Kcyds of Dredge Material + Complex Grading +Willow	$26,328.00	17.33
K	300Kcyds of Dredge Material + Complex Grading +Willow	$30,419.00	20.87
L	400Kcyds of Dredge Material + Complex Grading +Willow	$35,689.00	26.23

Woodland Islands Section 204 200-400Kcyds [New Planning Set 1] v2.0.9.1 1/22/2018

Figure 5.2 The Plan Description for each alternative along with their associated costs and benefits (Output)

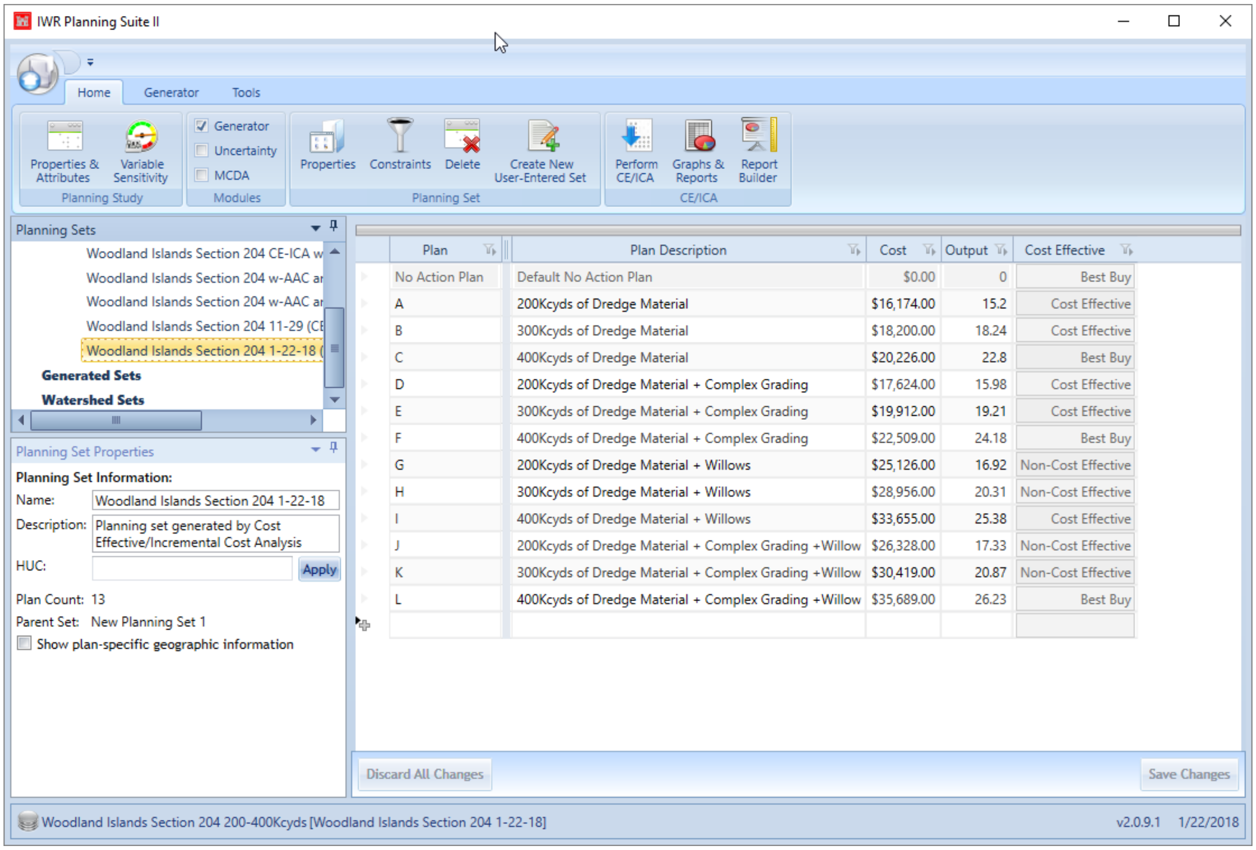
5.3. SOLUTION RELATIONSHIPS – DEPENDENCY AND COMBINABILITY

When formulating plans, it is important to understand which management measures under consideration can be combined with other management measures. Analysis of functionally dependent, mutually dependent and independent management measures becomes especially important for plan formulation and use of the IWR-PLAN software. For this Woodland Islands Section 204 study, the dependent measures (complex grading and the planting of Willows) are manually combined with their associated base measure, the amount of placed dredged material. The manually entered solutions have one scale for each solution, and is run independent and not combinable with any of the other solutions.

6. COST EFFECTIVENESS AND INCREMENTAL COST ANALYSIS (CE/ICA) ALTERNATIVES EVALUATION

Traditional benefit-cost analysis is not possible for this restoration study because costs and benefits are expressed in different units. Rather, cost effectiveness and incremental cost analysis was used to assist the process of determining what project features and design alternatives should be built based on comparison of quantified habitat benefits (outputs) and estimated costs of the full range of alternative features. Cost effectiveness analysis is conducted to ensure that the least cost plan is identified for each possible level of ecosystem restoration output and that, for any level of investment, the maximum level of output is identified. Subsequent incremental cost analysis of the cost effective plans is conducted to reveal changes in costs as output levels are increased. The cost effective plans that provide the greatest incremental increase in output for the smallest incremental increase in cost is called a "best buy" plan.

Given the IWR Planning Suite inputs described in Section 5 above, a total of 13 plans were entered into the parent planning set. Of these 13 plans (including the No-Action Alternative), nine plans were identified as being cost effective using the cost effectiveness analysis. Cost effective plans are identified as either "Best-Buy" or "Cost Effective" plans in Figure 6-1 below, along with the "Non-Cost Effective" plans.



Planning Set Information:

Name: Woodland Islands Section 204 1-22-18

Description: Planning set generated by Cost Effective/Incremental Cost Analysis

HUC:

Plan Count: 13

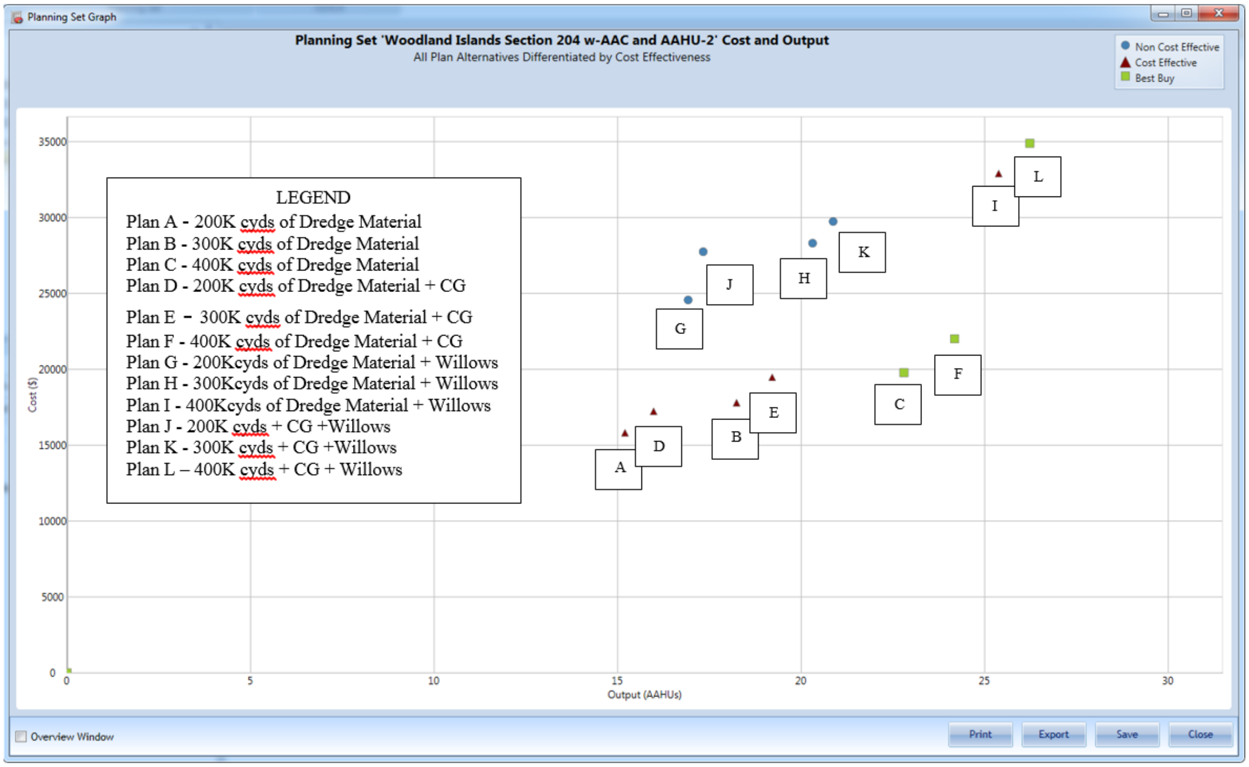
Parent Set: New Planning Set 1

☐ Show plan-specific geographic information

Plan	Plan Description	Cost	Output	Cost Effective
No Action Plan	Default No Action Plan	$0.00	0	Best Buy
A	200Kcyds of Dredge Material	$16,174.00	15.2	Cost Effective
B	300Kcyds of Dredge Material	$18,200.00	18.24	Cost Effective
C	400Kcyds of Dredge Material	$20,226.00	22.8	Best Buy
D	200Kcyds of Dredge Material + Complex Grading	$17,624.00	15.98	Cost Effective
E	300Kcyds of Dredge Material + Complex Grading	$19,912.00	19.21	Cost Effective
F	400Kcyds of Dredge Material + Complex Grading	$22,509.00	24.18	Best Buy
G	200Kcyds of Dredge Material + Willows	$25,126.00	16.92	Non-Cost Effective
H	300Kcyds of Dredge Material + Willows	$28,956.00	20.31	Non-Cost Effective
I	400Kcyds of Dredge Material + Willows	$33,655.00	25.38	Cost Effective
J	200Kcyds of Dredge Material + Complex Grading +Willow	$26,328.00	17.33	Non-Cost Effective
K	300Kcyds of Dredge Material + Complex Grading +Willow	$30,419.00	20.87	Non-Cost Effective
L	400Kcyds of Dredge Material + Complex Grading +Willow	$35,689.00	26.23	Best Buy

Figure 6.1 A list of all Cost Effective, Best Buy and Non-Cost Effective Plans

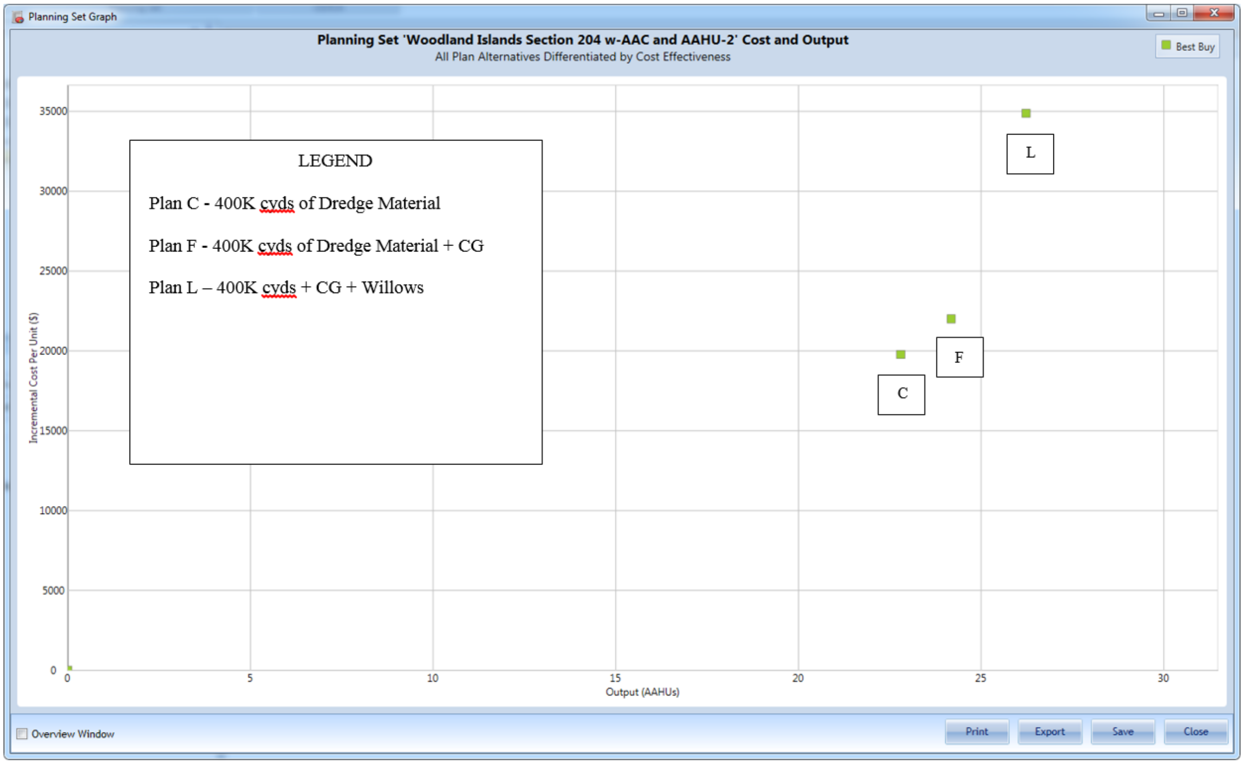
A Cartesian graph of all possible plans are displayed in Figure 6-2, with those plans which provide a given level of output at the lowest cost denoted by red triangles and green squares. Those plans which are not cost effective are denoted by blue circles. Figure 6-3 displays simply the "best buy" plans, and are the plans that are carried forward into the final array of alternatives. The process used to carry these plans forward is described in Section 7



LEGEND

Plan A - 200K cyds of Dredge Material
Plan B - 300K cyds of Dredge Material
Plan C - 400K cyds of Dredge Material
Plan D - 200K cyds of Dredge Material + CG
Plan E - 300K cyds of Dredge Material + CG
Plan F - 400K cyds of Dredge Material + CG
Plan G - 200Kcyds of Dredge Material + Willows
Plan H - 300Kcyds of Dredge Material + Willows
Plan I - 400Kcyds of Dredge Material + Willows
Plan J - 200K cyds + CG +Willows
Plan K - 300K cyds + CG +Willows
Plan L – 400K cyds + CG + Willows

Figure 6.2 A Cartesian Graph of all plans, the non-cost effective plans, best-buy plans and the cost effective plans.



LEGEND

Plan C - 400K cyds of Dredge Material

Plan F - 400K cyds of Dredge Material + CG

Plan L – 400K cyds + CG + Willows

Figure 6.3 A Cartesian Graph of just the Best Buy Plan, which are carried forward for the final array of alternatives

7. FINAL ARRAY OF ALTERNATIVES

The alternatives carried forward for detailed evaluation in the final array were chosen based on CE / ICA results. The three Best-Buy plans constitute the final array of alternatives. "Best Buy" plans are defined as those cost effective plans which provide the greatest incremental increase in output (benefits) for the lowest incremental increase in cost. The total cost and output were used to calculate the incremental cost and output, which then were used to calculate incremental cost per incremental output. The least cost plans that provide the greatest ecological lift for the smallest increase in costs are carried forward into the final array of alternatives. The final array of alternatives includes the No-Action Plan, the placement of 400,000 cubic yards of material (Plan C), the placement of 400,000 cubic yards of material along with additional complex grading (Plan F) and the placement of 400,000 cubic yards of material plus complex grading and the planting of Willows (Plan L). Figure 7.1, the bar chart below, portrays the three additional plans in addition to the No Action Plan to visually compare the incremental output in relation to the incremental increase in costs.

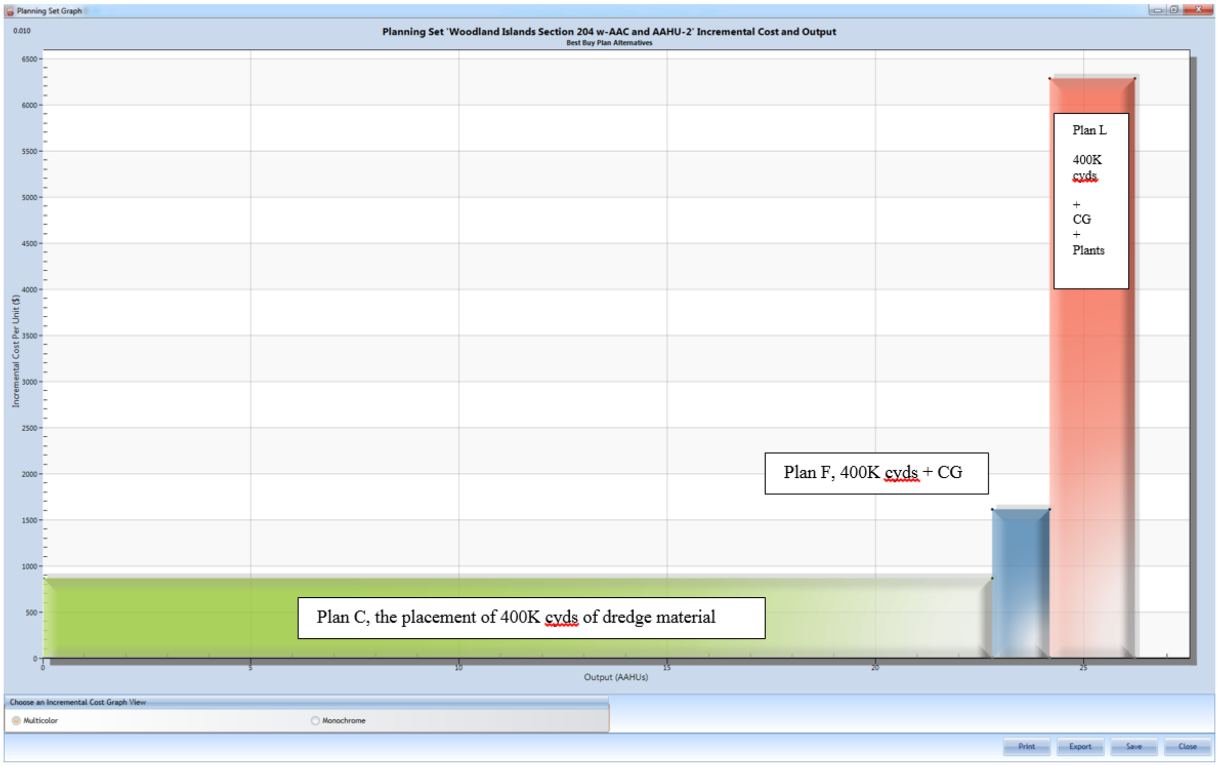
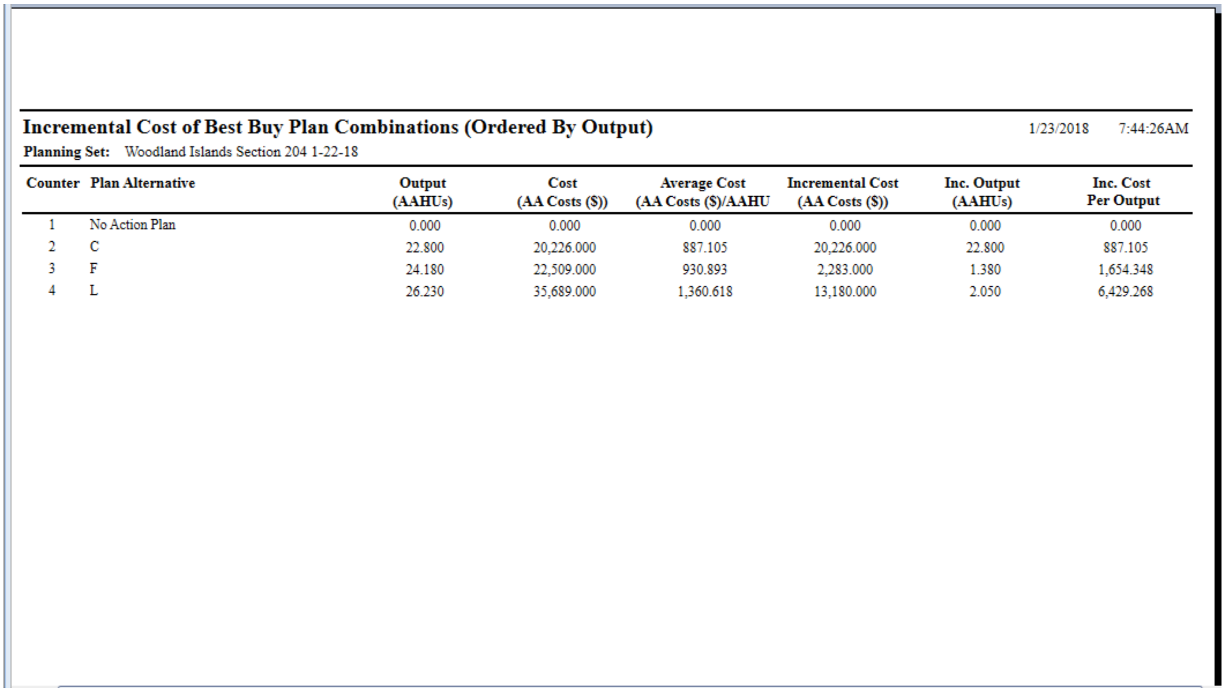


Figure 7.1 Bar chart of the best buy plans

8. SELECTION OF THE NATIONAL ECOSYSTEM RESTORATION PLAN

Table 8.1 below displays the incremental cost of the Best-Buy Plans, ordered by increasing output. Note the Incremental Cost Per Incremental Output for Plan F is almost twice that of Plan C. Also note that Incremental Cost Per Incremental Output for Plan L is almost 7 times that of Plan C.



Incremental Cost of Best Buy Plan Combinations (Ordered By Output) 1/23/2018 7:44:26AM

Planning Set: Woodland Islands Section 204 1-22-18

Counter	Plan Alternative	Output (AAHUs)	Cost (AA Costs ($))	Average Cost (AA Costs ($)/AAHU	Incremental Cost (AA Costs ($))	Inc. Output (AAHUs)	Inc. Cost Per Output
1	No Action Plan	0.000	0.000	0.000	0.000	0.000	0.000
2	C	22.800	20,226.000	887.105	20,226.000	22.800	887.105
3	F	24.180	22,509.000	930.893	2,283.000	1.380	1,654.348
4	L	26.230	35,689.000	1,360.618	13,180.000	2.050	6,429.268

Table 8.1 Incremental Cost of the Best Buy Plans

Evaluation of the alternatives is based on a comparison of the without-project condition (no action) and each of the with-project alternative conditions. The benefits are measured as the net gain (change) in environmental outputs over the existing condition. The costs of implementing each of the alternatives are then compared with the benefits of each alternative, using both the cost-effectiveness and incremental cost analysis as described above.

Conducting cost effective and incremental cost analysis through use of the IWR Planning Suite yielded those plans that were both a cost effective means of accomplishing the project objectives and make a significant contribution in addressing the opportunity to restore and improve the ecosystem function at Woodland Islands. The HEP model though lacked sufficient inputs to account for all necessary investment considerations to ensure the best realization of the project objectives. This is especially true for factors that protect the Federal investment and to restore the habitat as expeditiously as possible to maximize its sustainability by providing additional critical habitat for the endangered salmonid species. Intentionally the model did not weight the juvenile salmonids, although there is institutional significance for the species.

At first glance, the most cost effective alternative for accomplishing the restoration outputs would appear to be simply the placement of 400,000 cubic yards of material as it yields the greatest incremental output for the smallest incremental increase in cost. The National Ecosystem Restoration (NER) plan, however, is the suite of all measures: the placement of 400,000 cubic yards of material, the additional grading of the placed material (complex grading) and the manual planting of Willows (Plan L).

This plan is a best buy plan and is considered affordable, as the plan is estimated to only cost approximately one million dollars, and provides the greatest protection of the Federal investment. With the addition of plantings and additional grading, the site has increased stability to withstand potential shear forces resulting from higher flows due to climate change and the potential resulting change in hydraulics. The implementation of all measures also expeditiously establishes important habitat and detrital material for a greater complex ecosystem, providing superior foraging opportunities for the juvenile salmonids and improved protection and rearing opportunities for the yellow warblers.

The establishment of Willows better protects the Federal investment, as the plants help prevent disturbance from potential recreators who normally would prefer the sandy loam of a non-vegetated beach, such as fishermen, sunbathers, ATV use, etc. The additional habitat complexity resulting from the complex grading and the planting of willows also reduces the risk of implementation of additional adaptive management measures should monitoring activities indicate the need for additional features or activities.

Although complex grading and the planting willow stakes may be considered expensive in regard to the amount of incremental increase in ecological benefits received by implementing these measures, after careful consideration of the plan that best meets the planning objectives and constraints and reasonably maximizes environmental benefits while passing tests of cost effectiveness and incremental cost analyses, Plan L is identified as the NER plan.

It is reasonable in costs. It best meets the four planning formulation criteria of completeness, effectiveness, efficiency and acceptability. It passes the tests of CE / ICA. It maximizes environmental benefits, while accomplishing the planning objectives and constraints. It reasonably maximizes net benefits, when considering the significance of the outputs. And, it is the best alternative for protecting the Federal investment.

9. REFERENCES

USACE (U.S. Army Corps of Engineers). 2012. Economic Guidance Memorandum, 13-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2013. Available online: http://planning.usace.army.mil/toolbox/library/EGMs/EGM13-01.pdf (Accessed 25 September 2013).

USACE. 2000. ER 1105-2-100: Planning Guidance Notebook, CECW-P, 22 April 2000, as amended. Available online: http://140.194.76.129/publications/eng-regs/ER_1105-2-100/toc.htm (Accessed 25 September 2013).

USACE, Institute for Water Resources. 1994. Cost Effectiveness Analysis for Ecosystem Restoration Planning: Nine EASY Steps, IWR Report 94-PS-2, October 1994. Available online: http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/94-PS-2.pdf (Accessed 25 September 2013).

USACE, Institute for Water Resources. 1995. Evaluation of Ecosystem Restoration Investments Procedures Manual - Interim: Cost Effectiveness and Incremental Cost Analyses, IWR Report 95-R-1, 31 May 1995. Available online: http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/95-R1.pdf (Accessed 25 September 2013).

USACE, Institute for Water Resources. 2006. IWR Planning Suite User's Guide, November 2006. Available online: http://www.pmcl.com/iwrplan/IWR%20Planning%20Suite%20Users%20Guide.pdf (Accessed 25 September 2013).

U.S. Water Resources Council. 1983. Economic and Ecosystem Restoration Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G), 10 March 1983. Available online:

http://planning.usace.army.mil/toolbox/library/Guidance/Principles_Guidelines.pdf (Accessed 25 September 2013).

WOODLAND ISLANDS
COWLITZ COUNTY, WASHINGTON
BENEFICIAL USE OF DREDGED MATERIAL

APPENDIX F
ECOSYSTEM OUTPUTS MODEL

Integrated Feasibility Report and
Environmental Assessment

November 2017

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Appendices

Appendix A – Photographs of Woodland Island, taken January 20, 2017.

ACRONYMS

BiOp	Biological Opinion
Corps	United States Army Corps of Engineers
DO	Dissolved Oxygen
ERTG	Expert Regional Technical Group
ESU	Evolutionary Significant Unit
HEP	Habitat Evaluation Procedure
HSI	Habitat Suitability Index
HU	Habitat Units
LCRE	Lower Columbia River Estuary
MHHW	Mean Higher High Water
NOAA	National Oceanic and Atmospheric Administration
OCS	Oregon Conservation Strategy
ODFW	Oregon Department of Fish and Wildlife
RCG	Reed Canary Grass
SBU	Survival Benefit Unit
SI	Suitability Index
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WSEL	Water Surface Elevation

LOWER COLUMBIA RIVER BENEFICIAL USE OF DREDGED MATERIAL FOR ECOSYSTEM RESTORATION

HABITAT EVALUATION MODEL

1 EXECUTIVE SUMMARY

Since 2000, the U.S. Army Corps of Engineers (USACE or Corps) has used the Water Resource Development Act Section 204 authority to plan and implement ecosystem restoration projects in the Lower Columbia River and estuary. The Corps, with local partner Columbia River Estuary Study Taskforce (CREST), studied ecosystem restoration opportunities for Woodland Island, near St. Helens, Oregon, in 2017. The goal of this study, the Lower Columbia River Beneficial Use of Dredged Material for Ecosystem Restoration Study, at Woodland Island is to improve long-term, sustainable aquatic habitat function and increase aquatic areas and habitat values for fish and wildlife in the Lower Columbia River estuary. Selection of the preferred restoration alternative was facilitated by an economic analysis, where habitat benefits and cost were compared among the candidate restoration alternatives. This report describes the habitat benefits model and results used for the Study.

Habitat benefits were modeled with a Habitat Evaluation Procedure (HEP), where the study area is assessed by its suitability for target species, for each restoration measure. For each indicator species, habitat suitability was assessed with published Habitat Suitability Indices (HSIs), modified if necessary, based on specific project conditions.

The Study area is important for multiple fish and wildlife uses, but was represented by the wildlife species and life stages of yellow warbler nesting and juvenile Chinook salmonid rearing. These specific wildlife uses were selected because of resource significance, study relevance, and HSI model availability. Habitat suitability for the yellow warbler was determined by the availability of riparian deciduous shrubs that provided nesting resources. Habitat suitability for juvenile Chinook salmon was determined by the presence of rearing and resting habitat during out-migration. The yellow warbler and Chinook habitat areas and habitat benefits were not weighted to emphasize either species.

During the subsequent economic analysis, restoration measures were combined to form candidate restoration alternatives, with associated habitat benefits and cost. Various ecosystem restoration alternatives were considered, and placement of up to 400,000 cy in peninsulas configured on the islands' eastern shoreline, modified by complex grading and willow plantings, was determined to be the alternative that would provide the greatest habitat benefits. This configuration would provide young salmonids with high-frequency access to low velocity refugia in the Columbia River and would establish additional nesting habitat for a guild of passerine birds, represented by yellow warbler, that nest within the river's floodplain. Benefits were achieved primarily by gains in juvenile salmon rearing habitat and warbler nesting habitat established on the dredged material plain.

2 INTRODUCTION

Since 2000, the U.S. Army Corps of Engineers (USACE or Corps) has used the Water Resource Development Act Section 204 authority to plan and implement ecosystem restoration projects in the Lower Columbia River and estuary. Many of these projects emphasize salmonid population recovery and management, which is a key resource concern in the Columbia River. The Portland District has developed a program to investigate the feasibility of using dredged material placement as a habitat management initiative to provide restoration of habitats for salmonids and other wildlife present in the Willamette - Lower Columbia River (WLC) recovery domain.

The District, with local partner Columbia River Estuary Study Taskforce (CREST), studied ecosystem restoration opportunities using dredged material in 2017. The project team formulated the Lower Columbia River Beneficial Use of Dredged Material for Ecosystem Restoration Study, which considers the feasibility of strategic placement of dredged material to restore shallow water riverine and riparian habitat in the Lower Columbia River estuary (LCRE) at Woodland Island, near St. Helens, Oregon.

The goal of the Lower Columbia River Beneficial Use of Dredged Material for Ecosystem Restoration Study at Woodland Island is to improve long-term, sustainable aquatic habitat function and increase aquatic areas and habitat values for fish and wildlife in the Lower Columbia River estuary. This report describes the habitat benefits model and results used for the Study. Selection of the preferred restoration alternative was then facilitated by a CE/ICA economic analysis, where habitat benefits and cost were compared among the candidate restoration alternatives.

This study is consistent with the national initiative to identify, plan, and finance beneficial use projects using dredged material (US EPA and USACE 2007). This study is also consistent with the objectives of the NMFS Biological Opinion of Federal Columbia River Power System Operations (BiOp) to implement estuarine restoration that benefits the survival and productivity of ocean and stream type juvenile salmon (NMFS 2008, 2014).

2.1 Study Area

To select the study site, many potential habitat restoration sites from River Mile (RM) 20 to 105 on the Columbia River were considered initially and screened to identify the ten most promising sites based on proximity to shoals dredged by a pipeline dredge, area available for potential habitat restoration, hydraulic complexity, and other factors. These ten sites were then evaluated in greater detail and ranked, and the highest ranking site was chosen for detailed feasibility analysis.

The selected site, referred to as “Woodland Islands”, consists of a string of small dredged material islands lying between the main channel and a side channel on the Washington side of the Federal Navigation Channel from River Mile (RM) 86 to RM 84.5 near St. Helens, Oregon (Figure 1). Based around the major longitudinal pile dike constructed in 1885, the islands are remnants of previous dredged material placement from decades of navigation channel maintenance dredging of the St. Helens Bar. The Lewis River confluences about 1 ½ miles upstream from the Woodland Islands and augments the flow of the Columbia River. Through further evaluation, the downstream (northern) island was chosen as the project site (Figure 2). The proposed project would encompass about 20 acres on the eastern side of the island.

Figure 1. Woodland Islands Project location near St. Helens, Oregon.

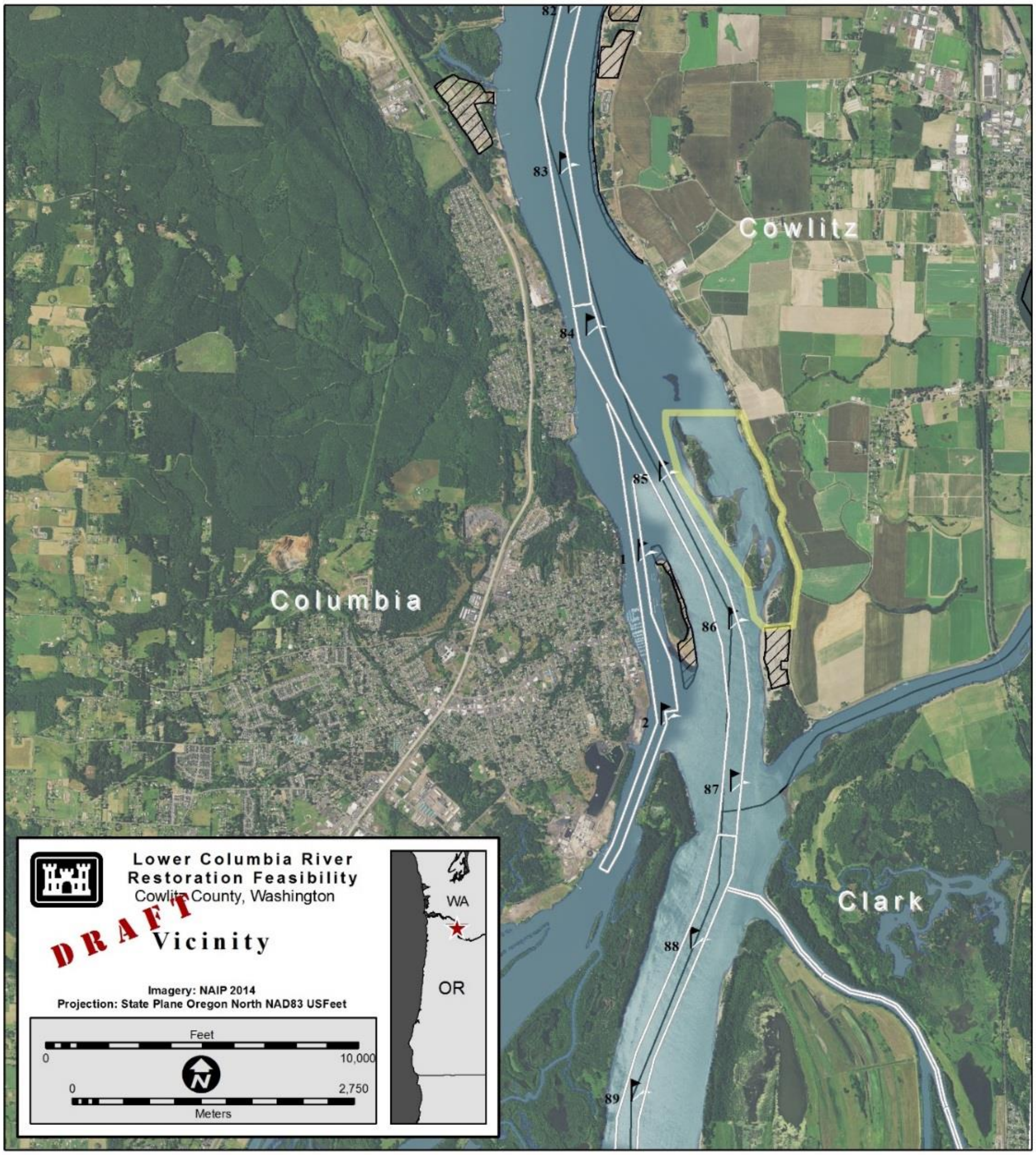


Figure 2. Aerial photograph of the Woodland Islands project site.

2.2 Problem Identification

The term ecosystem integrity is used to describe the condition of an ecosystem – the assemblage of plants and animals within its physical environment. Many watersheds, including the Columbia River basin, display a decline in ecosystem integrity resulting from the various perturbations associated with human development.

The Lower Columbia River is a large, low-gradient river with average annualized daily discharge of 288,000 cfs. With the flow alterations that have occurred through river re-regulation, available habitat for migrating salmonids and other native fish species is limited in the Lower Columbia River and its tributaries. Key habitat types and features such as off-channel habitat, shallow water habitat, channel and bank complexity and large woody debris are insufficient to support the migratory and rearing life stages of the migrant salmonid species. Rearing habitat is found in tributary sloughs but is much reduced in the mainstem Columbia River. Changed flow regimes and water temperature patterns have altered the availability and quality of off- channel habitat including backwater sloughs, floodplain ponds, and other slow-moving side-channel habitat. Overall, native species that are adapted to a fast moving river of cooler temperatures have declined in the warmer, slower moving river.

Key factors adversely affecting natural riverine functions in the mainstem of the river, some of which could be improved locally by the proposed project, include:

- Altered hydrology. The marked reduction in peak flows from upstream dams and other water uses has altered the timing, size, and frequency of runoff and flood events that are critical for maintaining healthy riparian, floodplain, in-channel, and off-channel habitats. Increases in base flows have also occurred. The proposed project would have very localized effects and would not influence hydrology at the watershed level.
- Loss of habitat complexity. Dredging, channel straightening, and bank stabilization have

all changed the main channel of the Columbia River from a multiple channel, structurally complex system dominated by shallow water areas to a deep, steep-banked channel with little diversity in structure or depth. Loss of channel complexity, woody material, and shallow water habitats adversely affect a wide range of fish and wildlife species. In many locations, invasive plant species have replaced diverse native plant communities, with a resulting decrease in ability to support a wide diversity of fish and wildlife species or species that are co-adapted to the region's vegetative communities. The proposed project would have very localized effects and is not designed to influence channel complexity of the main river channel at the watershed level, but is an opportunity to locally establish approximately 20 acres of riparian and shallow water habitats.

- Loss or degradation of off-channel habitats. Extensive fill, development in the floodplain, and alterations in channel banks have destroyed or degraded floodplain and off-channel habitats by filling them or by reducing or eliminating the frequency with which floodplain habitats are inundated. The proposed project is not designed to fill or alter existing channel banks or lateral floodplains of the main river channel.
- Reduction in nutrients and woody material. As a result of the loss of riparian vegetation, stabilization of shorelines, and the development of the floodplain, the input of naturally derived nutrients and woody debris has been reduced. Reduced input of woody debris is detrimental to aquatic habitat quality as wood provides habitat diversity, cover, and sediment retention. There has also been a loss of nutrient input from salmonid carcasses, although this source of nutrient input would generally occur in the tributaries or higher in the Columbia River system where spawning grounds are found. The proposed project would have very localized effects and is not designed to influence natural nutrient or woody debris inputs.
- Degraded water quality. Water quality has been adversely affected by urbanization and agricultural land uses over the last 150 years. Industrial and non-industrial wastes, along with contaminants in agricultural and urban runoff have contributed to degraded water quality. Water temperatures have also increased due to impacts from major dams, reservoirs, and loss of riparian vegetation. The proposed project would have very localized effects and is not designed to influence waste inputs or temperature changes at the watershed level.
- Contaminated sediments. Various types of contamination occur in some areas of the river and these contaminated sites appear on EPA's National Priorities List. Ecosystem restoration work proposed under this study will comply with USACE guidance for Civil Works projects with hazardous, toxic, and radioactive wastes (e.g., ER 1165-2-132). The St. Helen's Bar material was tested by the Portland District Sediment Quality Team and is not of concern.

Physical, hydraulic, and chemical parameters that are known to affect riverine baseline habitat quality in the study area include:

- Tidal influence. Tidal range in the Columbia mainstem typically is between 0-3 feet. Because the influence of tidal fluctuation varies depending on discharge from the Columbia River, the influence of tidal inundation on velocity and water surface elevation is difficult to predict in the absence of extensive hydraulic modeling. However, stage data developed by use of USGS gauges on the Columbia River indicate that the average water surface elevation under normal winter flows is between 9.7 and 9.9 ft NAVD for sites on the mainstem.
- Salinity. The upstream extent Columbia River estuarine mixing zone occurs at about

RM 30. The Woodland Island site lies between RM 84 and 86, therefore, the water is expected to be fresh (oligohaline; ~0.5 psu) depending on the seasonal volume of the river's discharge.

- Velocity. It is not possible to completely predict water velocity at island edges or in side channels. The mainstem Columbia River is low gradient and water velocities tend to be relatively low, ranging 0 to 3 cfs. This range of velocities is expected at the site.
- Dissolved oxygen (DO). DO levels range 5 to 10 mg/L in the mainstem Columbia River (Aroner 2001). The river is turbulent and low DO (<4 mg/L) is not expected to be problematic except rarely during drought conditions.
- Temperature. Water temperature is probably not a concern in the project area although total maximum daily loads (TMDLs) were established for temperature in the Columbia River mainstem (ODEQ 2006). Numeric temperature criteria have been designated in Oregon that are specific to salmonids life stages. The mainstem Columbia River is considered a migration corridor and has a 64.4°F seven-day moving average standard of daily maximum temperature for rearing and migration (ODEQ 2006). Water temperature in the mainstem Columbia River can reach > 73°F during the summer/fall low flow period (July-Sept.). However during the winter and spring, including the spring runoff when juvenile salmonids are out-migrating, temperatures rarely exceed 58°F (USGS 2014).

The following two sections briefly describe the groups of bird and fish species that were considered for analysis in this study, but the project benefits of vegetated riparian and shallow-water habitat restoration are not limited to these groups and would provide varying levels of habitat enhancement for a variety of other resident and migratory fish, birds (neotropical migratory birds, wading birds, waterfowl, osprey, and bald eagles, others), mammals, reptiles and amphibians and invertebrates. The project will incidentally provide some additional habitat for threatened Columbian white-tailed deer [*Odocoileus virginianus leucurus*]), which were observed on site during field surveys in 2017.

2.2.1 Fish – Mainstem Columbia River

Aquatic habitat for native fish species in the Columbia River differs from historical conditions. In the larger Lower Columbia River estuary, varying peaks of use by fish are driven by species, life-history strategy, water conditions, and other factors. Depending on the salmonid evolutionarily significant unit (ESU), the emigration peaks for both juvenile and adults vary between species, as well as for years. Chinook out-migrating juveniles have a peak approximately between March and July/August (Carter et al. 2009, FERC 2009, Bonneville unpublished data). The current fish assemblage is a combination of native and non-native species. In consultations with USACE, the National Marine Fisheries Service (NMFS) identified six salmonids that could be present at varying times in the LCR around Woodland Island (BiOp; NMFS 2008, 2014).

1. LCR Chinook Salmon (*Oncorhynchus tshawytscha*) - assume fall run [populations exhibit three different life history types based on return timing and other features: fall-run (a.k.a. "tules"), late-fall-run (a.k.a. "brights"), and spring-run].
2. Upper Willamette River (UWR) chinook salmon - This species includes all naturally spawned populations of spring-run Chinook salmon in the Clackamas River; in the Willamette River and its tributaries above Willamette Falls, Oregon; and progeny of seven artificial propagation programs.
3. Columbia River chum salmon (*O. keta*) - This species includes all naturally-spawned populations of churn salmon in the Columbia River and its tributaries in Washington and

Oregon, and progeny of three artificial propagation programs.

4. LCR coho salmon (*O. kisutch*) - This species includes all naturally-spawned populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon, and progeny of three artificial propagation programs.
5. LCR Steelhead (*O. mykiss*) - This species includes all naturally-spawned steelhead populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between and including the Cowlitz and Wind rivers, Washington; in the Willamette and Hood rivers, Oregon; and progeny of ten artificial propagation programs; but excluding all steelhead from the upper Willamette River basin above Willamette Falls, Oregon, and from the Little and Big White Salmon rivers, Washington. Summer steelhead return to freshwater long before spawning. Winter steelhead, in contrast, return from the ocean much closer to maturity and spawn within a few weeks. Summer steelhead spawning areas in the Lower Columbia River are found above waterfalls and other features that create seasonal barriers to migration. Where no temporal barriers exist, the winter-run life history dominates.
6. UWR steelhead. This species includes all naturally-spawned steelhead populations below natural and manmade impassable barriers in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River.

2.2.2 Songbirds – Warblers

Migratory bird populations have declined with habitat fragmentation and reduction, and the national bird conservation goal is to stabilize and increase these populations. Neotropical warblers, including American yellow warbler (*Dendroica petechia*), are a focal species group of passerine songbirds with high management interest given their species-specific habitat requirements. These are Western Hemisphere species in which the majority of individuals breeds north of the Tropic of Cancer and winters south of that same latitude. Oregon has 21 confirmed warbler species (ODFW; the Oregon Field Ornithologists are reviewing other records, bringing the total to 40 warbler species possibly occurring in Oregon), and Washington reports 35 species of migrant warblers (WDFW). Warblers can be grouped based on their foraging and nesting requirements, and many of these warbler species breed in the riparian floodplain of the Lower Columbia River, where willow thickets in the floodplain and associated riparian areas are important habitats meeting most of the life history needs of many of the warbler species.

The nesting life history stage is an important use by warblers of the Woodland Island riparian shrub community. Nesting is correlated with the months of the year when shrubs have a leafy canopy. Deciduous shrubs in the Columbia River floodplain lose their leaves in the fall and remain leafless until spring, when the leaves erupt again after the winter period. While leafless in winter, shrubs provide perching and foraging habitat for some resident birds that over-winter in the area. At leaf-out, shrubs provide migrant warblers, and others, with foraging and nesting habitat. May, or earlier, through August, is the general breeding season inclusive of most species' breeding periods in the river floodplain according to the ODFW (Oregon Conservation Strategy) and WDFW. Warbler adults and fledged young of the year migrate from the floodplain after the breeding season.

As explained below in the species selection section, USACE anticipates that the proposed project will provide increased salmonid rearing habitat and warbler nesting habitat.

2.2.3 Lower Columbia Conceptual Habitat Model

The Pacific Northwest National Laboratory (PNNL) developed a conceptual model of habitats or ecosystem structures within the Lower Columbia estuary for the USACE Portland District, which attempts to describe the complexity of the Columbia River Estuary (LCRER-GI Phase 1 Report, PNNL 2011).

Woodland Islands displayed a well-established, mature cottonwood gallery forest (a Supratidal Activated Floodplain) at higher elevations of the island, and a border of willows (Forested Tidal Floodplain), emergent herbaceous vegetation (Emergent Tidal Marsh – Low and High), and inundated substrate (Intertidal Mud/Sand Flat) variously at lower elevations. These plant communities are typical of riverine islands in the LCE and are unlikely to change significantly over the projected time period without a significant event such as massive flood, or infestation by disease or pest, unless the natural cycle of disturbance and regeneration in the floodplain no longer occurs.

Based on USACE's field observations and evaluations for this study, several habitat classes identified in the model are generally lacking in this reach of the Columbia River and could be created and/or supported by the strategic placement of dredged material at Woodland Island including intertidal mud/sand flat, tidal channels, emergent tidal marsh – low and high, and forested tidal floodplain (see the following Table 3.1, from PNNL).

"Table 3.1. Habitat classes and vegetation species [from PNNL 2011]."

Class	Vegetation Species	Site
Supratidal Activated Floodplain	cottonwood, horsetail, scotch broom, Himalayan blackberry	Higher elevation areas of Woodland Island
Forested Tidal Floodplain	tree line - willow. red alder	Shoreline of Woodland Island
Emergent Tidal Marsh - High	reed canarygrass, common monkey flower, purple loosestrife, noddings beggarstick, tufted hairgrass, bentgrass	Shoreline of Woodland Island
Emergent Tidal Marsh - Low	wapato, spike rush, baltic rush, swamp smartweed, common forget me not, water stalwort	Shoreline of Woodland Island
Tidal Channels	Vegetated or unvegetated	Constructed within placed material
Intertidal Mud/Sand Flat	Unvegetated to sparsely vegetated with various SAV	Shoreline of Woodland Island

Note: Class type and associated vegetation species described by the PNNL Conceptual Model.

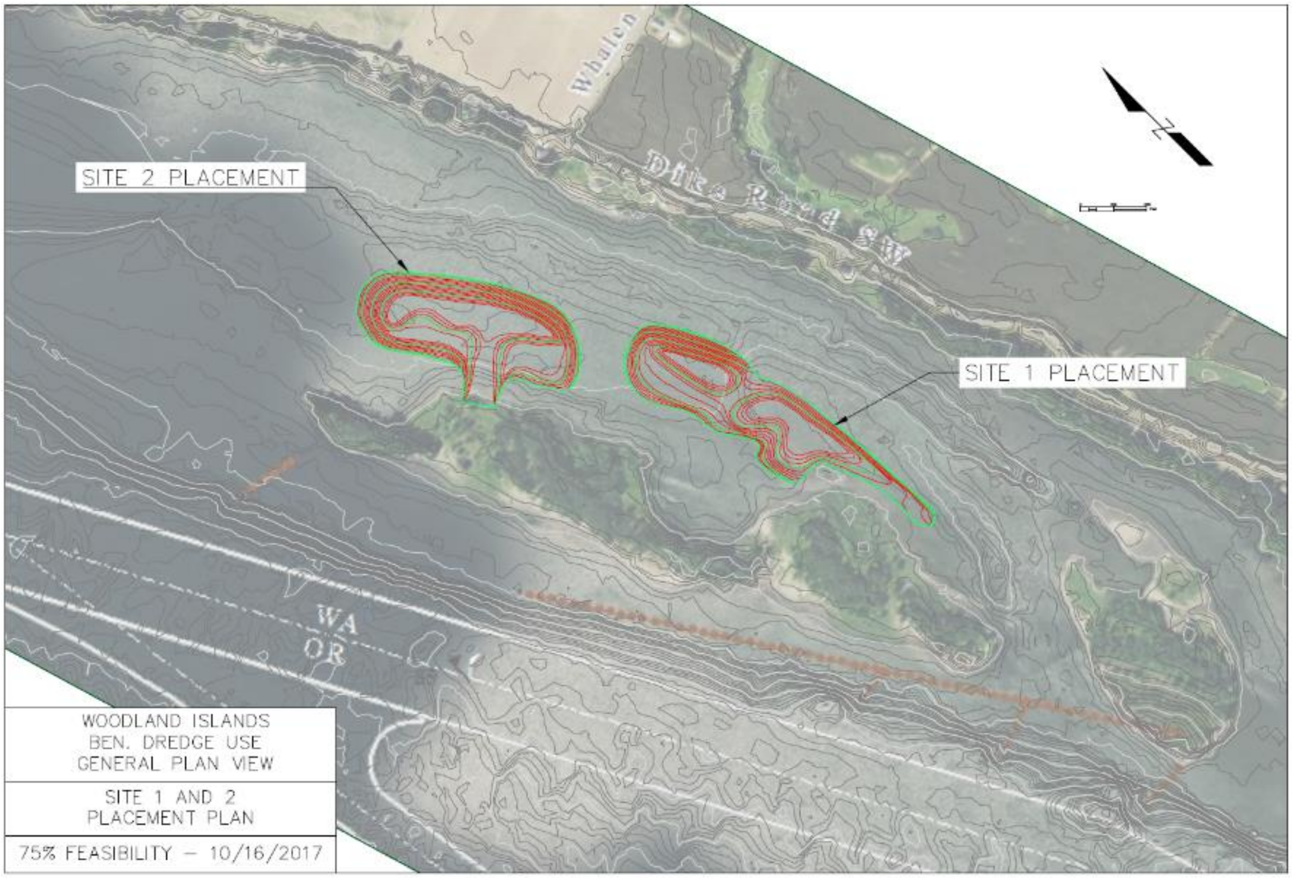
2.3 Restoration Measures

Habitat creation through the beneficial placement of dredged material on Woodland Island provides an opportunity for the Portland District to address two general ecosystem limitations in the Columbia River basin – lack of rearing habitat by using dredged material to create shallow water habitat for out-migrating juvenile salmonids, which thereby contributes to the goals of the NFMS Columbia River Power Systems BiOp; and lack of nesting habitat by establishing an expanse of riparian shrubs attractive to many of the migrant passerine birds nesting in the region, which thereby contributes to the goals of the Neotropical Migratory Bird Conservation Act; and to restore ecological processes to benefit other native fish and wildlife species in the lower Columbia River and estuary. A comprehensive restoration plan for species in the

Salmonidae family, as keystone species, effectively restores habitat and nutrient input for a broad suite of over 130 other native plant and animal species (Cederholm et al. 2000). Similarly, restoring riparian shrub complex benefits a broad suite of both terrestrial and aquatic wildlife.

The study area is an ideal site for the strategic placement of dredged material due to the relatively large area suitable for placement, the proximity to a reliable source of dredged material, and the need for habitat restoration in this particular reach of the river. The island complex currently has an upland spine supporting a cottonwood gallery forest, which slopes down to lower elevations supporting wetland scrub-shrub habitats, and to sandy shorelines transitioning to lower velocity embayments lying on the protected eastern side of the islands (Figure 3).

Figure 3. Conceptual terrain model of the Woodland Island habitat restoration site.



The conceptual restoration measures planned for use at the Woodland Island site involve augmenting the shoreline of the downstream-most island with dredged material from the St. Helen's Bar to form two peninsular features extending from the east side of the island into the side channel, grading the material, and re-vegetating it with native wetland shrubs (willows and other native plant species) to accelerate vegetation establishment, establish shrub thickets on the material to deter attracting piscivorous birds common in the Columbia River basin to the island, and increase the island's resistance to erosion. Because the Corps has an initiative underway to manage the populations of cormorants and terns, birds that are piscivorous on ESA-listed threatened and endangered salmonids, planting shrubs on the areas of dredged material that are not regularly inundated (above 11 feet MHHW) would be a strategy to make the placed dredged material unattractive for nesting. Placing dredged material on the island's shore in the side channel would increase the areal extent and availability of shallow intertidal and submerged aquatic, and forested scrub-shrub floodplain habitats, habitat types that are considered of high value in this section of the river.

2.4 Assessment Method

2.4.1 Habitat Evaluation Procedure (HEP) Method

The Habitat Evaluation Procedure (HEP) is a procedure to facilitate the identification of effects of various types of actions on fish and wildlife habitat framework developed by the U.S. Fish and Wildlife Service (USFWS 1980a, 1980b). The project was modeled using multiple species Habitat Suitability Indices (HSIs) analyzed within the Habitat Evaluation Procedures (HEP). The basic premise of HEP is that habitat quantity and quality can be described numerically such that HEP can provide a comparison of habitat quality between different sites, different alternatives, or between different times at one site (for example, pre-construction versus post-construction). A key assumption in HEP is that an individual species "prefers" habitats where it survives or reproduces better, and these habitats have certain physical characteristics that can be measured. For example, if yellow warblers typically nest in deciduous shrubs, then sites with deciduous shrub cover are more suitable for yellow warblers than sites that have little or no deciduous shrub cover.

A Habitat Suitability Index (HSI), the analysis parameter used in HEP, is a mathematical relationship between a physical, chemical, or biological habitat attribute and its suitability for a single species or assemblage of species. The Suitability Index (SI) is a unit-less number between 0 and 1 that describes the requirements of a species for certain attributes such as cover, distance to foraging, water temperature, etc. A set of one or more SIs that represent key habitat requisites for the species during one or more life history stages are combined arithmetically into an overall HSI by adding or multiplying the individual indices. The attributes are measured in the field and/or via remote sensing or GIS analysis and their corresponding index values are inserted into the model to produce a score that describes existing habitat suitability. The overall HSI value is also an index score between 0 and 1.

This index value can be multiplied by the area of habitat evaluated at the site to yield Habitat Units (HUs), or it can be used as an index score for a comparison of habitat quality only. The future with- and without-project HUs are compared to determine the net difference (either positive or negative) between alternatives. Habitat units are determined by multiplying the combined HSI scores by the area of habitat that may be affected by each alternative. The area of habitat is determined by the project boundaries and area of influence around the project boundaries (i.e., area that would be shaded by riparian vegetation, area opened up by construction of tidal channels, or area around newly installed cover features where juvenile fish may venture to). Average annual habitat units (AAHUs) are computed by annualizing the HU score by planning increments over the 50-year planning horizon of the project.

2.4.2 Species Selection Guidelines

The HEP procedure suggests five guidelines that should be used to select the species included in a model: 1) the project vicinity includes the species' geographic range; 2) the species must use the habitat type or types that are currently present, or are proposed for restoration; 3) species with existing HSI models are preferred (using previously developed and verified models provides a greater level of scoring certainty); 4) suitable HSI models must include habitat variables for which data collection is possible, given the availability of time and resources; 5) variables must likely show a change in score between the existing and proposed condition. If the project does not affect the SI score for a species, it will not be possible to quantify an effect. Habitat variables that do not meet the above requirements should be omitted.

The indicator species generally must have a USACE-certified HSI model available to be considered for benefit modeling, although the CAP Section 204 program also allows the use of models that are not certified as long as they are reviewed during the ATR process. USACE-certified HSI models have been published as peer reviewed technical documents (https://cw-environment.erdc.dren.mil/ model-library.cfm?CoP=Restore&Option=Start). Further, the HSI models need to be regionally applicable. A model is regionally applicable if it was developed and calibrated for a region that includes the Study area, or if the model variables, scoring criteria, and structure are transferrable to the Study area. The HSI models also need to be locally applicable, in terms of the life stage evaluated by the HSI. For example, an HSI for salmonid spawning would not be appropriate for a project area that is only used by salmonids for rearing. HSI models that cover multiple life stages can be pared down to the variables that are relevant and appropriate for that life stage. Using these generalized guidelines, representative species that had relevance to the study area’s current habitat types and anticipated Corps-induced future changes in those habitats and had available HSI models were screened and selected to represent habitat benefits from the ecosystem restoration project actions.

2.4.3 Species Selection

The initial approach to selecting fish and wildlife species for a HEP study is to identify what species occur in the study area, and what are their crucial life history requirements. The Lower Columbia River region hosts many taxa of fish and wildlife, which are described thoroughly by the Oregon Department of Fish and Wildlife (ODFW) (http://www.dfw.state.or.us/species/index.asp) and the Washington Department of Fish and Wildlife (WDFW) (http://wdfw.wa.gov/viewing/), and many other references.

Two recently completed studies, the Lower Willamette General Investigation (GI) Ecosystem Restoration Study and the LCR General Investigation (GI) Ecosystem Restoration Study, which overlap geographically with the selected site and encompass similar habitats, thoroughly screened relevant fish and wildlife species in selecting the models used in those studies. Because the habitats and species in this study were similar to those two completed studies, we considered the species evaluated for inclusion in those studies to inform the species screening process for this study.

We reviewed published HSIs for 12 species with various life history requirements – 8 birds, 1 fish, 1 mammal, 1 reptile, and a guild of native amphibians for potential inclusion in the HEP analysis (Table 1). Of these, those not selected had habitat requirements that were not scaled to the spatial area of the project site such as large territories where the population would not respond usefully to the proposed project, data for use in the species’ model were not available, or they were not key species of regional management interest (Table 1).

Table 1. Species, associated habitat types, model variables, selection status and rationale for selection of species considered for the HEP model.

Species/Guild	Associated Habitat Type	Variables/Attributes	Selection Status	Rationale for Selection
Yellow Warbler (*Dendroica petechia*)	Riparian and floodplain vegetation communities (particularly	Deciduous shrub crown cover, canopy cover, height of shrub canopy, % hydrophytic shrubs in	Yes	Yellow warblers occur in the river floodplain; increasing willow scrub-shrub habitat will increase the potential number of warbler

Species/Guild	Associated Habitat Type	Variables/Attributes	Selection Status	Rationale for Selection
	cottonwood and willow)	canopy cover (Schroeder 1982)		territories; territories are 0.15 ha; relatively small so notable lift would result; habitat parameters can be modeled reliably.
Modified model - Native salmonids (mainstem) (juvenile Chinook) (*Oncorhynchus tshawytscha*)	Mainstem out-migration and rearing (shallow water margins, floodplain side channels and backwaters)	Substrate, depth, and percent cover of bank vegetation (Raleigh et al. 1986)	Yes	Dredged material does not require extensive re-shaping and re-contouring to create suitable habitat; substrate quality is not a driving parameter; wide range of depths are usable; site has demonstrated capacity to grow scrub-shrub community at shoreline.
Beaver (*Castor canadensis*)	Riparian and floodplain vegetation communities (particularly cottonwood and willow)	Tree canopy closure, tree size class, shrub crown cover, height of shrub canopy, species composition (Allen 1982).	Considered, Not selected	Beaver are present on site; probably 1-2 family groups; they have large territories and improving aquatic and scrub-shrub habitat will not increase number of family groups.
Great Blue Heron (*Ardea herodias*)	riparian trees, shallow embayments	Distance between foraging areas and heronry sites, shallow clear water, distance from human activities (Short and Cooper 1985)	Considered, Not selected	One probable great blue heron nest was observed at the south end of the island; depositing dredged material will not decrease the distance to other heronries, or reduce the distance from human activities..
Wood duck (*Aix sponsa*)	Riparian and floodplain vegetation communities and near shore aquatic habitats	Cover (Sousa and Farmer 1983)	Considered, Not selected	The project will not increase cover (numbers of large trees with perching or nesting); baseline data not available.
Western pond turtle (*Actinemys marmorata*)	Off-channel ponds, sloughs, and backwaters	Water depth, water temperature, percent cover, availability of nesting sites (Morreale and Gibbons 1986)	Considered, Not selected	Turtles have mid-sized upland territories; baseline data not available; depositing dredged material without extensive re-shaping and re-contouring to create upland micro-habitats will not result in lift.
Native amphibians (Northwestern salamander, long-toed salamander, red-legged frog, Pacific treefrog, Oregon spotted frog, roughskin newt	Slow velocity stream reaches/alcoves, off-channel ponds, sloughs, and backwaters and other wetlands	Permanent water, water velocity, emergent and submergent vegetation, ground cover along water's edge, riparian zone width, water temperature, land use (WDFW 1997)	Considered, Not selected	Herptiles have small to mid-sized upland or aquatic territories; habitat parameters are limiting; baseline data are not available; depositing dredged material without extensive re-shaping and re-contouring to create upland micro-habitats will not result in lift.

Species/Guild	Associated Habitat Type	Variables/Attributes	Selection Status	Rationale for Selection
Bald eagle (*Haliaeetus leucocephalus*)	Lacustrine or estuarine	Size of waterbody for foraging; morphoedaphic index; distance from nest to foraging area (Peterson 1986)	Considered, Not selected	Model designed for breeding season at lacustrine habitats and based on volume of forage base. Not relevant to project area or proposed alternatives. Could have created new model for wintering habitat, but primarily based on availability of perching habitat and proximity to waterbodies, which will not change significantly as a result of proposed restoration measures.
Black-capped chickadee (*Poecile atricapilla*)	Forest	% Tree canopy closure, average height of trees, # of snags (Schroeder 1983)	Considered, Not selected	Restoration of floodplain and riparian habitats will benefit these attributes and habitat requirements, but are not directly predictable from proposed changes.
Downy woodpecker (*Picoides pubescens*)	Forest	Basal area per hectare, # snags/ha (Schroeder 1982)	Considered, Not selected	Will likely benefit from floodplain/riparian restoration, but attributes are not directly relevant.
Osprey (*Pandion haliaetus*)	Lacustrine or estuarine	Obstructions over water, transparency, human activities (Vana-Miller 1987)	Considered, Not selected	Attributes will not show a significant change
Red-winged blackbird (*Agelaius phoeniceus*)	Lacustrine or estuarine marsh	Dominant emergent vegetation type, water present/absent, carp present/absent, larvae of odonates, patchiness of vegetation, layers of wetland vegetation (add cit)	Considered, Not selected	Will benefit from floodplain wetland restoration, but attributes not directly relevant.

2.4.4 Model Development Process

It is often recommended that HSIs for several species be used to capture the range of benefits that could be provided by habitat restoration projects. However, where the purpose of a project is focused on a limited set of habitat parameters, and the project area is small, it is appropriate to select species that would benefit distinctively from the proposed action. For the Woodland Island site, the recommended HEP model includes two species:

> (1) yellow warbler, a neotropical migrant common but in need of additional nesting habitat in Oregon and Washington; In the Columbia River basin. The yellow warbler represents a guild of insectivorous migratory neotropical warblers and associated passerines that use riparian habitat while they are present in the river floodplain; and
>
> (2) mainstem juvenile chinook salmon, as a surrogate for the suite of juvenile salmonids

known to need rearing habitat as they out-migrate in the river. Chinook are native salmonids that are listed as threatened under the federal Endangered Species Act and occur in the Lower Columbia River basin.

2.4.4.1 Model Acceptability

The models used in this study are on the list of models approved for use by HQUSACE, or were approved for use in previous regional studies.

A certified HSI model was available for yellow warbler, in which the focal life history stage is nesting, and was regionally applicable (Schroeder 1982).

For salmonids, the available USACE certified HSI models were compared to the species associated with the BiOp management plan objectives, and their relevant life stages. Certified HSI models were available for many of the salmonid species that out-migrate through the Columbia River. Although the LCR provides habitat for multiple life stages of anadromous fish, the focal life history stage of anadromous salmonids is juvenile rearing, and the juvenile rearing components are the relevant components of the models. The ocean-type Chinook and chum salmon have overlapping requirements, in that they are subyearlings as they out-migrate and rear in LCRE wetlands. Chinook juveniles are present in the LCRE year-round and account for nearly 85 to 90% of juvenile salmon abundance, and are composed of multiple stocks from throughout the Columbia Basin (Johnson et al. 2011). Given the overlap in juvenile habitat suitability requirements, the shorter period spent by chum salmon juveniles in the freshwater tidal estuaries and the paucity of modeling variables for chum salmon, the Chinook salmon HSI was selected to represent ocean-type salmonid rearing in the Study HEP model. Because the study area is in the lower mainstem river, a stream-type salmonid rearing model was not appropriate to the study's HEP model. As the habitat requirements for juvenile life stage of salmonids differ between the mainstem Columbia River and the tributaries, a salmonid model specific to the habitat requirements of juvenile Chinook in the mainstem was selected. The juvenile rearing component of the Chinook salmon HSI considers water quality, channel morphology, and substrate characteristics. The juvenile chinook modified model was approved previously for use on the Lower Willamette GI Ecosystem Restoration Study and also used on the LCR GI Ecosystem Restoration Study.

These two HSI models meet the five model selection guidelines listed above and they are recommended as the analysis species for the Woodland Island Project. The yellow warbler model describes the breeding habitat needs of this neotropical migrant warbler that occurs as a breeding bird from approximately May to August throughout suitable nesting habitat in Oregon. The juvenile main-stem chinook salmon model describes the habitat requirements of out-migrating juvenile salmonids as they occupy resting and rearing habitat during out-migration from the spawning sites. Based on a review of habitats at site and PDT discussion, these two species should show a response to changes in the area of the project's design habitat classes (forested tidal floodplain and emergent tidal marsh – high, emergent tidal marsh – low, tidal channels, and intertidal mud/sand flat). The associated habitat types supported the use of two species – yellow warbler and juvenile Chinook salmon - for the Woodland Island HEP.

Although a species of interest in the LCRE, Pacific lamprey are not included in the study's HEP Model for three reasons: (1) a USACE-certified HSI model does not exist for the Pacific lamprey, (2) the importance of this site for lamprey ammocoetes is not known, (3) the habitat requirements for lamprey ammocoetes are similar to the requirements for subyearling Chinook and chum rearing. To the extent that Pacific lamprey have overlapping habitat requirements, they are represented by the Chinook/(chum) model component.

The proposed habitat evaluation model is a combination of HSIs for multiple individual species. The following factors were considered in formulating the model.

2.4.4.2 Description of Input Data

All HSIs proposed for use in this model were documented previously. The yellow warbler model has been used widely for more than 30 years. The mainstem juvenile chinook model, developed by a multi-agency team based on regional literature and expert opinions, was approved and used previously in the Lower Willamette River GI Study and the Lower Columbia River GI Study. Input data used for this model were collected from on-site field surveys at the project site and from remote sensing using aerial photography and GIS modeling. The input data required varies from one HSI to another. All suitability indices and equations used in the HEP model are specifically stated. Example variables that were measured or interpreted include percent canopy cover, vegetation composition, water depth, etc. These measured variables were then assigned an SI value based on the suitability curve or discreet suitability values or thresholds developed in the model.

Acreages for the model were developed by mapping the area where restoration actions were both implementable and would have an effect on habitat quality, then creating a model terrain for the proposed project. The acreage for with- and without- project conditions was comparable although no material had been placed in the without project condition.

2.4.4.3 Description of Output Data

The output data from a HSI, one or several individual suitability indices, were entered into the HSI model equation to yield an overall habitat suitability index for the species. Calculations were done in standard spreadsheet software (i.e. Microsoft Excel), the model formulae are transparent, and all assumptions can be verified.

2.4.4.4 Capabilities and Limitations of the Model

A major assumption of HEP is that there is a linear relationship between the HSI and either carrying capacity for a species or an observed preference/requirement for a specific habitat feature. When developing specific HSI models, it is necessary to define varying qualities of habitat (i.e. optimum, good, fair, poor) based on observed relationships in the literature. For example, if the majority of observations of yellow warbler nests were in deciduous shrubs ranging from 1.5 to 4 meters, then deciduous shrubs of that height are assumed to provide optimal nesting habitat and, thus, yield a high index score (in the range of 0.8 to 1.0). Shrubs of lesser or greater height would be assumed to be less or unsuitable and yield lower index scores.

Another limitation in the use of ecological models is that other factors beyond the specific parameters evaluated in the models could be influential on species response. While these factors may influence the success of any habitat restoration project, they were excluded in this study. Two potentially influential local effects, acknowledged but not considered, are:

- Climate change**.** The Corps addresses apparent climate change in NEPA evaluations, and acknowledges that climate change effects could affect the proposed project. Because the small scale of the project would not influence the regional climate conditions, we did not attempt to predict the effects this process could have on parameters that directly affect the species whose life requirements were used to construct this model. Other studies have suggested that increasing air temperatures may cause warmer water temperatures, higher base flows in the winter and spring and lower base flows in the summer and fall, and less predictable tidal fluctuation. While the effects of climate change would not be measured in this HEP model, long-term monitoring and adaptive management strategies could be developed, if appropriate, to measure these effects and respond to them effectively.

- Invasive species: The Columbia River basin is infested with several invasive plant species and controlling them is problematic at any restoration site. Plant community development will be exerted passively at the Woodland Island site because invasive plant control was screened out (refer to the feasibility study report). This project would restore a viable native riparian and wetland plant community by revegetating areas of placed dredged material with native species, and creating conditions under which native species are initially competitive with invasive species. Although invasive plant control can improve habitat quality where it can be implemented effectively, specific measures were not developed as part of this study to reduce the effects of invasive species because their seed sources are ubiquitous in the landscape and invasive plant species control would be problematic at this site, requiring laborious maintenance regularly throughout the annual growing season for the 50-year planning period. These effects are not planned to be measurable in this model. Monitoring and adaptive management strategies for reestablishing native plant communities are outlined in Section __ of the Feasibility Study.

2.5 Yellow Warbler Model

The yellow warbler is a neotropical migrant warbler with declining populations that is a focal species indicator of the ecological integrity of riparian scrub-shrub wetlands (Lowther 1999, Campos et al. 2014). Yellow warbler was selected to represent a guild of neotropical migratory warblers and other passerines that nest in shrub thickets surrounding shallow wetlands and riparian habitat in the Columbia River floodplain. The yellow warbler's breeding habitat is typically deciduous hydrophytic (water loving, i.e., growing in moist soils) shrubs, in particular willows (*Salix* spp.), in shrub wetlands, edges of freshwater wetlands, and riparian zones. Breeding warblers select relatively dense willow thickets with associated terrestrial invertebrate production in which to forage and build their cup nests. The yellow warbler is insectivorous and forages on primarily terrestrial insects by gleaning (searching in the leaves and branches) in shrubs and on tree branches, and by hawking (swooping through the air like a hawk) prey that tries to fly away in deciduous shrubs. Yellow warblers are a breeding bird throughout the U.S; they migrate to the Pacific Northwest in May and nest, then leave in August, and winter in Central and South America.

2.5.1 Yellow Warbler Model

The existing model and generic habitat requirements are described in Schroeder (1982). This model was prepared in the early 1980s and used the wetland naming conventions and definitions of the time (e.g., Deciduous Shrubland [OS] and Deciduous Scrub/Shrub Wetland [DSW]); the current terms describing these wetland types are palustrine emergent marsh (PEM, "freshwater marsh"), palustrine scrub-shrub (PSS, "freshwater shrub marsh"), and palustrine forested wetlands (PFO, "freshwater forested wetlands") (Cowardin et al. 1987). These are generally comparable to the habitat classes of emergent tidal marsh – low and high, and forested tidal floodplain described by PNNL (2011).

This model considers the quality of the reproduction (nesting) habitat needs of the yellow warbler to determine overall habitat suitability. The yellow warbler HSI model lists suitable habitat as including deciduous shrubland and palustrine scrub-shrub (willow thickets) where optimal habitats are composed of 100% hydrophytic deciduous shrubs. Potential habitat types at Woodland Island that fit the criteria for suitable yellow warbler habitat are deciduous shrubs within the palustrine scrub-shrub (PSS) category. In the project area these shrubs are Columbia River willows (*Salix fluviatilis*), observed at the lower elevations, or other willow species, mixed with a few small black cottonwoods (*Populus balsmifera trichocarpa*) and scattered red osier dogwood (*Cornus sericea*) as the dominant shrub species occurring at the site; shrub densities between 60 - 80% crown cover[1]; and shrub heights of ≥ 2 m (6.6 ft).

The Yellow Warbler model is comprised of three variables to account for area suitability, shrub height, and canopy cover:

$$HSI_{\text{Yellow Warbler}} = (V_1 + V_2 + V_3) / 3$$

The complete HSI nesting model is applicable to the breeding range of the yellow warbler and has the following characteristics (Table 2):

1 $^{YW}V_1$ = Percentage (%) of deciduous shrub crown cover (both deciduous shrub and deciduous shrub in wetlands).

2 $^{YW}V_2$ = Average height (m) of deciduous shrub canopy vegetation that equals or exceeds 2 m in height above the ground/water surface.

3 $^{YW}V_3$ = Percentage (%) of deciduous shrub canopy comprised of hydrophytic shrubs.

Table 2. Yellow warbler variables.

V	Variable	Used	Rationale
V_1	Percent deciduous shrub crown cover	X	Identified as a limiting factor that could be measurably improved.
V_2	Average height of deciduous shrub canopy	X	Identified as a limiting factor that could be measurably improved.
V_3	Percent of shrub canopy comprised of hydrophytic shrubs	X	Identified as a limiting factor that could be measurably improved.

The rationale for the selection of yellow warbler as an analysis species is that the variables used in the yellow warbler HSI are present at the study site. The yellow warbler prefers riparian habitats composed of abundant, moderately tall, deciduous shrubs ranging in height from 1.5 to 4 meters. Shrub densities between 60 and 80% are considered optimal and coniferous areas are avoided. Greater than 90% of prey are insects and foraging takes place primarily on small limbs in deciduous foliage. Nests are generally located 3.0 to 7.9 feet (0.9 to 2.4 meters) above the ground in willows, alders, and other hydrophytic shrubs and trees, including box elders and cottonwoods. Male yellow warblers have greater mating success in shrubs less than 3 meters

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[1] Definition of crown cover: Crown cover is the proportion of a stand covered by the crowns of live trees/shrubs.

tall. The regional applicability of this model is for the breeding range of the yellow warbler. The suitability index (SI) variables are representative of local conditions in the Study area.

Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. The minimum habitat area needed for yellow warblers was interpreted as the territory size for yellow warbler males of 0.15 ha (0.37 acre), with a density of two territories per ha. In comparison, the Sierra Nevada habitat restoration strategy established a target of 0.54 yellow warblers per acre (equivalent to ~1.35 yellow warblers per ha) (Campos et al. 2014). Habitat suitability among site locations is highly variable for yellow warblers and results among studies show this variability.

Since warblers nest in the riparian shrub community, the habitat of interest in this study is willow shrubs. The proposed action would create about 10 to 21 acres of dredged material within the approximate 10 to 14 foot contours, which is the elevation that presently supports stands of Columbia River willow or other shrub species.

2.5.2 HSI Model Modifications

This model considers the quality of the reproduction (nesting) habitat needs of the yellow warbler to determine overall habitat suitability. The Study area is in the freshwater tidal zone of the LCRE, where willows, dogwood, and cottonwoods, the dominant shrubs and small trees in the floodplain, grow prolifically. Potential habitat types at Woodland Island are stands of deciduous shrubs growing at lower elevations in moist soil. Optimal habitats contain 100% hydrophytic deciduous shrubs (willows, with a few small black cottonwoods and scattered red osier dogwood, are the dominant species occurring at the site), shrub densities between 60 - 80% crown cover, and shrub heights of ≥ 2 m (6.6 ft).

The Yellow Warbler HSI model lists suitable habitat as including deciduous shrubland and palustrine scrub-shrub (willow thickets). The scrub-shrub wetland identified at this site fits the criteria for suitable Yellow Warbler habitat and can be used for design of bird habitat. The Yellow Warbler model is comprised of three variables to account for area suitability, shrub height, and coverage. All the variables are relevant to the model. Thus, the averaged values of the three variables will be used to calculate the yellow warbler HSIs: $HSI_{\text{Yellow Warbler}} = (V_1 + V_2 + V_3) / 3$.

Variable 1 (V_1) is determined by the number of bird nesting territories that fit within the suitable habitat region. The model assumes 2 males (i. e., territories)/ha; with each territory having a minimum area = 0.15 ha. This is determined by fitting 0.15 hectare circles within the palustrine scrub-shrub area, which is defined by the area between elevation bands at 10 to 14 feet NAVD, and summing the total number of complete circles. Areas where the band is too narrow within which to fit a complete circle will be skipped, so the distribution of circles may be discontinuous. These gaps between territories reflect areas where the willow cover is too sparse (not sufficiently dense) to support a nesting territory.

V_1 = % deciduous shrub cover (Schroeder 1982)

% Cover	Suitability Index Value
0	0
25	0.4
50	0.75
60	1.0
80	1.0
90	0.8
100	0.6

Variable 2 (V_2) describes the relationship between shrub height and HSI, where full value is not attained until the willows are 2 m (6.6 ft) or higher. The assumption is that stands of willows (or occasional alder, red-twig dogwood, or cottonwoods 2 m or taller) could be 100% usable. Both naturally established and planted willows are assumed to take 3-5 years to reach 2 m in height.

V_2 = Average height of deciduous shrub canopy height (Schroeder 1982)

Canopy Height (m)	Suitability Index Value
0	0
1	0.5
2+	1.0

Variable 3 (V_3) is a cover density criterion where the willows should have shrub crown cover between 60 - 80% to provide optimal (SI = 1.0) nesting substrate. Willows have rates of growth varying by species. Typically, the shrub must become established with a good root system before the crown cover develops broadly, and requires three to five years for root establishment and sufficient cane growth for the shrub to reach 2 m in height. Naturally dispersed seeds are often distributed irregularly within target habitat. The rate of achieving the target crown cover can be accelerated by planting willow whips or stakes in a closely spaced pattern of approximately 5 feet on center, which would ensure an evenly spaced stand of willows is established, instead of relying on erratic waterborne or airborne seed distribution.

V_3 = % canopy comprised of hydrophytic shrubs (Schroeder 1982)

% Hydrophytic Shrubs	Suitability Index Value
0	0.1
25	0.3
50	0.55
75	0.8
100	1.0

2.6 Native Salmonid Model

Juvenile Chinook salmon in Lake Quinault at the mouth of Falls Creek.

Juvenile Chinook salmon have a high potential for rearing in the Study area. The LCR is currently listed as critical habitat for the Lower Columbia River Fall Chinook. These fish are mostly subyearlings and therefore prefer shallow aquatic habitat to avoid predation of larger fishes. These fish also benefit from prey productivity in emergent wetlands. These “ocean-type” rearing requirements are shared with chum salmon juveniles. Chum juveniles are expected to spend less time in the freshwater tidal portion of the estuary, but are still a significant part of the juvenile salmon presence in these shallow habitats.

For these reasons, the HSIs for Chinook provide a useful representation of anadromous fish use in tidally connected floodplains and wetlands, and may reflect benefits gained by restoring increased connectivity with the Columbia River. Specifically, juvenile salmonids could benefit from increased floodplain inundation, and access to backwater refugia via increased connectivity.

2.6.1 Chinook Salmon Model

The original Chinook salmon HSI model contains habitat suitability variables for all life stages - adult migration and holding, spawning/ egg incubation, and juvenile rearing, and includes water quality, sediment, riparian, stream flow, and channel morphology variables. It emphasizes stream systems, as opposed to lacustrine and large river systems. The adult migration phase emphasizes water quality variables that are likely applicable in the estuary, and in the natal stream. The spawning/ egg incubation variables are specific to spawning habitat, with fast moving waters and spawning gravels. Juvenile rearing variables include some habitat variables that could also be applicable to large river and lacustrine wetlands situations. The smolt stage is focused on water quality variables during seaward outmigration.

Raleigh et al. (1986) described 12 potential habitat variables for the juvenile stages of Chinook salmonids. This list precludes adult, fry, and smolt life-history stages, as they would not preferably use the mainstem riverine habitat type.

1. $^{CH}V_1$ = Annual minimum and maximum pH
    a. Measured during the summer to fall season
2. $^{CH}V_2$ = Maximum temperature
    a. Measured during the warmest period when species are present
    b. Taken at areas that are problematic for high temperatures
    c. (coho temperature is the same range but more restrictive for optimal (9-12 vs. 12- 18 for CHS)
3. $^{CH}V_3$ = Minimum D.O. during periods of occupation
    a. CHS Temperature Range is divided into 3 categories with separate SIs :
        i. ≤ 5 C°
        ii. 5- 10 C°
        iii. >10C°
4. $^{CH}V_4$ = Percent pools during low water, late growing season
    a. (Virtually the same between salmon, though more curve-like and more restrictive optimal range for coho)
5. $^{CH}V_5$ = Pool class rating during low water, late growing season
    a. One of three classes, A-C, defined in the model
6. $^{CH}V_6$ = Average annual base flow
    a. During late summer to winter low-flow as percentage of annual daily flow
7. $^{CH}V_7$ = Average annual peak flow

    a. As multiple of average annual daily flow

8. $^{CH}V_{8}$ = Predominant substrate class in riffle run areas for food production indicator
9. $^{CH}V_{9}$ = Average % riffle fines in riffle run areas
10. $^{CH}V_{10}$ = Nitrate-nitrogen levels in late summer after spawner die-off
11. $^{CH}V_{11}$ = Percent escape cover
    a. During late summer early fall
    b. Average low flow period
    c. Bottom velocities ≤ 40 cm/s; During late summer early fall
    d. Depths ≥ 15 cm
    e. (this differs from coho since it is shallower cover)
12. $^{CH}V_{12}$ = Percent stream areas with 10-40 cm average sized boulders
13. Measure at the same time and areas as escape cover

2.6.2 HSI Model Modifications

Existing and future conditions of the Lower Columbia River at the Woodland Island project site are and will be tidally influenced riverine shallows adjacent to riparian wetlands associated with the mainstem estuary. Thus, juvenile Chinook SI variables that are for stream habitats were not relevant and were not considered. These variables included those describing pool class; pool/riffle/run distribution; riffle/ run substrate; flow variables related to egg/ alevin/ fry development; and nitrogen-related water quality variables. Although adults may use the backwater habitat as refugia during migration, variables describing juvenile life history requirements were considered most applicable to habitats potentially affected under the possible action alternatives. While pH and dissolved oxygen are variables affecting water quality suitability, the project cannot influence land use and pollutant sources that could locally or regionally affect these variables. Given these conditions, pH and dissolved oxygen variables were excluded from this analysis. Annual maximum water temperature (CHV2) was not retained, again because this is a run-of-the-river project and the design would not influence water temperature. Existing conditions have been documented from published sources, and the effect of measures can be estimated at a coarse level (Table 3).

Table 3. Variables included in the original Chinook salmon HSIs and the rationale for use or exclusion.

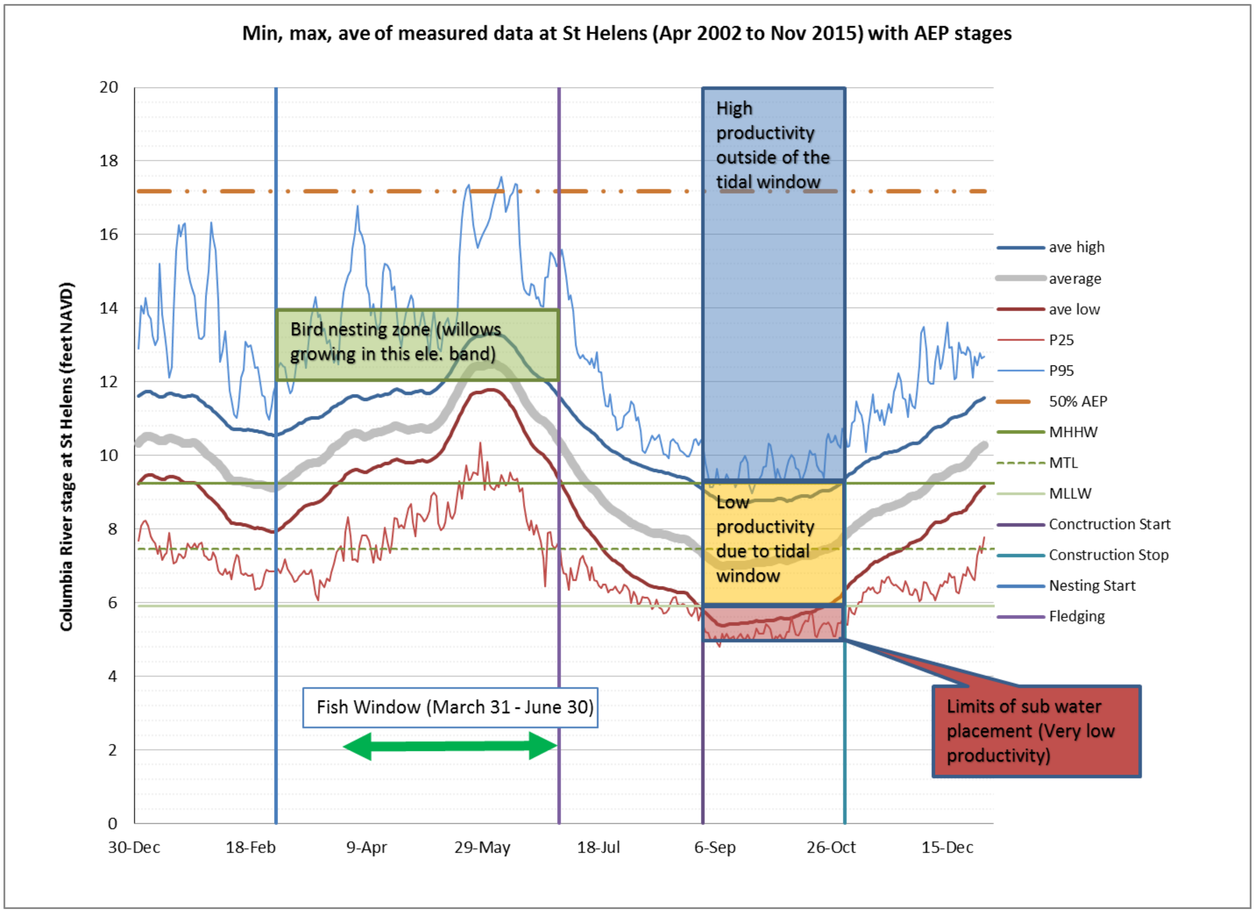
Species	V	Variable	Used	Not Used	Rationale
Native Salmonids					This model was adapted from the model created based on recent literature of Chinook use of mainstem Willamette River shallow water habitats -- based off of existing HSIs from Allen and Hassler 1986 and site specific data collected by Friesen et

Species	V	Variable	Used	Not Used	Rationale
					al 2004 and 2007. Mainstem LCR riverine conditions are similar.
Juvenile Chinook – Modified					
	V1	Temperature (°C)		X	The optimal water temperature for outmigrating salmonids is 12-13°C (53- 55°F) (Allen and Hasler 1986). The scale of the proposed project is too small to affect temperature in the LCR where the restoration sites occur.
	V2	Salinity (ppt)		X	Lethal salinity level for juvenile salmonids is between 15-30 ppt (Allen and Hasler 1986). The study area is upstream of Columbia River estuarine mixing zone and saline conditions do not exist, therefore, salinity was not included as an evaluation parameter.
	V3	Dissolved Oxygen (mg/L)		X	The tolerance level for DO for juvenile salmonids is >4.5 mg/l (Allen and Hasler 1986). DO in the mainstem is between 6.0-14.8 mg/l, therefore, not identified as a limiting factor during the season of peak out- migration (February – May), for which the project is designed, and no restoration measures were developed to address this variable. The scale of the proposed project is too small to affect DO in the LCR where the restoration sites occur.
	V4	Substrate	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V5	Depth	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V6	Water Velocity (ft/s)		X	Optimal water velocities for juvenile salmonids are between 0.06-0.24 m/sec (. Side channels and backwaters by definition are low

Species	V	Variable	Used	Not Used	Rationale
					velocity habitats and have been designed for this project to have the geometry and other criteria specifically to ensure low velocities (< 30 cm/s). Developing velocity estimates at this stage of the study would require extensive hydraulic modeling of the lower Willamette River, beyond the scope of this study. Proposed side channels and backwaters do not currently exist, therefore, there is no baseline to compare benefits.
Juvenile Chinook – New					
	V_1	Depth (<20m from shore)	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V_2	Substrate	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.
	V_3	Percent cover bank vegetation	X		Identified as a limiting factor and showed a relationship with fish presence in Friesen et al. (2007) study.

The modified juvenile salmonid HSI model lists three habitat criteria with variable V_1 as area of depth 0-10 ft within 20 meters of the shoreline, V_2 as substrate taken as an area and type, and V_3 as percent of vegetation cover along the shoreline. For this site and study, the shoreline will be delineated on the 10 ft NAVD contour. This elevation was selected as the interface of the scrub-shrub and fringe wetlands where vegetation which may be considered velocity cover and the velocity refugia are initially inundated. This elevation lies within mean low and high river stage during the assumed period of occupation by salmonids and will provide intermittent velocity cover and refugia (Figure 4).

Figure 4. Minimum, maximum, and average annual exceedance probability (AEP) stages (feet, NAVD88) at St. Helens, Oregon for the period April 2002 to November 2015.



The HSI for mainstem salmonids is described in the following equation:

$$HSI_{\text{Salmonids Mainstem}} = (V_1 + V_2 + V_3) / 3$$

Variable 1 (V1) – Salmonid response to percent vegetative bank (shoreline) cover will be evaluated by the percent cover scaled by the length of vegetated shoreline. Unvegetated and vegetated shoreline length will be calculated (at 10 ft NAVD) to feed the HSI model variable of percent cover bank vegetation. Fully established shoreline (defined at 10' NAVD) in sheltered areas are assumed to have a V1 HSI value of 1.0, whereas shorelines in unprotected areas where regularly higher velocity will prevent permanent vegetation establishment will have a HSI value of 0.0. The suitability index value of bank vegetation becomes maximal at around 30%.

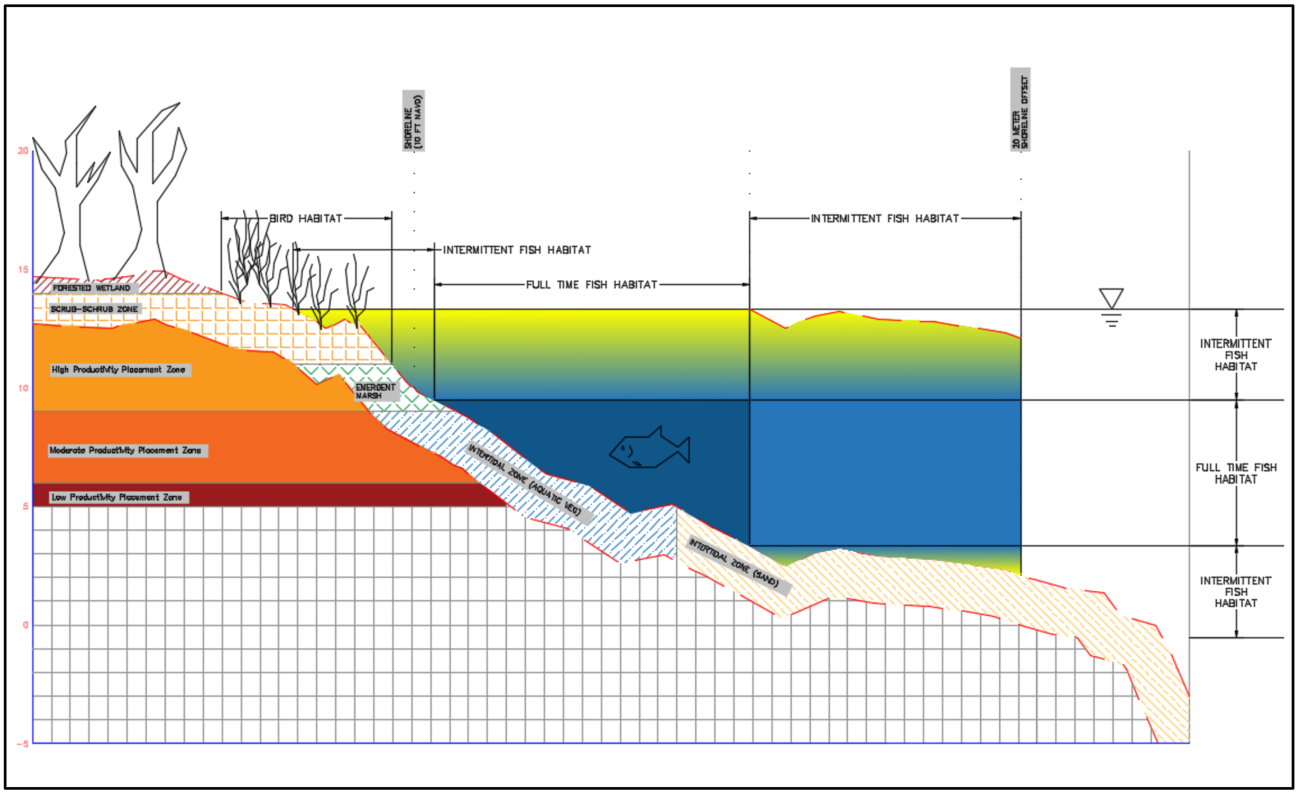
V1 will also change with time as vegetation cover will require at least one growing season to begin initial establishment such that the benefits will not be available immediately in areas that are disturbed or constructed.

V_1 = % Cover Bank Vegetation (Friesen *et al.* 2004)

% Cover	Suitability Index Value
0-10	0
11-20	0.3
21-30	1
31-40	0.6
41-80	0.2
81-100	0.1

The target habitats that were identified to benefit salmonids and resident and migrant passerines and the placement capabilities identified through the hydrologic modeling of riverine elevations were diagrammed to show the relationships of the target habitats (Figure 5).

Figure 5. Relationship of the target habitats identified to benefit salmonids and resident and migrant passerines and the placement capabilities identified through the hydrologic modeling of riverine elevations.



The time required to develop full cover will vary depending on the approach to establishing vegetation on the site – whether plants are allowed to establish through natural seed dispersal or whether a planting plan is used. Unplanted areas will develop bank vegetation from ambient seed sources and will slowly self-seed and fill in, but development of this shoreline cover will likely be patchy and have a longer establishment horizon than if the shoreline were to be planted. Uneroded areas will develop rooted seedlings and these will grow to about 2 m at YR5 with associated crown cover. It is assumed the rate of benefit accumulation will be faster if the site is planted versus allowing it to revegetate naturally. For areas that are planted, it is assumed that the method will be to plant willows as stakes and stakes will develop about 30% crown cover in Y0-5; thereafter, cover will maintain and some periodic self-seeding will occur annually in response to material erosion that will slowly increase stand density but also reset shrub height through succession.

Several species of willows grow commonly in the Columbia River basin floodplain and could be used for restoration planting. Columbia River willow is the likely species on the shoreline edge; it is shorter with sparser crown cover than the other several species of willows that are local to the area and could be planted at lower elevations on the dredged material plain. Demonstration plantings of Scouler's, Hooker's, and Pacific willows, which had grown to six feet or greater in height in approximately five years, were observed at a few sites on Sauvie Island in the Willamette River, about 30 miles south of Woodland Island, in summer 2017 (Figure 6).

Figure 6. Typical local growth rate of willows: Scouler willow stake (example planting from NRCS manual) (left), and approximately five year old shrub observed at Sauvie Island, Columbia County, OR (summer 2017) (right).

Variable 2 (V2) – This variable examines depth of the area from the 10 ft contour outward to a distance of 20 m offshore. This 20 m wide band parallels the shoreline of the dredged material. Salmonids are assumed to use this segment of river for rearing and refuge from at least March 31 to June 30 annually (NMFS 2011; Figure 2-1). For this plan and study, extending the period of analysis for fish presence results in diminished elevation ranges of continuously submerged substrate. This will omit the inclusion of EAV substrate and dilute the relative difference in performance between evaluated planforms. The average daily stage during this period ranges from 13.3 ft at high tide to 9.5 ft at low tide at the site. To meet the depth criteria of 0 – 10 ft identified for 100 percent of the rearing period, the maximum elevation of rearing habitat is 9.5 ft

and the minimum elevation of rearing habitat is 3.3 ft within 20 meters of the shoreline. There are bands of intermittent fish habitat as defined within 13.3 ft to 9.5 ft and also within 3.3 ft and -0.5 ft. It is expected that the upper band, which encompasses the scrub-shrub and emergent fringe wetlands, provides significant value to foraging juvenile fish through primary production and refuge; however, these intermittent bands will be omitted for the purpose of this modeling effort in determining the placement locations and whether or not to grade the dredge placement for increased complexity.

Chinook juveniles appear to prefer areas with slow to moderate velocities, < 30 cm/s (Healey 1991). Juvenile salmonids have been found along channel margins during outmigration through the large rivers, where velocities are lower and cover is more abundant (Murphy et al. 1989, Beechie et al. 2005). Additionally, outmigration studies have shown that juvenile Chinook are found off-channel floodplain habitats, particularly sloughs and channel edges, and off-channel terrace tributaries and tributary mouths (Murphy et al. 1989; Sommer et al. 2001, 2005; Brown 2002). However, Chinook were virtually absent from beaver ponds or off-channel sloughs. In these studies, velocities along banks in large rivers have been found to have mostly low velocities (<0.5 ft/s [15 cm/s]) (Beechie et al. 2005) and all backwater habitats had mean water velocity of <0.5 ft/s (Murphy et al. 1989 and Beechie et al. 2005). Therefore, juvenile Chinook are attracted to habitats that are by definition low in velocity. Additionally, numerous studies conclude that younger age classes of juvenile salmonids are highly associated with shallow, nearshore beach habitats with sandy substrate (e.g., Lister and Genoe 1970, Johnsen and Sims 1973, Dauble et al. 1989). Bank cover is also an important variable in out-migrating habitats and juvenile Chinook were found by Beechie et al. (2005) to be associated with all potential cover types present.

These behavioral observations supported using a variable that characterized the distance from shore as an indicator of where fish would congregate. The selected plan will be further evaluated and refined with regard to intermittent wetted emergent marsh and scrub-shrub wetland.

Variable 2 (V2) is calculated as the intersecting area that meets the depth criteria (translated to the area between elevation bands at 9.5 and 3.3 feet NAVD) and the distance from shore criterion (20 m from shoreline, which is defined by the 10 feet NAVD contour) divided by the total area within 20 m of the shoreline. V2 will change over the life of the project as the terrain responds to periodic fluvial forcing. The rate of change is expected to vary based on location, design, and any benefits obtained by accelerating more extensive plant cover on the dredged material plain via a planting plan as opposed to having the site revegetate naturally. See the H&H appendix for a more detailed discussion of fluvial morphology.

V_2 = Depth (<20 m from the shore) (Allen and Hassler 1986, Friesen *et al*. 2004)

Depth (m)	**Suitability Index Value**
0	0.5
0.55	0.5
0.55	1
3.05	1
3.05	0.6
10	0.6
10	0.1
15	0.1

Variable 3 (V3) – Salmonids respond to different substrates within the range of distance from shore and depths in the habitat identified in V1. There are three dominant identified substrates at the site within the known habitat elevation: sand, SAV, and EAV. The island is formed of previously placed dredged material and sand is the ubiquitous substrate, forming all shorelines, the bank descending into the water, and occurring as the prevalent unvegetated substrate in [all] other areas below approximately 9 ft NAVD. Submerged aquatic vegetation (SAV) occurs growing on sand typically in the shallow water zone of 0 – 6 ft NAVD within protected embayment areas that are sheltered from high water velocities in the major conveyance channels. SAV distribution is rarely continuous so patches of sand will occur within this elevation range. Areas that are hydraulically sheltered will be qualitatively assessed and regions of aquatic vegetation will be assumed to determine the effects of aquatic substrate. Emergent aquatic vegetation (EAV) occurs as wetland plant colonies fringing the shoreline from approximately 9 ft NAVD to the upper limits of the salmonid habitat (9.5 ft). EAV distribution is also rarely continuous, so patches of sand will occur within this elevation range. A vegetated intertidal emergent marsh provides important feeding habitat for salmonids. For example, small subyearling Chinook salmon enter emergent marshes and consume chironomids, which themselves feed on decaying marsh macrodetritus (Bottom et al. 2011). This analysis assumes that one of the three substrate types will characterize the 20 m distance buffer from the 10 ft contour and did not calculate HSI scores for each independent region.

During the development of plans and specifications, the elevational contours could be evaluated separately and weighted by their relative spatial contribution. *[If implemented, the approach would be: The site will be divided into the three substrate types (EAV, SAV, and Sand) by contours at the above mentioned elevations and within the shoreline habitat criteria defined as 20m from the 10' contour, and the total acreage of each substrate type will calculated. V3 is the weighted average of the three substrate types calculated with the following formula, where A is area (acres) and HV is a habitat value. EAV, SAV, and sand have HVs of 1.0, 1.0, and 1.0, respectively:* $V_3 = (A_{EAV}*HV_{EAV} + A_{SAV}*HV_{SAV} + A_{sand}*HV_{sand})/(A_{EAV} + A_{SAV} + A_{sand})$*].*

V_3 is will change over the life of the project as the terrain responds to periodic fluvial forcing, however, those forces are intermittent and unpredictable. Typically, in a riverine system, dredged material moves progressively downstream and gradually infills or subsides with repeated turbulent flows. Over the life of the 50 year planning horizon the erosion pattern will be measurable using GIS/remote sensing change detection analysis.

V_3 = Substrate (Allen and Hassler 1986, Friesen *et al*. 2004)

Substrate Type	**Suitability Index Value**
Bedrock	0.25
Riprap	0.35
Sand	1.0
SAV	1.0
EAV	1.0
Fines	0.45

The summary model combines the yellow warbler and juvenile Chinook variables (Table 4).

Table 4. Summary of the attributes measured for each species or species assemblage in the selected model.

HEP Model	
Yellow Warbler	V_1 = Percent deciduous shrub crown cover V_2 = Average height of deciduous shrub canopy V_3 = Percent of shrub canopy comprised of hydrophytic shrubs $HSI_{\text{Yellow Warbler}} = (V_1 + V_2 + V_3) / 3$
Native Salmonids (Mainstem)	V_1 = Depth (<20m from shore) V_2 = Substrate V_3 = Percent cover bank vegetation $HSI_{\text{Salmonids Mainstem}} = (V_1 + V_2 + V_3) / 3$

2.7 Period of Analysis

The period of analysis is 50 years, since most project benefits would continue as long as the project sites are protected from development and not significantly altered by natural processes or disasters. The 50-year period of analysis is based upon Corps' guidance, which states "The period of analysis shall be the time required for implementation plus the lesser of: (1) the period of time over which any alternative plan would have significant beneficial or adverse effects, (2) a period not to exceed 50-years except for major multiple purpose reservoir projects, or, (3) a period not to exceed 100 years for major multiple purpose reservoir projects. Appropriate consideration should be given to environmental factors that may extend beyond the period of analysis (Corps 2000)."

2.8 HSI Calculation

For the analysis species, the habitat suitability index (HSI) (between 0 and 1) was derived and the index scores for each site were averaged. The overall resulting index score was multiplied by the acreage of potential alternative restoration plans to yield habitat units. HSIs were calculated for existing conditions, conditions at 5 years without the project, 25 years without the project, and 50 years without the project; and at 5 years after restoration, 25 years after restoration, and at 50 years after restoration, through the projected 50 year life-of-the-project. It was assumed that conditions found at these intervals would reflect milestone changes in the habitat conditions as the site matured after the project was implemented. The total HSI score was divided by 50 (years; the period of analysis) to derive the Average Annual Habitat Suitability Indices, which are later multiplied by the acreage to determine the AAHUs.

These HSI scores were then combined to produce a combined HSI score using the following equation for the project sites suitable for use in a cost effectiveness and incremental cost analysis (CE/ICA).

HSI Equation Woodland Island	$HSI_{All} = (HSI_{Yellow\ Warbler} + HSI_{Salmonids\ Mainstem})$

2.8.1 Assumptions

The following assumptions were made when scoring each variable for without- and with-project conditions.

2.8.1.1 Without-Project Condition Assumptions

The assumptions used to score the baseline future conditions of the restoration site at incremental planning periods of 5 years, 25 years, and 50 years were:

- *Vegetation.* The project site is unvegetated open water.
- *Water Quality.* Localized water temperature varies typically with the discharge volume and ambient air temperatures. Existing water quality parameters including turbidity and pollution from stormwater and industrial outputs are expected to improve over time due to increased regulation of water resources and better management of stormwater within the watershed.

2.8.1.2 With-Project Condition Assumptions

The assumptions used to establish the future conditions of the restoration site after implementation of restoration measures are:

- *Vegetation.* Through placement and grading of dredged material, the area of target habitats to be restored - Forested Tidal Floodplain, Emergent Tidal Marsh – Low and High, and Intertidal Mud/Sand Flat habitats would increase. Submergent vegetation would develop in regularly submerged areas at appropriate depths (typically to depths of 2 m). The shrub community composition is unlikely to change from baseline without intervention (i.e., planting). Riparian zones are dynamic ecosystems, and observations of patchy distribution of willow clumps on the existing island shoreline suggests that future shrub density is likely to be patchy due to irregular seed placement and variable material erosion. After 5 years, it was assumed that the characteristics of the site would reflect conditions expected in a maturing riparian ecosystem that is beginning to realize the full benefits of vegetation plantings and terrestrial invertebrate production. Fast-growing trees such as willows, cottonwoods, and Oregon ash are typically well-established within a 5 year period.
- *Water Quality.* Localized water temperature varies typically with the discharge volume and ambient air temperatures. Some localized temperature decreases may occur as a result of increased canopy cover along the edge of the shoreline. The project would not influence other water quality parameters including turbidity or pollution from stormwater and industrial outputs that could improve over time due to increased regulation of water resources and better management of stormwater within the watershed.

2.8.2 Existing Habitat at Project Site

The HEP model uses acreages from area-volume relationships developed from analysis of coarsely developed terrain models from earlier iterations of the project. The analysis included a number of simplifying assumptions of the relationship between habitat area and placement volume, and looked at effect of location and complex grading at various project sizes. Area-volume relationships of 200 Kcy, 300 Kcy, and 400 Kcy were used to calculate habitat areas in the HEP analysis. The 500K alternative was removed from further consideration after USACE Waterways Maintenance Section determined that the amount of dredged material would not be available from the St. Helens Bar within the project implementation schedule. Table 5 indicates the habitat acres of dredged material available to juvenile salmon and yellow warbler at the Woodland Island complex (Table 5).

Table 5. Acres used to calculate habitat areas in the HEP analysis.

	Basic, Total (acres)			**Complex Grading (acres)**		
V, Kcy	Total	Basic Salmon	Basic, Warbler	Total	Complex Salmon	Complex, Warbler
200	18.0	3.6	14.4	18.6	4.7	14.0
300	21.6	4.3	17.3	22.5	5.6	16.9
400	27.0	5.4	21.6	28.2	7.1	21.2

Note: The planting measure can be applied optionally to the ‘Basic’ or ‘Complex Grading’ measures.

HSI Scores under existing conditions and after restoration occurs were summarized as the derivation of Habitat Units (Average Annual Habitat Units (AAHUs) for each alternative) for Yellow Warblers, the indicator species for a number of terrestrial species, especially passerine avian species (Table 6). The highest possible index score is a 1.0 and indicates the best possible conditions for each group of species. Scores between 0.7 and 1.0 indicate good to excellent quality habitat. Sites scoring below 0.3 are considered to have limited or no suitable habitat for the species selected.

Table 6. HSI scores, acres by alternative, and Average Annual Habitat Units for yellow warblers.

	Yellow Warbler HSI					
Alternative	**V1**	**V2**	**V3**	**Aggregate**	**Area (acres)**	**AAHU for Warblers**
No Action	0.5	0.9	1.0	0.8	N/A	N/A
Place 200 Kcyds	0.5	1.0	1.0	0.8	14.4	11.60
Place 200 Kcyds, CG	0.5	1.0	1.0	0.8	14	11.28
Place 200 Kcyds, Plantings	1.0	1.0	1.0	1.0	14.4	14.28
Place 200 Kcyds, CG, PP	1.0	1.0	1.0	1.0	14	13.88
Place 300 Kcyds	0.5	1.0	1.0	0.8	17.3	13.94
Place 300 Kcyds, CG	0.5	1.0	1.0	0.8	16.9	13.61
Place 300 Kcyds, Plantings	1.0	1.0	1.0	1.0	17.3	17.16
Place 300 Kcyds, CG, Plantings	1.0	1.0	1.0	1.0	16.9	16.76
Place 400 Kcyds	0.5	1.0	1.0	0.8	21.6	17.40
Place 400 Kcyds, CG	0.5	1.0	1.0	0.8	21.2	17.08
Place 400 Kcyds, Plantings	1.0	1.0	1.0	1.0	21.6	21.42
Place 400 Kcyds, CG, Plantings	1.0	1.0	1.0	1.0	21.2	21.02

Notes: (1) CG = coarse grading; (2) PP = plantings. (2) The without project condition is shown as N/A because accretion and erosion rates were not calculated over the 50 year period of analysis.

The table below summarizes the derivation of the Habitat Units for Chinook salmon, the indicator species for aquatic anadromous fish (salmonids) (Table 7).

Table 7. HSI scores, acres by alternative, and Average Annual Habitat Units for juvenile Chinook salmon.

	Chinook HSI					
Alternative	**V1**	**V2**	**V3**	**Aggregate**	**Area (acres)**	**AAHU for Juv-Chinook**
No Action	0.3	1	1.0	0.8	N/A	N/A
Place 200 Kcyds	1.0	1.0	1.0	1.0	3.6	3.6
Place 200 Kcyds, CG	1.0	1.0	1.0	1.0	4.7	4.7
Place 200 Kcyds, Planting	0.2	1.0	1.0	0.7	3.6	2.6
Place 200 Kcyds, CG, PP	0.2	1.0	1.0	0.7	4.7	3.4
Place 300 Kcyds	1.0	1.0	1.0	1.0	4.3	4.3
Place 300 Kcyds, CG	1.0	1.0	1.0	1.0	5.6	5.6
Place 300 Kcyds, Plantings	0.2	1.0	1.0	0.7	4.3	3.2
Place 300 Kcyds, CG, Plantings	0.2	1.0	1.0	0.7	5.6	4.1
Place 400 Kcyds	1.0	1.0	1.0	1.0	5.4	5.4
Place 400 Kcyds, CG	1.0	1.0	1.0	1.0	7.1	7.1
Place 400 Kcyds, Plantings	0.2	1.0	1.0	0.7	5.4	4.0
Place 400 Kcyds, CG, Plantings	0.2	1.0	1.0	0.7	7.1	5.2

Notes: (1) CG = coarse grading; (2) PP = plantings. (2) The without project condition is shown as N/A because accretion and erosion rates were not calculated over the 50 year period of analysis.

The table below is a sum of the Average Annual Habitat Units for each species (yellow warblers and Chinook salmon) and is used as the ecological lift (benefits or outputs) in the IWR Planning Suite Software (Table 8).

Table 8. Sum of Average Annual Habitat Units for each species (yellow warbler and Chinook salmon (juveniles)) – Total AAHUs by alternative.

Alternative	**Total AAHUs**
No Action	N/A
Place 200 Kcyds	15.20
Place 200 Kcyds, CG	15.98
Place 200 Kcyds, Planting	16.92
Place 200 Kcyds, CG, PP	17.33
Place 300 Kcyds	18.24
Place 300 Kcyds, CG	19.21
Place 300 Kcyds, Plantings	20.31
Place 300 Kcyds, CG, Plantings	20.87
Place 400 Kcyds	22.80
Place 400 Kcyds, CG	24.18
Place 400 Kcyds, Plantings	25.38
Place 400 Kcyds, CG, Plantings	26.23

3 CONCLUSIONS

USACE anticipates that the proposed project restoration measures would provide juvenile salmonid rearing and foraging habitat for threatened fall Chinook salmon subyearling life histories and for threatened chum salmon, both Endangered Species Act (ESA)-listed Evolutionarily Significant Units (ESUs), as well as for coho salmon, a threatened species. Other salmonids including threatened and endangered spring/summer Chinook salmon, Snake River sockeye salmon, threatened steelhead trout, and coastal cutthroat trout also are expected to benefit indirectly from habitat restoration. The proposed project also is anticipated to provide habitat for Pacific lamprey, an ESA-listed species of concern.

USACE selected the cost effective alternative that would efficiently meet the project objective. This HEP analysis shows that the proposed project would provide about 20 acres of floodplain habitat and approximately 21.2 acres (21.0 AAHU) warbler AAHU and 7.1 acres (5.2 AAHU) juvenile chinook AAHU as lift to the habitat availability of the two selected indicator species if dredged material were placed at Woodland Island, indicating that the ecological integrity of the watershed and associated values and functions would be improved for these, and other species with similar habitat requirements. This project is intended to restore functioning out-migration rearing and warbler nesting habitat in the Lower Columbia River basin to support ecosystem integrity with associated values and functions over time, rather than creating a specific static habitat type, restoring or managing habitat for a single species, or increasing the population of a single species.

This HEP analysis provides the data used by USACE in the “cost effectiveness and incremental cost analyses (CE / ICA)” to assist in decision making and to identify the National Ecosystem Restoration plan. The implementation of CE / ICA helps in the formulation of efficient and effective ecosystem restoration solutions for ecosystem restoration projects. This approach is discussed in Appendix ___. Use of these scores to populate the cost effectiveness/incremental cost analysis model shows that these projects are “best buy” plans, meaning that they are good plans that are worth implementing.

4 REFERENCES

Allen, A.W. 1982. Habitat suitability index models: Beaver. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.30. 20p.

Allen, M.A., and T.J. Hassler. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) – Chinook salmon. U.S. Fish and Wildlife Service Biological Report 82(11.49). U.S. Army Corps of Engineers, TR EL-82-4.

Aroner, W.E. 2001. Willamette River Watershed Water Quality Status and Trends Report. Report to Portland Bureau of Environmental Services.

Beechie, T.J and M. Liermann, E.M. Beamer, R. Henderson. 2005. A classification of habitat types in a large river and their use by juvenile salmonids. Transactions of the American Fisheries Society 134:717-729.

Bottom, D. L., C. A. Simenstad, J. Burke, A. M. Baptista, D. A. Jay, K. K. Jones, E. Casillas, and M. H. Schiewe. 2005. Salmon at river's end: the role of the estuary in the decline and recovery of Columbia River salmon. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-68.

Bottom et al. 2011. p109

Brown, T. G. 2002. Floodplains, flooding and salmon rearing habitats in British Columbia: a review. Research document 2002/007, Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia, Canada.

Campos, B.R., R.D. Burnett, H.L. Loffland, and R.B. Siegel. 2014. Evaluating meadow restoration in the Sierra Nevada using birds and their habitat associations . Report to the National Fish and Wildlife Foundation. Point Blue Contribution No. 2005. Point Blue Conservation Science, Petaluma, CA

Cornell University. https://www.allaboutbirds.org/guide/Yellow_Warbler/lifehistory.

Corps. 2000. Dauble, D.D., T.L. Page, and R.W. Hanf, Jr. 1989. Spatial distributions of juvenile salmonids in the Hanford Reach, Columbia River. Fishery Bulletin 87:775-790.

Cowardin, L. M., Carter, V., Golet, E C. & LaRoe, E. T. 1979. Classification of wetlands and deepwater habitats of the United States. US Fish and Wildlife Service FWS/OBS 79/31.

Friesen, T.A., and J.S. Vile, A.L. Pribyl. 2004. Migratory Behavior, Timing, Rearing, and Habitat Use of Juvenile Salmonids in the Lower Willamette River. Oregon Department of Fish and Wildlife Columbia River Investigations. Clackamas, Oregon.

Friesen, T.A. (Ed.) 2005. Biology, Behavior, and Resources of Resident and Anadromous Fish in the Lower Willamette River. Final Report of Research, 2000-2004. City of Portland Bureau of Environmental Services, Portland, Oregon.

Friesen, T.A., J.S. Vile, and A.L. Pribyl. 2007. Outmigration of juvenile Chinook salmon in the lower Willamette River, Oregon. Northwest Science. 81(3):173-190.

Healey, M. C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 311–394 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver.

Johnsen, R.C., and C.W. Sims. 1973. Purse seining for juvenile salmon and trout in the Columbia River Estuary. Transactions of the American Fisheries Society. 102:341-345.

Lister, D.B. and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of Chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada. 27:1215-1224.

Lowther, P. E., C. Celada, N. K. Klein, C. C. Rimner, and D. A. Spector. 1999. Yellow Warbler (Dendroica petechia). In The Birds of North America, No. 454 (A. Poole and F. Gill, eds.). The Birds of North America Online, Ithaca, New York.

McMahon, T.E. 1983. Habitat Suitability Index Models: Coho Salmon. Report FWS/OBS-82/10.49, Western Energy and Land Use Team, U.S. Fish & Wildlife Service, Washington, DC.

Morreale, S.J. & J.W. Gibbons. 1986. Habitat Suitability Index Models: Slider Turtle. Biological Report 82(10.125), National Ecology Center, U.S. Fish & Wildlife Service, Washington, DC.

Murphy, M.L., and J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (Oncorhynchus) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 46:1677-1685.

National Marine Fisheries Service (NMFS). 2008. Remand of 2004 Biological Opinion on the Federal Columbia River Power System (FCRPS) including 19 Bureau of Reclamation Projects in the Columbia Basin (Revised pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon). Portland, OR.

National Marine Fisheries Service (NMFS). 2011. Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead. NMFS Northwest Region. Portland, OR. January. Prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc., subcontractor.

National Marine Fisheries Service (NMFS). 2014. Endangered Species Act 7(a)(2) Supplemental Biological Opinion: Consultation on remand for operation of the Federal Columbia River Power System (FCRPS). Portland, OR.

North American Bird Conservation Initiative, U.S. Committee. 2014. State of the Birds 2014 Report. U.S. Department of Interior, Washington, DC.

Oregon Department of Environmental Quality (ODEQ). 2006. Willamette Basin TMDL Order. http://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Willamette-Basin.aspx. Salem, OR.

Partners in Flight. 2012. Species assessment database.

Peterson, A. 1986. Habitat suitability index models: Bald eagle (breeding season). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.126). 25 pp.

Raleigh, R.F., W.J. Miller & P.C. Nelson. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Chinook Salmon. Biological Report 82(10.122). National Ecology Center, U.S. Fish & Wildlife Service, Washington, DC.

Roegner, G.C., E.W. Dawley , M. Russell, A. Whiting & D.J. Teel (2010) Juvenile Salmonid Use of Reconnected Tidal Freshwater Wetlands in Grays River, Lower Columbia River Basin. Transactions of the American Fisheries Society. 139:4, 1211-1232.

Rosenberg, D., J. Gervais, D. Vesely, S. Barnes, L. Holts, R. Horn, R. Swift, L. Todd, and C. Yee. 2009. Conservation Assessment of the Western Pond Turtle in Oregon. Version 1.0. Sponsored by: Bureau of Land Management, U.S. Fish and Wildlife Service, U.S.D.A. Forest Service, Oregon Department of Fish and Widllife, City of Portland, Metro.

Schroeder, R.L. 1982. Habitat suitability index models: Yellow warbler. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.27. 7p.

Schroeder, R.L. 1982. Habitat suitability index models: Downy woodpecker. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.38. 10p.

Schroeder, R.L. 1983. Habitat suitability index models: Black-capped chickadee. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.27. 21p.

Short, H. L., and R. J. Cooper. 1985. Habitat suitability index models: Great blue heron. U.S. Fish Wildl. Servo 8iol. Rep. 82(10.99). 23 pp.

Short, H. L. 1985. Habitat suitability index models: Red-winged blackbird. U.S. Fish Wildl. Serv. Biol. Rep. 82/10.95. 20 pp.

Sommer, T. R., W. C. Harrell, and M. L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. North American Journal of Fisheries Management 25:1493–1504.

Sommer, T. R., M. L. Nobriga, W. C. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325–333.

Sousa, P.J. and A.H. Farmer. 1983. Habitat suitability index models: Wood duck. U.S. Department of the Interior, Fish and wildlife Service. FWS/OBS-82/10.43. 27pp.

Teel, D.J., and C. Baker, D.R. Kuligowski, T.A. Friesen, B. Shields. 2009. Genetic stock composition of subyearling Chinook salmon in seasonal floodplain wetlands of Lower Willamette River, Oregon. Transactions of the American Fisheries Society 138:211-217.

U. S. Army Corps of Engineers (USACE). 2015. Channel Improvements Columbia and Lower Willamette River EIS, Volume 2. https://books.google.com/books?id=GPoyAQAAMAAJ&pg=RA3-PA34&lpg=RA3-PA34&dq=great+blue+heron+rookery+st.+helens+oregon&source=bl&ots=MFEu6ipkLw&sig=Sbb0njzTtIkqxMA5zMQRRnRiG08&hl=en&sa=X&ved=0ahUKEwjqoPr3scXRAhUB_GMKHc4DA4wQ6AEIOjAF#v=onepage&q=great%20blue%20heron%20rookery%20st.%20helens%20oregon&f=false

USACE. 2015. Lower Willamette River Ecosystem Restoration Project Habitat Evaluation Model (Appendix F - Habitat Evaluation Procedure Model). Portland, OR.

U. S. Environmental Protection Agency (USEPA) and U. S. Army Corps of Engineers. 2007. Identifying, Planning, and Financing Beneficial Use Projects Using Dredged Material; Beneficial Use Planning Manual. October 2007. Oceans and Coastal Protection Division, Office of Wetlands, Oceans, and Watersheds, Office of Water, U.S. Environmental Protection Agency, Washington, DC. Internet: https://www.epa.gov/sites/production/files/2015-08/documents/identifying_planning_and_financing_beneficial_use_projects.pdf. Accessed 5/1/2017.

U. S. Fish and Wildlife Service (USFWS). 1980a. Habitat as a Basis for Environmental Assessment. 101 ESM. USDI Fish and Wildlife Service. Division of Ecological Services. Washington, D.C.

USFWS. 1980b. Habitat Evaluation Procedures (HEP). 102 ESM. USDI Fish and Wildlife Service. Division of Ecological Services. Washington, D.C.

U. S. Geological Survey (USGS) Patuxent Wildlife Research Center. 2015. Longevity Records of North American Birds.

USGS Patuxent Wildlife Research Center. 2014. North American Breeding Bird Survey 1966–2014 Analysis.

USGS. 2014. National Water Information System. Accessed from: http://nwis.waterdata.usgs.gov/nwis

Vana-Miller, S.L. 1987. Habitat suitability index models: osprey. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.154). 46 pp.

Washington Department of Fish and Wildlife (WDFW). 1997. Draft Habitat Suitability Index Model: Pond Breeding Amphibian and Cover Model. Prepared for the U.S. Army Corps of Engineers, Columbia River Channel Deepening Project.

5 APPENDIX A

Photographs of Woodland Island (January 20, 2017)

Photo 1. Typical growth habit of willows along the south shoreline, partially inundated by the high river flow.

Photo 2. Typical growth habit of willows and red-twig dogwood along the northern shoreline; the shrubs are partially inundated by the high river flow.

Photo 3. Typical growth habit of willows on the north shoreline of the island; the willows are partially inundated by the high river flow; emergent EAV and terrestrial grasses growing under the willows.

Photo 4. Typical growth habit of willows and black cottonwood saplings (a cottonwood sapling is visible in the foreground).

Photo 5. Typical growth habit of willows along the south shoreline.

Photo 6. Typical growth habit of willows along the south shoreline; many scattered, recently established, willows occur in the foreground, while a stand of more established willows is visible in the background.

Photo 7. Typical growth habit of willows and cottonwoods along shoreline; survival affected by microtopography.

Photo 8. Typical growth habit of willows pruned by beaver; the moss covered stumps are cut off willows that are frequently submerged (east side of island in beaver foraging area).