LOWER WILLAMETTE RIVER ECOSYSTEM RESTORATION PROJECT

FEASIBILITY STUDY AND INTEGRATED ENVIRONMENTAL ASSESSMENT

DRAFT REPORT

APPENDIX A: GEOMORPHOLOGY

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BUILDING STRONG.

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1. INTRODUCTION

The U.S. Army Corps of Engineers, Portland District, and the City of Portland (City) are proposing to implement restoration measures at five sites in the Lower Willamette River and some of its tributaries. Previous analyses and consultation with project stakeholders have identified five potential restoration sites located along the Lower Willamette River, Columbia Slough, and in the Tryon Creek watershed (Figure 1). Conceptual restoration designs to enhance habitat have been developed for each site, which consist of varying combinations of: culvert replacement, side channel excavation, revegetation, installation of large wood (LW), and grading the channel banks.

This appendix details the geomorphic evaluation that was conducted at the restoration sites to identify potential design constraints and risks to the proposed restoration projects. A preliminary review of the geomorphology of the Lower Willamette River is presented followed by site specific evaluations. The proposed restoration sites are located in the North Reach (Columbia River confluence to River Mile 6), Columbia Slough, the South Reach (Ross Island Bridge [River Mile 14] to Sellwood Bridge [River Mile 16.6]), and Tryon Creek Figure 1.1).

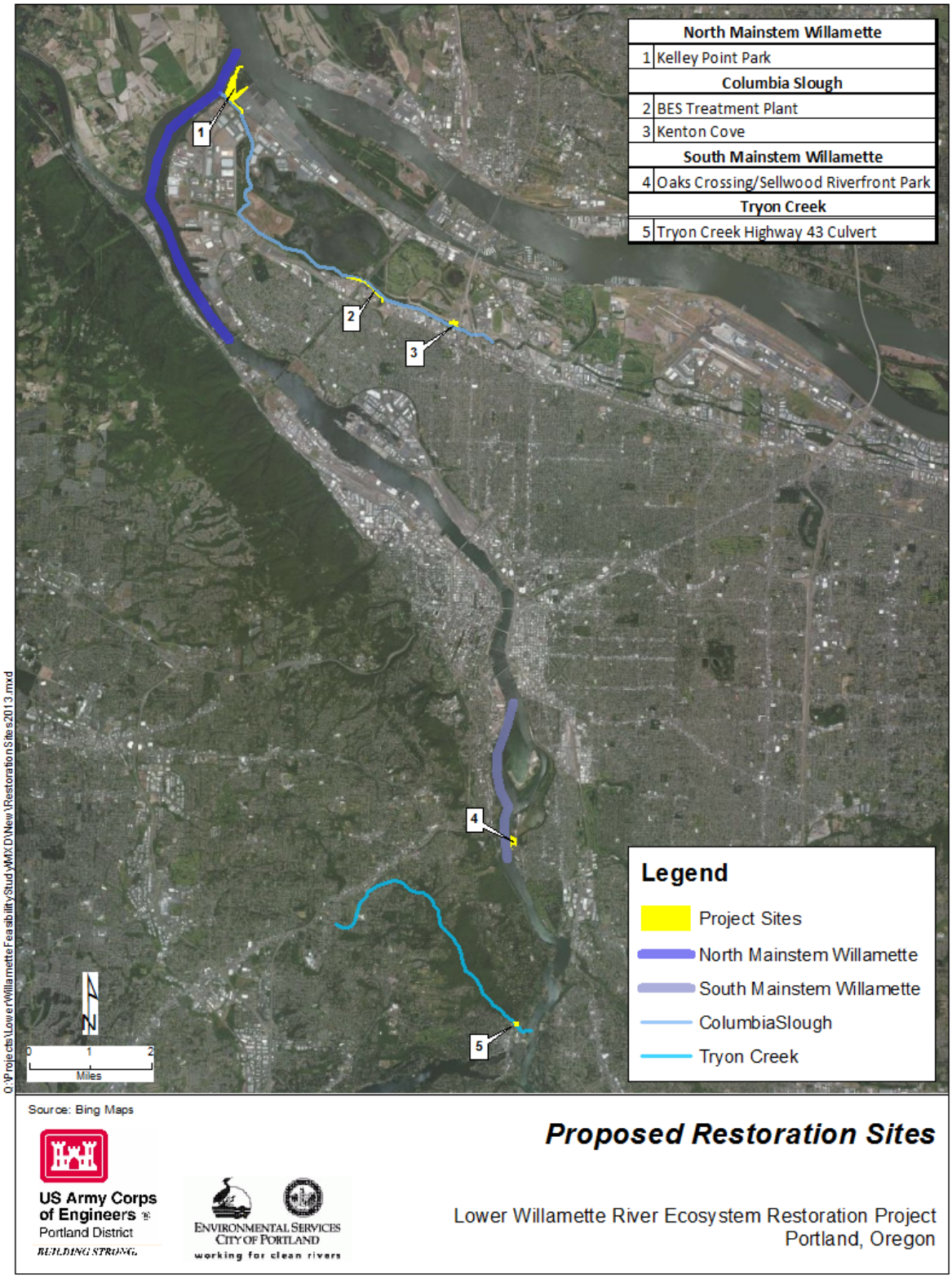

Figure 1.1. Proposed Restoration Sites

2. GEOMORPHOLOGY OF THE LOWER WILLAMETTE RIVER

The Willamette River has formed within a geologic setting created by volcanic outcropping and sediment deposits of the Missoula Floods. The dominant geological formation of the region is Columbia River basalt originating in lava flows from the eastern Columbia Basin. Willamette Falls, a basalt outcrop, provides significant hydraulic control for the river upstream of the Falls. Underlying the basalt is the Scappoose formation of late Oligocene to early Miocene age (approximately 22 million years ago), which is a sandstone and shale deposit that was formed when the region was ancient ocean bottom.

The Missoula Floods occurred approximately 13 to 15 thousand years ago during the last ice age and consisted of a series of massive floods from Glacial Lake Missoula discharging up to 100 million cubic feet per second (cfs) down the Columbia River Gorge that resulted in flooding across much of eastern Washington and the Willamette Valley in western Oregon. The floods were the caused by periodic failure of ice dams formed by the advancing glacial ice repeatedly damming the Clark Fork of the Columbia River. Sediment transported during the floods filled the valley floor. The Willamette River subsequently incised through the flood deposits and combined with the influence of the basaltic outcropping, the main channel planform has remained relatively stable (Hulse et al. 2002).

The Lower Willamette River is now a predominantly single-thread channel through the study area (Hulse et al. 2002). The channel gradient is very flat and flows are tidally influenced by the Columbia River as far upstream as Willamette Falls (River Mile 26)

Historically, streambed diversity was found in the form of floodplain marshes, side channels, braiding and islands. Following urban development, the extensive network of islands and sloughs of the historic delta are mostly gone, although a few islands remain, and there have been significant changes to the channel banks and the hydraulic characteristics of the river, most notably with the increase in average depth and decrease in the amount of shallow water and associated habitat.

Construction of the upstream dams on the Columbia and Willamette Rivers has significantly reduced frequency and magnitude of peak flows of the overbank flows, as well reduced the sediment supply to the Columbia and Willamette Rivers.

2.1 Channel Bed Material

The historical channel bed material characteristics of the Lower Willamette River are not known, but it is likely they were comprised of sand and fine-grained sediments along much of its length. The extensive changes in flow patterns, construction of dams, and extensive changes in channel structure and floodplain connection in both the Columbia and Willamette have almost certainly had an effect on sediment transport and deposition through the lower river, but the data to verify or quantify these potential changes are lacking (Portland Bureau of Environmental Services [PBES] 2006).

Presently, the sediments throughout the Lower Willamette River vary from coarse sand in the upstream portions near its confluence with the Clackamas River to mainly sandy mud near the mouth where it joins the Columbia River. Sand, sandy mud, and muddy sand comprise the vast majority of the sediment types, accounting for over 80 percent of the sediment composition through the lower river (Hill and McLaren 2001). Bedrock comprises 10 percent of the bottom with the majority of the bedrock located between Willamette Falls and Portland (PBES 2006).

2.2 North Reach

Historically, the North Reach, which was probably the most dynamic reach below the Falls, consisted of a complex channel with in-channel islands and the river was strongly connected to the extensive low-lying wetlands formed by the Columbia Slough and Sauvie Island. The channel banks were described as gently sloping, and the channel geometry was more varied, providing a range of flow depths, including a significant amount of shallow water habitat. The pre-dam hydrology would have favored channel movement and reworking of the large island delta system at the mouth. Large accumulations of wood would have been present in and along the channel, along the banks, and throughout the floodplain, and would have had a large role in influencing channel morphology (PBES 2006).

Compared to historical conditions, the channel area has been reduced by approximately 10 percent due to encroachment of the floodplain and concentration of flows in the channel caused by dredging and bank armoring. The channel is now deeper, the banks have been steepened and there is now a weak connection to a greatly reduced floodplain area. All of these factors have contributed to a loss of approximately 780 acres of shallow water habitat. Historically, water less than 20 feet deep used to comprise 71 percent of the channel area and now comprises 12 percent; water from 40 to 60 feet deep used to be 1 percent of the total channel area in this segment and is now 47 percent of the channel area. Significant accumulations of large wood are absent which has greatly simplifying channel and bank structure (PBES 2006).

Presently, many of the banks consist of riprap, structures, unclassified fill, and sea walls. Twenty-six percent of the banks consist of natural and river beach banks, and 2 percent are biotechnical and bioengineered banks. Bank hardening is most prevalent along the port facilities in the southern portion of this segment. Banks have been diked and steepened with dredge fill over the years, which has further confined the channel and limited connection to the floodplain (PBES 2006).

Two tributaries that join the Willamette River at the North Reach are Miller Creek and Columbia Slough. Columbia Slough is approximately 19 miles long and drains a 32,700-acre watershed. This watershed historically consisted of a series of wetlands, lakes, and channels located between the Columbia and the Willamette Rivers. Although the Columbia Slough has undergone extensive structural alterations including development on its immediate overbank area, historical records indicate that the channel confluence with the Willamette River has remained in approximately the same location (PBES 2006). A review of historical aerial photos of the Columbia Slough indicates that the channel planform has been relatively stable at the proposed sites over the last 30 years

2.3 South Reach

Historically, the South Reach had more shallow water habitat than the North Reach, with 95 percent of the segment composed of water less than 20 feet deep. The segment is tightly constrained on the west bank by the West Hills. There are few streamside lowlands in this portion. The channel and floodplain broadened considerably near Ross Island and Oaks Bottom. The main channel flowed to the west of Ross Island and a smaller secondary channel flowed to the east of the island. An 1850s vegetation survey shows the island split in two by a channel and 1888 surveys show the island as a single large island nearly split in two by a channel (PBES 2006).

The South Reach is the only segment in which total channel area increased over the last 150 years, due to the decrease in the amount of uplands on Ross Island. Similar to the other segments, the channel has been significantly deepened, which has resulted in the shallow water depth being reduced from 95 percent under historic conditions to 44 percent under existing conditions, and 40- to 60-foot depths have gone

from less than 1 percent to 21 percent of the segment. Despite these modifications, the South Reach retains the greatest amount of remaining shallow water habitat of the four segments.

Under existing conditions, approximately 60 percent of the bank length is beach habitat. Twenty-three percent of the banks have been converted to artificial bank structures such as riprap and bulkheads, by far the lowest of any of the segments. Bank hardening is most prevalent along the western shore opposite Ross Island.

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3. GEOMORPHIC EVALUATION OF THE RESTORATION SITES

A geomorphic evaluation of the restoration sites was conducted to assess the potential risks to the proposed projects. The sites are separated into three areas: the Columbia Slough, Willamette River, and Tryon Creek. In general, the geomorphic conditions and proposed restoration features are similar within each project area.

Site inspections were conducted on January 16 and 17, 2013, and the field observations, together with observations from previous field work, aerial photographs, topographic mapping, and existing hydraulic model output, were used to develop the site evaluations. During the January 2013 field inspection, the Highway 43 site on Tryon Creek was visited, along with both sites on the Willamette River mainstem and both sites on Columbia Slough. In addition, field data collected during previous field trips were used in the site assessments. The site observations were documented using field notes, field mapping and photographs, and the locations of the observations were recorded using a handheld GPS. Some of the key features observed at the sites include the channel planform, channel geometry, hydraulic structures, existing restoration features, indicators of channel aggradation/degradation and lateral channel migration, sediment composition of the channel and overbanks, bank stability, and channel and overbank vegetation.

3.1 Columbia Slough Restoration Sites

The BES Plant and Kenton Cove sites are located along Columbia Slough. The proposed restoration plans for these sites consist of varying combinations of the following measures:

- Installation of LW for turtle habitat.
- Revegetation with native plants.
- Grading of channel banks to increase low-flow refugia.
- Excavation of portions of the overbank to increase high-flow refugia and connections under normal winter flows.
- Removal of fill material, installation of erosion control features.

Restoration plans for the BES Plant site include an excavated channel that links an existing pond to the main part of the slough (Figure 3.1). High-flow refugia will be excavated to correspond to normal winter flows (occurring roughly between November-April) so these sites will be inundated for up to 6 months of each year. Large wood will be keyed into the bank and anchored with large wood posts, so risk of mobilization is low. Elevations at which wood would be installed have not been developed at this stage of design, but at this site the primary purpose of installing wood is to provide cover for small fish and basking areas for turtles, therefore the elevations would be set such that wood would be partially submerged under low flows, and would emerge to allow for turtle basking areas and perching locations for birds. In this case, wood would not be installed to manipulate hydraulic features, and is not expected to do so due to very low velocities in the area. The upland area surrounding the pond and proposed channel is quite flat and stable and sediment input from upland sources is likely to be minimal. However, there is the potential for sediment deposition along the excavated channel between the pond and Columbia Slough, particularly in the vicinity of the confluence. Occasional maintenance may be required at this location to ensure that the channel remains open. The river banks are steep but appear to be stable due to the vegetation reinforcement and the sediment cohesion. The banks will be graded to a flatter slope to increase the amount of shallow water habitat and to widen the riparian zone (Figure 3.2). This, combined with low velocity of currents in Columbia Slough, indicates that risk of bank failure is minimal at this site.

The Kenton Cove site is a small embayment adjacent to Columbia Slough. It has high banks and levees around much of the site, which separates the embayment from the river. There is an open water connection to Columbia Slough at the downstream end of the embayment (Figure 3.3). The water-surface elevations in the embayment are tidally influenced and the velocities during the inflowing and outflowing tides are likely to be very low. The river banks at the site appear to be stable and, combined with the low velocities, the potential risks to the restoration features are considered low. Similar to the BES Plant site, elevations at which wood would be installed have not been developed at this stage of design, but at this site the primary purpose of installing wood is to provide cover for small fish therefore the elevations would be set such that wood would be partially submerged under low flows, and would emerge to allow for turtle basking areas and perching locations for birds. Wood would not be installed to manipulate hydraulic features, and is not expected to do so due to very low velocities in the area.

Figure 3.1. Off-channel swale at BES Plant Site.

Figure 3.2. Steep banks and inlet to ponded area, BES Plant Site.

Figure 3.3. Overview of Kenton Cove, facing west. Connection to Columbia Slough is visible in upper right of the photo.

3.2 Willamette River Sites

The banks of the Willamette River sites have a mild slope and comprised of sand-sized material. (Figures 3.4 and 3.5). During flood stage, the flow depths and velocities are sufficiently high to transport LW onto and off of the river banks; therefore, it will be important to ensure the LW proposed in the restoration plan is adequately anchored. Due to the higher velocities that are likely to occur adjacent to the river and associated higher sediment transport rates, revegetation is proposed at the higher river bank elevations.

Proposed restoration measures at the Oaks Crossing/Sellwood Riverfront Park site include swale features constructed on the river bank and an excavated channel linking the swales to the river. Bottom elevations of the swales and the channel have been set at approximately 0.5 ft below the water surface elevation at normal winter flows, which is approximately 9.9 ft NAVD88 at this site. The channel is designed to connect directly to the river, with the swales connecting to the channel. At this preliminary level of design, the channel has been designed to ensure low velocities (< 1.0 f/s) during inundation and draining of the newly connected swales and existing wetlands. Similar to the Columbia Slough sites, there is the potential for sediment deposition along the excavated channel, particularly in the vicinity of the confluence with the Willamette River.

The proposed design of the Kelley Point Park site includes constructed side channels in the overbank to create off-channel habitat. Design features including elevations of the side channels, frequency of inundation, and connection to the river correspond to the methods described for the Oaks Crossing/Sellwood Riverfront Park site, above. The right bank of the river at this location is comprised of sand sized material and significant sand deposits were observed on the low-lying floodplain up to 300 feet away from the river. In addition, significant amounts of LW were observed in the overbank area, indicating the potential for LW to be transported on the floodplain during floods.

Elevations at which wood would be installed at these sites have not been developed at this stage of design, but at these sites the primary purpose of installing wood is to provide cover for small fish, therefore the elevations would be set such that wood would be partially submerged under low flows, and would emerge to allow for perching locations for birds. In this case, wood would not be installed to manipulate hydraulic features, and is not expected to do so due to very low velocities in the area.

Given the significant amount of sand deposits observed at the Kelley Point and Oaks Crossing/Sellwood Riverfront Park sites, including in the vicinity of the proposed inlet and outlet locations of the side channels, and the low gradient of the side channels, careful consideration will be given to the design of the side channels to prevent them from being blocked with sediment.

Figure 3.4. Looking downstream along the right bank of the Willamette River at the Kelley Point Park site at the approximate location of the outlet of the proposed side channel.

Figure 3.5. Looking upstream at banks of the Oaks Crossing/Sellwood Riverfront Park site.

3.3 Tryon Creek Highway 43 Culvert Site

The Tryon Creek watershed is located in southwest Portland and covers approximately 6.25 square miles. Tryon Creek flows from its headwaters near Multnomah Village southeast for about 7 miles to its confluence with the Willamette River in Lake Oswego. The watershed has been developed with mostly single-family residential housing. Approximately 20 percent of the watershed is parks and open space areas, with the Tryon Creek State Natural Area comprising a large portion of this area. In general, the watershed consists of predominately sandy loams and the hill slopes are very steep. The increase in impervious surface area due to development from housing and roads, as well as the steep topography, has resulted in a flashy hydrologic regime. Compared to historical conditions, the flood duration is longer and the magnitude of the peak flows has increased. Previous hydrology studies have shown that urbanization can increases peak flow rates by 2 to 5 times the predevelopment flows (Booth and Reinelt 1993). Although no data is available, it is likely that this altered hydrologic regime has contributed to channel incision and bank and slope instability, which resulted in an increase in sediment load to the system and a loss of riparian habitat.

The restoration plan at the Tryon Creek Highway 43 Culvert site (Figure 3.6) includes the replacement of the existing culvert with a 30-foot arch bottom culvert and revegetation of portions of the overbank upstream and downstream of the culvert.

The channel gradient immediately upstream of the culvert is relatively steep (approximately 4 percent), compared to the overall reach of approximately 2 percent. Upstream of the culvert, both banks are very steep and confine all the flows within the channel. The 2- and 100-year peak flow events are 264 cfs and 544 cfs, respectively (Tetra Tech 2013). The channel and banks are composed of boulder-sized material with the in-channel boulders forming a series of step-pools that provide grade control, energy dissipation and pool resting areas under low-flow conditions.

Figure 3.6. Looking downstream at the Tryon Creek Highway 43 Culvert inlet.

Upstream of the culvert, the channel has a pool-riffle planform and the bed is composed of gravel- to cobble-sized material (Figure 3.7 and Figure 3.8) with an approximate median size (D50) of 30-40 mm. Boulder-sized material line the margins of the channel. The channel width typically varies from 10 to 20 feet and the average channel slope is approximately 2 percent. No studies have been conducted to assess the mobility of the bed material or the sediment load along Tryon Creek. Field observations indicate that the bed material is periodically mobilized and erosion of the channel banks and valley walls contributes fine sediment to the creek. Large wood (LW) was observed along the creek and ranged up to 18 inches in diameter (Figure 3.6 and Figure 3.9). If mobilized, the LW could potentially block the existing culvert; however, the replacement culvert has been sized to pass large objects including trees, therefore this risk is considered to be low.

The channel is confined by the ravine walls and there were very few indicators to assess historic incision (Figure 3.8). Point bars have formed on the inside bends at wider sections of the ravine. The channel appears to be relatively stable, mature trees grow down to the margins of the channel and there are no signs of channel or bank instability between the culvert and approximately 600 feet upstream of the culvert. Although there is currently no evidence that large amounts of vegetation or woody debris mobilize during high flows, it is assumed that as ongoing upstream restoration efforts mature, additional wood will be available for recruitment into the stream. Therefore, the culvert has been sized to pass trees and other large debris.

Depending on the final design of the culvert, and in particular the slope of the culvert, a series of step-pools may be installed at the upstream end to provide grade control and fish passage in the steeper channel section and will prevent channel incision upstream of the new culvert. It has been proposed that a series of cross vanes weirs constructed using boulders will be placed within the culvert to provide energy dissipation and low-velocity zones and resting areas for fish passage. The boulders within the culvert will be adequately sized and anchored to remain stable under high flow conditions. Also, due to the large size of the culvert, it is anticipated that culvert will be less susceptible to blockage compared to the existing culvert. Monitoring of the culvert will be recommended as part of the ongoing maintenance plan.

At the downstream end of the existing culvert, there is a large plunge pool which provides energy dissipation and acts as a launching pool for upstream migrating fish (Figure 3.10). Downstream from the pool is a roughened chute (plane-bed section) that was constructed as part of the City of Portland's Lower Tryon Creek Stream Enhancement Project (Herrera Environmental Consultants 2007). The chute is composed of boulder-sized material, large wood, and imported streambed substrate. The upstream end of the chute provides the tailwater control for the pool. In general, the City's restoration appears to be functioning well; however, there are localized areas of bank instability downstream from the chute (Figure 3.11) due to the undersized channel and the alignment of the overbank flow path.

In summary, the channel upstream and downstream of the culvert appears to be stable, and there do not appear to be any significant limitations or adverse effects associated with replacing the culvert. As part of any design, it will be necessary to ensure that a sewer line that follows the creek alignment is protected.

Figure 3.8 Representative bed material size in Tryon Creek upstream from the culvert.

Figure 3.7 View looking upstream along Tryon Creek. Photo taken from approximately 100 feet upstream of the culvert.

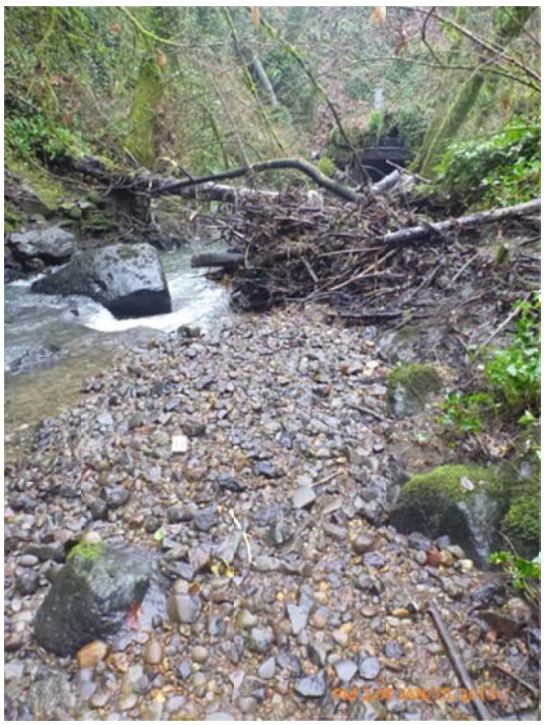

Figure 3.9 Large woody debris in channel upstream of the Highway 43 culvert.

Figure 3.10 Looking upstream at the outlet of the Tryon Creek Highway 43 Culvert.

Figure 3.11 View upstream of Tryon Creek at localized bank failure at a previous restoration site.

4. SUMMARY

The five potential restoration sites were separated into three areas with similar geomorphic characteristics: Willamette River, Columbia Slough, and the Tryon Creek watershed. The Willamette and Columbia Slough sites are tidally influenced and the channel gradients are very low. It is predicted that these projects will have a relatively low risk of failure due to the relatively low velocities. Under flood conditions, it is anticipated that sand-sized material will be transported into the overbanks; therefore, it will be necessary, to the extent practical, to design the overbank side channels to minimize sediment the amount of sediment deposition, particularly at the upstream and downstream confluences.

The Tryon Creek Highway 43 site is located near the confluence of Tryon Creek and the Willamette River. The upper portions of Tryon Creek have steep channels, and due to urban development, the watershed hydrology is flashier with likely higher peak flows compared to predevelopment conditions. As a result, the channels have incised resulting in: (1) higher banks and a disconnection between the main channel and the floodplain, (2) culverts that are impassable to fish, and (3) bank and slope instability, which has resulted in an increase in sediment load to the channel.

Culvert replacement has been proposed at the Tryon Creek Highway 43 site. Step-pool grade control structures have been proposed on the upstream side of the culvert to provide grade control and fish passage during low flow conditions. At all of the sites, it has been proposed to install LW to provide habitat to increase channel stability. The LW will be designed and installed to ensure it remains in place under high flow conditions. There is likely a low risk of project failure and no adverse effects are anticipated at this stage; however, as with any restoration project, the risk of project failure is typically highest immediately after construction before the vegetation has become reestablished and the site stabilized.

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