Steigerwald Lake National Wildlife Refuge Habitat Restoration Project Effectiveness Monitoring & Adaptive Management Plan

Lower Columbia Estuary Partnership
September 2021

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Introduction

The Lower Columbia Estuary Partnership (Estuary Partnership) is proposing to restore approximately 1,000 acres of historic Columbia River floodplain habitat within the Steigerwald Lake National Wildlife Refuge (Refuge). The Refuge is located east of Washougal, Washington at the west boundary of the Columbia River Gorge National Scenic Area (CRGNSA). The Refuge is owned and managed by the U.S. Fish and Wildlife Service (USFWS). It is bounded by a private ranch to the east, the Columbia River to the south, the Port of Camas-Washougal (Port) to the west, and the Burlington Northern Santa Fe (BNSF) railroad to the north. The Refuge property is contiguous except along the northern boundary where Washington State Route 14 (SR 14) runs east-west through the Refuge. The Refuge extends along the historical Columbia River floodplain from River Mile (RM) 124 to 128. A perennial stream, Gibbons Creek, flows into the Refuge from its watershed north of the Refuge, and a second stream, Lawton Creek, borders the private ranch east of the Refuge (Figure 1 and Figure 2).

Figure 1: Regional location of Steigerwald Lake National Wildlife Refuge (NWR).

The purpose of the project is to restore floodplain processes and hydrologic connectivity between Gibbons Creek, the Columbia River, and the adjacent floodplain habitats within the Refuge. Restoration is intended to benefit Endangered Species Act-listed salmonids, as well as other native fish, wildlife, and plant species.

Restoration will be achieved by removing 2.2 miles of the levee that currently disconnects the Refuge from the Columbia River and constructing channels between the Refuge and the river, as well as restoring Gibbons Creek's alluvial fan. New (setback) levees will be constructed at the east and west extents of the project to maintain flood protection for the Port and other adjacent properties and infrastructure. The SR 14 roadway along the northern boundary of the Refuge will also be raised approximately 3 feet to reduce water level impacts to the road. Gibbons Creek restoration will include removal of the diversion structure, the elevated channel (an engineered structure resembling an aqueduct that allows Gibbons Creek to flow over the floodplain and discharge to the Columbia River through a culvert located near the crest of the levee system), and the culvert and fish ladder at the downstream end of the elevated channel. Other project measures include grading within the Refuge to expand wetland habitat, placing large wood in floodplain channels and wetlands to enhance aquatic habitat, removing 0.5 miles of rip-rap, and constructing pedestrian bridge crossings along the primary floodplain channels and Gibbons Creek. Approximately 235 acres of wetland and riparian areas within the Refuge will also be revegetated with native plant species (Figure 2). The reforested riparian areas are concentrated along Gibbons Creek (including its 53-acre alluvial fan) and the Columbia River.

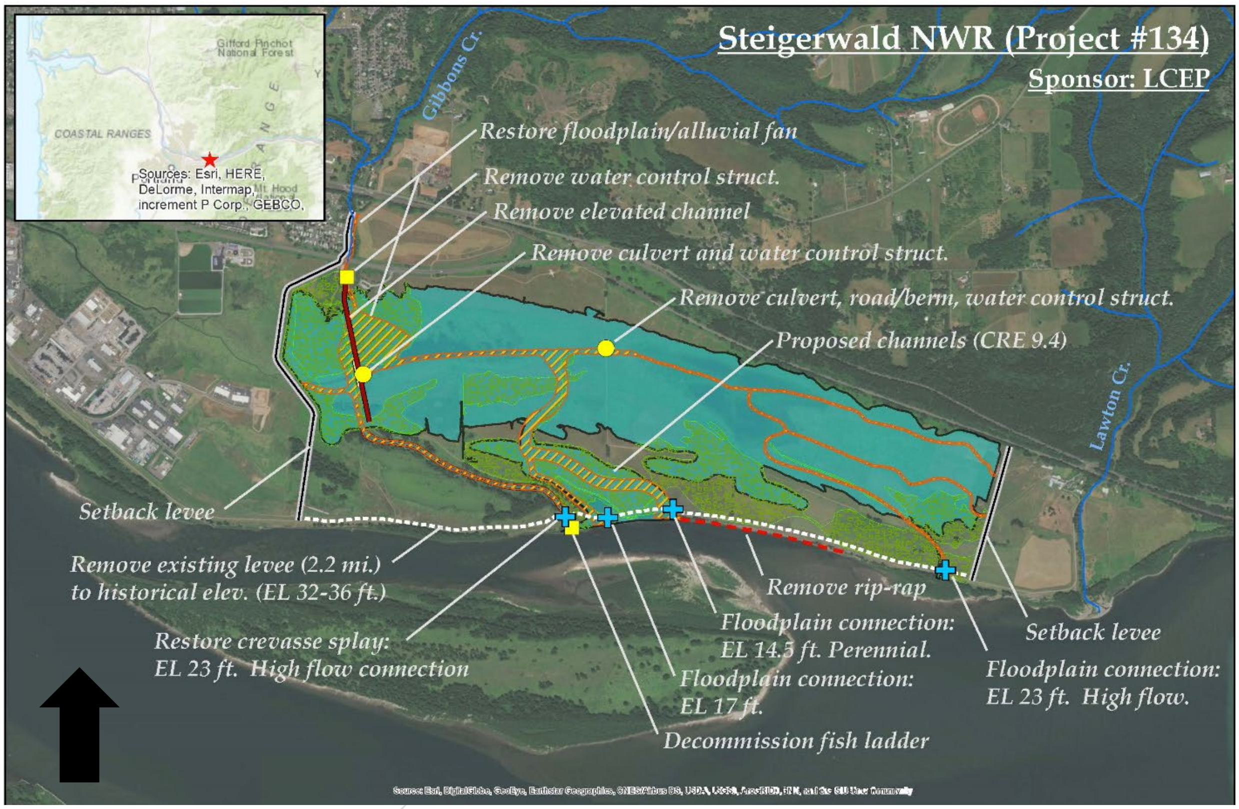

Figure 2: Map of Steigerwald Lake NWR restoration actions. The extent of wetlands and riparian areas highlighted in blue.

Steigerwald Lake NWR Project Goals

The ecological goals of the Steigerwald Lake NWR Restoration are:

1) Restoration of aquatic connectivity (to the greatest extent practical given alterations to Columbia River hydrology) between the site's wetland complex, Gibbons Creek, and the Columbia River at the full range of flows, resulting in the restoration of fish access between the Columbia River and site for all native fish species and life stages.

2) Recovery of physical, habitat-forming, and food web processes, including: more normative flow patterns, a functional alluvial fan on Gibbons Creek, and a moderated thermal regime resulting from the re-establishment of hyporheic flow.

Site Conditions

The Refuge is located on a historically dynamic portion of the Columbia River floodplain. The oldest recorded mapping of vegetation on the Refuge is c. 1860 Government Land Office (GLO) survey data. This mapping included areas of open water and wetland, dry and wet prairie, and riparian and wetland forest. Before floodplain alterations for agricultural and industrial uses in the early 1900s, the Steigerwald Lake basin (area now considered the Refuge) included the alluvial fans of Gibbons and Lawton Creeks, extensive emergent wetlands, and bottomland hardwood forests and willow bottoms, which dominated the higher elevation areas. Both creeks routinely flooded the site, and the Columbia River inundated the site annually for several months during the spring freshet and storm events. Historical aerial photographs show the floodplain as a series of seasonally-flooded, open-water areas surrounded by vegetated marsh with meandering connection channels. Higher ground along the riverward margins of the Steigerwald Lake basin was likely formed by natural, fluvial floodplain processes of inundation and sedimentation from the Columbia River. Downstream of the Gibbons Creek alluvial fan, channels connecting the floodplain depressions flowed west and eventually through low points in the natural fluvial levee of the Columbia River at the west end of the Steigerwald Lake basin. Habitat conditions within the Steigerwald Lake basin have been significantly altered since the late 1800s and early 1900s. Primary alterations include:

- A constructed flood control levee separating the Refuge and other properties from the Columbia River;
- Relocation and channelization of Gibbons Creek, including the construction of an elevated channel;
- Conversion of wetlands and forests into agricultural lands;
- Railway and highway corridor construction along the northern margin;
- Urban and industrial development adjacent to the Refuge and associated alteration of Gibbons Creek and Steigerwald Lake hydrology; and
- Proliferation of invasive species like reed canarygrass *(Phalaris arundinacea*).

Project Actions and Anticipated Outcomes

The Estuary Partnership will implement the following actions at the Refuge:

Remove 2.2 miles of Columbia River levee that separates the Refuge from the river.

- Design levee connection channel invert elevations that mimic historic conditions but use current hydrological conditions, while accommodating potential changes to the Columbia River hydrograph in combination with expected sea level rise and over the project lifespan (approximately 50 to 75 years).

  Anticipated outcomes:
  - Create floodplain habitats, including self-sustaining emergent wetland, herbaceous wetland, and riparian native plant communities.
    - .
  - Provide fish access between the Columbia River and the Refuge for all native fish species and life stages at the full range of hydrologic conditions.

Restore the Gibbons Creek channel downstream of the SR 14 bridge.

- Remove the Gibbons Creek water control structure and elevated channel that impedes sediment transport and fish passage, and impairs hydraulic and habitat conditions on the creek's alluvial fan and its deltaic connection with the floodplain. Design floodplain channels that accommodate anticipated future changes in stream flows resulting from climate change and urbanization in the watershed, including both lower flows and depths associated with decreases in spring and summer base flows, and higher flows and depths associated with increases in peak flows in the restored Gibbons Creek. Install wood habitat structures at densities similar to those found in reference streams and wetlands.

  Anticipated outcomes:
  - Enhance water quality by increasing the spatial and thermal diversity of Gibbons Creek, including the location, size, and extent of cold-water refugia within the alluvial fan.

- o Increase fish access between the Columbia River and Gibbons Creek for all native fish species and life stages at the full range of hydrologic conditions.

Restore a healthy riparian community composed of a mix of native species.

- Recovery of historic habitat-forming processes resulting in the restoration of a riparian community, which contributes leaf litter and other organic matter to the food web.

  Anticipated outcomes:
  - o Restoration of the native riparian plant community

Construct setback levees that match the design crest elevations of existing levees and meet USACE design standards.

Anticipated outcomes:
- o Maintain current level of flood protection for infrastructure and adjacent properties.

Monitoring Approach

Sample Design

Effectiveness monitoring will use a before-after/control-impact sample design (Stewart-Oaten et al. 1986). A relatively undisturbed nearby tidal wetland will be used to establish existing reference conditions and provide context for data collected at the restoration site. Monitoring will occur pre-restoration at Steigerwald and the reference sites to determine baseline conditions (see Appendix A).

Within channel construction zones, visual surveys and photo documentation will take place annually during low flows and within 30 days of flood events greater than a 5-yr event. Observations and concerns from visual surveys may be reported to the Project Review Team to potentially initiate comprehensive monitoring such as UAV surveys, cross-section surveys, longitudinal surveys. Annual data collection will also include sediment accretion and erosion monitoring, water surface elevation, water temperature, planting survival, and fish use (PIT array). Annual monitoring will cease after 5 calendar years from the date of project construction with a check-in monitoring event occurring on year 10 (Table 1). Outside of the reporting schedule, annual check-ins with the Project Review Team will provide updates on data collection, potential changes to the monitoring plan, and any adaptive management suggestions that may need to occur. These check-ins will occur annually at the time of research permit renewal and/or as needed depending on if/when triggering events occur (see adaptive management section for further details).

Habitat and macroinvertebrate monitoring metrics will be evaluated 1, 3, 5, and 10-years post-restoration (Table 1). This will include a fishing check-in event at year 5 post-restoration. Overall, data collection will focus on monitoring biological and physical habitat parameters, including hydrology, sediment accretion, and erosion. For a full suite of data collection metrics and timeframes see Table 1.

All monitoring outcomes will be reported following the timeline presented in Table 1. If an adaptive management trigger is identified during annual visual assessments of the site’s conditions (Table 2), a check-in will be performed with the Project Review Team, to identify if more timely actions are required. The Project Review Team will be composed of project partners which may include but is not limited to:

- Bonneville Power and Administration: Project COTRs, Estuary Lead, Compliance Lead
- USFWS Columbia River Fish and Wildlife Conservation Office (CRFWCO): Project Lead
- Steigerwald Lake National Wildlife Refuge: Refuge Biologist, Deputy Project Leader
- National Oceanic and Atmospheric Administration (NOAA): Supervisory Fish Biologist

- Lower Columbia Estuary Partnership: Principal Restoration Ecologist PM, Senior Scientist, and Chief Scientist

Table 1: Monitoring metrics timeline for Steigerwald and reference sites, metrics listed for monitoring in 2019-2020 have already been collected. Current Federal mandates prohibit the use of UAVs on the Refuge and further coordination will be required to implement UAV monitoring across the site. All items listed in Table 1 are considered fully funded as of May 2020. *In addition to scheduled surveys depicted in this table visual surveys and photo documentation of channel areas will take place annually during low flows and within 30 days of flood events greater than a 5-yr event.

Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2033
Project Phase	Pre	Pre	Construction		1 Yr Post	2 Yr Post	3 Yr Post	4 Yr Post	5 Yr Post	10 Yr Post
Water Levels and Temperature	X	X	X	X	X	X	X	X	X	X
Plant Community and Soil Survey	X		X		x		x		X	X
UAV Mapping: Plant Communities		X	X		X		X		X	X
Planting Survival				X	X	X	X	X	X	
Sediment Accretion and Erosion *(and visual assessment of channel development)*	X	X	X	X	X	X	X	X	X	X
Channel Cross-Sections* *(and visual assessment of channel development)*			X (as-built)		X		X		X	X
UAV Mapping: Topographic		X	X		X		X		X	X
Macroinvertebrate Monitoring	X		X		X		X		X	X
Fish Monitoring (net)									X	
Fish Monitoring (PIT)				X	X	X	X	X	X	
Monitoring Reports (publish dates listed)	Monitoring Plan Development				X (2024)		X (2026)		X (2028)	X (2034)

Effectiveness Monitoring Goals and Objectives

The goals of Steigerwald Effectiveness monitoring are:

1. Determine if the restoration project meets established restoration goals and ensure the structural and ecological function is performing given inter-annual river variability.
2. Provide data and interpretation to assist adaptive management.
3. Provide project partners with information that will be useful for communicating project results to funders and the public.
4. Provide data to help guide and inform similar projects to other practitioners and resource managers.

Objective 1: Wetland Physical Conditions - Quantify the changes in hydrologic, topographic, soil characteristics related to tidal reconnection in the floodplain, and alluvial fan habitats.

Metrics: Water Surface Elevation, Water Temperature, Soil pH, Soil Oxygen Reduction Potential (ORP), Soil Conductivity, Sediment Accretion/Erosion, Aerial Topographic Surveys.

Objective 2: Wetland Plant Community – Quantify the changes in wetland plant community and composition related to changes in inundation regime.

Metrics: Absolute Cover, Relative Cover, Species Richness, Species Diversity, Native and Non-native Plant Community Mapping.

Objective 3: Floodplain Planting Survival – Track planting survival to ensure the establishment of restored riparian areas.

Metrics: Plant Survival, Shade, Dominant Understory Native and Non-native Plant Cover.

Objective 4: Target fish species access, use, prey resources, and habitat– Quantify changes in juvenile salmonid access, habitat opportunity, suitability, salmonid resources, and fish use of the restoration site.

Metrics: Fish; Fish Presence, Abundance, Diversity, and Species Richness. Prey resources; Aquatic Macroinvertebrate Community and Composition. Habitat; Opportunity, Water Temperature, Tidal Channel Morphology, Alluvial Fan Large Wood Abundance.

Objective 5: Gibbons Creek Physical Conditions - Quantify the changes in hydrologic, topographic, and thermal regime.

Metrics: Water Surface Elevation, Water Temperature, Alluvial Fan and Channel Morphology, UAV Thermal mapping.

Effectiveness Monitoring Sites

Steigerwald Project Site

The Steigerwald project site is located a Columbia River kilometer 203 (Figure 1). Effectiveness monitoring will occur within the two-year floodplain of the project site. The site monitoring will focus on three areas – Gibbons Creek alluvial fan area, the pastures and low areas adjacent to the constructed channels, and the greatest area of riparian revegetation (Figure 2).

Least-disturbed Reference Sites

Multiple reference sites including long-term Ecosystem Monitoring Program sites Franz Lake and Campbell slough and Reed Island will be used given the variety of expected habitat types following restoration actions focusing on plant community, hydrology, macroinvertebrate communities, and fish (Figure 3). Reed Island State Park will be used as the primary reference due to its proximity to the restoration site and will represent the potential wetland riparian community for this portion of the river. Franz Lake will be used to represent wetland habitat adjacent to the reconnection channels related to beaver activity, which can alter duration and depth of floodplain flooding.

Campbell Slough will be used to represent wetland habitat adjacent to slough channels, which are dominated by a fluvial input with minor tidal effects and will be used to compare fish PIT tag community results (Figure 3). For a full description of these reference sites and their monitoring see Appendix A.

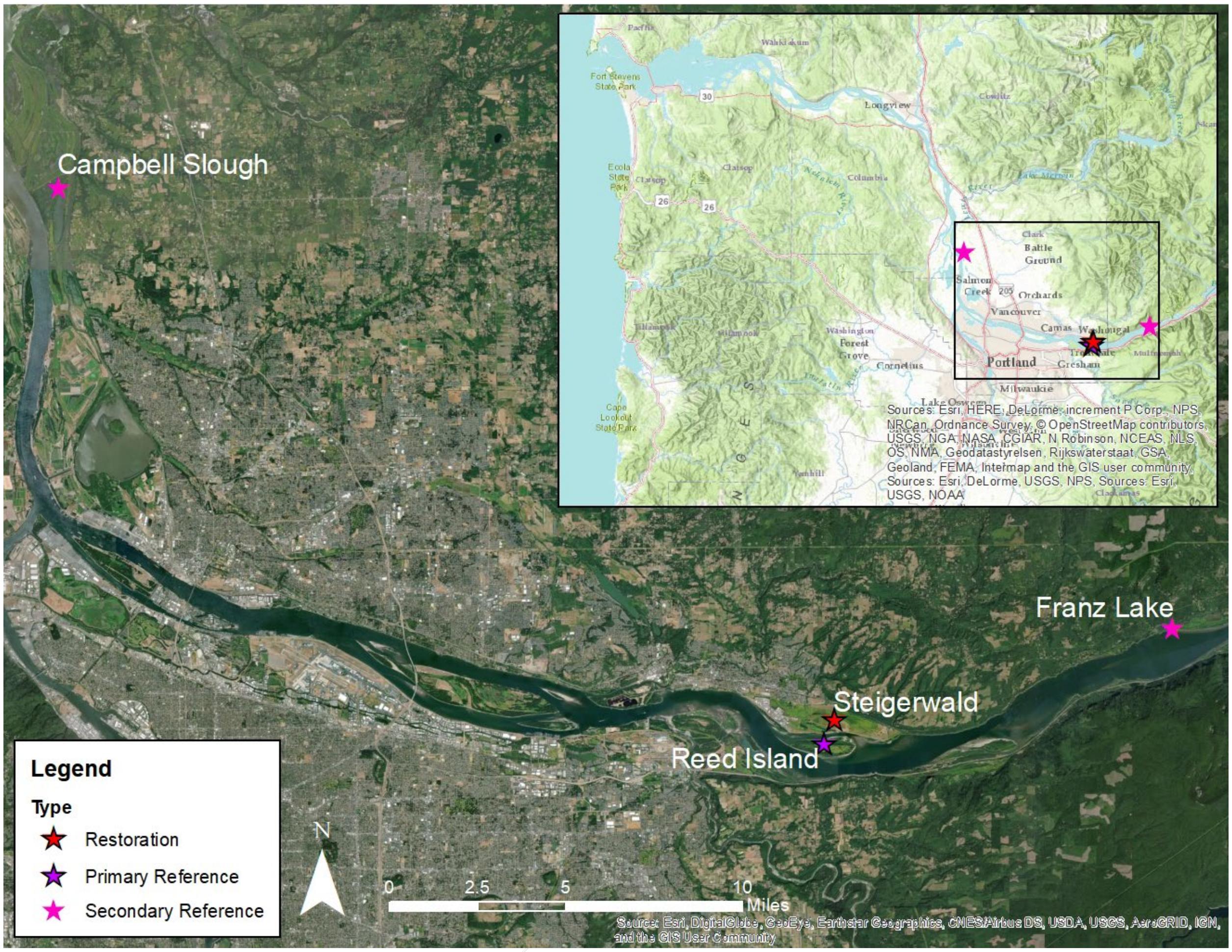

Figure 3: Location of Steigerwald Restoration site and reference sites in the lower Columbia River

Effectiveness Monitoring Protocols

Protocols used for restoration effectiveness monitoring will be the same as previous monitoring efforts in the lower Columbia River and estuary (Roegner 2009). Additional metrics will follow cited protocols and reflect best monitoring practices (Kidd et al. 2019). Applicable monitoringmethods.org links are provided. Monitoring locations are preliminary and will be finalized during pre- and post-restoration monitoring; updates will be provided in future monitoring reports. Portions of monitoring that are considered funded as of May 2021 are highlighted as “funded” in the text below, these monitoring efforts are considered adequate for meeting all regulatory requirements of site construction.

Water Level and Water Temperature

Funded (5/2021): Water level and water temperature will be monitored in Gibbons Creek and the newly developed tidal channels in Steigerwald and within the reference sites (Figure 4). We will follow protocols in Roegner et al. (2009, [Method ID 814](#)). Deployed water level loggers will collect continuous data hourly during the pre-restoration baseline period. Following project construction, loggers will be re-deployed in the same locations to collect water level and water temperature data hourly from year one-post restoration through year five and in year 10 post-restoration. Water levels will be spatially referenced to NAVD 88 and CRD. As time and budget allow, post-construction, dissolved oxygen may be included in the water quality monitoring at the same locations as the temperature and water level monitoring throughout Gibbons Creek and Steigerwald Lake. Additionally, during post-construction monitoring, effort will be made to identify thermal seeps and stratification which may impact salmonid habitat conditions.

Not funded (5/2021): Detailed temperature study of Gibbons creek alluvial fan including groundwater wells installed within the newly created alluvial fan to identify changes in water table depth and temperature.

Vegetation

Plant community

Funded (5/2021): Vegetation will be monitored in 100 stratified random plots in designated areas in the restoration site (Figure 4). Sampling plots will be located along randomly established transects located in three distinct sampling areas. An ecosystem functions vegetation model will be used to identify areas predicted to shift to a desired vegetation community (see Appendix B for model details). Vegetation cover and composition at the Steigerwald project site and reference sites will be sampled using 1 m^2 quadrats. Location and elevation of each quadrat will be collected (Method ID: 818). Vegetation monitoring will occur during peak growing season, July-August, one-year pre-restoration, and in years one, three, five, and ten post-restoration. At reference sites, 75 to 100 permanent plots will be monitored following the same sampling protocols used at the restoration site. For reference site monitoring details see Appendix A.

Soil Survey

Funded (5/2021): Within each vegetation sampling quadrat across both restoration and reference sites, in-situ surface soil salinity, conductivity, soil redox potential (ORP), pH, and temperature data will be collected using soil probes placed 5 cm below the soil surface (Figure 4, Bledsoe and Shear 2000, Neckles et al. 2002, Davy et al. 2011, Mossman et al. 2012, Gerla et al. 2013, Kidd 2017, Kidd et al. 2020). All soil surveys will be conducted in saturated soil conditions. Although these soil parameters are dynamic over time, depending on the environmental conditions present and the duration of tidal flooding, the logic in taking these in-situ samples is to capture the general gradient that existed among the different plant communities at the time of sampling. These soil data are critical for understanding plant community development outcomes, especially when outcomes are unexpected such as increases in bareground or non-native plant cover (Table 2).

UAV Mapping: Plant Community

Funded but pending UAV restrictions being lifted 5/2021: Plant community mapping will be accomplished using a small Unmanned Aerial Vehicle (UAV) to collect aerial multispectral images to determine changes in native and non-native communities. Images will be ground-truthed using ground control points (GCP), which will be distributed across the site to encompass changes in elevations and dominant plant community data (Assmann et al. 2018) . Location and elevation of GCPs will be recorded using a Real Time Kinematic GPS. This information will be used to create large scale topographic and vegetation maps (Figure 5).

STEIGERWALD MONITORING LOCATIONS: WATER LEVELS & TEMPERATURES, SEDIMENT ACCRETION/EROSIONS, AND VEGETATION TRANSECTS

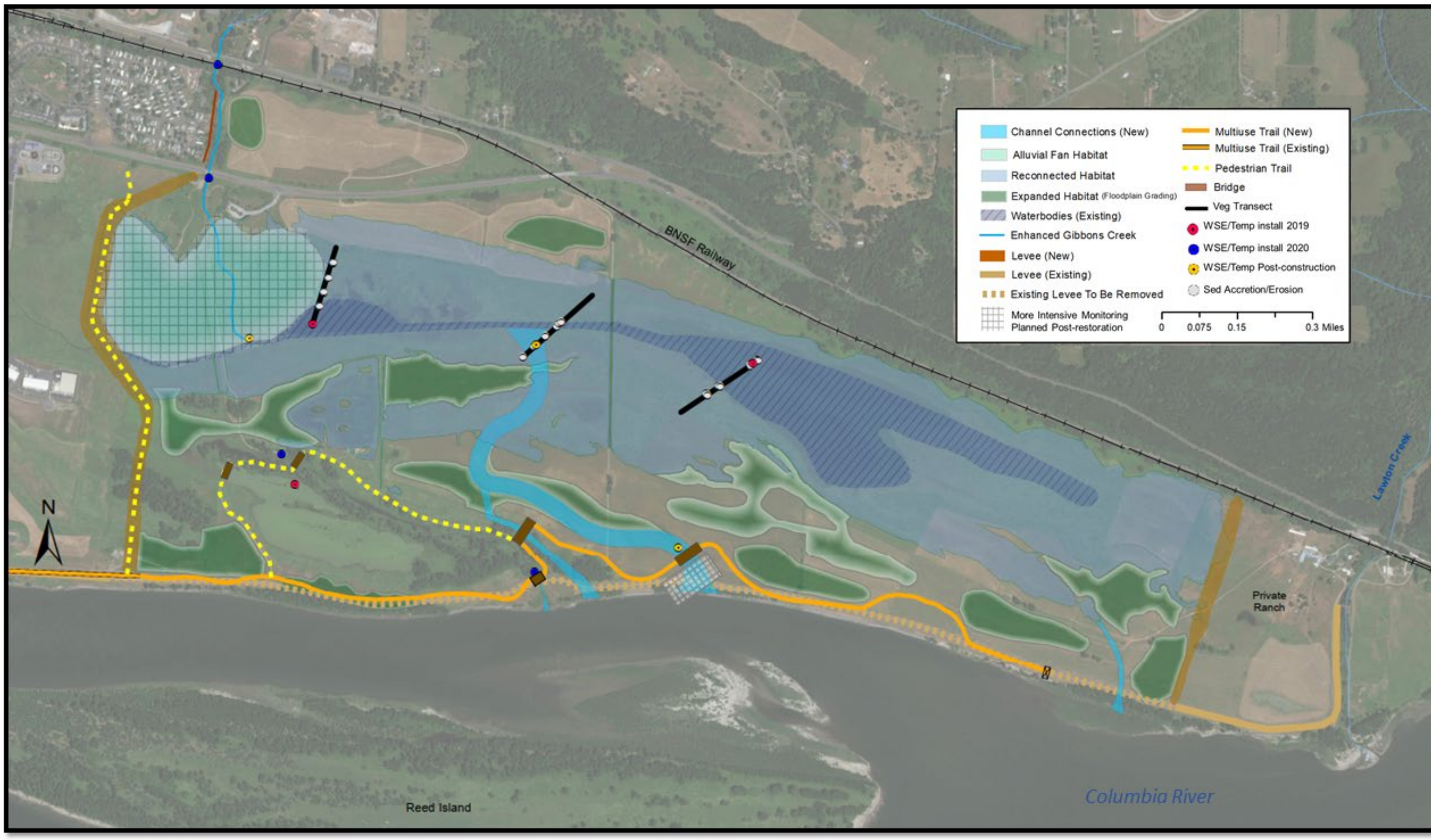

Figure 4: Monitoring locations of water level and temperature data loggers, sediment accretion and erosion benches, vegetation transects, and the intensively monitored alluvial fan portion of Gibbons Creek which will include a robust temperature and sediment study post-restoration. Additionally, the new main connection point of Gibbons Creek to the Columbia River will be the location of further stream cross-sections and a PIT-tag array for continuous fish monitoring (cross-hatched area in map above, see Figure 7 for more details). For a detailed map of restoration actions see Figure 2.

Steigerwald UAV Ground Control Point Distribution: Co-located with Ground Elevation Survey and Vegetation Observations

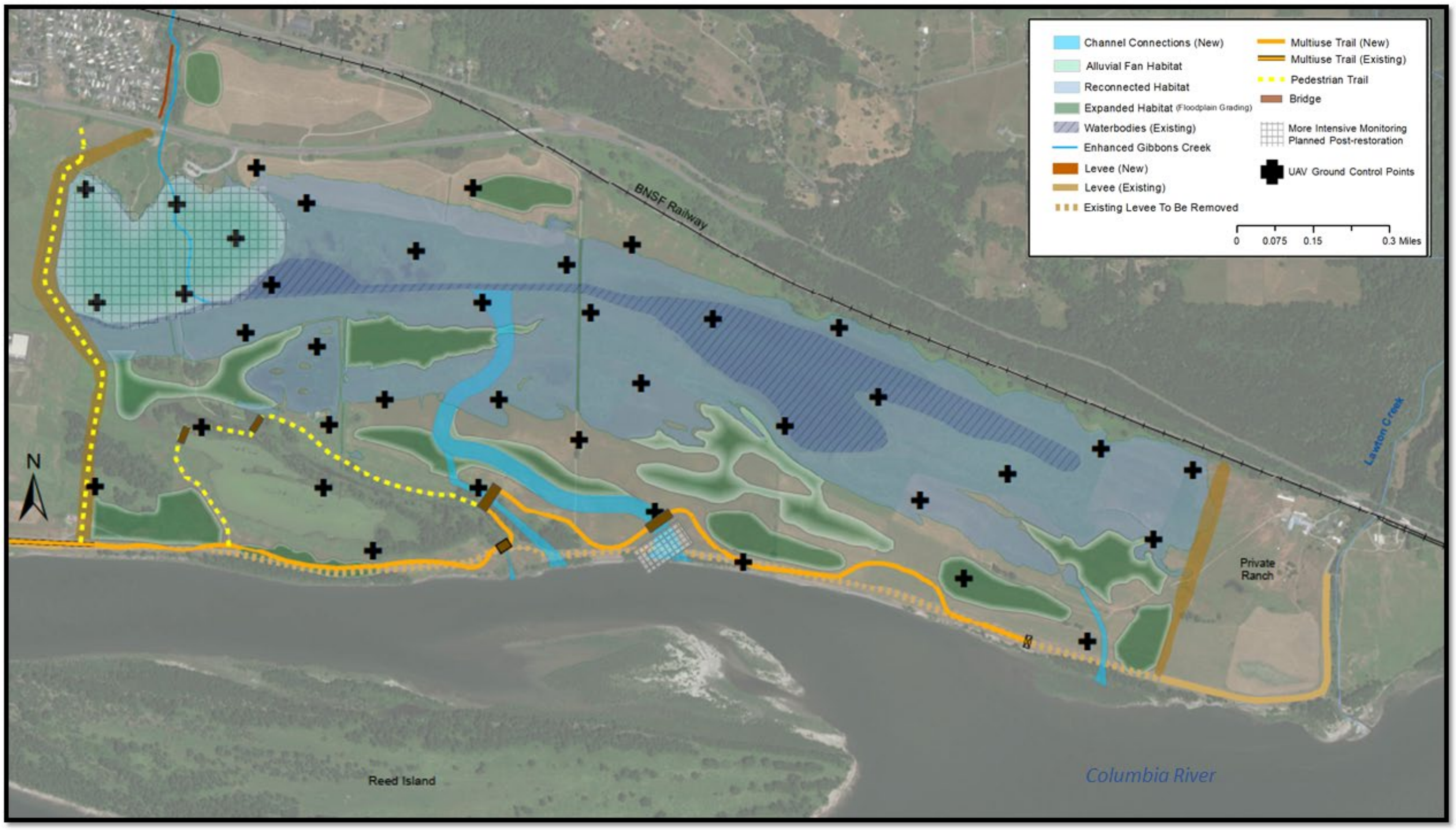

Figure 5: Ground control point (GCP) monitoring locations for vegetation and topographic mapping. These GCPs will be co-located with ground elevation data collection and dominant plant community surveys which will be used to process UAV sensor data for large scale plant community and topography mapping. Further GCPs will be included in the alluvial fan portion of Gibbons Creek and co-located with water temperature monitoring for thermal UAV sensor monitoring. For a detailed map of restoration actions see Figure 2.

Plant Survival

Planting Survival

Funded (5/2021): Planting survival will be tracked at multiple planting locations across the site. Plant survival sampling will represent the designated planting habitats and will be based on the corresponding size of those planted habitat areas. Sampling plots will be established within each of the planting habitat types; approximate sampling areas have been designated (Figure 6). Permanent sampling plots will be randomly established within those sampling areas. All live native plants within a sampling plot will be counted, identified to species level, and assigned a plant health class based on a visual, qualitative assessment. Plant health will be classified into one of four categories: dead, poor, live, and vigorous. Based on the total quantity of native plants counted and cumulative size of the plots, plant densities will be calculated and compared to contractor planting densities to estimate survival for a given planting habitat type. Periodic survival monitoring will occur during the first five growing seasons post-planting with an objective of achieving at least 80% survival or an adequate level of native revegetation established by that time.

Endangered Plant Species Survival

USFWS Partner Monitoring: Areas where endangered Nelson's checker-mallow, *Sidalcea nelsoniana,* populations exist will be monitored to ensure changes to floodplain hydrology do not impact overall plant community abundance. Visual inspections of these populations will be performed annually by the USFWS. An objective of no less than with 80% survival will be evaluated, with additional monitoring and planting required if this is not achieved. This monitoring will be ongoing annually, until this species is no longer considered endangered.

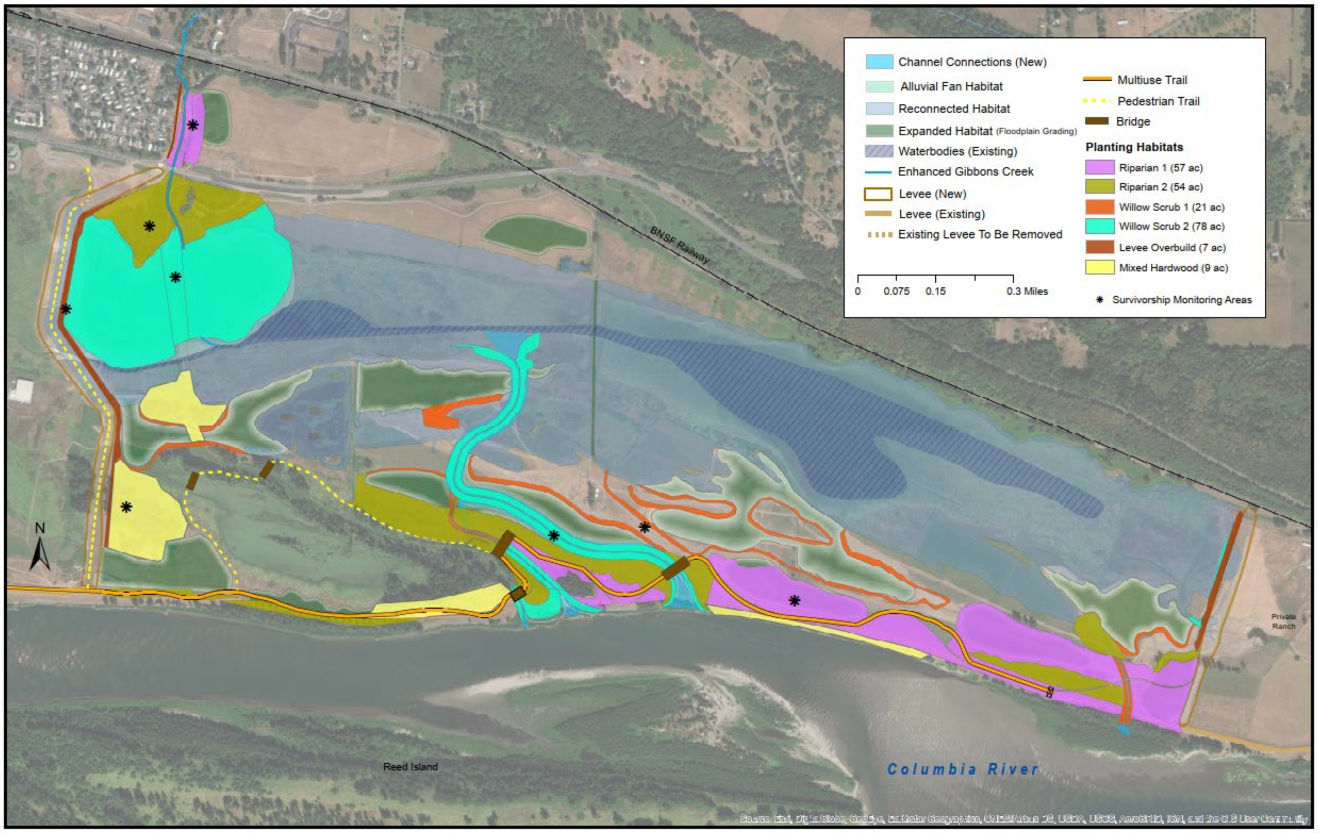

Figure 6: Designated planting areas and survival monitoring locations. For a detailed map of restoration actions see Figure 2.

Sediment Accretion/Erosion and Channel Cross-Sections

Funded (5/2021): Sediment accretion/erosion will be monitored using sediment accretion stakes following protocols in Roegner et al. (2009, Method ID 818). A minimum of four stakes will be placed across the elevation gradient of the vegetation transects (Figure 4). Elevation and locations of sediment accretion stakes will be spatially referenced.

Additional visual assessments, annually and within 30 days of high-water events (i.e., a 5-year flood event for this watershed), will be used to monitor the Gibbons Creek alluvial fan development, and channel morphology within the newly constructed waterways throughout the site, including newly established connection points with the Columbia River (Figure 2). Specific areas planned for visual assessments are identified in the photo-point methods section and in Figure 9. Where safe and feasible channel cross-sections will also be monitored in these areas with surveying techniques outlined in Roegner et al. (2009) protocols on years 1, 3, 5, and 10 and/or when further monitoring is deemed necessary by annual visual assessments. Instances of dramatic shifts in sediment (>1'), channel head cutting, or any potential salmonid barriers will trigger further monitoring and recommendations from the Project Review Team (Table 2).

Not Funded 5/2021: Additional sediment pin monitoring throughout the site and alluvial fan.

UAV Mapping: Topography

Alluvial Fan and Channel Development and Morphology

Funded but pending UAV restrictions being lifted 5/2021: Alluvial fan and channel development will be monitored using geo-referenced aerial photo surveys generated from small unmanned aerial vehicles (UAV). The elevation corrected, three-dimensional RGB model will be generated to track the change in the shape and volume of the alluvial fan. UAV flights will also track channel development and change across sampling events. These changes will be surveyed using a TOPCON real-time kinematic (RTK) GPS.

Elevation data of the site will be surveyed using a Trimble or TOPCON real-time kinematic (RTK) GPS with survey-grade accuracy. All surveying will be referenced to the NAVD88 vertical datum; the horizontal position will be referenced to NAD83. Data collected from the base receiver will be processed using the automated Online Positioning User Service (OPUS) provided by the National Geodetic Survey. OPUS provides a Root Mean Squared (RMS) value for each set of static data collected by the base receiver, which is an estimate of error. A local surveyed benchmark will be located whenever possible and measured with the RTK to provide a comparison between the local benchmark and OPUS-derived elevations.

If detailed UAV monitoring is prohibited (restrictions not lifted) this will be replaced with ground photography and visual assessments annually and within 30 days after high water events (5 yr. flood event for this watershed). These data will be used to track changes and identify issues in channel and alluvial fan development. Specific areas planned for visual assessments are identified in the photo-point methods section and in Figure 9. Results from these assessments may result in more detailed monitoring and discussion with project partners to identify adaptive management approaches (Table 2).

Partner no longer capable of work (5/2021): In collaboration with USFWS, thermal infrared (TIR) data will also be collected to track changes in Gibbons Creek's thermal regime and cold-water seep development in the newly formed alluvial fan. On the ground sediment pins (to monitor sediment dynamics) and channel cross-sections (Roegner et al. 2009, Method ID 818), will be paired with groundwater and surface water temperature monitoring, these monitoring clusters will be used to calibrate and ground truth UAV sensor data (Halpern, 2019; Langhammer, 2019).

Macroinvertebrate Monitoring: Fish Prey Resources

Funded 5/2021: We shall sample salmonid prey resources by collecting invertebrate samples from along the edge of marsh with neuston nets by performing two tows from the marsh edge. The neuston net (250 µm mesh) shall be pulled through a 10-m transect parallel to the water's edge in water at least 25 cm deep to enable samples from the top 20 cm of the water column (Kidd et al. 2019). This sampling is conducted once each spring to capture invertebrate community data during peak salmonid migration, in 2019 and 2021 (pre-restoration) these samples were collected near the south end of the first vegetation transect within Steigerwald Lake (located nearest to the alluvial fan, Figure 5). Post-restoration sampling locations will be finalized post-construction and included in future monitoring reports. Annual neuston sampling will be conducted on years 1, 3, 5 and 10 post-restoration.

Fish Monitoring: Distribution, Diversity, and Abundance

Net sampling, Genetic Testing, and Stomach Content Analysis

Not funded 5/2021: A memo outlining multiple fish monitoring approaches that could be implemented at Steigerwald and their associated costs are provided in Appendix C. The following description is of the fish monitoring approach taken at the long-term status and trends (reference) sites monitored through the Ecosystem Monitoring Program (Rao et al. 2020). Fish will be collected post-restoration in March, April, and May using a 38 x 3-m variable mesh bag seine (10.0 mm and 6.3 mm wings, 4.8 mm bag). Bag seine sets will be deployed using a 17 ft Boston Whaler or 9 ft inflatable raft. Up to three sets will be performed per sampling month, as conditions allow. At each sampling event, the coordinates of the sampling locations, the time of sampling, water temperature, weather, habitat conditions, and tide conditions will be recorded. The monitoring protocol can be found on monitoringmethods.org (Method ID 826). All non-salmonid fish are to be identified to the species level and counted. For salmonid species other than Chinook, up to 30 individuals will be measured (fork length, nearest mm), weighed (nearest gram), and released. Up to 30 juvenile Chinook salmon will be euthanized in the field, measured, weighed, and retained for subsequent laboratory analyses (diet, genetic, lipid, and otolith). If present, an additional 70 Chinook will be measured and released. Any additional Chinook will also be counted and released. All salmonids will be checked for adipose fin clips, or other external marks, coded wire tags, and passive integrated transponder tags to distinguish between marked hatchery fish and unmarked (presumably wild) fish.

Fish bodies retained in the field will be frozen and stored at -80°C. At the end of the sampling season, fish will be necropsied and samples will be collected for laboratory analyses. Stomach samples for taxonomic analyses will be preserved in 10% neutral buffered formalin. Fin clips for genetic analyses will be collected and preserved in alcohol, following protocols described in Kidd et al. (2019). Otoliths for age and growth determination will also be stored in alcohol. Whole bodies (minus stomachs) for measurements of lipids will remain frozen until processed. These methods are currently being employed at Campbell Slough and Franz Lake, which have been identified as reference sites for Steigerwald project.

Funded 5/2021: In lieu of the detailed fish and macroinvertebrate sampling described above, a two-day fish check-in will be performed at year 5 post-restoration following standard AMER protocols described in Kidd et al. 2020. Fish will be collected using a bag seine (BS; 37 x 2.4 m, 10 mm mesh size). All sets will be deployed using a 9-ft Zodiac inflatable raft. The objective of the sampling is to determine the fish community and whether salmon were present or absent, given this there will be no limits on the number of seine efforts at the site. All non-salmonid fish will be identified to the species level counted and released. All salmonids will be measured (fork length, nearest mm), weighed (nearest g), and released. A genetic sample will be taken from the caudal fin on all captured Chinook salmon. All salmonids will be checked for adipose fin clips, or other external marks, coded wire tags, and passive integrated transponder tags to distinguish between marked hatchery fish and unmarked (presumably wild) fish. A fish condition index (Fulton's) will be calculated using the following equation: K = (W/L3) x 100,000.

Passive Integrated Transponder Array (PIT) Sampling

Funded 5/2021: Following completion of the project, a Passive Integrated Transponder Array (PIT) will be installed at the site. The location of the PIT array will be at the new main channel connection between Gibbons Creek and the Columbia River near the new foot bridge that crosses this location (Figure 2, Figure 4, Figure 7). The PIT array will document species and residence time of tagged fish. The array is intended to monitor the presence and to estimate residency of PIT tagged fish in the site's floodplain. For more information on the fish data collected through the PIT array (such as genetic stock, hatchery or wild, and resident time) please see the Data Analysis section below.

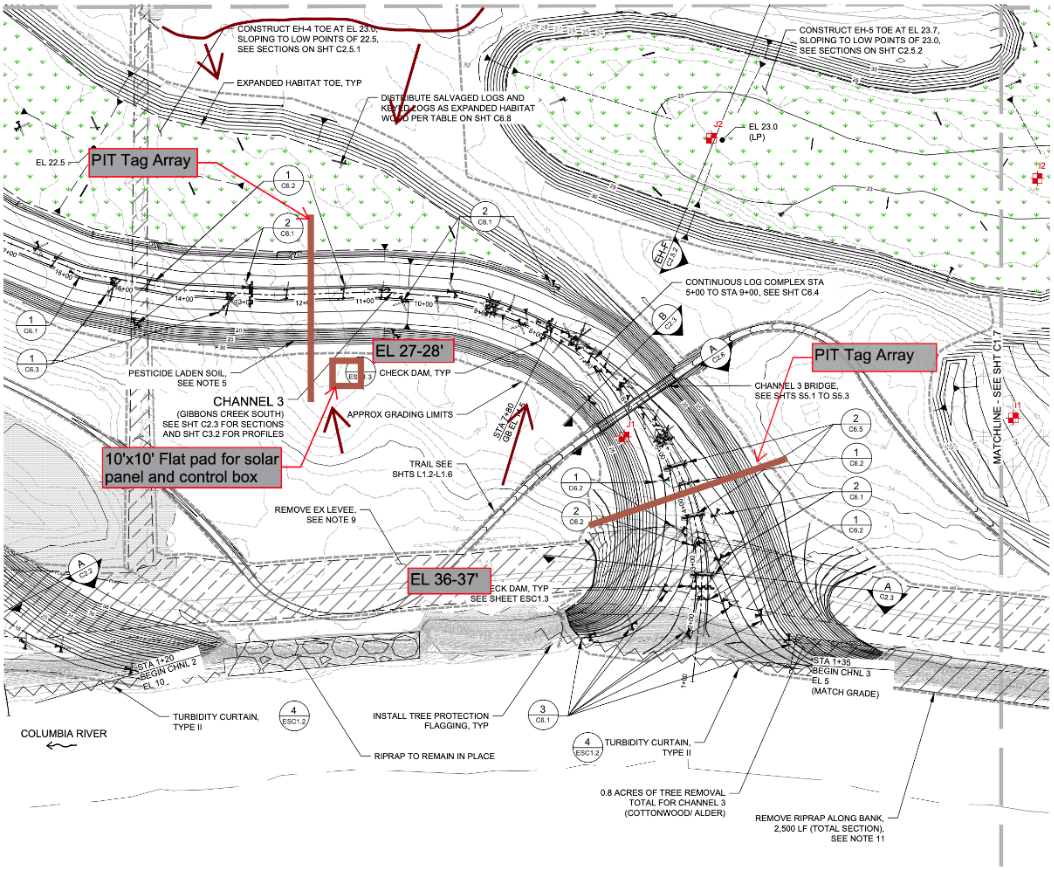

Figure 7: The location of equipment, including each array and solar array: The job box which will house the master controller, solar charge controller, batteries, modem etc. will be located between the two arrays in an inconspicuous location TBD.

PIT array description

The PIT array at Steigerwald will be a dual array configuration consisting of six antennas total. Each array will be similar in construction, consisting of a large primary antenna (~85' by 7.5') which will match the bottom contour of the location. A triangular antenna will be located on each bank that will extend from the primary antenna support structures (engineered logs) to the bank while matching the bottom contour (Figure 8).

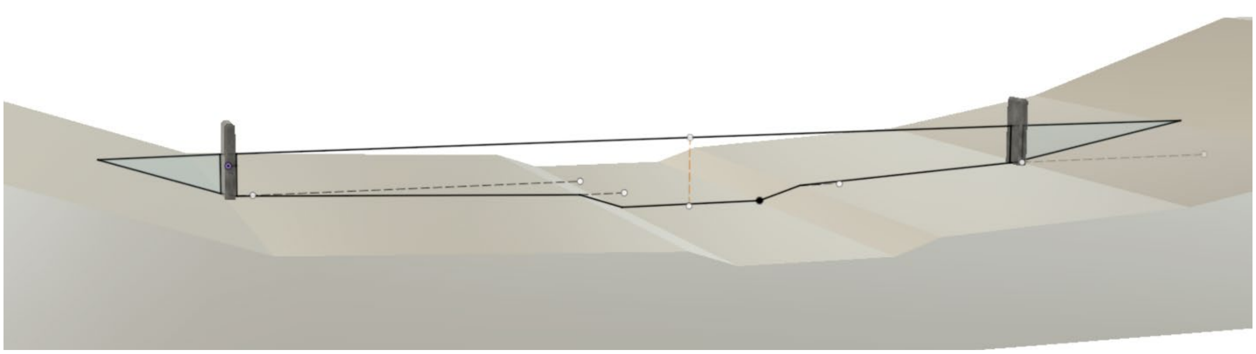

Figure 8: Steigerwald Antenna Array Design

Photo Monitoring

Funded and partially pending UAV restrictions being lifted 5/2021: Overall site plant community and channel dynamics will also be monitored using photo points both on the ground and in the air using UAV technology following protocols in Roegner et al. (2009). Photo points are used to support both vegetation mapping and to visualize the restoration dynamics observed across the site. Photo points will be taken at sediment accretion and erosion pins and benches, WSE/Temp data logger locations (Figure 4), at all UAV GCPs (Figure 5). Additionally, project implementation photo monitoring will occur across the site to demonstrate specific construction and restoration activities were conducted to meet funder monitoring requirements as well as document and assess project features over time. Approximately 50 project implementation photo points will be established throughout the restoration site including traditional ground photos, drone photo waypoints and several panoramic photos (Figure 9). If UAV restrictions are not lifted where applicable UAV photography will be replaced with ground photography. Photo monitoring will follow the schedule of each metric being photo monitored (see Table 1).

STEIGERWALD MONITORING LOCATIONS: PHOTO POINTS

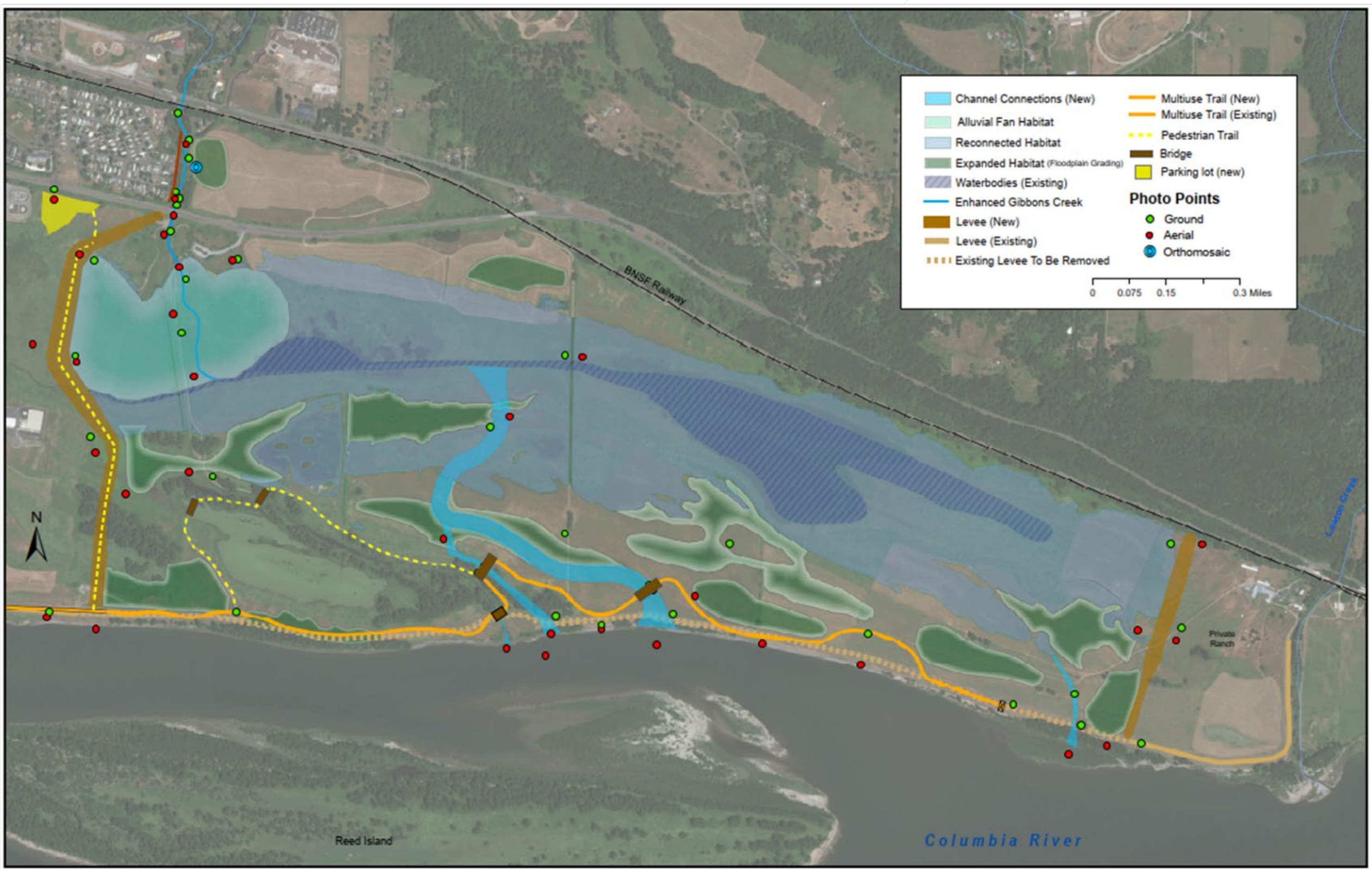

Figure 9: Photo point monitoring locations. For a detailed map of restoration actions see Figure 2.

Data Analysis

Sampling locations were selected to capture expected changes related to restoration actions at Steigerwald restoration site. Water surface elevation and temperature, vegetation, soil parameters, and sediment accretion are co-located in order to measure how physical, chemical, and biological processes interact and hence affect ecological conditions. These metrics will also be monitored at the reference sites for comparison. Additionally, fish and macroinvertebrate data will also be collected at two of the reference sites, Franz Lake and Campbell Slough. In the monitoring reports, all metrics will be compared to conditions observed across reference sites. Additionally, water temperature and habitat opportunity will also be compared to known salmonid habitat preferences and thresholds. These analyses will provide valuable feedback on project development and potential adaptive management opportunities. ***Only funded portions of these data analyses will be performed, see methods sections above for details on which data collection components were funded.***

Water-Surface Elevation

2-year flood elevation

To determine the extent of hydrologic reconnection at the restoration site, we will compare the WSE time series of daily data from inside and outside the restoration area before versus after restoration. The proportion of time when the sites WSE exceeded the 2-year flood elevation will be evaluated (Johnson et al. 2018). Proportions of time exceeding the 2-year flood elevation are computed by dividing the total number of WSE measurements exceeding the 2-year flood elevation by the total number of measurements in a given time period. Exceedance proportions will be calculated monthly. Because of the natural variability in flow conditions, it is possible that the 2-year flood will not occur during the first few years of monitoring. However, there is a 75% probability of a 2-year flood occurring in the first two years, and a 97% chance that a 2-year flood will occur within the first 5 years. Since the monitoring period is 10 years, we should have several events of sufficient magnitude to evaluate relative inundation pre- and post-restoration.

Duration and timing of flooding

Duration and timing of wetland flooding within the site will be compared across years and to reference sites (Kidd et al. 2019). These data will provide insight into changes in vegetation community and soil metrics observed. Additionally, these data will also be compared to our hydrologic and ecosystem modeling efforts to identify how accurate our models were at identifying future flooding and habitat conditions across the site.

Water Temperature

The 7-day maximum moving average (7-DMA) pre- and post-restoration will be evaluated and compared to the mainstem and reference conditions. An average of the 7-DMA water temperatures from the Center for Coastal Margin Observation & Prediction (CMOP) S8 (Washougal, EP) monitoring station will be used for the mainstem comparison (Kidd et al. 2019). These temperatures will also be compared to known thermal thresholds for salmonids. Similar analyses can be found in Johnson et al. (2018).

UAV Thermal (TIR) imagery will be utilized to create a thermal model of the site. The model will be calibrated using continuous temperature data obtained from deployed loggers, which will allow site-wide comparisons with the mainstem and thermal thresholds for salmonids. It will also allow identification of cold-water refuges at the site. Methodology for thermal modeling can be found in Chung et al. (2015) and Harvey et al. (2019).

Habitat Opportunity

We will determine how overall salmonid habitat opportunity (days/month) changed pre- and post-restoration at the restoration site. Using the post-restoration WSE data, the number of days the WSE was at or above 0.5 meters in depth will be calculated. This analysis will use mean daily WSE data and 7-DMA water temperatures. When the depth of the water is 0.5 meters or greater in the main channel connection to the Columbia (Figure 4) and the temperature is ≤17.5° C access will be considered optimal, when the temperature is 17.5-22° C, access will be considered marginal (Johnson et al. 2018). When the depth of the water is <0.5 meters, then it is assumed there is no salmonid access. Wetland habitat conditions within Steigerwald Lake will similarly be compared using average wetland elevations and temperatures at monitoring points across the site (Figure 4).

Sediment Accretion and Channel Cross-sections

Withing the site, PVC stakes-placed one meter apart were driven into the sediment and leveled. The distance from the plane at the top of the stakes to the sediment surface is measured as accurately as possible every 10 cm along the one-meter distance. The stakes are measured at deployment then subsequently on an annual basis. The stakes, termed sedimentation stakes, benches, or pins, are used to determine gross annual rates of sediment accretion or erosion (Roegner et al. 2009). The accretion or erosion rate is calculated by averaging the 11 measurements along the one-meter distance from each year and comparing the difference. The monitoring protocol can be found on monitoringmethods.org (Method ID 818). These rates will be compared across the site, reference sites, and elevation gradients (Kidd et al. 2019).

Channel Cross-section data will be analyzed to identify changes in channel shape, volume, bank-full width, and overall stability post-restoration. Specific attention will be paid to the newly created channel located just downstream of State Route 14, the Gibbons Creek alluvial fan, the channel connecting the floodplain to the mainstem Columbia, and the new high-flow channel connections to the Columbia. Visual inspection of these areas will identify if changes observed could impair the anticipated morphology and function of these channels, e.g., fish passage and sediment transport.

Vegetation

Plant community

To assess species richness (number of species) and percent cover for the herbaceous vegetation community at a given restoration or reference site, we will categorize plant species by native/non-native and by wetland status. Native, non-native, and wetland indicator status will follow the information provided by the U.S. Department of Agriculture (USDA) plants database at http://plants.usda.gov/. We will calculate species richness, species diversity, and relative cover for native and non-native plants out of the total assemblage for sampling events before and after restoration. To compare wetland vegetation of the restoration site to reference sites we will calculate the relativized response ratio (Meli et al. 2014, Lajeunesse 2015, Kidd 2017, Kidd et al. 2019).

Plant community mapping

Dominant plant communities will be identified at the site and marked with geo-located polygons. Supervised classification of vegetation will be conducted using inputs from a multispectral camera and a digital surface model. Extent and total estimated cover of dominant native and non-native plant communities will be calculated (Kidd et al. 2020).

Planting survival

To determine planting survival, a count of the number of planted stems and determination of the plant status (Live/Dead) will be conducted within each survival sampling plot.

Soil pH, Conductivity, ORP

Soil data will be compared across the site and across elevations with the reference site conditions. Soil data will provide further evidence to identify if the desired hydrologic conditions have been restored to promote native wetland plant community establishment (Kidd 2017, Kidd et al. 2020).

Alluvial Fan/Channel Development and Morphology

Elevation data collected on site will be imported into Trimble Geomatics Office (TGO) software and processed. Benchmark information will be entered into TGO and rover antenna heights will be corrected for disc sink (measured at each survey point to the nearest centimeter) at each point. The survey will then be recomputed within TGO and exported in a GIS shapefile format (Kidd et al. 2019). This information will also be used to calibrate the topographic model created from UAV images.

Geo-referenced RGB images will be used to reconstruct the topographic structure of the site into 3D Model from which a Digital Surface Model (DSM) and an ortho-image will be obtained. Spatial and quantitative information will be extracted from the processed outputs to analyze changes in stream channels, riparian zone vegetation and the alluvial fan (Langhammer 2019). TIR ortho-image created from the thermal images will be used to identify areas of groundwater upwelling and thermal regimes of the alluvial fan (Harvey et al. 2019)

Fish Prey Resources: Macroinvertebrates

Descriptive statistical analysis of the whole invertebrate community will be calculated, in addition to specific analyses of the order Diptera (flies) and amphipod taxa that have been shown to be important prey of juvenile Chinook salmon in the lower Columbia River (Lott 2004, Spilseth and Simenstad 2011). For neuston tows, the density and biomass of taxa in each sample will be calculated as the total count or weight for a given taxon divided by the meters towed (# individuals/m towed, mg/m towed). To compare taxa densities and biomass between restoration and references sites, density and biomass data for each taxon will be summed across replicate samples taken within a given site each month, and then divided by the number of replicates to give an average total density and biomass at each sampling site per month. Multivariate analyses will be used to examine differences in the invertebrate assemblage between sites using the PRIMER (Plymouth Routines In Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory (Clarke and Warwick 1994, Clarke and Gorley 2006, Kidd et al. 2019).

Fish

Net Fishing Analysis

Fish species richness and fish species diversity will be calculated by month and year. Fish species diversity is calculated using the Shannon-Weiner diversity index (Shannon and Weaver 1949). Catch per unit effort (CPUE) and fish density are calculated as described in Roegner et al. (2009), with fish density reported in number per 1000 m^2.

Genetic stock identification (GSI) techniques will investigate the origins of juvenile Chinook salmon captured in habitats of the Lower Columbia River Estuary (Manel et al. 2005, Roegner et al. 2010, Teel et al. 2009). Stock composition will be estimated by using a Single Nucleotide Polymorphism data set that includes baseline data for spawning populations from throughout the Columbia River basin (described in Johson et al. 2019). The overall proportional stock composition of Lower Columbia River samples will be estimated with the GSI computer program ONCOR (Kalinowski et al. 2007), which implemented the likelihood model of Rannala and Mountain (1997). Probability of origin is estimated for the following regional genetic stock groups: Deschutes River fall; West Cascades fall; West Cascades spring; Middle and Upper Columbia River spring; Spring Creek Group fall; Snake River fall; Snake River spring; Upper Columbia River summer/fall; Upper Willamette River spring; Rogue River fall; and Coastal OR/WA fall (Teel et al. 2009, Roegner et al. 2010). West Cascades and Spring Creek Group Chinook are Lower Columbia River stocks.

PIT data analysis

Detection data from the Steigerwald NWR PIT array will be automatically uploaded to ptagis.org, making the data immediately available to the public. Analysis of the data will include classification of detected fish according to species, origin and age. Examples of classifications include: Snake River steelhead-adult, Upper Columbia Chinook-smolt, lower Columbia Chinook-smolt, etc. Any fish of natural origin will be noted, but we anticipate most detections will be of hatchery fish because those are the majority of fish that are PIT-tagged. Within each classification we will enumerate the number of individuals per group and determine date of first and last detection to describe the timeframe in which they were accessing the newly available habitat. As data allow, we will also look at individual metrics such as overall residence time (first to last detection for an individual), channel residence time (if an individual makes multiple entries and exits with clear upstream and downstream movement), and stage of tide or water level at channel entry and exit. PIT detection data will be qualitatively compared to genetic data collected from salmon captured with traditional sampling gear (beach seines/Oneida nets).

Data Synthesis

Data analysis will include statistical comparisons across reference sites and between monitoring years (Kidd et al. 2020). Descriptive statistics will be used to describe individual monitoring metrics. Relational statistics will be evaluated to identify correlations and/or statistical relationships between monitoring metrics. All data analysis will be conducted to support the monitoring objectives identified in project objectives outlined in the Effectiveness Monitoring Goals and Objectives section of this report. A reporting and monitoring timeline is outlined in Table 1.

Adaptive Management

Project Review Team Triggers

The Project Review Team will be notified if monitoring demonstrates values outside of the below outlined thresholds. Table 2 outlines triggers for adaptive management or assessment by the project review team.

Table 2: Summary of Monitoring and Adaptive Management Plan Project Review Team Triggers. Project Objectives are described in detail in the Effectiveness Monitoring Goals and Objectives section of this report. In addition to pre-restoration baseline conditions, all monitoring metrics are also being collected at the reference sites and these data will be used for identifying how restoration outcomes compare to established natural conditions. *Metrics are required for HIP compliance.

Project Objectives	Monitoring Metrics	Baseline Conditions	Monitoring Frequency	Monitoring Techniques	Trigger	Applicability	Adaptive Measure or Action
Objective 1 & 2	Water Levels	Pre-Restoration Baseline	Continuous Pre-5 yrs, 10 yr	Hobo Data Loggers	Water levels remain below 2 yr. flood threshold	Floodplain Lake	Project Review Team assessment
Objectives 4 & 5	Water Temperature	Pre-Restoration Baseline	Continuous Pre-5 yrs, 10 yr	Hobo Data Loggers	Dramatic Increase in >19 °C days (7DMAM)	Gibbons Creek and Floodplain Lake	Project Review Team assessment
	Channel Cross-Sections: Presence of head cut or fish passage barrier*	Post-Construction As-Built	Annual Pre-5 yrs, year 10	Visual and Channel Cross-section surveys	Head cut >1' Thalweg <6" at low flow	Main Channels and Side Channels	Project Review Team assessment
Objective 1 & 5	Sediment Accretion and Erosion*	Pre-Restoration Baseline	Annual Pre-5 yrs, year 10	Visual and Sediment Pins	>1' shift in sediment	Alluvial Fan and Floodplain Lake	Project Review Team assessment
Objectives 1-3	Wetland Plant Community and Soil Conditions	Pre-Restoration Baseline	Pre, 1, 3, 5, 10 years Post	Visual, Transects, UAV Imagery	>25% bareground or Invasive species abundance, paired with non-hydric soil conditions	Floodplain Lake	Project Review Team assessment
Objective 3	Planting Survival	Planting Baseline	Pre-5 yrs.	Visual, Transects, UAV Imagery	<80% survival	Planted Areas	Revegetation and Project Review Team assessment
	Endangered Nelson's checker-mallow, *Sidalcea nelsoniana*	Pre-Restoration Baseline	Pre-5 yrs.	Visual	<80% survival	Existing Populations	Revegetation and Project Review Team assessment
Objective 4	Macroinvertebrate Monitoring	Pre-Restoration Baseline and Reference Sites	Pre, 1, 3, 5, 10 years Post	Neuston Tows	Significant Difference from Reference Conditions	Floodplain Lake	Project Review Team assessment
	Fish Monitoring	Reference Sites	Year 1-5	PIT-Tag Monitoring, Net Fishing Year 5	Significant Difference from Reference Conditions	Gibbons Creek	Project Review Team assessment

Data Storage & Reporting

Monitoring data will be stored and maintained by the Lower Columbia Estuary Partnership. Data will be maintained in standard database(s), and will be made available upon request, generally within 30 days. Data tables will be normalized to avoid redundant data structures and to ensure consistent data formats among sampling events.

Monitoring will be conducted per Table 1. A monitoring report will be provided by the LCEP in years 1, 3, 5, and 10. The reports will include:

- Summary of metrics for which data were collected;
- Deviations from established methods and protocols used to collect data;
- Tabular and graphical summaries of results; and
- Narrative discussions to explain results in the context of project goals, success criteria, and performance standards.

Monitoring Quality Assurance Plan

To ensure the quality of the monitoring program, the LCEP will implement quality assurance (QA) and control (QC) procedures. QA and QC procedures will be applied to the following aspects of the monitoring plan:

1. Data collection
2. Data storage
3. Data analysis and reporting

The monitoring program manager for the LCEP will be responsible for quality assurance.

Conclusion

This project monitoring plan represents a subset of potential monitored metrics. Depending on management priorities, additional monitoring metrics can be added to answer new or evolving questions. Monitoring reports will be provided summarizing these data (Table 1) and provide feedback on project development corresponding directly to the project objectives outlined in the *Effectiveness Monitoring Goals and Objectives* section of this report. These monitoring reports will also provide recommendations for potential adaptive management actions moving forward.

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Appendix A: Reference Site Details

<u>Franz Lake Site Descriptions</u> (Taken from EMP 2020, Rao et al. 2020):

The long-term Ecosystem Monitoring Program site Franz Lake has been monitored since 2008. Franz Lake is in Reach H, EM Zone 5, at rkm 221, which is part of the Ridgefield National Wildlife Refuge Complex. The site has an expansive area of emergent marsh extending 2 km from the mouth of the slough to a large, shallow ponded area. Several beaver dams have created a series of ponds along the length of the channel resulting in large areas of shallow-water wetland with fringing banks gradually sloping to an upland ecosystem. The sample site is located approximately 350 m from the channel mouth, spanning an area impacted by a beaver dam. The site is primarily high marsh with scattered willow saplings, fringed by willows, ash, and cottonwood (Figure 10).

Franz Lake site (rkm 221) has a small tidal signal (in between 0.2-0.3 m) which is difficult to distinguish from diurnal variation from dam operations (Jay et al. 2015). The beaver dam that has been present in most years just below our sample area was gone in 2016, resulting in lower water levels in the channel. The beaver dam was re-established during 2017, 2018 and 2019, elevating the water level in the sampling area above that of the tidal exchange signal in the dry months of August and September. In most years, the winter and spring high WSE are both discernable. However, the spring levels are usually considerably higher than those in winter. The elevation range of the wetland at Franz Lake is 1.11 meters on average, and not well predicted by tidal signal. The high marsh of the site is dominated by a combination of reed canarygrass, *Phalaris arundinacea*, and water smartweed, *Polygonum amphibium*, with a robust shrub scrub plant community composed of willows and ash (Figure 10). More details about this site, data, and data collection methods can be found in the most recent EMP report (Rao et al. 2020). Current monitoring layout can be seen in (Figure 11).

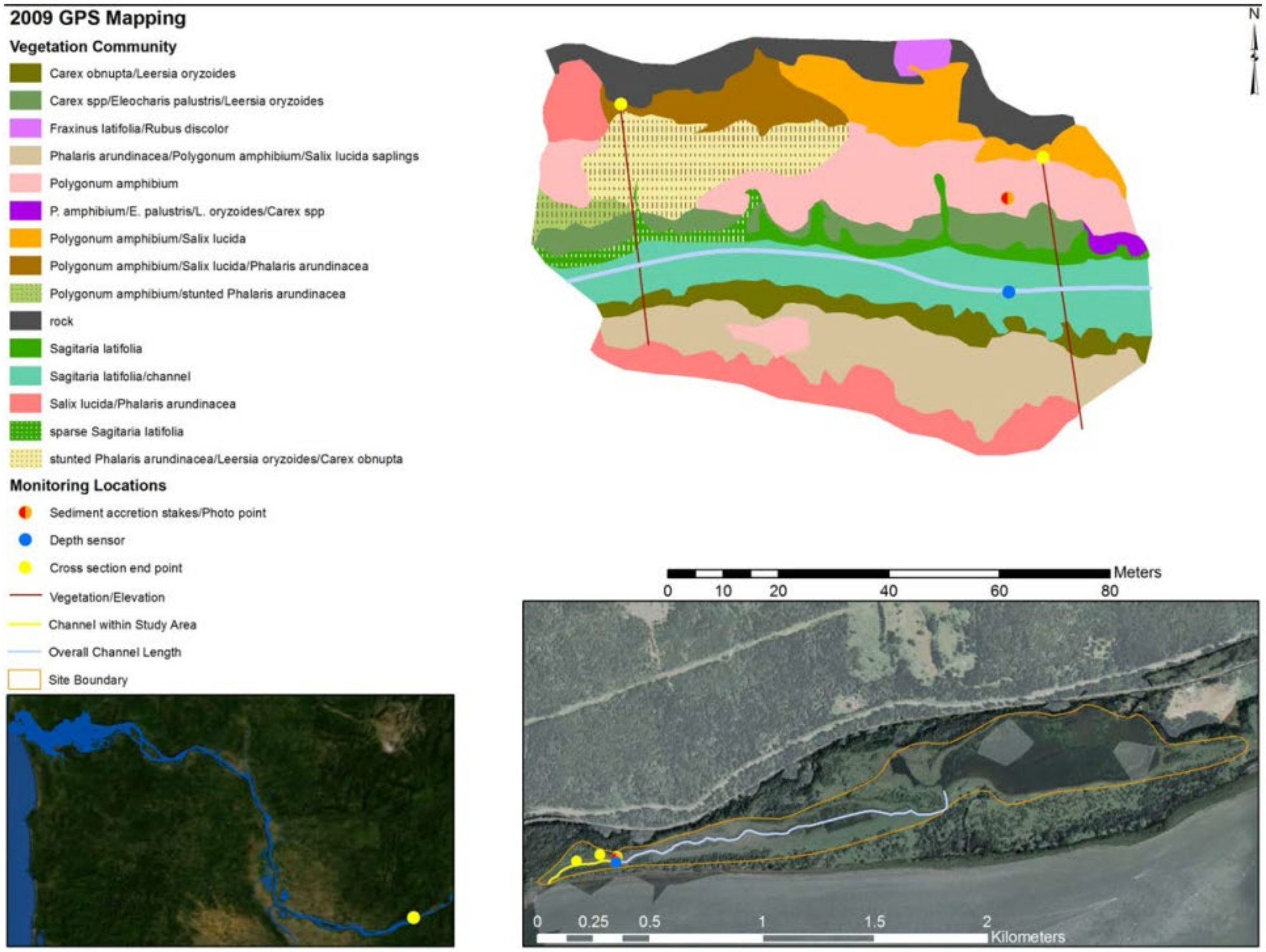


Figure 10: Map of dominant plant communities taken from PNNL-21433 2012 report (reference site study).

Franz Lake

Monitoring Data 2020

- Water levels follow Bonneville Dam gage
- Species Lists: https://www.dropbox.com/s/3zv25ly9zguj96w/Franz_SpeciesListandData_2019.xlsx?dl=0
- Maps: https://www.dropbox.com/s/kd9dmbum0q2lpub/Franz2019_Map.pdf?dl=0
- KML: https://www.dropbox.com/sh/m03s0zkrgw9xv7z/AABcXowbAh5WlLIn93awBAtha?dl=0
- Permits: https://www.dropbox.com/s/xktsozzvyvl46hn/Signed_Permit_Franz_2019_20_Final_UAVincluded.pdf?dl=0

Figure 11: Long-term monitoring design at Franz Lake, light green circles are transect vegetation plots, black is WSE/TEMP data logger location, red and olive green are biomass sampling location in 2020.

Veg Monitoring (Established 2008)

- Three transects with 1m^2 quads every 2 meters starting at 0 meters and going to 46-56 meters (see map for details). Biomass sampling locations change annually and are conducted in winter and during summer habitat sampling.

Sed Bench Monitoring (Established 2008)

- Found along transect 1 and 3: two sed benches.

WSE Monitoring (Established 2008)

- One is established within site (see map), additional water quality monitoring is conducted by OHSU.

Channel Cross-sections

- Taken at each transect.

Fishing and Neuston Sampling

- Conducted by NOAA between March-July, only collected when water temperatures and water levels allow for net fishing.

Drone Monitoring GCPs and Notes

- 5 GCPs placed during each drone flight, flights conducted at the discretion of the monitoring permit during habitat sampling. No drone flights allowed in 2020 and 2021.

Reed Island Site Description:

Reed Island is located in reach G at rkm 201 and is the closest natural reference wetland to the Steigerwald wildlife refuge. This island site was originally surveyed for the 2012 PNNL reference site study and monitoring work was re-established in 2018 and 2019 to develop baseline wetland condition characteristics for tracking Steigerwald's restoration progress (Figure 12). Unlike Franz Lake, which is a slough with a main channel controlled by both Columbia River water levels and beaver activity, the Reed Island monitoring area consists of a marshy shoreline along the Columbia river (no back water slough). The Reed Island Monitoring area is primarily composed of mid to low marsh conditions (Figure 13) and has extremely high species richness, likely due to its location right on the Columbia, and its mix of sandy to clay loam substrates. A detailed site description including species dominance and hydrology will be included in the Steigerwald year one post-restoration report.

The combination of Reed Island and Franz Lake should provide a robust range of possible restoration outcomes for Steigerwald. In addition to these sites, Campbell Slough, another long-term Ecosystem Monitoring Program site, will be used to compare PIT tag fish data collection. Campbell slough is located in Reach F at rkm 149 and has been monitored since 2005. For further details on Campbell slough please see the latest EMP report (Rao et al. 2020).

Reed Island, Reference
Monitoring Data 2020

- Washougal NOAA Gage, post-restoration
- Species List: https://www.dropbox.com/s/1mxthrnftxn27gu/ReedIsland_SpeciesListandData_2019.xlsx?dl=0
- Map: https://www.dropbox.com/s/tuphtdjdc99lecv/Reedisland%20MonitoringMap2.pdf?dl=0
- KML: https://www.dropbox.com/s/vrz0bed278oyez3/ReedislandMonitoringGPS.kmz?dl=0

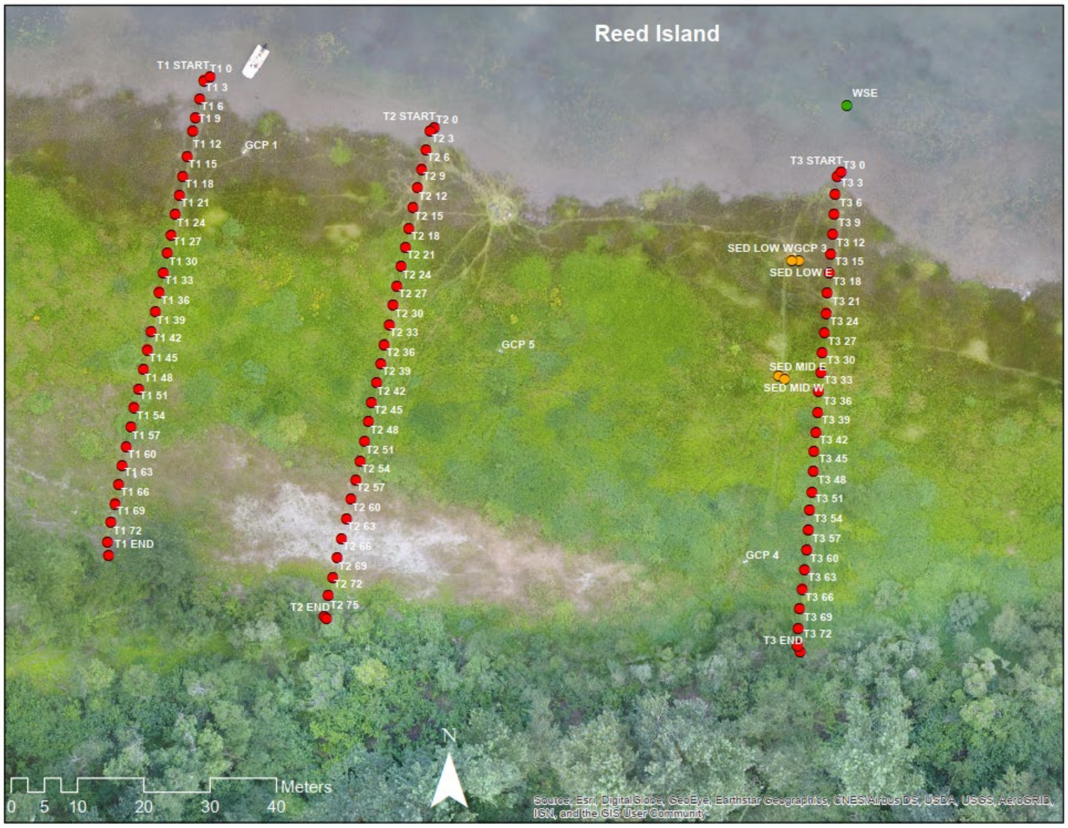


Figure 12: Established monitoring design at Reed Island (2019), red circles are vegetation monitoring plots, orange are sediment accretion benches, and green is the WSE/Temp logger location.

Veg Monitoring (Established 2019)

- *Three 1m^2 quads every 5-10 meters (see exact spacing below)*
- *Numbering*
    - *Tran 1, Every 3 meters starting at 0 through 72, and also sampled at 73*
    - *Tran 2, Every 3 meters starting at 0 through 48, then 52, 55, 57, 60, 63, 66, 69, 72, 75, 76*
    - *Tran 3, Every 3 meters starting at 0 through 72*

Sed Bench Monitoring (Established 2019)

- Found along transect 3: three sed benches located in the high, mid, and low marsh zones.

WSE Monitoring (Established 2019)

- One is established within site (see map: Figure 12)

Channel Cross-sections

- No Channel (Island Shore Line)

Neuston Sampling

- Collected (2018 and 2021) near transects.

Drone Monitoring GCPs and Notes

- 5 GCPs placed during each drone flight, flights conducted annually 2019-2021 during habitat sampling.

Figure 13: Reed Island map of dominant plant communities (2009) taken from PNNL-21433 2012 report (reference site study).

Appendix B: Summary of Ecosystem Functions Model Developed for Steigerwald Project Design

MEMORANDUM: Ecosystem Functions Model Developed for Steigerwald Project Design
Lower Columbia Estuary Partnership
Paul Kolp, Matthew Schwartz, and Sarah Kidd
Developed in 2018-2019 and Finalized April 25, 2021

INTRODUCTION

This Memo summarizes ecological modeling efforts at Steigerwald Lake Wildlife Refuge (Steigerwald) by the Lower Columbia Estuary Partnership (Estuary Partnership). We used a paired hydraulic and ecological model to predict changes in hydrology and plant communities under restored conditions. Restoration actions at the site include removing portions of the existing levee along the Columbia River, installing high and low flow channels to the interior wetlands, decommissioning the engineered channel and fish ladder to allow Gibbons Creek to flow into the existing wetlands, reconnecting the historic alluvial fan and reestablishing native vegetation. Changes in plant assemblages have important ramifications for the site ecology, including existing terrestrial species that use the site. Native aquatic species, including salmonids and lamprey, are not able to access the interior wetlands due to levees. The ability to quantify potential changes under restored conditions can allow natural managers to understand and plan for potential changes across the landscape and to look at cost/benefit of restoration efforts.

In 2016 Bonneville Power Administration (BPA) funded restoration designs at the Shillapoo Lake site, led by the Washington Department of Fish & Wildlife (WDFW). As part of these efforts, BPA allocated funding to assist with training Estuary Partnership and WDFW staff in the development of an ecological model. The model allowed us to predict plant community and habitat changes from the proposed restoration actions. Even though the project did not advance beyond the planning stage, modeling efforts were able to quantity potential uplift and helped to inform site managers and restoration practitioners. As part of the Steigerwald project, we are leveraging this investment in ecological modeling and applying the same modeling approach.

The Ecosystem Monitoring Program (EMP) collects data at established reference sites in the Lower Columbia River Estuary. Ecological modeling efforts outlined in this Memo leveraged data collected and analyzed by the EMP. This has allowed us to develop a predictive tool that has implications for design, future monitoring and to test hypotheses related to future plant assemblages.

SUMMARY

Restoration projects in the Lower Columbia River Estuary frequently rely on analog sites to develop restoration designs. For projects hoping to reestablish native plants typically this means using plant elevation data from nearby locations that may have limited temporal data. The problem with this is approach is that elevation gradients alone are not adequate predictors of plant communities across the estuary. Some restoration sites may be miles away from the Columbia River up a slough, while others may be located adjacent to the Columbia River. Sites may also be physically (hydrologically) very different from the site being restored, including tributary inputs. The approach outlined in the Memo uses data from a long-term monitoring site, a paired hydrodynamic and ecological model, and a statistical approach to understand existing conditions at the monitoring site and to predict restoration outcomes at Steigerwald. Plant community responses under restored conditions is based on the interrelationship between topography, inundation frequency and water depths across the growing season.

Our predictions suggest that post-restoration Steigerwald will be wetter with more emergent plants with a decrease in shrubs and invasive plants (reed canarygrass). Specifically, compared to existing conditions, under restored conditions there is the potential to have an additional 109 acres of open water and/or mudflats that could support some emergent plants and an additional 37 acres would contain primarily emergent plants. Shrubs and reed canarygrass acreage would decrease by approximately 100 acres, while upland plant communities would decrease by 90 acres and towards shrub plant communities.

SITE CHARACTERISTICS

The 1,049-acre Steigerwald site is located between River Mile (RM) 124-128 along the Columbia River (Appendix B Figure 1). The site is owned by the United States Fish & Wildlife Service (USFWS). The site is currently disconnected from the Columbia River by a levee that surrounds the project area and protects the adjacent Port of Washougal to the west. The site is bounded to the north by Highway 14 and the BNSF railroad and to the South by the Columbia River. A fish ladder at the Columbia River provides access to an elevated channel that transports fish through the Steigerwald site and connects to Gibbons Creek near Highway 14 and in the area of the historic Gibbons Creek alluvial fan. Currently, fish do not have access to visa via the elevated channel to the Steigerwald site except during flood events.

During flood events some water from Gibbons Creek escapes the elevated channel and flows out into the wetlands. Flow from groundwater and tributaries also influence hydrology at the site. To assist with flooding concerns, the Port of Washougal has installed two pumps along the Columbia River, , to facilitate draining the site. The pumps generally operate between November-May when the Columbia River stage is sufficiently high. The pumps (which have screens that prohibit passage by fish) and existing structures function as barriers to anadromous fish, including salmonids, to the floodplain.

Prior to hydromodifications on the Columbia River the floodplains at Steigerwald would connect to the Columbia River. During the late fall to early winter rainfall events in the basin would increase the stage along the Columbia River and Gibbons Creeks and inundate the site. During the late spring into the summer months the freshet would occur from snowmelt in the basin. Historically, the freshet would last into July and inundate the site. This phenomenon no longer occurs and typically the freshet is completed before early June. Hydromodifications, and the current levee, have had a dramatic effect on plant communities as well as the ability of native aquatic species to access the site.

MANAGEMENT GOALS

USFWS has several management goals for the site, including recreational use for hikers, creating overwintering and nesting habitat for waterfowl, allowing for fish-passage and controlling invasive plants. Balancing these needs is an ongoing priority of the wildlife refuge. LCEP has worked with the USFWS (and other partners) to help meet these goals by:

- Removing barriers to flow, sediment and native aquatic species.
- Improving fish passage.
- Allowing for more natural alluvial processes.
- Reconnecting the Gibbons Creek alluvial fan.
- Improving habitat diversity and complexity.
- Restoring native plant communities.

MODELING OVERVIEW

A hydraulic and paired ecological model was used to predict habitat conditions under restored conditions at Steigerwald. The primary goal of the hydraulic modeling effort was to provide surfacewater inputs needed to run the ecological model. A different hydraulic model was developed under a seperate effort to evaluate hydraulics and flood risk across a wide range of flood flows (LCEP 2018). The hydraulic model used in this analysis wasa 7 month time series (growing season), which contains the 2-year flood event on the Columbia River and avarage daily flows from Gibbons Creek in order to develop water depths over the growing season.

The ecological model was used to synthesize hydrology and plant elevation data collected as part of the EMP efforts at Franz Lake. By pairing an ecological and hydraulic model we were able to predict plant communities under restored conditions. The ecological model helped us to answer questions about the relationship between timing and frequency of inundation through the growing season (February-September) and to quantify native vegetation habitat under restored conditions. Based on the ecological model results, we were able to predict plant communities across the entire site.

Appendix B Figure 1. Steigerwald project site location.

Methods

Existing Conditions

Hydrology

We evaluated water surface elevation from the Franz Lake monitoring site (Estuary Partnership 2008-2009 & 2011-2015), which is located along the Columbia River 8 miles upstream of Steigerwald. Continuous stage recordings at the two reference sites was conducted using Hobo Onset U20 water level data loggers. The data logger collects pressure-based water level information and is later converted to water surface elevations using survey data and barometric pressure information. GPS-RTK survey equipment was used to survey data logger locations. For more information on data collection protocols (Kidd et al. 2019). Water depth data was collected in hourly increments and converted to Columbia River datum to generate water surface elevations. Columbia River datum was later converted to NAVD 88 datum for internal consistency purposes. The locations of the data loggers were at several locations and in areas that do not go dry during the growing season. One of the locations was adjacent to a beaver dam that impounds water during the summer.

The Vancouver, Washington gage has long-term continuous hydrology data and is approximately 15 miles downstream of the site. We evaluated the average annual stage from 1998-2015 at the Vancouver gage (USGS 14144700) using HEC-DSS (USACE 2012 v. 2.01) and a Weibull statistical analysis. This allowed us to determine dry, average and wet years. We chose 2009 to represent an average year.

Vegetation

Vegetation data was collected at the Steigerwald site to develop an understanding of existing plant communities by members of the monitoring team. Data collected included site surveys and GIS data analysis.

Through LCEP's Ecosystem Monitoring Program (EMP) annual plant surveys were conducted during July and August from 2009-2016 at Franz Lake. The plant surveys used a transect approach, where transects were established along an elevation gradient from the low point in the wetlands into riparian and upland areas. Individual plant species were identified and keyed along with their corresponding elevation. The survey crews used GPS-RTK survey equipment to determine elevations. For more information on data collection protocols (Kidd et al. 2019).

The long-term Franz Lake EMP data show that for dominant plant community zones, there was very little change in average, minimum and maximum elevations over time. The elevations in which these dominant plant communities grow is primarily a function of site environmental conditions such as duration and timing of wetland flooding and topography, which also drives the ability of these plant species to compete with the non-native reed canarygrass (Kidd et al. 2019). Flooding duration and frequency at Franz Lake is primarily a function of is location adjacent to the mainstem Columbia and beaver dam activity within the sites main slough. The shrub community is largely comprised of willows and reed canarygrass.

To develop the vegetation predictive model information from the annual plant surveys (reference sites) was analyzed using a spread sheet approach where the plants were sorted based on frequency of occurrence and relative abundance. Based on frequency of occurrence we ranked and selected the top 10 plant species. The top 10 plants, and associated elevations, were assigned into ecological zones based on wetland indicator status and professional judgement. We used the annual surveyed elevations for each plant to develop minimum, average and maximum elevations that were placed in each of the five ecological zones. We averaged together plants from the emergent ecological zone to produce a single minimum, average and maximum annual elevation value.

We developed an ecological zonal approach to delineate and identify unique physical and biological characteristics within the project site, including plant communities. The following ecological zones were used to model proposed conditions: 1) open water; 2) emergent wetlands; 3) transition; 4) shrub-scrub and 5) upland. The zones comprise the following:

- Aquatic/emergent- open water, mud flat with emergent plants possible.
- Emergent dominant- emergent plants with reed canarygrass (RCG) present.
- Transition- emergent plants and shrubs with reed canarygrass present.
- Shrub/invasive plant- willows and reed canarygrass.

After evaluating the vegetation information, and conducting a preliminary analysis using statistical functionality in the ecological model, the data was reevaluated. It was determined that the beaver dam at Franz Lake was affecting hydrology and having an effect on the plant communities and the monitoring plots, as it was holding water higher during summer months than the surrounding landscape. EMP staff conducted additional plant surveys in areas that were not affected by the beaver dam and developed a small adjustment (see results section for more information on this) to the elevations of the plant communities identified in the back-water slough, influenced by the beaver dam. This adjustment was developed to more accurately predict the possible restored conditions in the wetland areas at Steigerwald, and essentially represents the plant community elevation at Franz Lake if the beaver dam was removed. At Steigerwald the invert and slope from the mainstem of the Columbia River visa via the breach channels will allow the site to function as a backwater to the Columbia River and comparable to the hydrologic conditions observed at Franz Lake.

Ecological Model

We used statistical functionality in HEC- EFM to synthesize hydrology and plant elevation data at the reference site in order to determine inundation frequency for each of the ecological zones (as outlined above). We synthesized daily average stage data from February- September (growing season) and plant elevations/ecological zones from Franz Lake from 2009-2014. We focused in 2009 due to the fact that it was an average year. Th analysis was conducted to establish a relationship between water stage, inundation frequency and ecological zone (plant) elevations during the growing season. We used HEC-DSS and HEC-EFM to analyze and synthesize this information. We synthesized the stage frequency curves with the ecological/vegetation zones to produce inundation frequency curves for each ecological zone. A synthesized stage frequency curve was produced for 2009.

The statistical query also utilized the reverse lookup function. This function allows the user to specify the range of elevations (referred to as stage) associated with each of the ecological zones (plant communities) and a value is returned for percentage of time that stage is equaled or exceeded. In this case we used the paired hydrology and plant community data from 2009 at Franz Lake.

The statistical query requires the user to enter seasonal constraints, flow duration, flow time series and plant elevation values. A detailed explanation can be found in the EFM user manual online on the USACE website- https://www.hec.usace.army.mil/software/hec-efm/documentation/HEC-EFM_40_Quick_Start_Guide.pdf

The inputs for the reverse flow lookup parameter are:

- 2009 stage time series (Franz Lake).
- Monthly seasonal times, including growing season (Feb- Sept) and summer months (June- August).
- 1- day flow duration.
- Reverse lookup.
- Elevation values for each of the plant communities (select flow regime).

Proposed Conditions

Hydraulic Model

The Hydrologic Engineering Center's River Analysis Systems Model [(HEC-RAS)-USACE 2016 v. 5.0.1] and the Ecological Functions Model [(HEC-EFM)-USACE 2016 v. 3.0.1.4] were utilized for this analysis. The two-dimensional hydraulic model HEC-RAS was used to evaluate restored conditions within the project site. We used 2009 data from the Columbia River Treaty model (USACE 2003) to mode restored conditions. As part of the Treaty Model, a hydraulic model was created for the entire Lower Columbia River, from Bonneville Dam to Tongue Point, Oregon. The Steigerwald model was run (January -September) to encapsulate the growing season. 2009 flows on the Columbia River were deemed to reflect average annual conditions. 2009 flows also included the 2-year flood (January 2009), average monthly flows and low flow periods (spring). Model development included:

- The USACE Treaty model was provided to LCEP in 2017. We utilized boundary conditions at RM 123 (stage) and RM 129 (discharge) from the Treat Model (Figure 2). The USACE model has been calibrated for low and high flows.

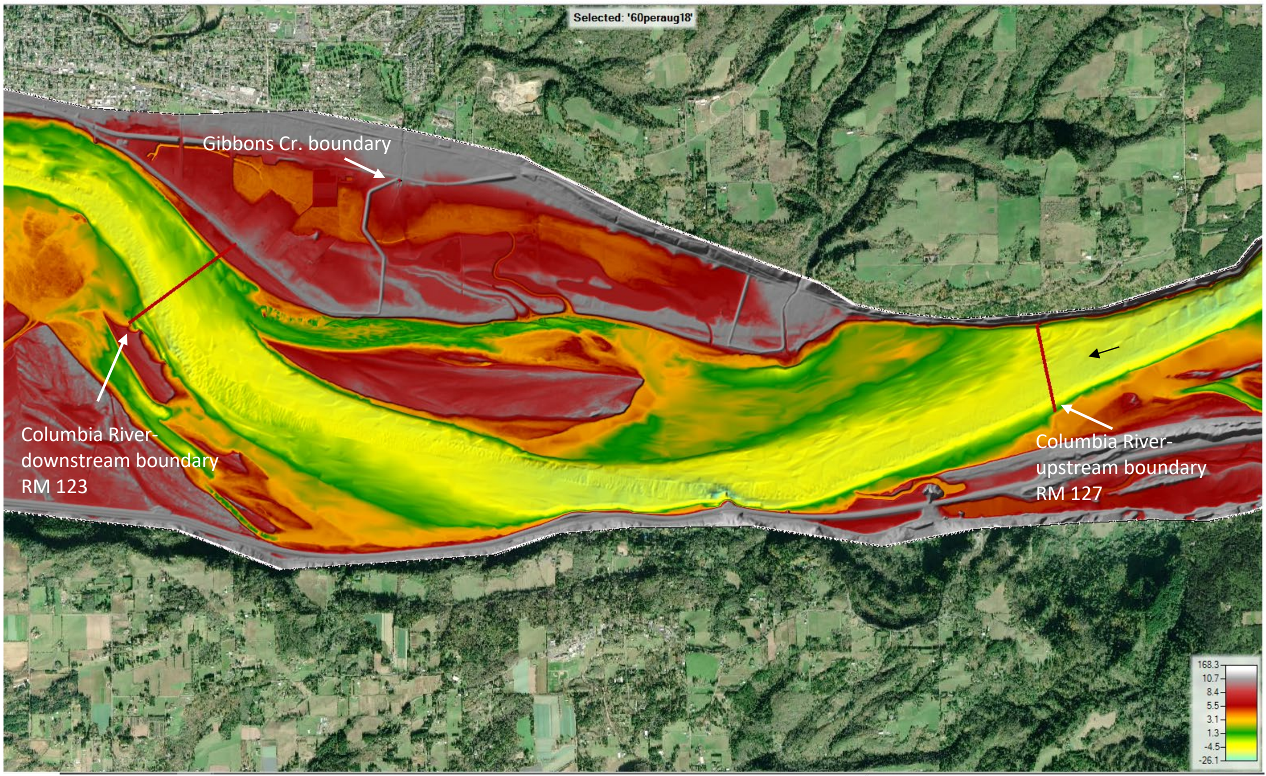
- Time-period that the model was run was from December 2008 to September 2009 using hourly data.

- Unsteady simulations were conducted using the full momentum equations, 5 second time step and a base Manning's N value of .02.

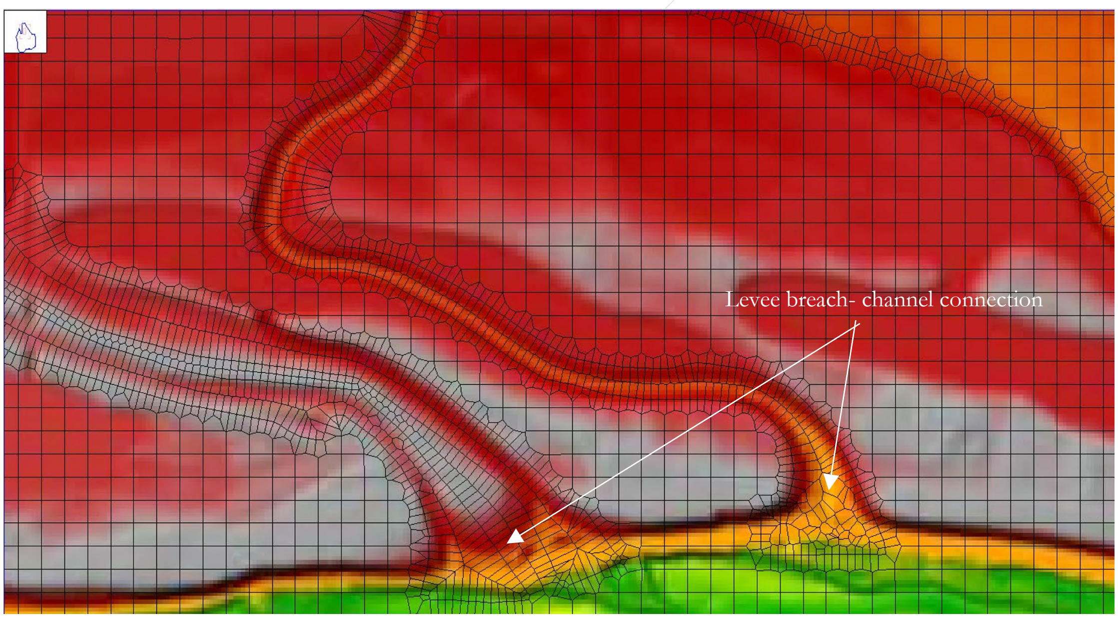
- To develop flow inputs for Gibbon Creek used basin physical data from the USGS StreamStats site (https://streamstats.usgs.gov/ss/) and climatic data from Northwest Alliance for Computational Science and Engineering (https://prism.oregonstate.edu/) to generate precipitation throughout the basin. We estimated the delivery to the site using professional judgement. This allowed us to develop average daily/hourly flows on Gibbons to input into the model.

- Model geometry included developing a flexible mesh approach and includes 26,349 computational cells across the site. Generally, 30 m^2 cells were used along Columbia River and Steigerwald floodplain. Cell resolution was a lot higher in the breach/connection channels and Gibbons Creek, including the alluvial fan (Figure 3). In these locations cell resolution varied from 1 m^2 to 5 m^2. Geometry also included break lines to separate higher terrain areas from lower terrain.

- Model surface elevations were based on the available topographic information as part of the engineering grading plan 60% design for Steigerwald. Elevations for the Columbia River are based on bathymetric survey data (USACE 2013).



Appendix B Figure 2. HEC-RAS model domain and upstream & downstream hydrology boundaries.



Appendix B Figure 3. Example of model mesh used- resolution was varied from 1 m^2-30 m^2. The smaller mesh resolution can be seen in the levee breach areas and the channels that connect to the wetlands.

To develop the ecological model at Steigerwald we used outputs from the hydraulic model. Since we did not have surface water and topographic information for Redtail Lake, it was not included in the ecological model. The following is a summary of inputs and steps used in HEC-EFM:

- Import HEC-RAS model results including average hourly stage and depth using HDF software. This process can be found online on the USACE website- https://www.hec.usace.army.mil/software/hec-efm/documentation/HEC-EFM_40_Release_Notes.pdf
- Apply seasonal criteria for plant communities: Feb. 1 to September 30 (growing season).
- Apply duration criteria- select daily time step.
- Apply time series specification- apply flow duration criteria.
- Apply depth criteria- for plant communities use criteria of $\geq$ 0.1 ft, and.
- Statistical query- apply stage frequency and select reverse lookup criteria.

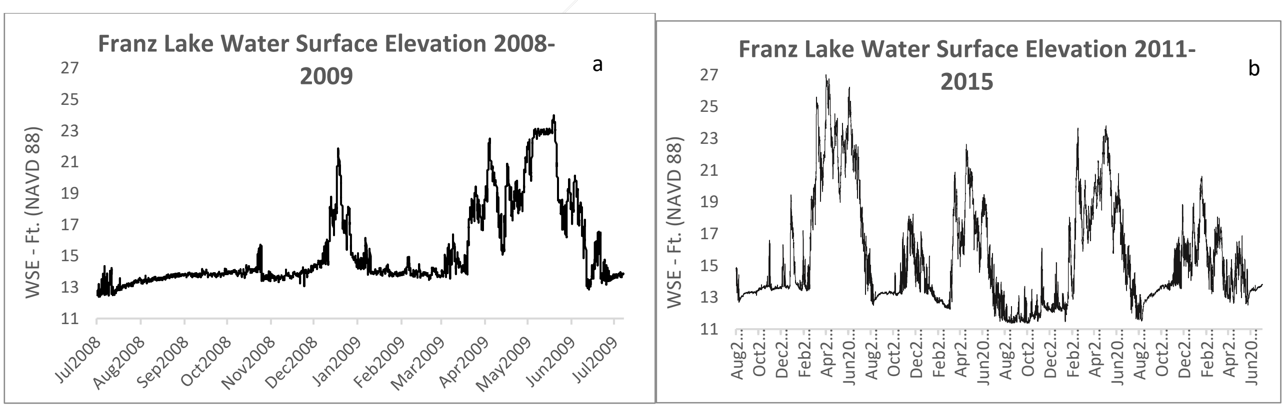
Once the above information was input into the ecological model and the computation was run. The output tabular data was then exported to Microsoft Excel. Model outputs represent the percentage of time a specific cell within the 2D grid area would be inundated. The data has unique spatial identifiers, which are associated with specific georeferenced cells within the hydraulic model domain. The model outputs were associated to the appropriate cells within hydraulic model domain to answer spatial and temporal questions related to available habitat for vegetation communities. The information was exported to ArcGIS to further evaluate results and to produce maps. Results were interpreted in ArcGIS specific to each species or vegetation community.

RESULTS

Reference Site- Franz Lake

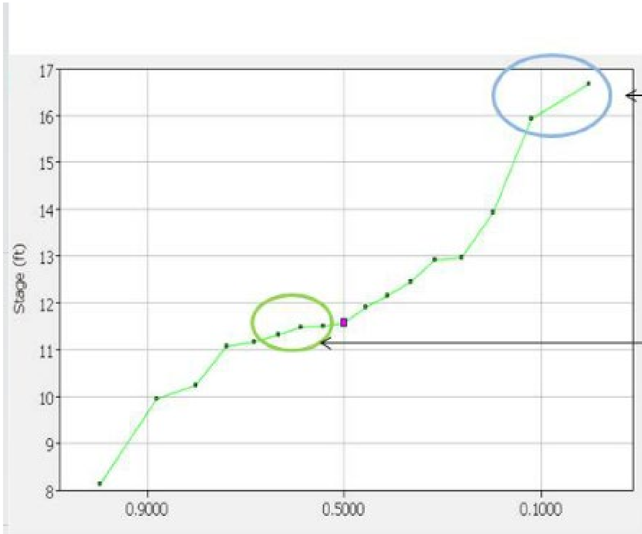
Hydrology

Figure 4 shows water surface elevations from the probe deployed in the channel below Franz Lake. We evaluated water surface elevation from the Franz Lake monitoring site (Estuary Partnership 2008-2009 & 2011-2015), which is located along the Columbia River 8 miles upstream of Steigerwald.



Appendix B Figure 4. Hourly water surface data at Franz Lake monitoring site from 2008-2009 (a) and 2011-2015 (b).

We compared results from Franz Lake to stage frequency curves (average daily stage), from the Vancouver, Washington gage (USGS 14144700). Results from the analysis allowed us to determine which year represented "average" hydrologic conditions during the growing season. Due to the relatively flat slope of the Columbia River between Franz Lake and the Vancouver gage, and the lack of tributary inputs between the two sites, we assumed that it was appropriate to use the USGS gage in Vancouver. Based on results from the statistical analysis (Figure 5), we chose 2009 to represent "average" conditions at Franz Lake and relied on 2009 data collected at Franz Lake.



Rank	Frequency	WY	Flow	Stage
1	0.0556	2011	16.7	16.673
2	0.1111	2012	15.9	15.925
3	0.1667	1999	13.9	13.937
4	0.2222	2014	13	12.96
5	0.2778	2006	12.9	12.926
6	0.3333	1998	12.5	12.453
7	0.3889	2008	12.2	12.155
8	0.4444	2002	11.9	11.913
9	0.5	2000	11.6	11.568
10	0.5556	2009	11.5	11.494
11	0.6111	2013	11.5	11.467
12	0.6667	2010	11.3	11.314
13	0.7222	2003	11.2	11.17
14	0.7778	2007	11.1	11.066
15	0.8333	2005	10.2	10.242
16	0.8889	2004	9.9	9.946
17	0.9444	2001	8.1	8.129

Appendix B Figure 5. Weibull analysis using daily average stage during the growing season at the Vancouver, WA gage (USGS) from 1999-2014. The years 2009- 2013 are highlighted to show overlap with data from Franz Lake. Overall, 2009 is close to the mean stage of 11.6 (NAVD 88 ft.).

Vegetation

Using transect data, and supplemental field surveys, we categorized the following plants into ecological zones using the following species:

- Aquatic/emergent: mostly open water and mud flats with some emergent plant potential primarily of Wapato, *Sagittaria latifolia* (SALA), and water smartweed, *Polygonum amphibium* (POAM). Wapato will grow in shallow standing water and water smartweed will float and grow into the wetland channels (running and standing water) when anchored by roots to the wetland bank. Other native and non-native emergent species require daily or seasonal drawdown of water levels to sustain growth long-term.
- Common emergent plants
  - native: spike rush, *Eleocharis palustris* (ELPA), wapato, *Sagittaria latifolia* (SALA), water smartweed, *Polygonum amphibium* (POAM), rice cutgrass, *Leersia oryzoides* (LEOR), sneezeweed, *Helenium autumnale*, (HEAU), Slough Sedge, *Carex obnupta* (CAOB), Columbia sedge, Carex aperta (CAAP), water purslane, *Ludwigia palustris* (LUPA), bearded sedge, *Carex comosa* (CACO)
  - non-native: reed canarygrass , *Phalaris arundinacea*, (PHAR).
- Transition zone/emergent to shrub: combination of emergent plants and shrubs.
- Shrub: willow species *Salix lucida* and *Salix hookeriana* (SASP) and reed canarygrass, *Phalaris arundinacea*, (PHAR).

For each ecological zone we developed minimum, average and maximum elevations. Results of this can be found in Table 1.

- Emergent: 12.2 ft.- 16.8 ft
- Transition emergent to shrub: 14.6 ft.- 15.7 ft.
- Reed Canarygrass Potential: 12.5 ft.- 16.8 ft
- Shrub: 14.8 ft.- 16.8 ft.

Plant Community Information	Mudflat/Open Water	Emergent							High Marsh/Shrub Transition	Reed Canarygrass	Shrub
Plant Species (Codes)	Mudflat/Open Water	SALA	LEOR	ELPA	POAM	HEAU	CAOB	LUPA	CACO	PHAR	SASP
Wetland Indicator Status		OBL	OBL	OBL	OBL	FACW	OBL	OBL	OBL	FACW	FACW
Native/Non-native Status		Native							Native	Non-native	Native
Average Cover (2009, %)	25	3	3	9	13	2	10	3	2	27	4
Frequency (2009)	28	10	21	21	25	6	14	29	2	31	5
Average of Elevation (ft -NAVD88)	**14.7**	**13.9**	**14.9**	**14.9**	**15.0**	**15.0**	**15.1**	**15.1**	**15.1**	**15.2**	**16.0**
Min of Elevation	**12.3**	**12.2**	**13.3**	**13.7**	**13.7**	**14.5**	**13.9**	**13.7**	**14.6**	**12.5**	**14.8**
Max of Elevation	**16.8**	**15.1**	**16.6**	**15.6**	**15.7**	**15.7**	**15.9**	**16.8**	**15.7**	**16.8**	**16.8**
Elevation ranges (ft -NAVD88)											
16.7											
16.4											
16.1											
15.7											
15.4											
15.1											
14.8											
14.4											
14.1											
13.8											
13.5											
13.1											
12.8											
12.5											
12.1											
11.8											
11.5											

Appendix B Table 1. 2009 plant community data at Franz Lake monitoring site. Results shows results from the 2009 plant community assemblages, including average cover (by percentage), plants and average, minimum and maximum elevations for each plant. RCG was found across large portions of the site and was found in the emergent, transition and shrub areas. Plant codes: wapato, *Sagittaria latifolia* (SALA), rice cutgrass, *Leersia oryzoides* (LEOR), *Eleocharis palustris* (ELPA), water smartweed, *Polygonum amphibium* (POAM), sneezeweed, *Helenium autumnale*, (HEAU), Slough Sedge, *Carex obnupta* (CAOB), water purslane, *Ludwigia palustris* (LUPA), bearded sedge, *Carex comosa* (CACO), reed canarygrass, *Phalaris arundinacea*, (PHAR), willow species *Salix lucida* and *Salix hookeriana* (SASP).

A beaver dam impounds water at a higher elevation throughout the summer months after flows on the Columbia River begin to recede at the Franz Lake site. We collected additional site data downstream from the beaver dam to correct the effects of the altered hydrology as the Columbia River receded in June and July. Based on surveyed elevations of plants from the surrounding landscape downstream of the site, we adjusted the mean and minimum elevations of the plant communities downward. Tables 2 and 3 below shows the results of this analysis.

Appendix B Table 2. Elevations for plant communities (average of all emergents). **Table 3.** Ajusted elevations from beaver dam impacts.

Elevation/Stan Dev.	Plants/Plant Community (ft. -NAVD88)		
	Emergent	RCG	Shrub
Min of Elevation	12.81	13.67	14.83
Mean of Elevation	14.88	15.31	16.03
Max of Elevation	16.34	16.82	16.82
StdDev	0.19	0.21	0.25

Adjusted 1.5 ft down for beaver dam impacts			
Elevation/Stan Dev.	Plants/Plant Community (ft. -NAVD88)		
	Emergent	RCG	Shrub
Min of Elevation	11.48	12.03	13.19
Mean of Elevation	13.24	13.68	14.39
Max of Elevation	16.34	16.82	16.82
StdDev	0.19	0.21	0.25

Using the reverse look up parameter in HEC-EFM we show an example of tabular data outputs for percent time inundated for the mean elevations for emergent, shrub-scrub and RCG (Table 4) at Franz Lake.

Appendix B Table 4. Reverse Lookup- flow duration for Franz Lake, 2009.

2009	
Relationship	**%X, in range**
Emergent Mean	36
Shrub-Scrub Mean	9
RCG-Mean	24

The results below show the percent of time each of the defined plant communities were inundated. The results are: upland 0-5%, shrub dominant 5-25%, transition from shrub to emergent vegetation 20-30%, emergent wetlands 30-45% and aquatic/emergent 45-100%. Reed canarygrass can be found both within the shrub and emergent vegetation plant zones and the percent time inundated was 10-40% (Table 5).

Appendix B Table 5. Percent time inndudated for plant communities using results from Table 4.

Percent Time Inundated																				
100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Aquatic/Emergent																				
												Emergent Dominant								
															Transition- Emergent to Shrub					
																Shrub Dominant				
																				Upland
													RCG Potential							

Restoration Site- Steigerwald

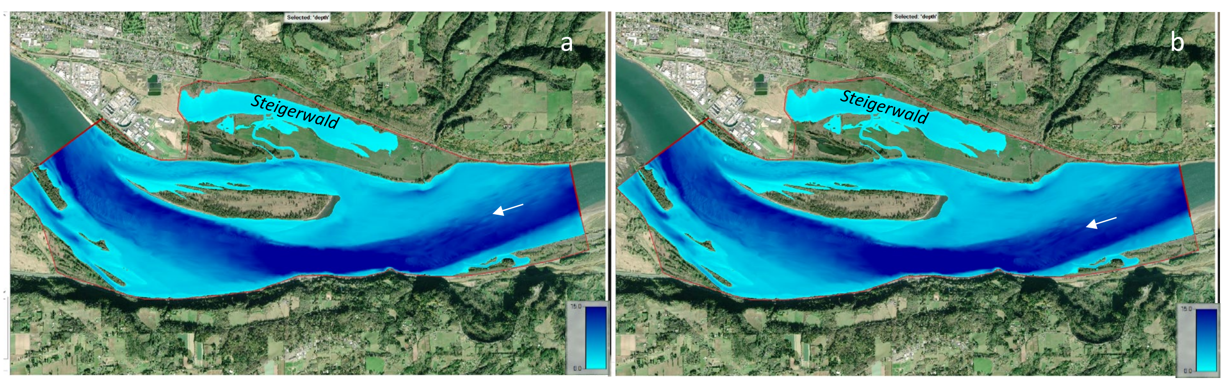
Plant Communities

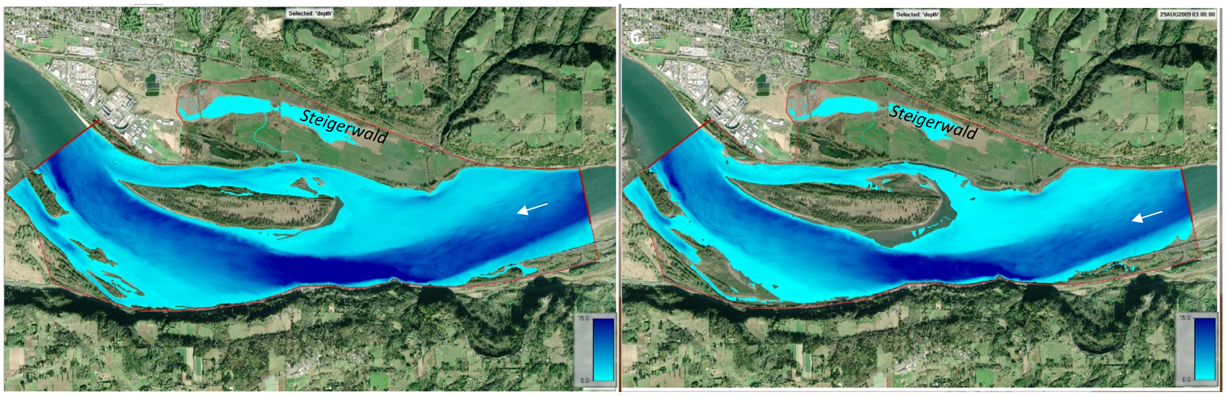
Figure 6 below shows the results for existing conditions related to plant communities. These results below omit Redtail Lake as part of the analysis. This was done, in part, due to the fact that under restored conditions the 2-year flood does not effect Redtail Lake. The existing plant communities include: open water- 32 acres, emergent- 47 acres, reed canarygrass/shrub- 308 acres and upland- 367 acres.

Appendix B Figure 6. Existing plant communities at Steigerwald.

Model Outputs

The HEC-RAS hydraulic model was run for the Steigerwald site during the growing season. Example model outputs (Figure 7) show water depths across the model domain from May- August under proposed conditions. Only the water depths in the Steigerwald project area were used to develop the ecological model.





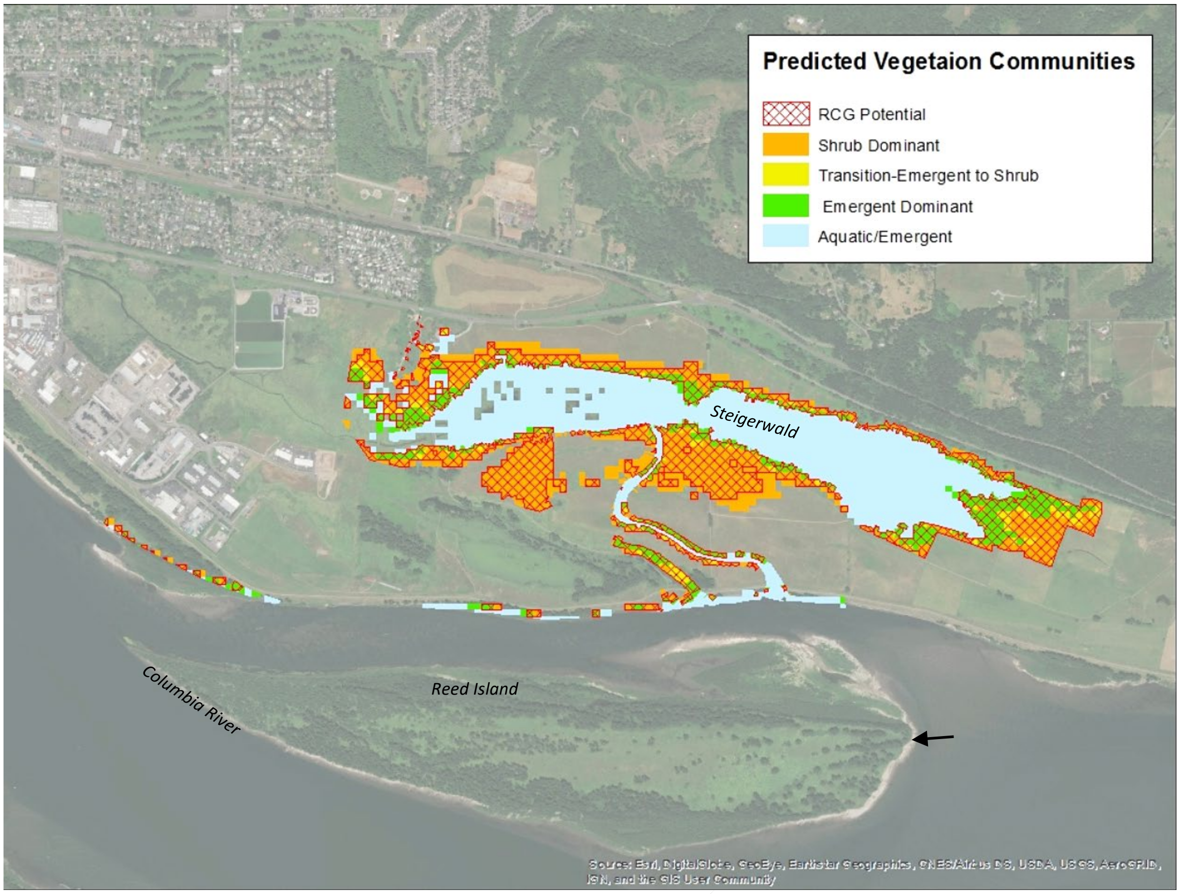
Appendix B Figure 7. Example hydraulic model outputs for water depth in May (a), June (b), July (c) and August (d). The scale is in meters with the darkest blue equaling 13-15 m (Columbia River) and the lightest blue equaling .1 to 2 meters. Generally, the Steigerwald site is less then 1 meter in depth.

After depths were extracted from the hydraulic model the ecological model was then run. Table 6 shows an example subset of cell and percent time innudated. Each of the 26,349 cells across the model domain were evaluated, however only the cells in Steigerwald were important for this project.

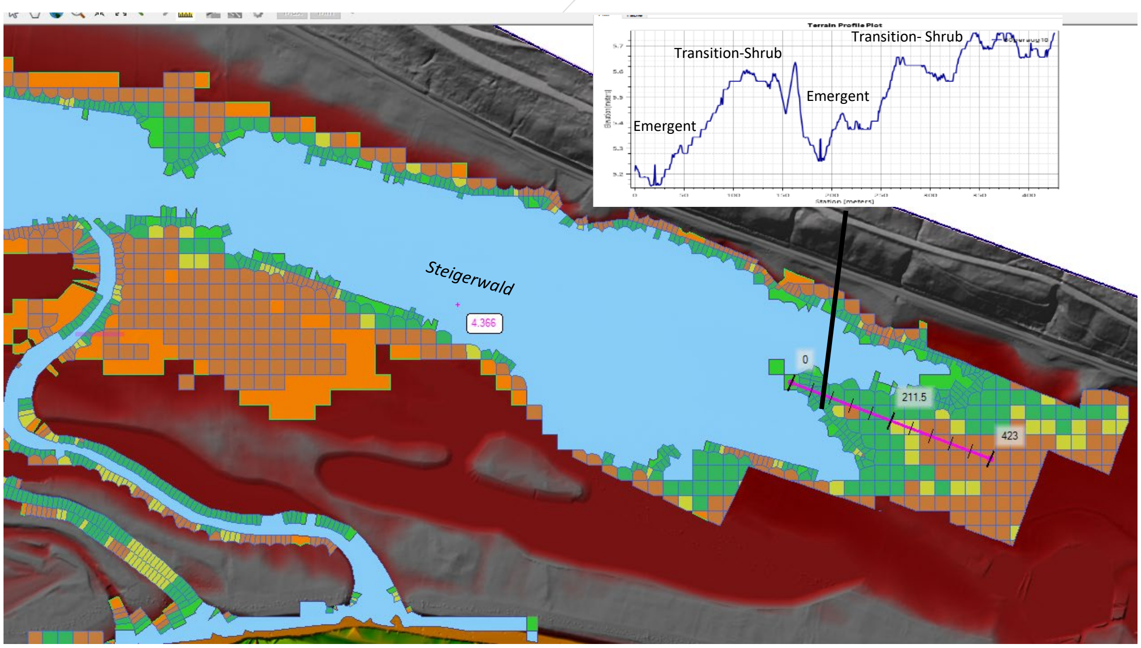
Appendix B Table 6. Example of tabular output from Steigerwald HEC- EFM model for cells 2126-2133.

Season/Cell	% time innundated
July-Sept /2126	86.9
July-Sept /2127	82.5
July-Sept /2128	82.6
July-Sept /2129	28.8
July-Sept /2130	26
July-Sept /2131	18.1
July-Sept /2132	10.1
July-Sept /2133	0

Figure 8 shows the predicted vegetation communities at the Steigerwald site for the different vegetation communities including: aquatic emergent- 141 acres, emergent dominant- 84 acres, transition from emergent to shrub/shrub dominant/reed canarygrass- 209 acres. Upland plant communities are not shown, however the potential is 276 acres. Figure 9 shows a cross section from the modeled results at the eastern portion of the site.



Appendix B Figure 8. Expected vegetation conditions at Steigerwald shown by vegetation community.



Appendix B Figure 9. Cross-section at the eastern most portion of the restoration site. The cross section inset shows the differences in plant communities as the elevation and site inundation change. The lower areas favor emergent vegetation, while the higher areas are dominated by shrubs as well as the potential for reed canarygrass.

SUMMARY

The combination of levee breaching, and reconnection of Gibbons Creek to the Steigerwald wetlands, has the potential to significantly change hydrology. Currently, the site is driven by precipitation and groundwater with occasional overflow from the Gibbons Creek elevated channel. Under restored conditions the existing wetlands have the potential to receive surface water the entire year. Overall, this should increase the magnitude and rate of change of inundation across the site. Modeling suggests that changes in hydrology have the potential to increase wetlands and emergent plant communities, while decreasing the extent of reed canarygrass and upland plant communities. Although this memo focused on plant communities, the reconnection of the interior wetlands to Columbia River flows could also have an important effect for biological communities and abiotic processes. Steigerwald will be more closely governed by timing, frequency, duration and rate of change of flows, be subject to an influx of sediments and an increase in nutrient exchange (Poff 1997). It is expected that the off-channel wetlands will also be available to lower and upper basin salmonids as well as salmonids migrating up Gibbons Creek.

HYPOTHESES TESTING

Hypothesis 1- Does the EFM and vegetation model accurately depict the wetland floodplain hydrology and plant community conditions on the site post-restoration (Years 1, 3, 5, and 10)?

If the plant community development does not follow the predicted trajectory, can differences in site hydrology, from those predicted, be used to explain these changes in native plant community development?

RECOMMENDATIONS

1. Calibrate and validate the Steigerwald ecological model.
2. Continue testing the predictive abilities of the ecological model using reference site data.
3. Collect post-project hydrology and plant community data. If possible, utilize capabilities of UAV remote sensing approaches.

Appendix C: NOAA Fish Monitoring Recommendations

Memo received from Regan McNatt and her team at NOAA regarding possible fish monitoring options and potential costs (May 2021).

The location of the Steigerwald NWR restoration area provides a unique opportunity to examine the recovery and recolonization of rare, off-channel wetland/floodplain habitat in the upper-most region of the Columbia River estuary. This area lies within a key transition zone for migrating ESA-listed and nonlisted salmon, where they are leaving the reservoir/dam landscape and entering the estuary where flow and tides dominate the system. It is critically important to evaluate the Steigerwald habitat modifications in order to measure the success of the efforts and to provide valuable guidance for similar future restoration activities.

To adequately assess the native and nonnative fish use within the channels and floodplains created in the Steigerwald area two types of sampling nets, passive and active, should be utilized. We propose the following: 1) Oneida trapnet (passive) for the floodplain, low/no flow areas. This net style has mesh wings that guide fish to a live box and can be deployed for a standard length of time. It is ideal for floodplains and lakes and has been proven to capture salmon and non-salmon species. This net does not have to be tended while deployed, thus expanding the sampling opportunity to include twilight and night time hours which are difficult to sample with active gear. By standardizing the deployment hours, a catch per unit effort can be calculated (CPUE). 2) Shallow-water beach seine (active) will be utilized in the channelized, deeper and more open water areas. This net is deployed by anchoring one end of the net to the beach and towing it via boat in an arc or by pulling it across a channel. By recording the area sampled for each effort, catch numbers can be standardized to CPUE or numbers of fish (by species) per square meter.

For each gear type, captured fish will be identified to species and enumerated. A subset of selected species will be measured and weighed. For salmon, a nonlethal tissue sample will be collected to determine genetic stock origin. All salmon will be checked for adipose clip status, marks or tags (CWT/PIT), and stomach content analysis would be performed.

The most effective sampling schedule would include a combination of passive and active gear types (Scenario A)
<u>Scenario A: first 3 years ($180K/yr)</u>
February-July : beach seine one day every other week, Oneida trap three days each month
August-January: beach seine one day each month (as temperatures allow)

<u>Scenario B: first 3 years ($110K/yr)</u>
January-December: beach seine one day every other week (as temperatures allow)

<u>Scenario C: ****($55K/yr)</u>
Sample same schedule as the existing long term monitoring sites; once a month February-June and one time in October/November

*****note– this scenario is the same as the current long-term monitoring schedule (Ecosystem Monitoring Program). The one day/month frequency has the least chance of adequately describing the success and recolonization of the restoration area. That minimal effort scenario is not in proportion with the amount of effort and money that has gone into Steigerwald and would only be worth a presence/absence description which would quickly feel lacking in information and ultimately would seem disappointing. The size and scope of the project should certainly justify a more robust sampling effort, which also is the only way to provide a measure of success for the project and any proposed future restoration projects.*