CITY OF PORTLAND
ENVIRONMENTAL SERVICES
1120 SW Fifth Avenue, Room 1000, Portland, Oregon 97204 ▪ Nick Fish, Commissioner ▪ Michael Jordan, Director

To: Sallie Edmunds and Mindy Brooks, Bureau of Planning and Sustainability

CC: Kaitlin Lovell, Paul Ketcham, Bureau of Environmental Services

From: Chris Prescott, Mary Bushman and Dave Helzer, Bureau of Environmental Services and Libby Smith, GSI Water Solutions

Date: **June 20, 2016**

Subject: Characterization of Current and Historical Habitat and Biological Conditions in the Lower Willamette River through Portland

The Bureau of Environmental Services' (BES) Watershed Services Division has been working on an ecological characterization of the lower Willamette River to support a number of river planning efforts, including the Bureau of Planning and Sustainability's (BPS) Central City Plan. The analysis and writing of this characterization are not completed, but we would like to submit the completed habitat and biological sections to support the Central City Plan.

The full characterization report will be organized around the four *Portland Watershed Management Plan* (City of Portland 2005) goals for hydrology, habitat, water quality and biological communities. The habitat and biological sections were prioritized as most relevant to the Central City Plan are included in this memo. In addition, the division recently completed a literature review of the large body of studies on pollutants in the lower river (GSI 2014), summarizing relevant pollutant investigations such as the Downtown Reach Study. This literature review is attached as an appendix[1].

As discussed in this document, the lower Willamette River is defined as the segment of the mainstem between Willamette Falls in Oregon City and the confluence with the Columbia River. BPS divides their river planning efforts for the lower river within the City into three reaches: the North, Central (Downtown), and South reaches. This document discusses these three reaches, but does not address the reaches from the upstream city boundary to the falls.

[1] The literature review also summarizes the 2011 Remedial Investigation and 2012 Feasibility Study for the Portland Harbor Superfund site. EPA's Proposed Plan for remediation of the site is expected to be released on June 8, 2016 for public comment.

Contents

1. Characterization

A. Landscape setting

The lower Willamette River through Portland marks the confluence of the 13th largest river in the country[2] with the fourth largest river in the country. Many of the ecological properties and economic importance of this location are due to the juncture of these two large river basins. In many ways the lower Willamette – the reaches from Willamette Falls to the mouth – is defined by and distinct because of the proximity and influence of the Columbia River. The Missoula Floods that coursed down the Columbia River over 10,000 years ago scoured many of the morphological features that still define the structure of the Lower Willamette River channel and surrounding areas, and its hydrology is daily and seasonally influenced by flows from the upper Columbia Basin, and the tidal effects transmitted from the coast.

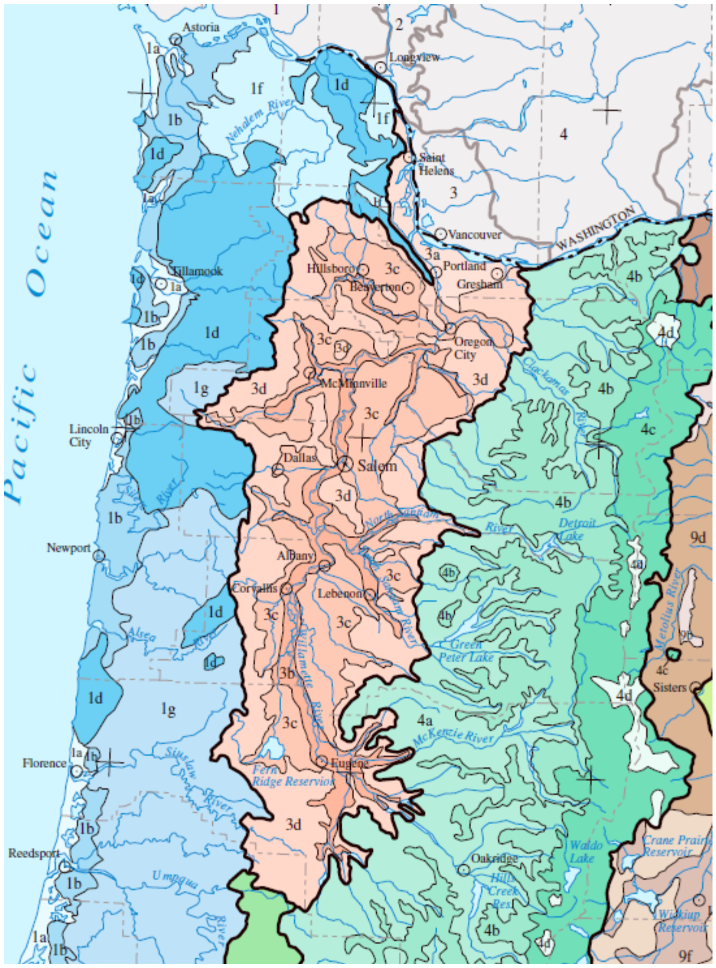
The lower Willamette River is quite different in nature from the rest of the Willamette Basin above it. Just below the Falls and in the southern section of the South Reach, the river is naturally incised into steep bedrock walls that confine the narrow channel. The floodplain is

[2] The river is the 13th largest in the conterminous United States in terms of discharge and is the largest of all major United States rivers in terms of discharge per square mile of drainage area (Uhrich and Wentz 1999).

very narrow or nearly non-existent, and the river reaches some of its greatest natural depths through this section (over 100 feet). However, as the Willamette approaches the Central Reach, landform constraints become less severe, the channel widens and, by the North Reach, conditions become increasingly influenced by the Columbia River. Historically the reduced landform constraints allowed the formation of floodplains and off-channel habitats, with large off-channel lakes such as Guilds, Doane, and Ramsey lakes. In particular, the Columbia Slough and Sauvie Island formed a large floodplain wetland complex near the confluence that provided high quality and extensive habitat for large numbers and types of biota at this ecological crossroads. For salmon, wildlife, and Native Americans, this segment was a historical gateway for one of the greatest salmon runs in the world. For birds, it is part of the Pacific flyway from north to south, and a key corridor between the coast and the interior of the Columbia Basin. For early settlements all along the river, the Willamette afforded transportation opportunities for both people and goods that contributed to the growth and prosperity of the basin over time.

The majority of the lower Willamette is in the Willamette Valley ecoregion (Figure 1). Thorson et al. (2003) describe this ecoregion as typically containing terraces and floodplains, scattered hills, buttes, and adjacent foothills. Historically, it was covered by prairies, oak savanna, coniferous forests, extensive wetlands, and deciduous riparian forests. The western bank of the lower Willamette is formed by the Tualatin Mountains, which are in the Coast Range ecoregion. This was historically a mosaic of western red cedar, western hemlock, and seral Douglas-fir blanketed inland areas of the Coast Range ecoregion (Thorson et al 2003).

Figure 1: Ecoregions of the Willamette Valley. From Thorson et al. 2003.



i) Climate

Uhrich and Wentz (1999) describe the climate for the overall Willamette Basin, summarizing that the proximity to the Pacific Ocean and exposure to prevailing westerly winds produce cool, wet winters and warm, dry summers. In the Lower Willamette area, winter is characterized by mild temperatures, cloudy skies, and rain. Freezing temperatures are rare. Spring is transitional: starting damp and cool in March, and turning more dry and warm after May, though overcast skies are common. Summer arrives in early July, when dry, warm afternoon highs in the 80s occur regularly. By early to mid- October, fall arrives with temperatures back into the 60s. As the night hours progress, the valley cools, and fog forms on clear nights.

Precipitation falls mostly as rain, with an average of only four days per year recording measurable snow. Nearly 90 percent of the annual rainfall occurs between mid-October and mid-May, and about 3 percent occurs in July and August, though this is variable across the area (NOAA 2010 pgs. 1 – 3). Destructive storms are rare, though thunderstorms can occur during any month. Thunderstorms in the winter and spring are weak; however, those in summer can produce lightning, strong winds and large hail.

ii) Geologic History

The geologic history of the lower Willamette River is as fascinating and violent as any place on Earth. Like many coasts bordering a subduction zone, the Willamette Valley was created by the piling up of ocean volcanoes as the Juan de Fuca plate slid beneath the growing Pacific coastline around 35 million years ago (MYA). Tectonic folding and uplift further helped create a valley separated from the coast and Eastern Oregon.

Around 14 – 17 MYA, massive lava flows began to emerge from fissures across the landscape of eastern Washington, Idaho and Oregon. The lava flowed down the ancestral Columbia River to the coast, and in the process laid a thick basalt layer from Portland to Salem. This created the Willamette Falls, and in so doing created a lower river much different in character from the basin above it.

The lower Willamette River was then repeatedly reshaped by a series of floods that are estimated to be the second largest floods ever to occur on Earth (O' Connor and Costa 2004). Madin (2009) describes the Missoula Floods:

> "Toward the end of the last ice age, the Portland Basin, Tualatin Basin, and Willamette Valley were swept by repeated colossal glacial outburst floods called Bretz, Missoula, or Ice Age Floods. These catastrophic events occurred between ca. 23–15 thousand years ago and dramatically reshaped the landscape of the Portland area. The outburst floods ended while sea level was still at its glacial low stand, so the Columbia and Willamette rivers in the Portland Basin flowed through canyons graded to that lower sea level. During the Holocene sea level rise, the canyons rapidly filled with alluvium to their current level, and the water surface of the Columbia and lower Willamette River are just at sea level today. http://www.geosociety.org/meetings/2009/SelfGuideFieldTrip.pdf

Madin also provides a geologic map of Portland at that link.

The Missoula Floods burst out of the highly constrained Columbia River Gorge landscape and fanned across east Portland. The original landscape of east Portland was obliterated and reshaped; many of these flood features are still obvious today. Alameda Ridge is an enormous gravel bar that deposited behind Rocky Butte. Sullivan's Gulch – down which highways, light and heavy rail travel – is a remnant Missoula Flood channel.

One of the most transformative events for the lower Willamette channel – and indeed for the entire Willamette Basin – came when the flood waters carrying ice, sediment, trees and bus-sized boulders, slammed into the resistant Tualatin Mountains that were nearly perpendicular to its path. Given the northwest angle of the West Hills, more than half of the flood likely deflected and followed the Columbia's abrupt northward turn at Portland. Flow backed up at the narrows at Kalama, WA, and forced the flood over Willamette Falls to fill the Willamette Valley and create temporary Lake Allison. The fertile soil from the plains of eastern Washington settled and was deposited in the Willamette Valley over the course of dozens of Missoula Floods.

A number of other geologic events are important to the lower Willamette's landscape. These include the formation and eruption of the Boring Lava Domes that formed Rocky and Powell buttes and Mt. Tabor, and the transport of wind-blown soils from eastern Washington that deposited throughout the West Hills draining to the river. These are described more fully in Madin (2009).

B. Habitat

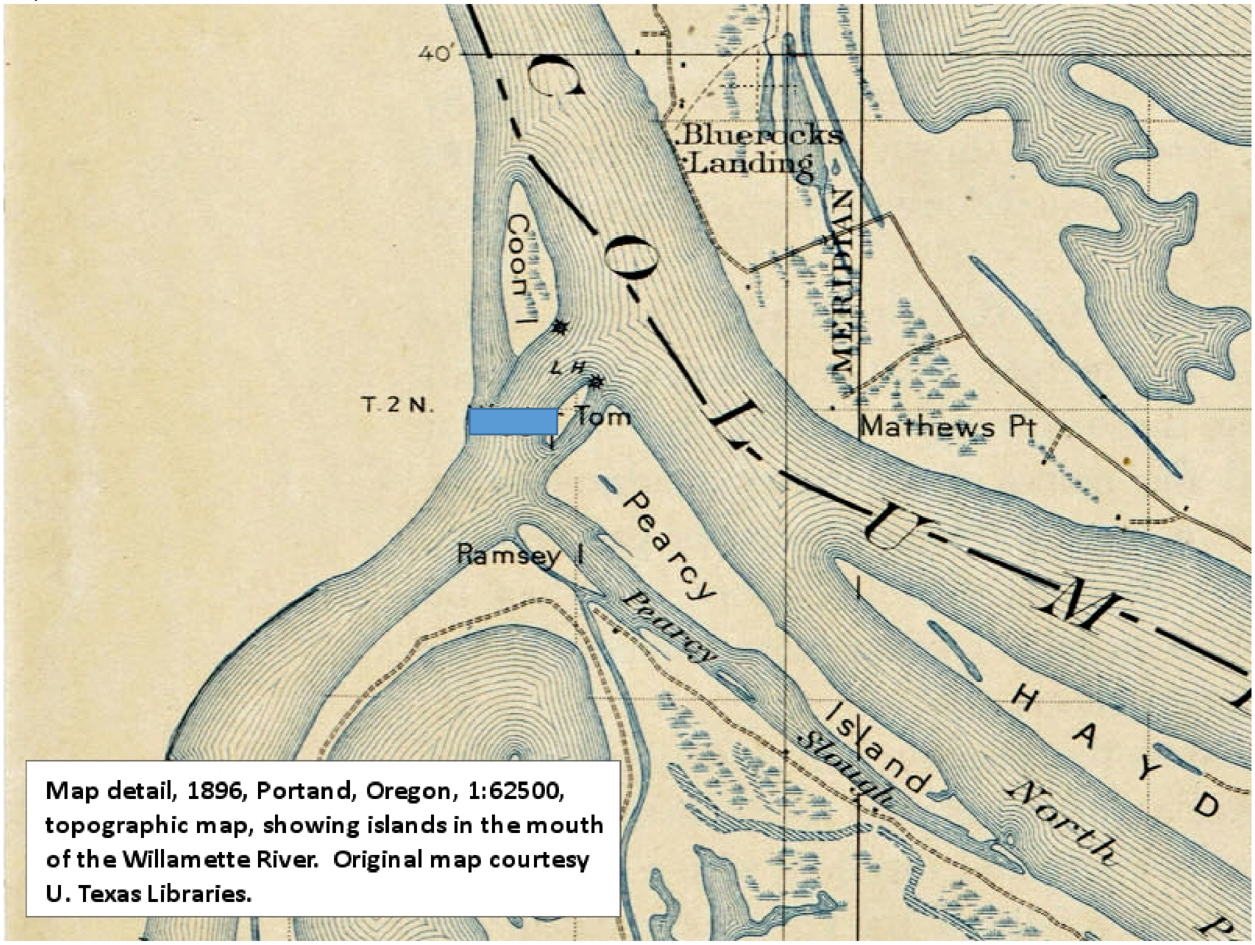
Adolfson (2003) provides a concise description of the historical natural setting of the Lower Willamette River prior to human development: "Historically, the Willamette River in the Portland area comprised an extensive and interconnected system of active channels, open slack waters, emergent wetlands, riparian forest, and adjacent upland forests on hill slopes and Missoula Flood terraces. Prior to settlement, the river was embedded in the regional forest network, and intricately connected to the Columbia floodplains." (p. 6)

This section provides an overview of historical and current aquatic and water-related habitat components of the north, central, and south reaches of the Lower Willamette River. These habitat components include: shallow water habitat, floodplains, off-channel, riverbank condition, and vegetation (both riparian and upland). The section concludes with a summary of the terrestrial habitat priorities and habitat types by reach.

i) Bathymetry/Shallow Water Habitat

Originally the lower Willamette channel was a transitional zone from a highly constrained basalt trench from the Willamette Falls to the South Reach, then a gradually widening and less constrained channel as it reached the confluence with the Columbia River. The general course of the channel through Portland has likely been consistent over time since the Missoula Floods dramatically reshaped the area. The one exception to this was the mouth of the river, where the Columbia Slough and Sauvie Island provided low-lying areas that were reconfigured during floods. Early maps of the mouth show multiple islands and channels that have been lost as the main channel was simplified for navigation and development (Figure 2).

Figure 2: Map of the mouth of the Willamette River. An offensive historical name has been covered in the original map.



Bathymetric surveys have been completed in the lower Willamette River through Portland in 1888 - 1895[3], 2001[4] and 2004[5]. It is difficult to compare these datasets quantitatively, however. The 2004 data are the only survey tied to a vertical reference point – Ordinary High Water (OHW[6]). The 1888-95 and 2001 surveys are not tied to a specific datum or elevation – they were conducted during a period of summer low flow that would have been approximately near Ordinary Low Water (OLW). Summer low flows have changed from 1888 to the present due to hydrologic alteration of the Willamette and Columbia rivers caused by dams, and tides can vary water depths in Portland by up to 3 feet over a tidal cycle (BES, In prep.[7]). Therefore, comparison amongst the datasets is limited to more qualitative analyses.

In order to provide a qualitative comparison of the changes in bathymetry over time, the data were mapped to address the question "how much shallow water habitat was present during the summer low flow conditions at the time of the survey?" For the purposes of this question shallow water was considered to be areas 20 feet deep or less during OLW. The 2004 OHW

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[3] Metadata: https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=52237 and http://www.fsl.orst.edu/pnwerc/wrb/metadata/ac1895p.html

[4] https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=53476

[5] https://www.portlandmaps.com/metadata/index.cfm?&p=1&s=abstract&b=9&c=50022&o=asc&action=DisplayLayer&LayerID=53396

[6] North American Datum of 1983/1991 (HPGN)

[7] The hydrology chapter of the full Willamette characterization report. This memo will be incorporated into that document.

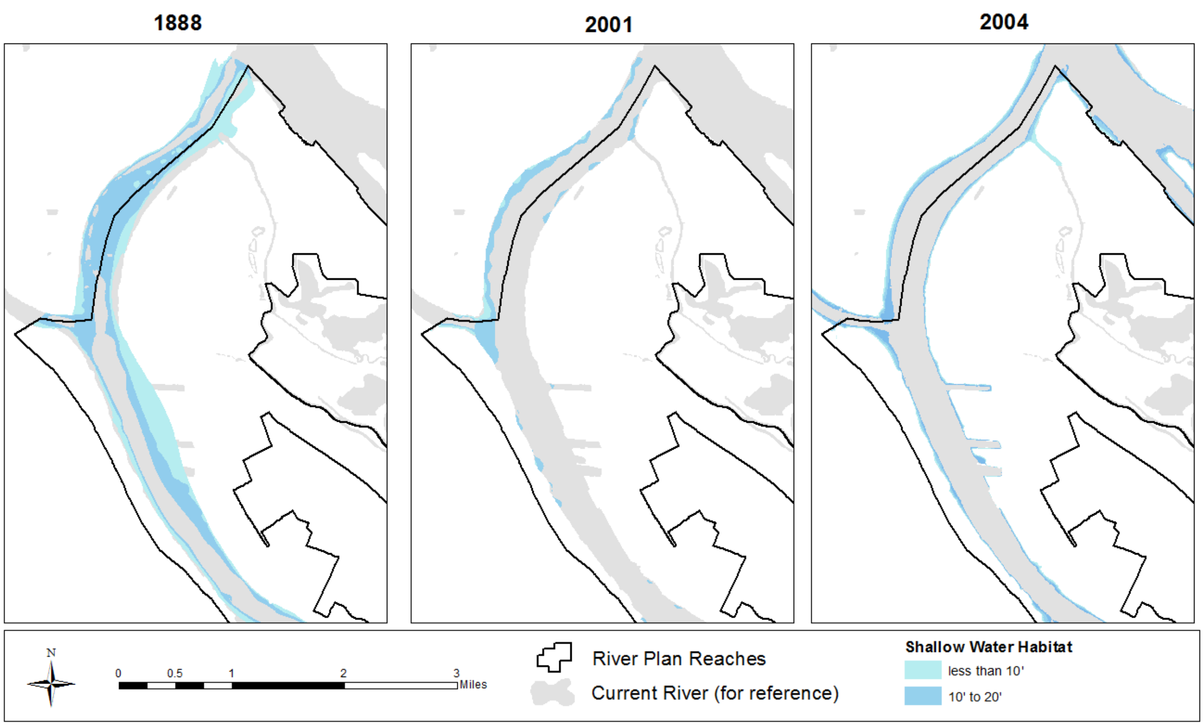
data were converted to OLW depths by subtracting 7.9 feet (Stillwater Sciences 2014). Comparison of shallow water habitat for the three reaches is described below.

(a) North Reach

The channel of the North Reach as it approached the confluence was the most dynamic and complex of the reaches from the falls to the mouth. The joining with the Columbia provided dynamic hydrology that reworked the low-lying topography through floods. Like the confluence of most Pacific Northwest rivers massive wood accumulations would have been present, and early settlers spent considerable time removing wood from the channel for navigation. It was noted that "Because the Willamette River provided the critical transportation route for moving wheat to Portland and then on to oceanic markets, the federal government funded the construction of a steam-powered "snag-puller" in 1869 to remove obstructions from the river." http://www.oregonencyclopedia.org/articles/willamette_river/#.VtjPQubX-I4

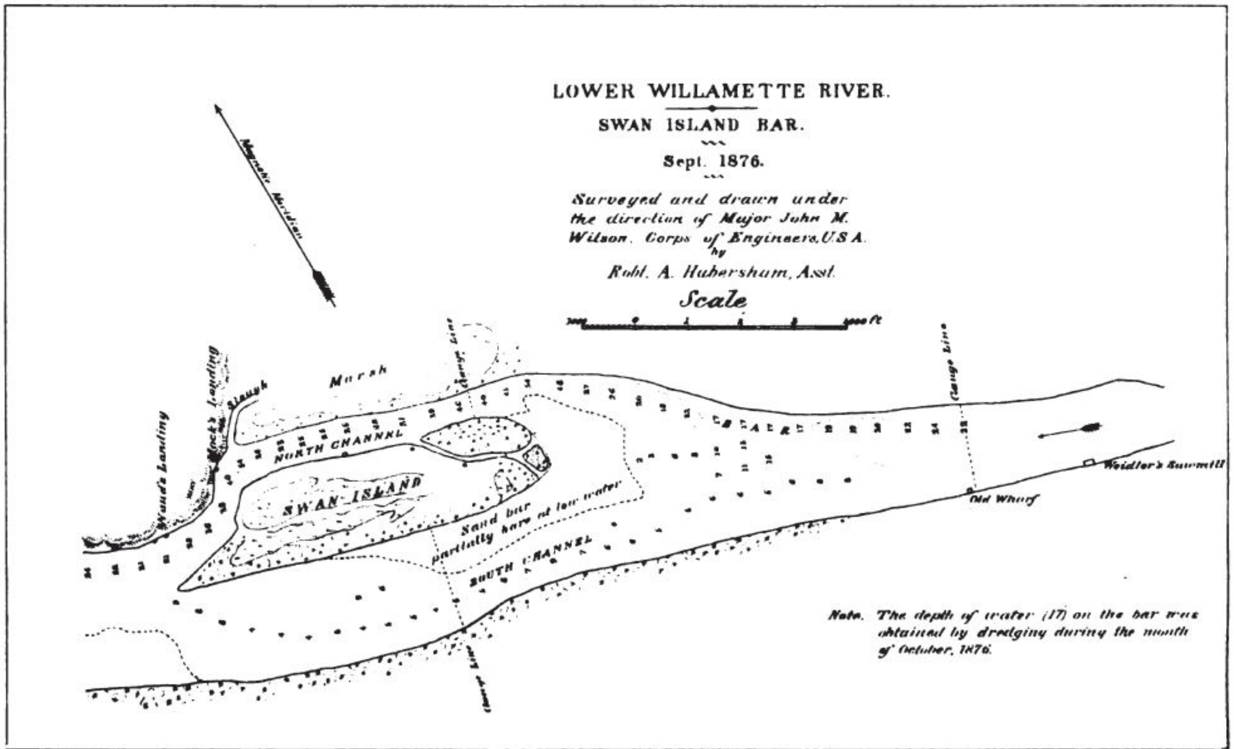
The earliest channel surveys showed extensive shallow water habitat from Multnomah Channel to the mouth (Figure 3). South of this area provided a more gradually sloping bathymetry, with more extensive shallow water habitat on the east shoreline (near the current terminal slips) than the west shoreline. The current channel conditions on both sides of the river in this area show very steepened slopes with a very narrow marginal band of shallow water during low flow conditions.

Figure 3: Shallow water habitat in the northern section of the North Reach.



Moving further upstream to the southern portion of the North Reach, historical comparison reveals one of the more dramatic changes in the channel. The historical channel flowed to the east of Swan Island – a proper island at the time – and what is currently the main channel was a secondary channel with the largest expanse of shallow water habitat across the entire lower Willamette mainstem. The main channel was filled and Swan Island connected to the eastern bank in order to build the original Portland Airport[8], the current main channel was directed through this former shallow water habitat, and Swan Island Lagoon was created out of the original main channel (Figure 4).

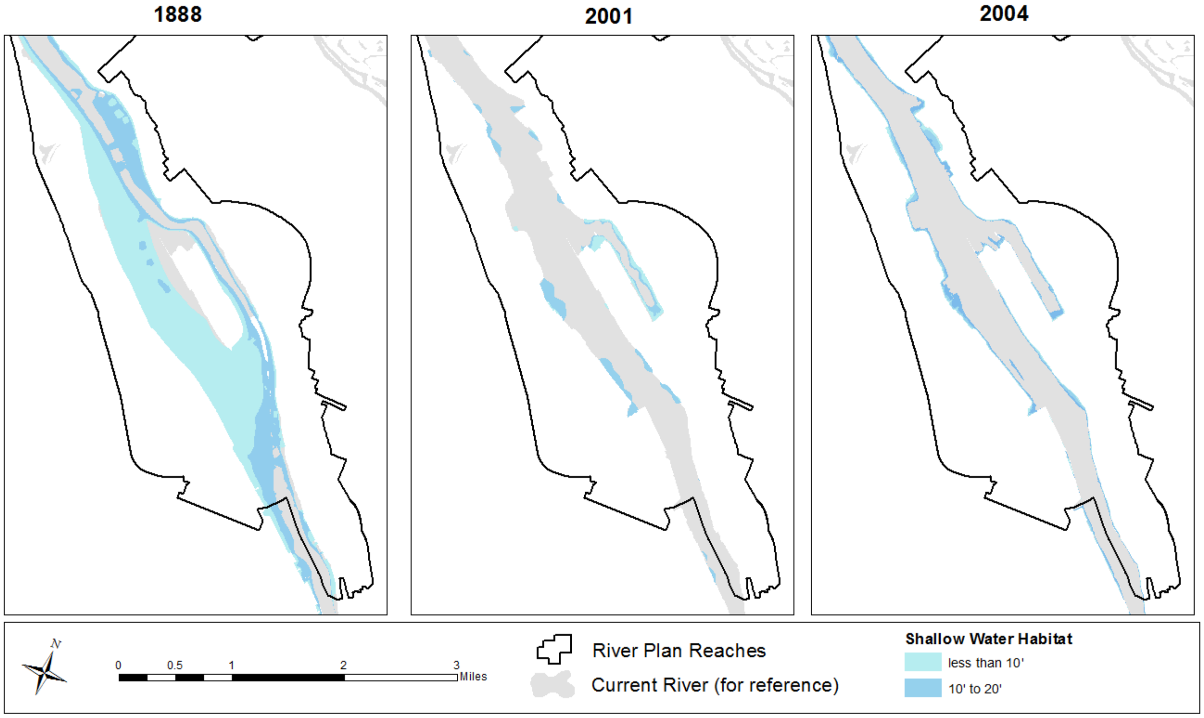
Figure 4: 1876 map of the original river configuration at Swan Island. http://www.portlandwaterfront.org/timeline2.html. The deeper main channel was historically to the east of Swan Island (towards the top of the map)



The primary remaining shallow water habitats in this section are small alcoves, wider areas, or backwaters that provide room for more gradual channel slopes such as Willamette Cove, Terminal 1 and the end of Swan Island Lagoon (Figure 5).

[8] Swan Island was first noted as Willow Island in 1844. Lt .Charles Wilkes did visit and chart Swan Island (the first to do so), calling it Oak Island in his diary and Willow Island a decade later when the four-volume account of his voyage was published. He said: "The grove of oak on this island was beautiful, forming an extensive wood, with no undergrowth. The species of oak that grows here is white oak, of very close grain."

Figure 5: Shallow water habitat in the southern section of the North Reach.

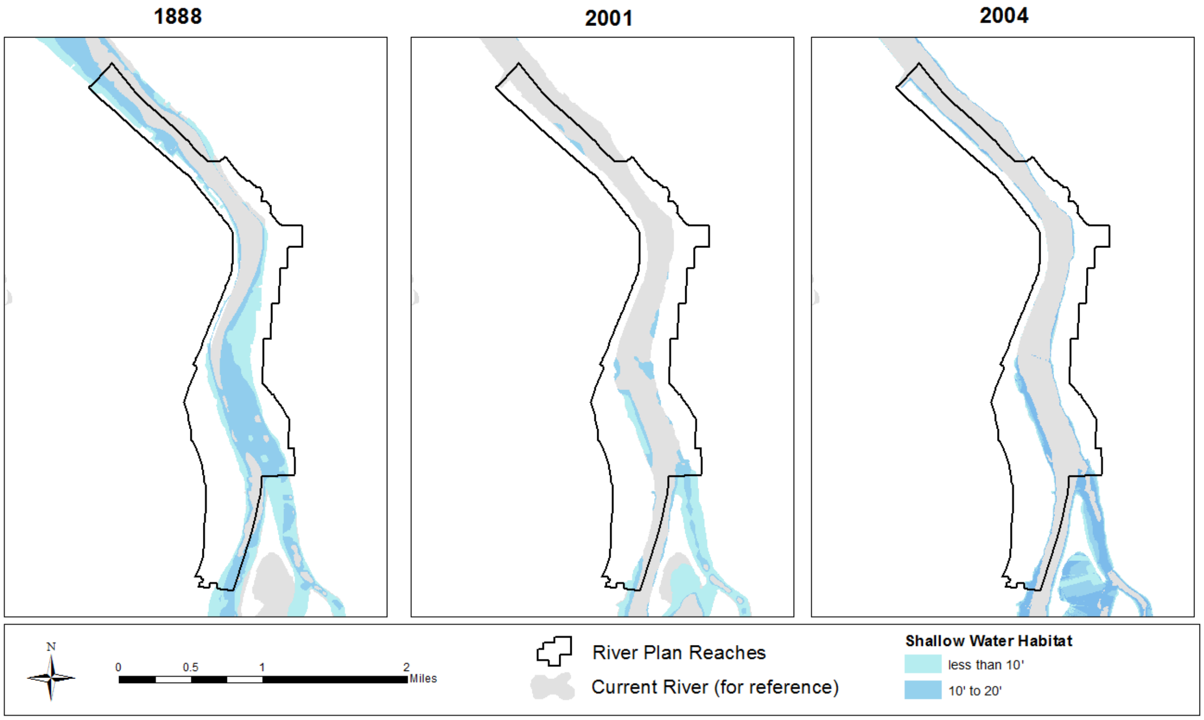


(b) Central Reach

The Central Reach was historically narrow and moderately constrained, with shallow water habitat across the channel downstream (north) of the tip of Ross Island. The thalweg (deepest portion of the channel) bounced back-and forth between the banks as it traversed this reach.

Currently, because of the downtown seawall, extensive riprapped banks, and steep channel slopes along this reach, shallow water habitat is limited to very small, steepened areas such as the northern half of South Waterfront and the east bank beneath the Hawthorne Bridge (Figure 6).

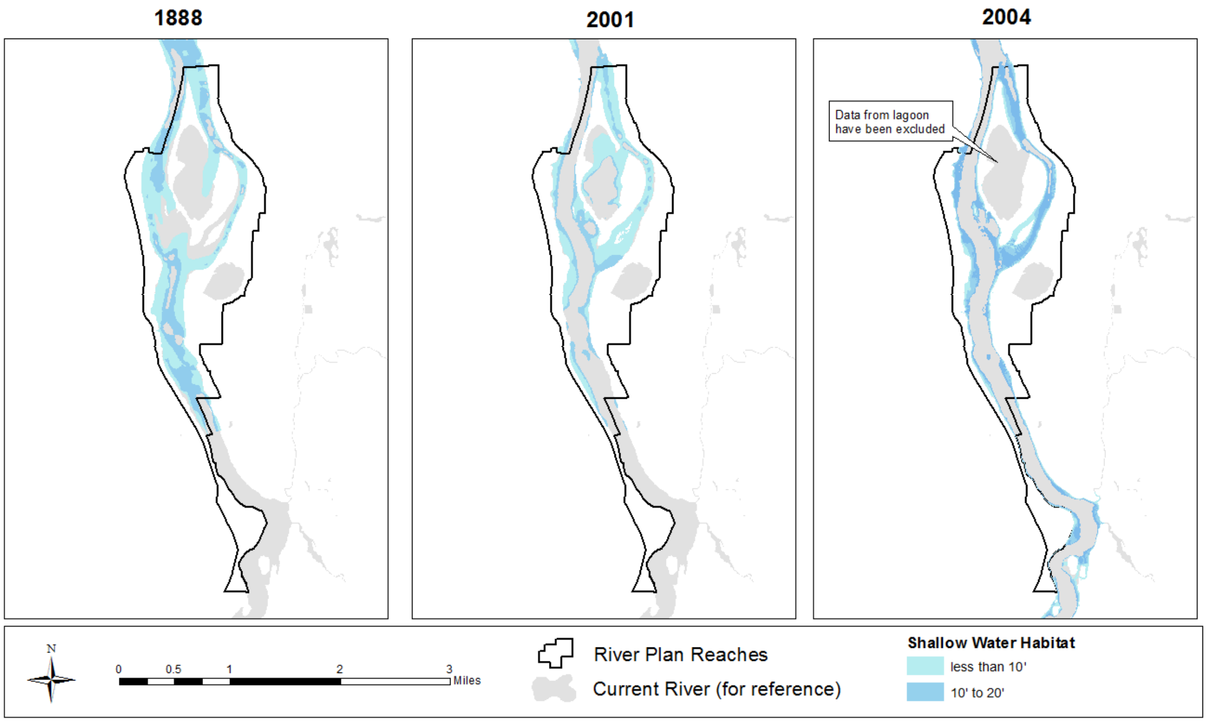
Figure 6: Shallow water habitat in the Central Reach.



(c) South Reach

The South Reach historically provided considerable shallow water habitat and channel complexity as the river flowed through and around Ross Island. Ross Island was originally a group of islands with shallow channels between them that changed form in response to large floods (see, for example, Figure 18). Most of the channel upstream of Ross Island other than the thalweg was less than 20 feet deep. Currently, much of the shallow water habitat upstream of Ross Island and in the main channel to the west of Ross Island has been lost, but Holgate Channel to the east of Ross Island provides one of the only secondary channels in the entire lower Willamette, and is mostly less than 20 feet along its course (Figure 7).

Figure 7: Shallow water habitat in the South Reach. Note: the 2004 data in Ross Island Lagoon are in error and are in the process of being corrected, and so have been excluded from the map.



ii) *Floodplains and Off-Channel Habitats*

From Multnomah Channel to the mouth, the Willamette River formed the southern portion of a vast floodplain system that included Smith & Bybee Lakes, Sauvie Island, and the Multnomah Channel, and Vancouver Lake and what is now Ridgefield Wildlife Refuge across the river.

Through Portland the floodplains are bounded by the Willamette Escarpment and the Tualatin Mountains. The channel and floodplain widen as the river flows through Portland, where landform constraints become less severe, and conditions become increasingly influenced by the Columbia River. Historically the reduced landform constraints allowed the formation of floodplains and off-channel habitats through Portland, with large off-channel lakes such as Guilds Lake, Doane Lake, and Ramsey Lake. Tributaries, including the Columbia Slough, and Miller, Doane, Balch and Tanner creeks were all connected to the mainstem. Prior to development, the mouth of the Willamette River provided one of the most extensive floodplain and off-channel habitats below the Falls. The Oregon History Project (Toll 2003) describes the city before construction of the dams:

> "The Willamette Valley was periodically flooded by late spring thaws in the Cascades. Portland's business district was overrun in 1853, 1854, 1862, 1871, and most severely in 1876 and 1894. On June 24, 1876, the water flooded stores along Second Street, reaching a high-water mark of twenty-five feet. In June 1894, the waters reached Northwest Tenth and Glisan and Southwest Sixth and Washington streets, a high water mark of over thirty-three feet…
>
> Boats floated through the downtown like gondolas in Venice, conveying produce and people to the second story of three and four story masonry buildings. Unlike fires, which city officials tried to prevent with building codes and to fight with a professional force,

floods seemed inevitable. Prevention of floods awaited the construction by the city of higher walls along the waterfront and ultimately the construction of dams on the upper Willamette by the Army Corps of Engineers." [www.**oregonhistoryproject**.org/articles/early-portland/pdf/](www.oregonhistoryproject.org/articles/early-portland/pdf/)

Figure 8: Picture of the 1894 flood inundating the North Park Blocks. http://www.oregonencyclopedia.org/articles/willamette_flood_1894_/#.V1fMcZErI2w

Along its length, riparian forests, mudflats, off-channel streams, lakes and wetlands were connected to the river during seasonal high flows. In-channel islands such as Sauvie, Swan and Ross islands provided high quality fish and wildlife habitat that would change configuration in response to floods. The historical floodplain provided storage for floodwaters and sediment, nutrient exchange, as well as groundwater and wetland recharge. The floodplain also served as a source of organic matter and food supply (e.g., insects) to the Willamette River, and as a refuge for fish and wildlife during floods, providing slower flows and hiding spaces to avoid the high flows of the main channel.

Processes that have led to changes from historical to current floodplain conditions primarily involve the placement of fill and structures to support industrial, commercial, transportation and residential development of the floodplain. Placement of fill alters floodplain function by disturbing native vegetation, modifying absorption rates, and isolating the floodplain from the channel, thereby reducing the frequency of inundation from flooding events. The placement of structures in the floodplain – buildings, roads, pipes and utilities – cover the floodplain, diminish or eliminate its ability to provide many functions to the river, and introduce pollutants.

As a result of these processes, off-channel habitat in the lower Willamette River is one of the habitat types most greatly diminished in quantity and quality from historical condition. Floodplain fill, vegetation removal, bank and channel alterations, and urban development have destroyed floodplain, off-channel, and riverine habitats or greatly altered their structure and function. Large off-channel lakes such as Guilds Lake and Ramsey Lake were filled to provide land for downtown and port development, while Doane Lake was reduced in size and its connection to the river severed. At the same time, tributaries all along the lower river were piped underground to support development and disconnected from the mainstem channel.

Most of the tributaries draining the Tualatin Mountains (West Hills) into the Willamette from the west have been disconnected by the presence of long culverted or piped sections.

The Portland Harbor Remedial Investigation (EPA 2016) describes many of the areas which received fill:

> "Anthropomorphic fill blankets much of the lowland area next to the river and is predominantly dredged river sediment, including fine sand and silty sand. Hydraulic dredge fill was used to fill portions of the flood plain, such as Doane Lake, Guild's Lake, Kittridge Lake, Mocks Bottom, Rivergate, and a number of sloughs and low-lying areas. The fill also was used to connect Swan Island to the east shore of the Willamette River and to elevate or extend the bank along significant lengths of both sides of the riverfront by filling behind artificial and natural silt and clay flood levee dike structures. Rocks, gravel, sand, and silt also were used to fill low-lying upland and bank areas. The thickness of this unit ranges from 0 to 20 or more feet." (pg 3-3).

This section provides an overview of historical and current floodplain conditions of the North, Central, and South reaches of the Lower Willamette River. Information is presented by reach, first for the east, and then the west bank.

(a) North Reach – East Bank

The floodplain on the eastern shore at the confluence with the Columbia consisted of a portion of Ramsay Lake, cottonwood and ash riparian forest, wetlands (emergent, forested, and scrub-shrub), and prairie (GLO vegetation surveys, Graves, et al. 1995). The largest of the tributaries flowing into the North Reach joined the Willamette at the northern tip of this subwatershed. The Columbia Slough, a 19-mile 32,700 acre watershed which was originally a large series of wetlands, lakes and channels, formed the floodplain of the Columbia mainstem and the Willamette mouth. Based on a visual estimate of 1964 and 1996 flooding events depicted in Hulse et al. (2002), an estimated 90% of this area was covered during historical floods. Ramsey Lake - the largest of the off-channel lakes in the lower Willamette at approximately 650 acres, was nestled between the lower several miles of the Slough to the east and the Willamette mainstem to the west, forming a large floodplain wetland complex. Vegetation surveys suggest these wetlands were connected to the main channel through marshy areas to the south in what is currently the International Slip and Schnitzer Steel.

Upstream of the confluence, topography increasingly constrained the channel and floodplain. In wider areas such as Willamette Cove and Mocks Bottom, the floodplain included wider bottomlands and wetlands at the foot of these escarpments. At Mocks Bottom an extensive floodplain historically bordered the main channel to the east, and contained a large marsh and forested wetland complex (Figure 9). When considered with the Guilds Lake bottomland on the opposite bank the Willamette River, the floodplain would have been over 2 miles wide at this point.

Extensive fill along the eastern banks has greatly reduced the extent of floodplain. Ramsey Lake and much of the low-lying land along the Rivergate area have been filled for industrial development. Small remaining pockets that are either in the Federal Emergency Management Agency (FEMA) 100 year floodplain or that were inundated in the 1996 flood include the lower lying areas of Kelley point Park, the low-lying areas surrounding International Slip, and the end of the Swan Island lagoon and southern end of Swan Island where the original main channel was filled to connect Swan Island to the eastern bank.

(a) North Reach – West Bank

Along the west bank of the North Reach a broad Willamette River floodplain historically existed from the confluence with the Columbia River to the Multnomah Channel that included large portions of Sauvie Island. Flooding may have extended up to 1,000 feet or more from the river at the marsh area south of the Miller Creek confluence. Historical maps show wetlands and an off-channel waterbody where Miller Creek joins the Multnomah Channel (Figure 9).

Upstream of the Multnomah Channel, the floodplain was constrained throughout the Linnton area as the channel flows near the base of the Tualatin Mountains, and flooding was limited to areas near the bank. South of Linnton on the west bank across from St Johns, the Tualatin Mountains begin to diverge from the main channel and a shelf of low lying bottomlands are present between the base of the mountains and the channel. It was on these bottomlands that the extensive off-channel floodplain lakes were present, from north to south including Doane Lake, Kittridge Lake and Guilds Lake, the latter an old cut-off meander of the historical channel. Along the length of the Tualatin Mountains a large number of perennial and intermittent streams flowed down the flanks of the West Hills onto the floodplain platform below, often passing through lakes and wetlands along the way.

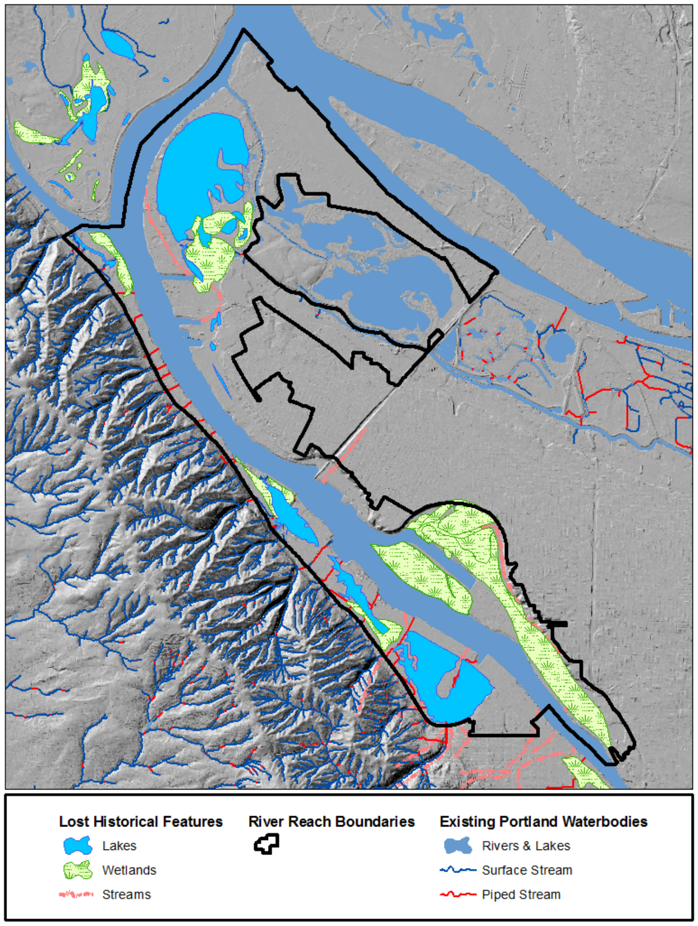
With a few exceptions, the current 100-year floodplain does not extend much beyond the existing channel boundaries (FEMA 1982 and 1986), due to filling for industrial and commercial use. The mouth of lower Miller Creek and the wetlands on the north and south of the PGE property are still subject to Willamette River flooding, and portions of the Morse Brothers, Owens Corning and Linnton Plywood properties were either flooded in 1996 or are within the 100-year FEMA floodplain. Sauvie Island – nearly all of which would have flooded under historical conditions – has been diked and much of its interior has been disconnected from the river. Much of the former Alder Creek Lumber property is outside of the dike and experiences flooding. This property was recently purchased by Wildlands, Inc., restored, and is being used to provide credits for Natural Resource Damage Assessment liabilities by providing high quality off-channel and floodplain habitats that are well-connected to the mainstem[9].

Miller Creek, at the junction with the Multnomah Channel, is the only creek draining Forest Park with any fish passage. Miller Creek is a forested, high quality watershed largely contained within Forest Park, the largest forested park within city limits in the country. The connection of Miller Creek to the Willamette is compromised by culverts underneath the railroad, and lower channel alterations including the redirection of the channel into the back end of a marina. The Oregon Dept. of Transportation replaced the culvert under Highway 30 with a bridge in 2003. Improvements to the confluence and lower channel are being developed as part of the Natural Resources Damage Assessment settlements (ref).

All other Forest Park streams – Doane, Saltzman, Balch and numerous unnamed perennial and seasonal streams – are piped from the foot of the West Hills under Highway 30 (and associated industrial development) and disconnected from the Willamette River (Figure 9). Doane Lake across from Willamette Cove was mostly filled during development, and the remnant portion is separated from the river and other habitats on all sides by railroad berms. Guilds Lake, the largest lake on the west side, and Kittridge Lake were completely filled.

[9] https://www.fws.gov/oregonfwo/Contaminants/PortlandHarbor/Documents/AlderCreekFactSheet.pdf

Figure 9: Historical off-channel lakes, wetlands and streams that have been lost over time in the North Reach.



(b) Central Reach – East Bank

The East bank of the Central Reach was described by Harvey Scott in 1890:

> "From Albina southward the surface sinks by small degrees, broken here and there by ravines, until at the site of East Portland, three profound chasms or gulches, unite to form an illuvial bottom, making easy ingress from the river, but a bad water front. The first of these on the north is Sullivan's Gulch, fifty feet deep and two hundred yards across; its bed a morass. It is down this cleft that the O. R. & N. R. R. finds a passage from the plain to the river level. Next south is Asylum Gulch, leading back to a powerful spring which leaps from under the plain behind, giving birth to a stream of water sufficient for the supply of the water works of East Portland. A mile south of this is Stephens Gulch, bearing off another clear stream, of many times the volume of the foregoing, which also springs bodily from the ground. It is by this depression that the O. & C. R. R. passes out of the city. South of the mouth of Stephens Gulch, the ground once more rises, gaining an altitude about the same as that of Albina, and it is called Brookland[10]. … The strip of alluvium in front of East Portland, at the mouth of the gulches, is but a few hundred paces across, and thence the surface rises easily, nowhere attaining an elevation of more than one hundred feet, and develops into a plain with many variations of surface leading out three miles further to Mt. Tabor."

[10] Currently the Brooklyn neighborhood – the bluffs on the east bank above Ross Island.

The historical floodplain in the east side of the Central Reach was not extensive, based on imagery (Hulse et al. 2002), vegetation descriptions (Christy et al. 2000), and the Coast Survey maps. It was generally limited to the shoreline, though the river would flood into the three the gulches; for example in Sullivans Gulch as far up as the present location of NE 16th Avenue (City of Portland Bureau of Planning, 1993).

The Surveyor General's Office map from 1852 indicates a creek flowing east to west in the approximate location of the current SE Belmont Street. This creek enters a lake at approximately the location of the current SE 12th and Morrison Streets (Surveyor General's Office, 1852). This was likely Asylum Creek –mentioned in Harvey Scott's description above and also known as Hawthorne Springs (Figure 10) – which was mentioned in the Oregon Journal in 1929[11]:

> "Interesting history of the Central East Side is recalled by completion of the Grand Central Public market, which occupies what once was the course of Asylum creek, a stream originating near Mount Tabor and meandering through the East Side past an insane asylum on what is now East 10th street, to the Willamette River near Oak Street.
>
> …Man-made alterations, made principally since 1900, have changed the terrain of the Central East Side section considerably. Grand Avenue ran along the crest of a bluff overlooking the river, and was regarded as "high land." It was a broad peninsula extending northward to Stark Street, where the declivity of Asylum creek caused a dip in the land.
>
> Another indentation of water into the east Side was Stephens slough and creek, over which the Inman-Poulsen mill now stands. Asylum creek, which passed through the center of the district, arose near Mt. Tabor, passed along the southern line of Lone Fir cemetery and in a southwesterly course went to East 12th and Hawthorne, swinging abruptly into a northwesterly course. At 12th and Hawthorne the stream was fed by a spring, which produced 1,000,000 gallons of water daily. This spring is still in action and has created an engineering problem for the city engineer and nearby residents"

The historical floodplain was filled and developed for the settlement of East Portland and the Central Eastside Industrial District. Currently, I-5 and industrial land occupy much of the floodplain closest to the river. A portion of the area under the I-5 freeway along the railroad tracks and SE 2nd Avenue flooded during the 1996 event, though development has effectively eliminated floodplain function in this area.

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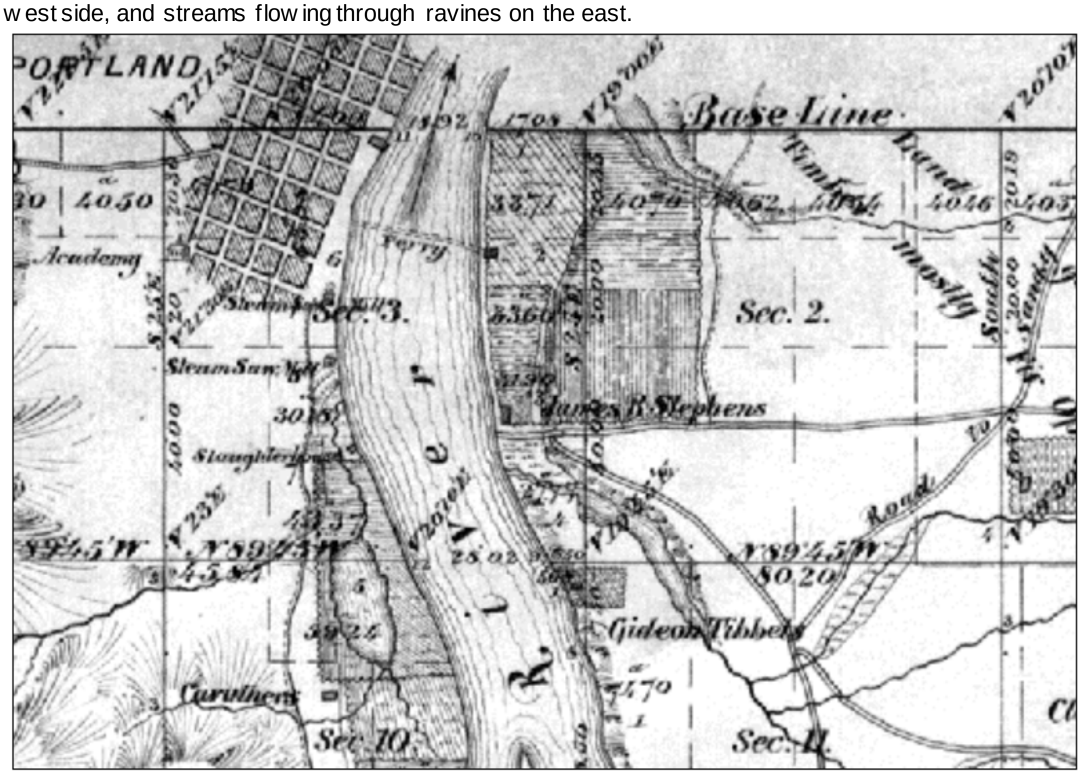
[11] 1 The Oregon Journal (Portland), 8 November 1929, page 31, col. 1. As found at: http://www.lenzenresearch.com/GCPMsite.pdf

Figure 10: Picture of slough at Hawthorne Springs.

Figure 11: Oregon General Land Office Cadastral Survey Map; digital image, University of Oregon Map Library (libweb.uoregon.edu/map/map resources/about_glo.html). The map shows an off-channel lake and streams on the west side, and streams flowing through ravines on the east.

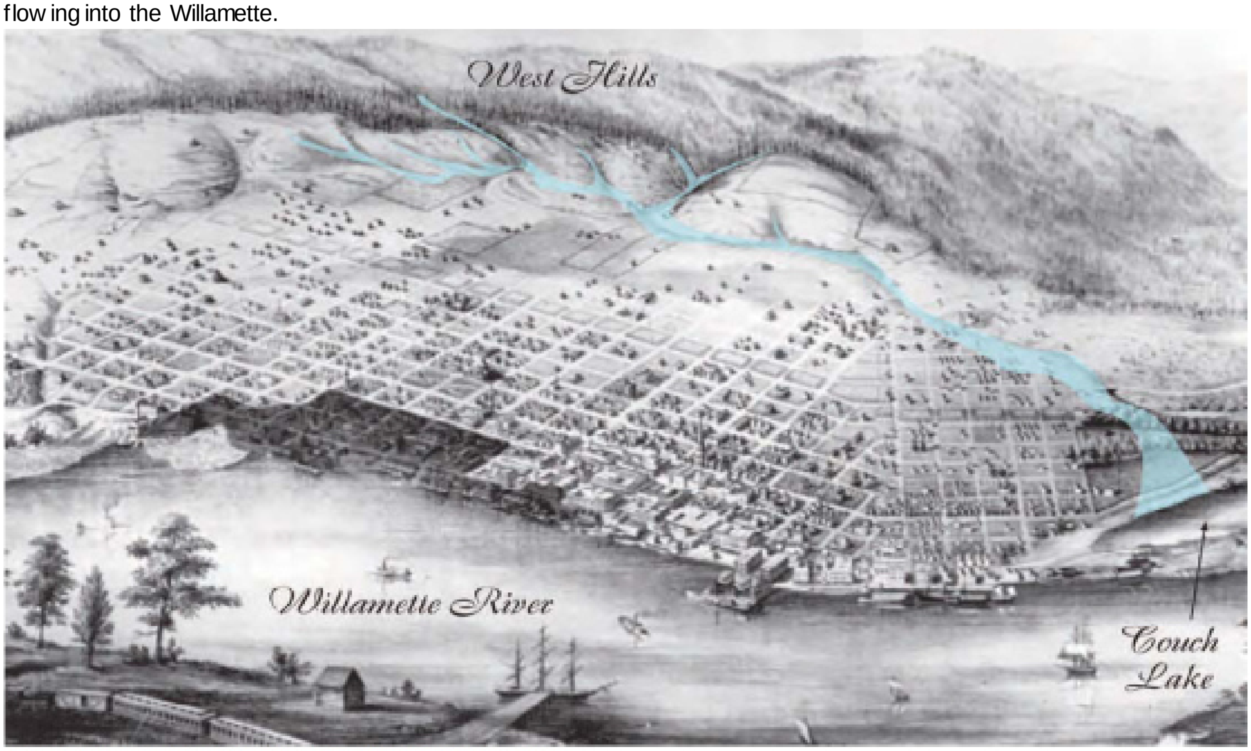


(c) Central Reach – West Bank

The 1964 flood extended up to a half mile inland from the Willamette River downtown and in what is now referred to as the South Waterfront area, and the quote in the introduction to this section make it clear that earlier floods regularly inundated downtown streets.

Tanner Creek was one of the few named creeks that flowed into the Central Reach on the west side. Tanner Creek flowed into Couch Lake, a low, swampy area within the floodplain that extended from just south of the Steel Bridge to the Fremont Bridge. (Figure 17; *Portland Online, re: Tanner Creek* http://www.portlandonline.com/bes/index.cfm?c=dbijg).

Figure 12: A map depicting Tanner Creek's origins in the West Hills and discharge into historical Couch Lake before flowing into the Willamette.



Other unnamed streams are currently piped underground and would have also provided off-channel habitat in this reach. There was also an unnamed lake and stream just north of Ross Island on what is now South Waterfront. (Figure 17).

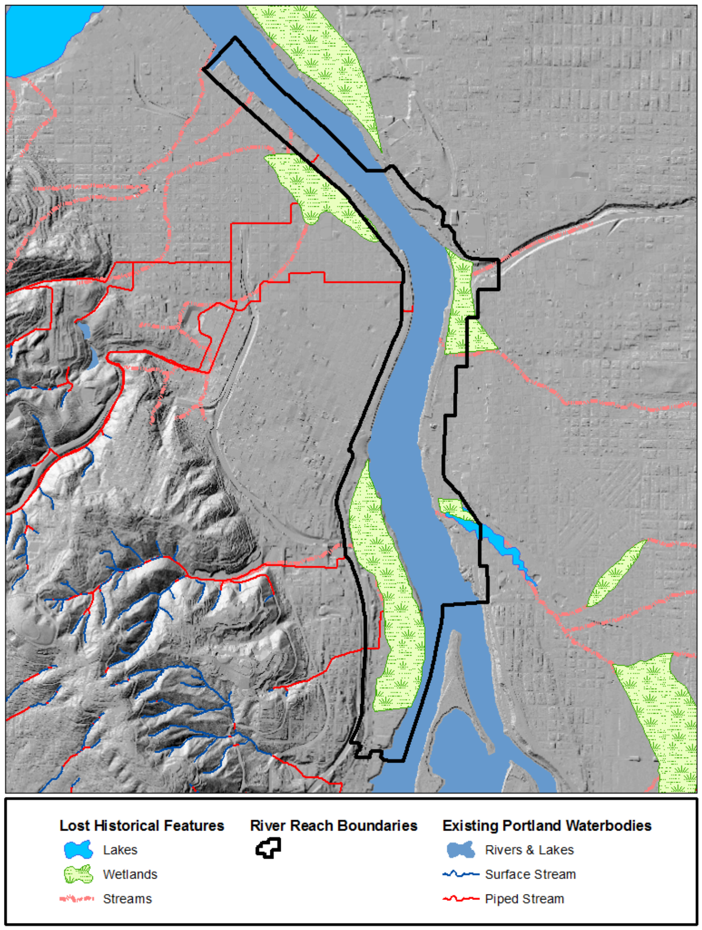
Fill for development of downtown limits the floodplain to the channel with a few small exceptions on the west side. Just south of Terminal 1 and south of the Fremont Bridge flooded in the 1996 flood up to Front Ave. Plywood walls and sandbagging kept the 1996 flood from overtopping the seawall, but most of South Waterfront flooded[12] and is included in the FEMA 100 year floodplain.

No tributaries currently join the mainstem above ground in the Central Reach. The off-channel habitat present in this reach was quickly filled in the early development of downtown and East Portland, and no off-channel habitat of any type currently exists in this segment. Tanner Creek

[12] Note: an error in the mapping data excludes South Waterfront from the 1996 flood footprint, but aerial photos of the event show much of the area inundated during the flood.

is currently piped underground and flows through a pipe to discharge beneath the former Centennial Mills site. The Portland Parks Bureau daylighted a small portion of Tanner Creek to construct Tanner Springs Park[13], and the Portland Harbor Natural Resource Damage Assessment Trustees have advocated for daylight and restoration of the confluence with the Willamette[14]

Figure 13: Historical off-channel lakes, wetlands and streams that have been lost to development over time in the Central Reach.



(d) South Reach – East Bank

On the east side of the South Reach Oaks Bottom – a large marsh, scrub-shrub, and forested wetland complex – bordered the main channel and extended approximately 2,000 – 2,500 east to the bluffs. This wetland complex (~ 292 total acres) was fed by springs and tributaries coming from the uplands.

The Willamette Park/Ross Island/Oaks Bottom complex provided a high quality combination of in-channel gravel islands, secondary channel, and off-channel habitat. In-channel islands and gravel deposits typically have a strong hyporheic connection to the river, and provide important functions for river health. The flow of river water through the gravel cools and cleans the water, and fish are often found at the upwelling sites common on these features. The

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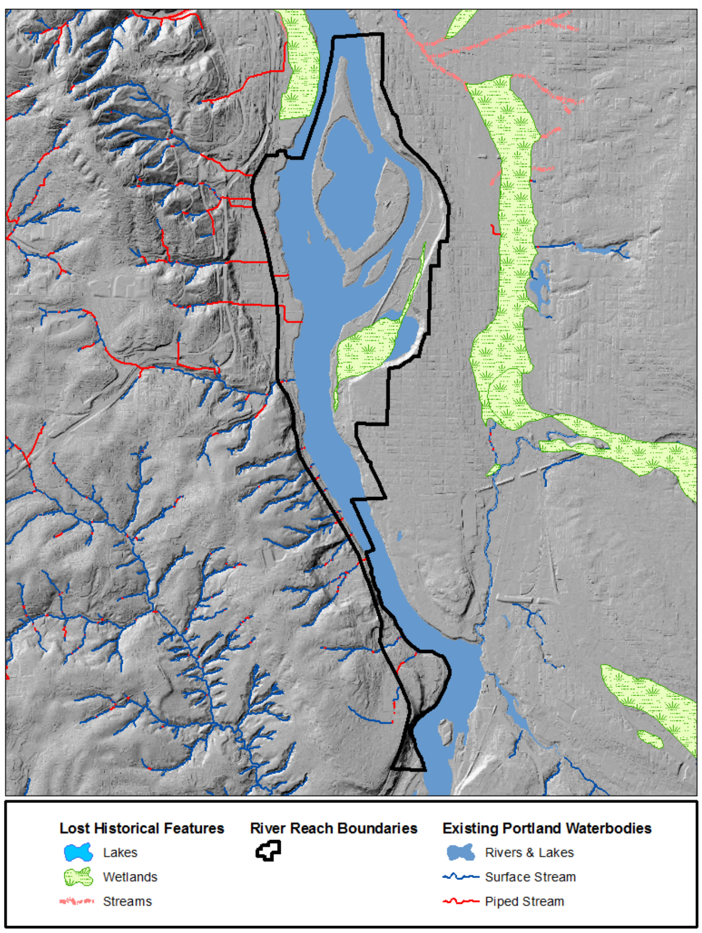
13 https://www.portlandoregon.gov/parks/finder/index.cfm?propertyid=1273&action=viewpark
14 http://www.fws.gov/oregonfwo/contaminants/portlandharbor/Documents/RestorationPort_AppA.pdf

island and Oaks Bottom wetland complex would have been inundated under flood flows, providing high quality habitat and refuge.

Although outside the boundaries of the South Reach and the city limits of Portland, Johnson Creek is a major tributary to the lower Willamette River. This creek – particularly the lower portion of this watershed with the abundant groundwater flow provided by Crystal Springs, would have provided valuable off-channel habitat and cool water refuge to juvenile salmon migrating through the lower river.

Ross Island provides the greatest amount of remaining connected off-channel habitat in the Lower Willamette River through Portland (Figure 14). The Holgate Channel provides relatively high quality secondary channel, although bank erosion is prominent along the eastern bank of the channel. The interior lagoon within Ross Island has actually increased in size and depth due to mining activities. Although the mining activities have considerable impacts on the quality of habitat in the lagoon, the island still provides high quality off-channel habitat relative to the rest of the reaches. In general, having a habitat complex of the quality and diversity of Ross Island and Oaks Bottom in such close proximity to the heart of downtown is an invaluable resource that is rare in urban areas across the country.

Figure 14: Historical off-channel lakes, wetlands and streams that have been lost to development over time in the South Reach.



The confluence with Johnson Creek still provides valuable off-channel habitat, but the impacts to Johnson Creek and in particular the excessive heating of Crystal Springs have diminished the quality of lower Johnson as an off-channel refuge (see Johnson Creek characterization (BES ??)).

(a) South Reach – West Bank

At the south end of South Waterfront in the vicinity of Cottonwood Cove the topography narrowed the historical floodplain considerably. To the south the floodplain expanded again as the topography curved away from the river in the Johns Landing area, the 1964 and 1996 floods covered the majority of what is now Willamette Park up to the rail line. The historical floodplain is estimated to be 1000 - 1500 feet wide in this area. The historical floodplain in the Stephens Creek and Riverview areas was constrained by the base of the Tualatin Mountains and the basalt trench through which the main channel flows (Hulse et al., 2002), and is therefore limited to only a very narrow frontage of the Willamette River. The banks in this subwatershed did not substantially overflow during historical (1861-1890) or recent floods (1940-1996) (Hulse et al. 2002). There were a number of small tributaries draining the West Hills and joining the mainstem along the length of this segment, the largest of these being Stephens Creek.

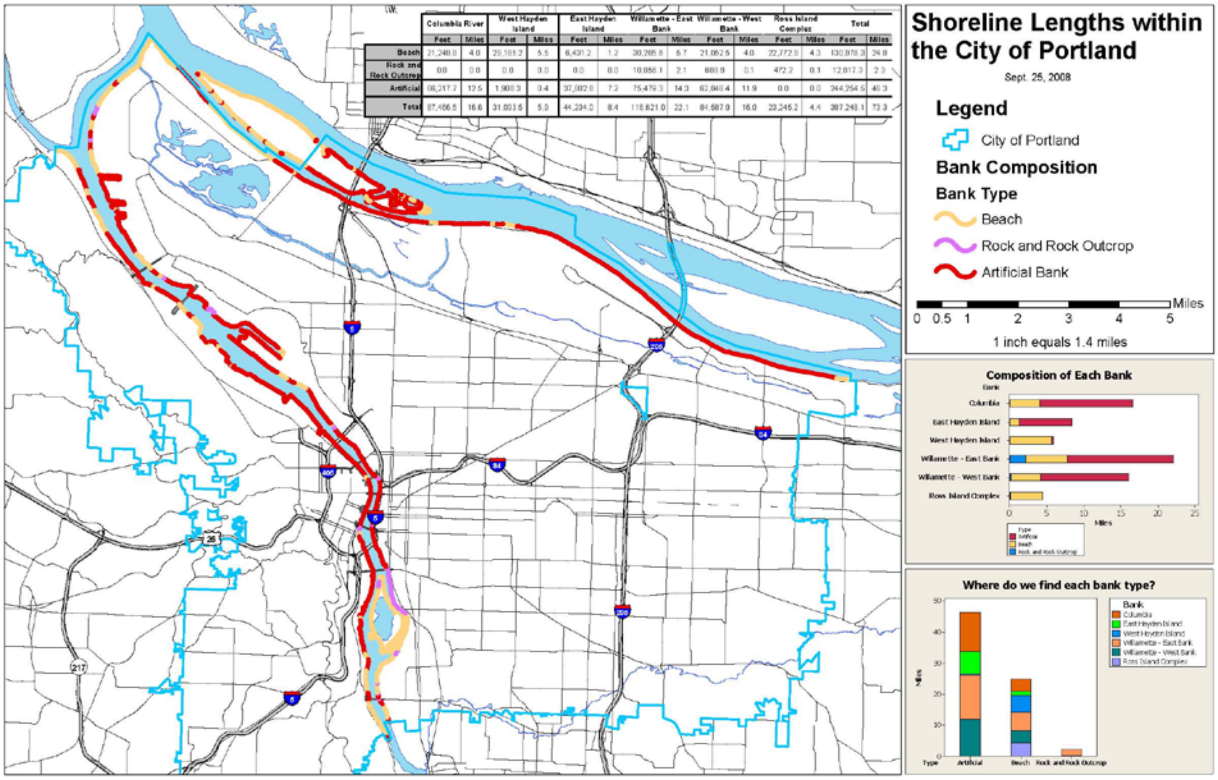
Many of the small tributaries draining the west side have been piped underground, and all of them pass through culverts and are disconnected from the mainstem. The lower portion of Stephen's Creek contains one of the highest quality remaining examples of bottomland forests surrounding tributary confluences with the mainstem, and contains one of the more diverse salmonid assemblages of the tributaries sites sampled so far within the City of Portland (ODFW 2002). This confluence has been extensively restored. A Combined Sewer Overflow pipe running along the stream was removed in 2008[15], the channel and floodplain improved and revegetated, and a culvert below the trail was replaced with a bottomless culvert that allowed fish, amphibian and other wildlife passage to an additional section of the creek.

iii) Bank Condition

ODFW documented bank composition in the ODFW fish study (ODFW 2005). Over time the City of Portland has filled in some gaps in the ODFW survey (e.g., Swan Island Lagoon) and extended the survey out into the Columbia river shoreline within Portland. The results of both surveys are show and summarized in Figure 15. The results within each reach are described in the sections that follow.

[15] https://www.portlandoregon.gov/bes/index.cfm?&a=192593

Figure 15: River bank composition along the Willamette and Columbia rivers through Portland.



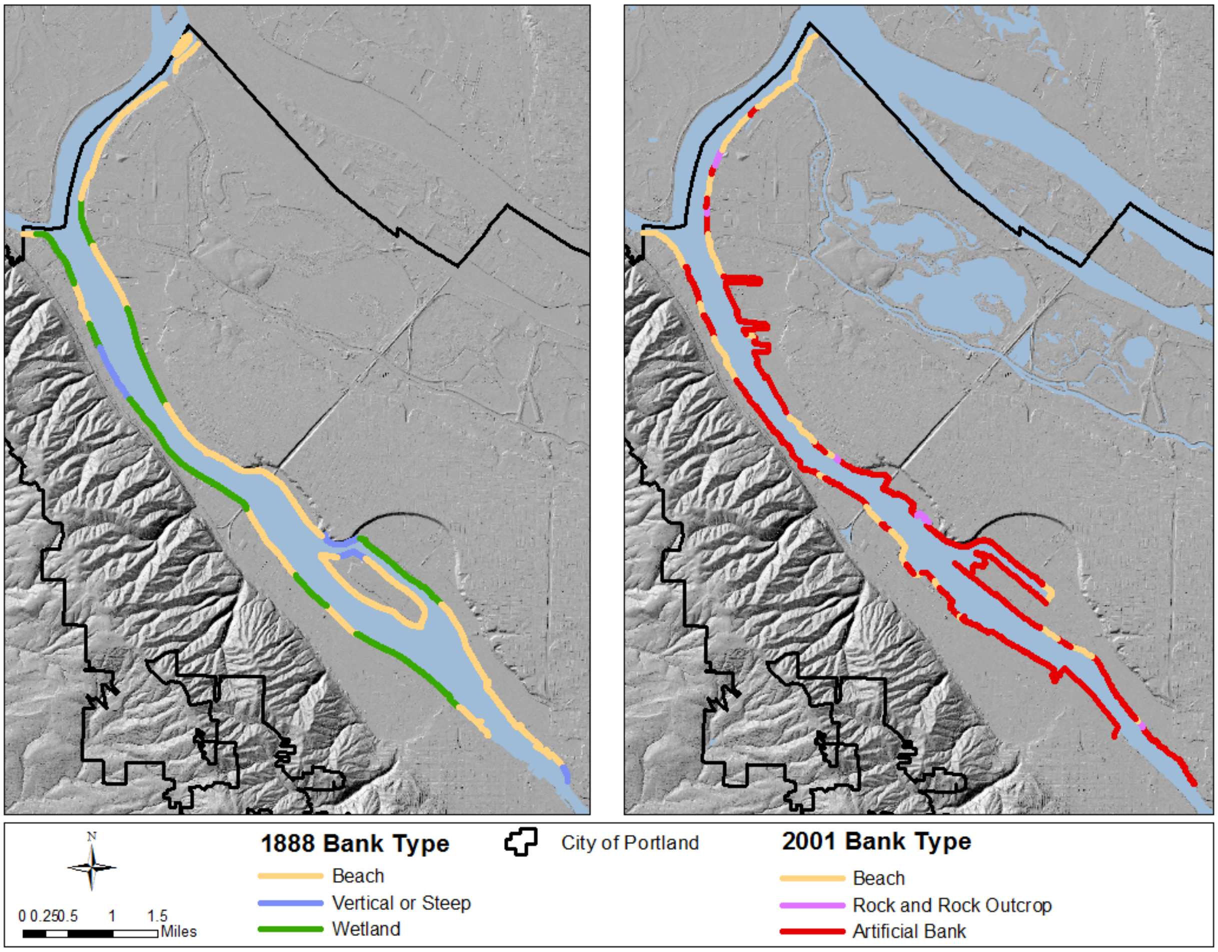
(a) North Reach

Historical. As discussed previously, the North Reach was one of the most unconstrained reaches below Willamette Falls. The low-lying floodplains and delta islands and dynamic river processes probably resulted in significant channel movement, and therefore, changing bank conditions. The *Willamette River Inventory* (Adolfson 2003) states that the river was historically a half mile wide with a large shoal along the east river bank, across from the Linnton subwatershed in the North Reach. Surveys from the 1800's indicate that the banks in the North Reach were dominated by beaches (59% of the bank length), followed by wetlands (33%) and steep banks (7%; Figure 16).

Current. Although the length of beach habitat has been reduced by over half of what was present historically, the reach currently retains a significant portion of beach habitat (25% of total reach length), particularly along the eastern bank of the north end of the reach and near the mouth of Multnomah Channel. However, no wetland habitat remains[16], and 73% of the banks have been converted to artificial bank structures such as rip rap and seawall. Bank hardening is most prevalent along the dock and industrial facilities throughout this reach (Figure 16). Banks have been diked and steepened with dredge fill over the years, which has further confined the channel and limited connection to the floodplain.

[16] Note that one exception would be the wetlands at the Portland General Electric. The banks are correctly classified as beach, but wetlands are present just beyond the banks.

Figure 16: Changes in bank types along the North Reach of the Lower Willamette River. Artificial banks now comprise 73% of the segment length, and wetlands are largely absent as a bank type.



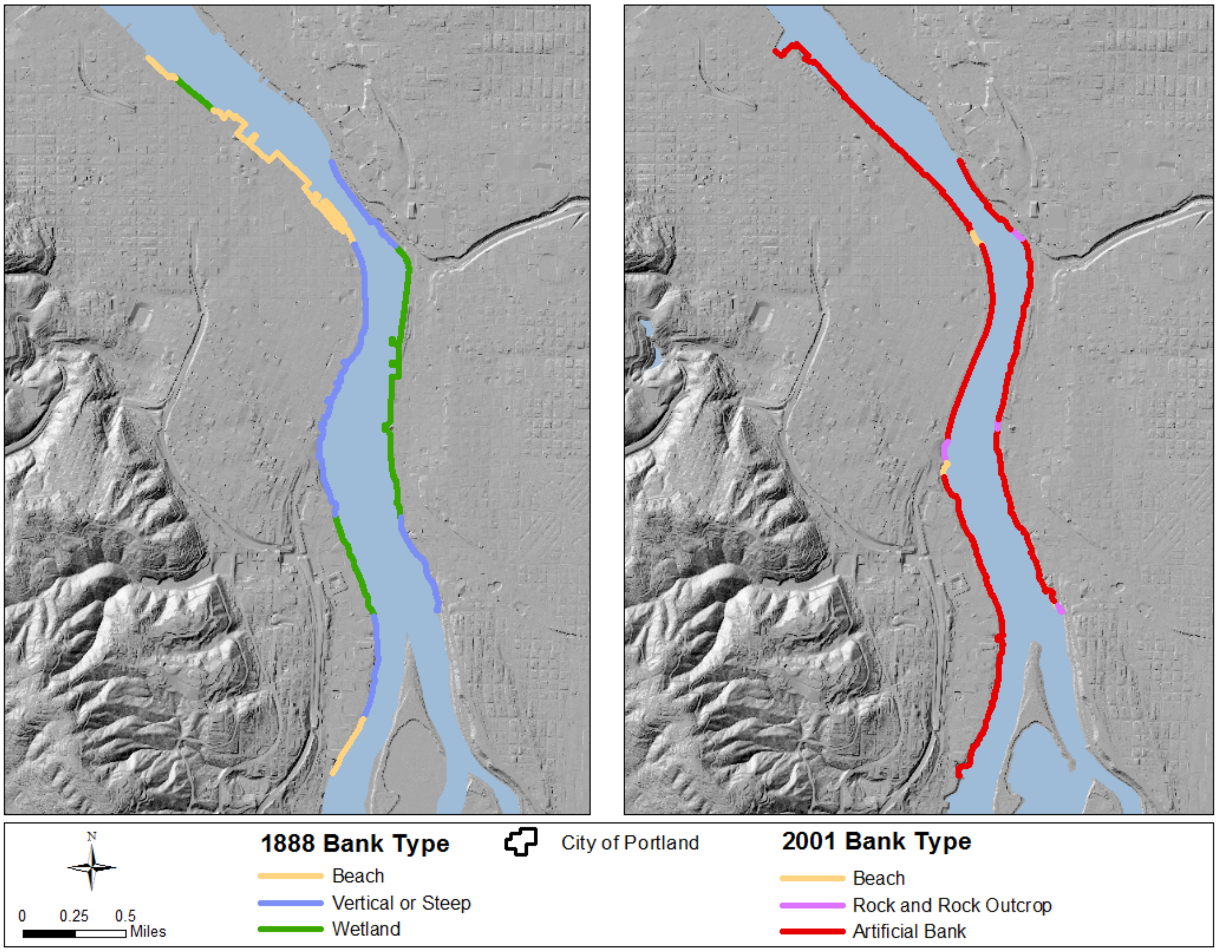
1888			2001		
Bank	Length	Percent	Bank	Length	Percent
Beach	71977	59%	Beach	32408	25%
Vertical or Steep	8930	7%	Rock	3707	3%
Wetland	40623	33%	Artificial Bank	95346	73%

(b) Central Reach

Historical. The Central Reach was historically moderately constrained. Surveys from 1888 indicate that the banks in this segment were equally divided between wetlands and vertical or steep banks, with steep banks dominating the west bank and wetlands along the east bank (Figure 17). Wetlands on the west bank were primarily along the low shelf provided in what is currently South Waterfront. On the east bank wetlands comprised about two-thirds of the reach, from Sullivan's Gulch to the south. Beaches were not nearly as prevalent in this reach as in the north and south reaches.

Current. The Central Reach has the highest percentage of artificial bank structures (93%), with only a few short stretches where natural bank remains. Seawall, unclassified fill, and vegetated rip rap are the most common bank types in this segment. Wetlands have been entirely eliminated and beach habitat has been reduced ten-fold from historical lengths.

Figure 17: Changes in bank types along the Central Reach of the Lower Willamette River. Artificial banks now comprise 93% of the segment length, and wetlands are absent as a bank type.



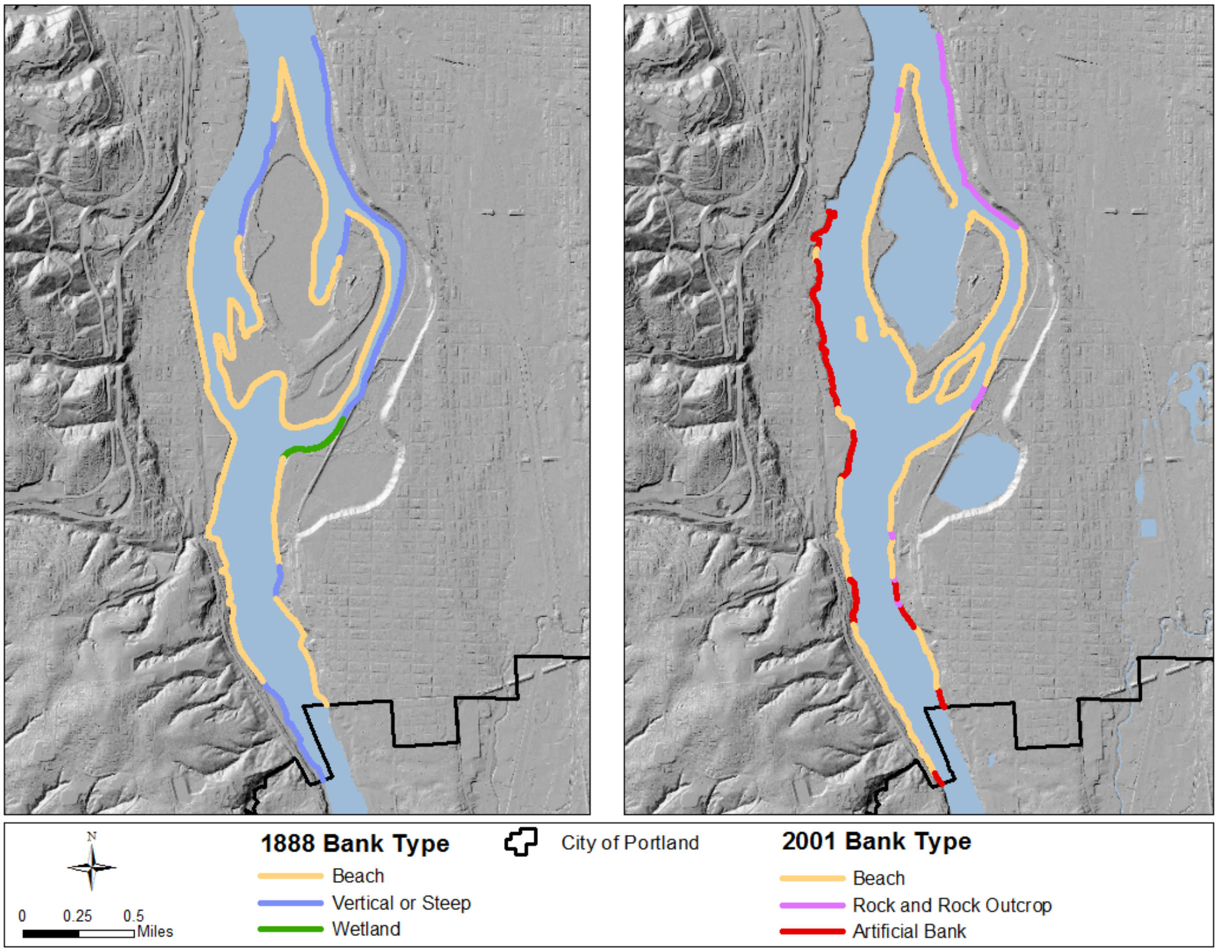
1888			2001		
Bank	Length	Percent	Bank	Length	Percent
Beach	11156	28%	Beach	1048	3%
Vertical or Steep	16110	40%	Rock	1389	4%
Wetland	12574	32%	Artificial Bank	33526	93%

Figure 18: An historical aerial photo from 1926 showing Oaks Bottom and Ross Island. Consistent with the bank survey, the banks adjacent to the southern tip of Ross Island are low-lying, and the wetland appears to be hydrologically connected to the mainstem, whereas the banks further north along Holgate channel appear steeper.

(c) South Reach

Historical. The nature of the north and south sections of the South Reach – the upstream Sellwood section and the downstream Ross Island section – are very different. The channel was historically confined in the upstream Sellwood portion, the most restricted portion within the management area. The channel is less confined upon reaching Ross Island and Oaks Bottom. Surveys from 1888 indicate that the banks in the South Reach were dominated by beaches (69% of the bank length, primarily on the west bank and around Ross Island), followed by steep banks (28%, primarily on the east bank around Ross Island; Figure 19). Wetlands did not appear to be common along the banks of this reach (4%), but did occur at the southern end between Ross Island and Oaks Bottom.

Figure 19: Changes in bank types along the South Reach of the Lower Willamette River. Artificial banks now comprise 17% of the segment length, and wetlands are largely absent as a bank type. Note that the interior of Ross Island is not included in 2001, since these are changing in adjustment to past mining and along the south from restoration.



1888			2001		
Bank	**Length**	**Percent**	**Bank**	**Length**	**Percent**
Beach	43620	69%	Beach	40601	71%
Vertical or Steep	17808	28%	Rock	6921	12%
Wetland	1824	3%	Artificial Bank	9452	17%

Current. The South Reach currently has slightly more beach habitat (71% of the bank length) than historically. This is in part due to differences in how banks were categorized in the two surveys – the 2001 survey did not have a "steep" category. Much of the shoreline along the Holgate Channel and northern part of Oaks Bottom is considered beach in the recent survey, in spite of the fact that the banks are steep due to the railroad berm separating Oaks Bottom form the mainstem. Twenty-three percent of the banks have been converted to artificial bank structures such as rip rap and seawall, by far the lowest of any of the segments. Bank hardening is most prevalent along the western shore opposite of Ross Island, along South Waterfront and Willamette Park.

iv) Vegetation

As stated in Christy and others (2009) assessment of vegetation change in Portland: "Urbanization has had inevitable and predictable effects on the region's vegetation. Wetlands have declined locally by 97 percent, coniferous forest by 92 percent, prairie and savanna by 90 percent, riparian and wetland forest by 58 percent, and oak communities of any sort by 40 percent." (pg. 2)

(a) North Reach

Based on surveys in the 1850's, the northern half of the North Reach was a vast complex of forested, scrub shrub, and prairie wetlands (Figure 20). The west hills and Willamette Escarpment formed the edges of the riparian area contributed to the diverse plant communities that supported the bountiful Willamette River wildlife.

Many forested and woodland areas both near the river and in the uplands had recently burned. The history of vegetation in the Portland area includes the indigenous people that managed vegetation for thousands of years before approximately 1840. The Cowlitz and Upper Chehalis Indians of the Puget lowlands and the Kalapuya tribes of the Willamette Valley regularly set fires to favor plants on which they depended for food and medicine. Important savanna plants were camas (Camassia sp.), wild onion (Allium sp.), and tarweed (Madia sp.). Some woodlands were deliberately left unburned to provide areas where deer, elk, grouse, and other game would concentrate. The remnant of the diverse habitats is noted in detail in the 1852 maps. (2012, Biodiversity Guide)[17].

Sauvie Island provided extensive wetland prairie habitat, with isolated patches of emergent wetlands and ponds. Ash-mixed deciduous forest occurred along the riparian portion of the island closest to the main channel and Multnomah Channel.

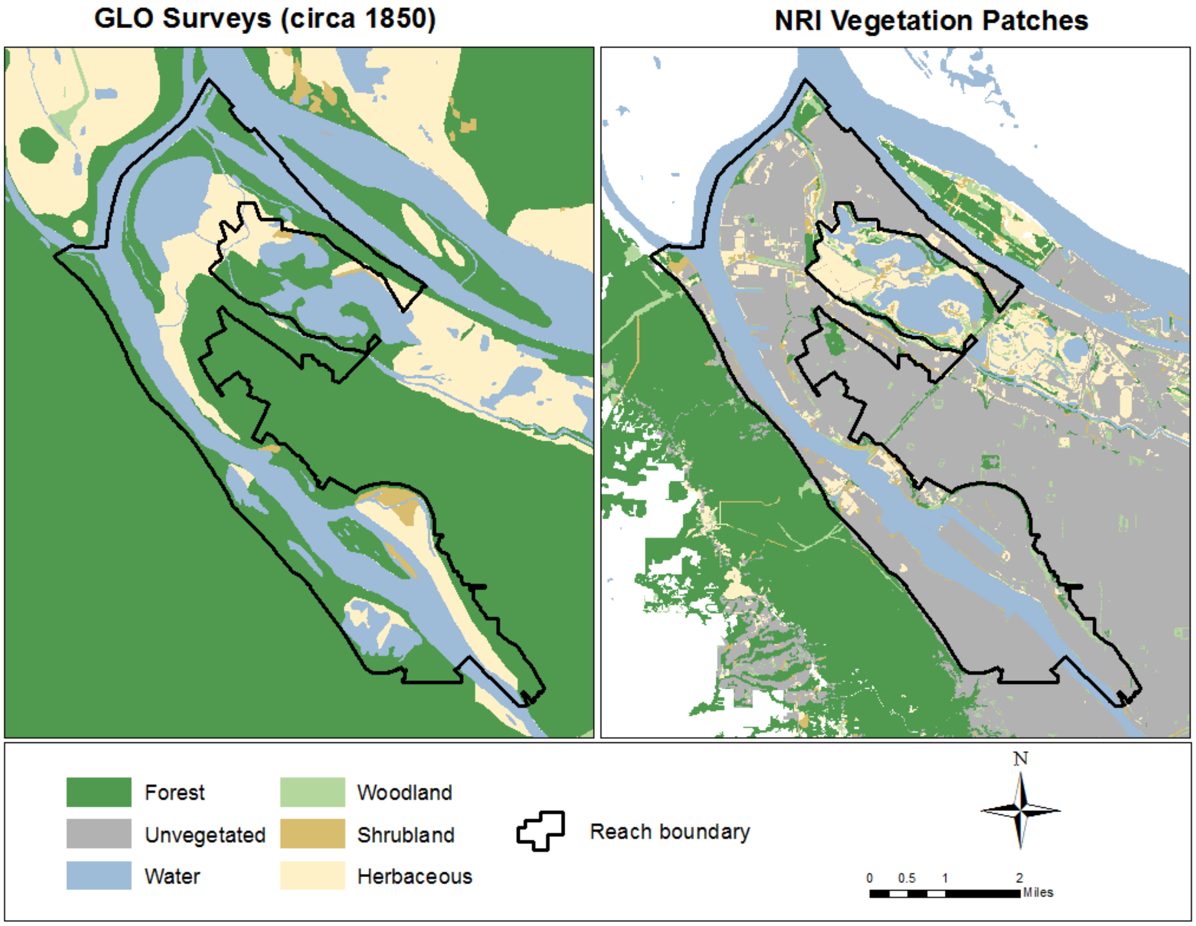
The most obvious change from the historical condition has been the large-scale removal and transformation of vegetation throughout the riparian and upland areas adjacent to the North Reach. Over time the floodplains and riparian areas have been filled and cleared of vegetation to provide industrial and port facilities along the mainstem, and agricultural and residential uses along Sauvie Island. In addition, physical and hydrological changes[18] have reduced the frequency with which the river interacts with the floodplain. This represents a major shift in conditions and stress to vegetation adapted to regular inundation, and so remaining or newly establishing vegetation in the riparian and floodplain reaches has adapted to these altered conditions.

Relative to the adjacent uplands – where Forest Park still provides a large contiguous upland forest – the riparian and floodplain areas of the North Reach have few remaining vegetated patches of significant size. The *Willamette River Inventory* (Adolfson 2003) describes the composition and nature of these few remaining habitat areas, which include Kelley Point Park, remnant riparian forest, and the Harborton Forest and Wetlands. These areas are generally comprised of bottomland forest, shrub and meadow structures. Cottonwood with willow, snowberry, and blackberry understory are prominent, with ash in the Linnton/Harborton area.

[17] The Intertwine Alliance. 2012. Biodiversity Guide for the Greater Portland-Vancouver Region. A. Sihler, editor. The Intertwine Alliance, Portland, OR. www.theintertwine.org

[18] Filling floodplains and the reduced range of flows (reduced peak flows and higher summer low flows. The will be described in the hydrology chapter of the full report.

Figure 20: Historical and current vegetation in the North Reach. Note that in the current NRI Vegetation Patches panel, "unvegetated" means that if any vegetation is present, it is of a size smaller than the 1/2 acre threshold used in the NRI.

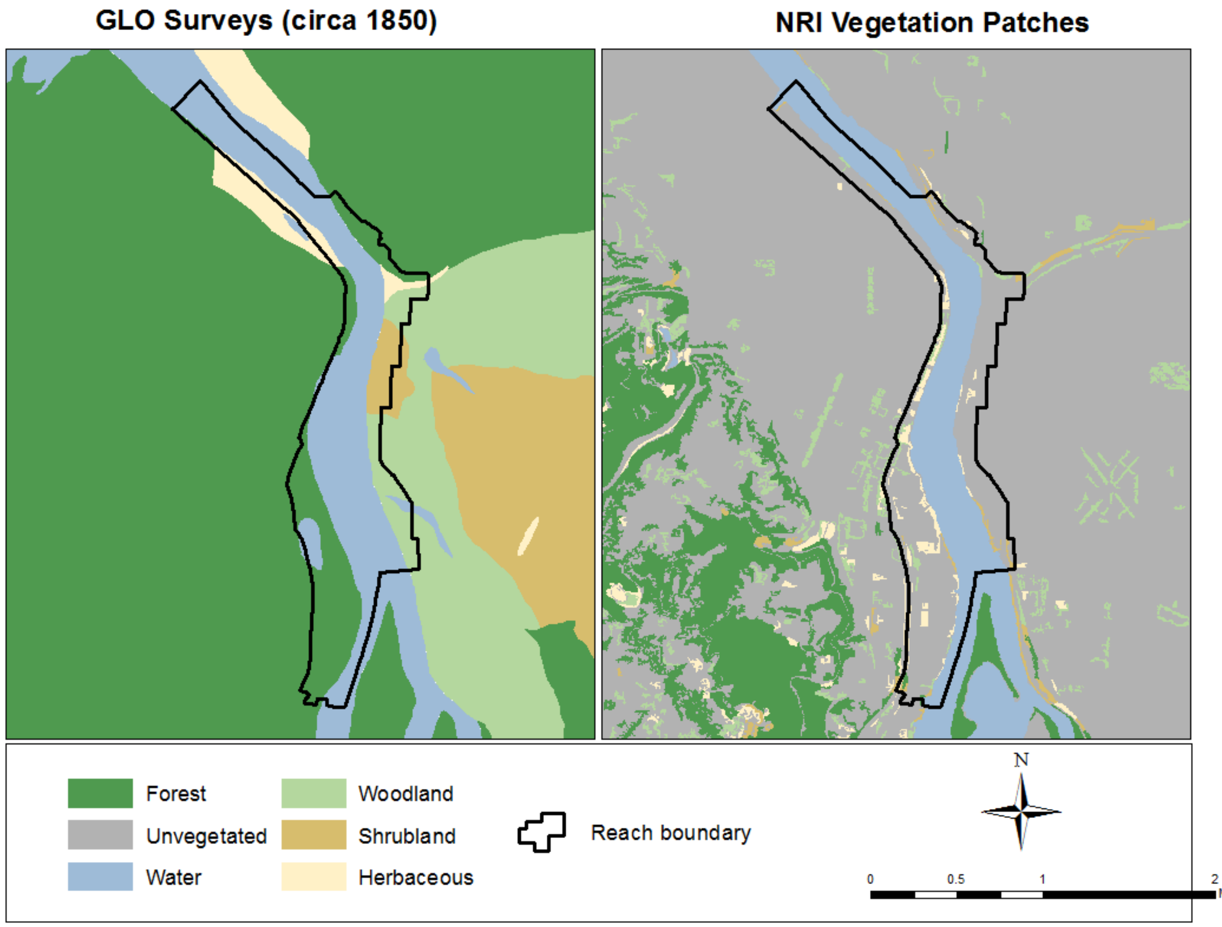


(b) Central Reach

Historically the vegetation was a diverse assemblage in the short Central Reach. Mixed conifer, red alder-mixed conifer, and prairie covered the western banks; Douglas fir-white oak, mixed conifer, and shrubland covered the eastern banks (Figure 21[19]). An emergent wetland was located at the mouth of Sullivan's Gulch. The 1850's vegetation maps show some small off-channel lakes that are not evident in the 1888 channel survey. These may have been filled by the 1888 survey, by which point downtown had undergone significant development. As in the North Reach the diversity of the vegetation was driven by disturbances such as floods and fire. The open woodlands and prairies on the east side were unhospitable landscapes for the typical coniferous forest of the NW, high water tables, and frequent fire maintained open woodlands and prairies. The lake at the confluence of Marquam Gulch provided wetlands functions in the Willamette River floodplain, and suggests that the high water table in this area influenced the vegetation community of the riparian area.

[19] Note that for comparison to the current Natural Resources Inventory the historical data are aggregated into the NRI categories (Forest, Woodland, etc.). However, the original GLO data did provide more detailed species composition and the species mentioned are from these more detailed data.

Figure 21: Historical and current vegetation in the Central Reach. Note that in the current NRI Vegetation Patches panel, "unvegetated" means that if any vegetation is present, it is of a size smaller than the 1/2 acre threshold used in the NRI.

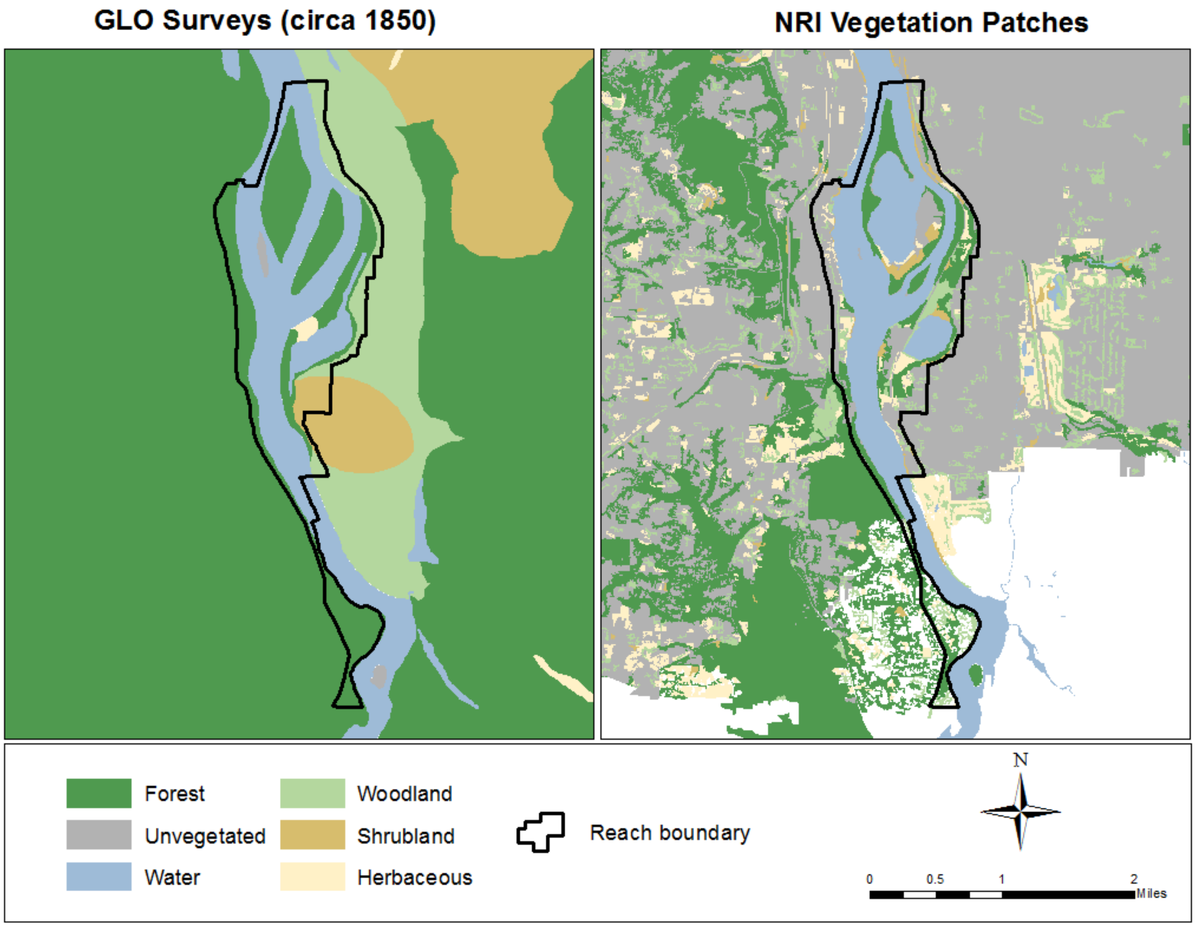


The Central Reach was the first reach to experience large scale vegetation removal as the city was platted and developed. The current density of street trees is actually higher than is evident in many of the early historical photos of downtown, although of no comparison to the amount, diversity, or composition of vegetation present in the 1850's survey. Little significant vegetation remains in the riparian areas of the Central Reach (Figure 21).

(c) South Reach

The western banks of the South Reach were dominated by mixed conifer, with a small patch of ash mixed deciduous riparian forest. That small patch is at Willamette Park which is home to 2-300 year old Oregon white oak. Aerial views of the park in the 1949 Memorial Day flood show the oaks in standing water. Oak woodlands are tolerant of winter and spring flooding and this is a good example of long lived oaks in the River's floodplain. The vegetation of the eastern banks was more varied, with mixed conifer, Douglas fir-white oak, savanna, and prairie present. Ash-mixed deciduous was present on Ross Island and in Oaks Bottom (Figure 22).

Figure 22: Historical and current vegetation in the South Reach. Note that in the current NRI Vegetation Patches panel, "unvegetated" means that if any vegetation is present, it is of a size smaller than the 1/2 acre threshold used in the NRI.



The South Reach still retains some vegetation in close proximity to the channel at Willamette Park, Powers Marine Park, Ross Island, Oaks Park, and Oaks Bottom. In addition, the physical and hydrological changes described earlier have reduced the frequency with which the river interacts with the floodplain. This represents a major shift in conditions and stress to vegetation adapted to regular inundation, and so remaining or newly establishing vegetation in the riparian and floodplain reaches would have to adapt to these altered conditions. There are remnant ancient oaks in the floodplain wetlands of Dunthorpe (Fielding Wetlands).

The *Willamette River Inventory* describes the composition and nature of these few remaining habitat areas, which include Ross Island, Oaks Bottom, Cottonwood Bay, Stephens Creek, Willamette Park, and Powers Marine Park. These areas are generally comprised of bottomland forest, shrub and wetland areas. Cottonwood with willow, red osier dogwood, and blackberry understory are prominent, with foothill savanna/oak woodland and conifer/hardwood forests also present.

v) Habitat Types

BES identified and mapped key natural resource features as part of the Portland Watershed Management Plan's terrestrial work (the Terrestrial Ecology Enhancement Strategy), including resources in the Lower Willamette River (BES 2010). Anchor habitats, special status habitats, special status species and habitat corridors were defined, identified, and in some cases, mapped. Special status habitats in the Lower Willamette include:

- herbaceous wetlands
- upland prairie and native grasslands
- oaks woodlands
- interior forests
- late successional conifer forests
- bottomland hardwood forests and riparian habitats

Some of these features are mapped with the BPS NRI process, including Special Habitat Areas. BES completed additional mapping, summarized for the Lower Willamette River in Table 1.

Table 1: Natural resource features identified as part of the terrestrial Ecology Enhancement Strategy.

Site	Anchor	Species Assemblages	Special Status Habitats	
			Interior Forest	Oak Woodland
NORTH REACH				
Kelly Point	✓	✓		
Ramsey Wetland Complex	✓	✓		
Harborton Forest & Wetland Complex	✓	✓		
Burlington Bottoms	✓	✓		
West Wye & Powerline Wetlands		✓		
Forest Park	✓	✓	✓	✓
Westside Wildlife Corridor[1]	✓	✓	✓	✓
Doane Lake & Wetlands	✓	✓		
Willamette Bluff Oak Corridor[2]		✓		✓
Balch Creek		✓		
Balch Creek Headwaters[5]			✓	
CENTRAL REACH				
Westside Wildlife Corridor[1]	✓	✓		✓
Cottonwood Bay[3]		✓		
Marquam Nature Park			✓	
SOUTH REACH				
Westside Wildlife Corridor[1]	✓	✓		✓
Willamette Park		✓		✓
Riverview Cemetery	✓		✓	
Ross Island	✓			

Oaks Bottom Wildlife Refuge	✓	✓		✓
South Portland Waterfront[4]	✓	✓		
Waverly Country Club				✓
Elk Rock Island	✓	✓		✓
Elk Rock Cliff		✓		✓
Tryon Creek State Natural Area	✓	✓	✓	
Willamette Bluff Oak Corridor[4]		✓		✓

1. Council Crest, Marquam Nature Park, Terwilliger Wilds, Stephens Creek Canyon, George Himes Park, Forest Park, Tryon Creek State Natural Area
2. Univ of Portland, Mock's Crest, Willamette Cove, Baltimore Woods, Marquam Oaks, Dunthrope Oaks, Oaks Bottom Bluff, Elk Rock Island & Cliff
3. West river shoreline across from Ross Island
4. Moorage Park & Powers Marine Park
5. Metro properties, Audubon Society of Portland Sanctuary, and private forest lands outside City of Portland

C. Water Quality and Sediment Contamination

i) Portland Harbor Investigations

In 2014, GSI summarized the available information on known upland and in-river sediment and water quality contamination issues for the North Reach (Attachment A). Information sources were used to identify preliminary asset areas and watershed health problems within the context of the Portland Watershed Management Plan (PWMP; City of Portland 2005) objectives. (Asset areas are those geographic locations that provide important or unique watershed health characteristics. Problems are issues that need to be resolved to a measured extent in order to achieve PWMP watershed health objectives.) Watershed health problems, as summarized in this report, principally affect attainment of the Pollutants objective[20] in the PWMP. Since the completion of this summary report, several key documents have been updated and are discussed below, with some background information provided.

The Lower Willamette River draft Remedial Investigation Report and draft Feasibility Study (RI/FS) findings identified watershed health problems, specifically:

- Preliminary areas of sediment contamination that pose unacceptable risk to human health and the environment
- Key sources of these pollutants (from land uses in the upland area and from within the river)
- Pathways, or mechanisms, by which pollutant sources were mobilized and deposited in the sediment (such as overwater activities or eroding soil)

The draft RI reports over one million sample results for multiple media for the time period between 1969 and 2008 (summarized in RI Report Table 2.1-1, not incorporated into this

[20] The intent of this objective is to "manage the sources and transport of stormwater and industrial pollutants and nutrients to limit surface water, groundwater, soil, and sediment contamination to levels that protect ecological and human health and achieve applicable water quality standards".

document). Indicator Chemicals (IC) were identified from the initial extensive list of Contaminants of Interest (COIs) to represent the nature and extent of the range of contaminants that potentially pose risk to human health and the environment in sediment, surface water, transition zone water/porewater, and biota. The ICs are: total PCBs, dioxins/furans (noted as PCDD/F), total DDx (i.e., the sum of DDT, DDD and DDE), and total PAHs. The Baseline Ecological Risk Assessment [BERA; Appendix G (not included in this literature review)] and Human Health Risk Assessment [HHRA; Appendix F (not included in this review)] were used in the FS to identify contaminants, receptors, and areas of concern to assess the protectiveness of the potential remedial alternatives.

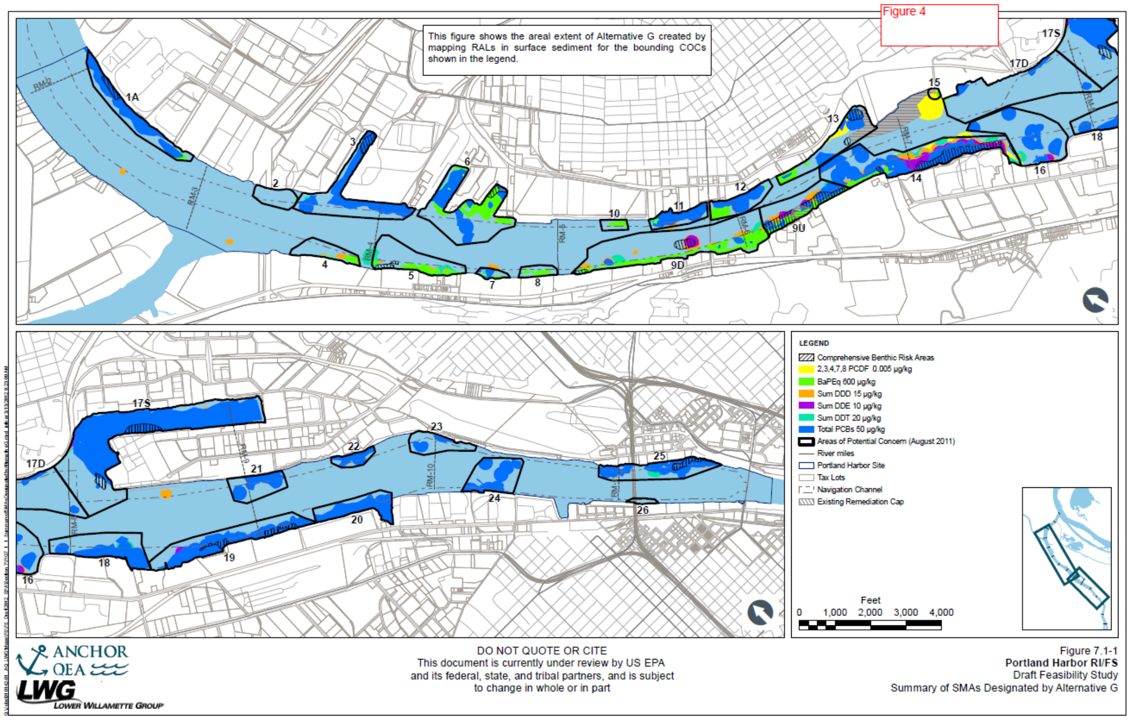
The risk assessments found that potential risks from PAHs and DDx are largely to benthic invertebrates and other sediment-associated receptors. Potential risks from PCBs and dioxin/furan are to receptors higher in the food chain who consume fish (birds, mammals and humans). The remaining contaminants potentially posing unacceptable risks account for less than 2 percent of the cumulative cancer risk on a Study Area-wide basis. The contribution of contaminants to the cumulative cancer risks varies on a localized basis (Integral 2011, page 87). Other contaminants pose potential risk to specific areas, media, or receptors.

The draft FS report uses the data to develop Area of Potential Concern (AOPC) and Sediment Management Area (SMA) to describe the spatial extents where primary potentially unacceptable risks exist from exposure to all media sampled (i.e., sediment, transition zone water, etc.). These areas are the focus for developing the remedial alternatives, though some risk may be outside of these areas.[21] Twenty eight (28) AOPCs were identified [DAR Figure 4: AOPCs and SMAs designated by Remedial Alternative F (FS Figure 7.1-1)]. SMAs are a refinement of the AOPCs, developed by looking at benthic risk areas, surface and subsurface sediment concentrations, and short term RALs for sediment cleanup. SMA boundaries and cleanup levels will be refined further in the remedial design stage (after the Record of Decision).

The FS also develops remedial alternatives by modeling the physical system and chemical data to project future contaminant levels in water, sediment and fish, and then these future contaminant levels are evaluated for risk reduction. As a result, the FS set forth twelve remedial alternatives, generally identified as Alternative A through Alternative G, as protective of human health and the environment over the long term. Alternatives B through F each have one variation that is "removal focused" (r) and one that integrates (i) different technologies (DAR Figure 4). The alternatives were evaluated for a number of "remedy selection criteria", including but not limited to protectiveness, effectiveness, implementability, and cost.

[21] Areas outside of the SMAs are included in the "Site-wide AOPC". The Site-Wide AOPC represents lower levels of contaminant concentrations that will not be the focus of active remedies.

Figure 23: Portland Harbor Superfund site AOPCs as identified in the draft Feasibility Study



Since submittal of the draft RI/FS to U.S. Environmental Protection Agency (EPA), (and the preparation of the 2014 GSI summary), EPA has revised the FS and issued its draft proposed plan for remediation on June 8, 2016. EPA selected Alternative I as its preferred alternative, which will involve dredging and capping approximately 290 acres of sediments (purple areas in Figure x) and approximately 19,500 lineal feet of river bank (blue areas in Figure 24). Over time, "natural recovery" is assumed to reduce remaining concentrations to acceptable levels.

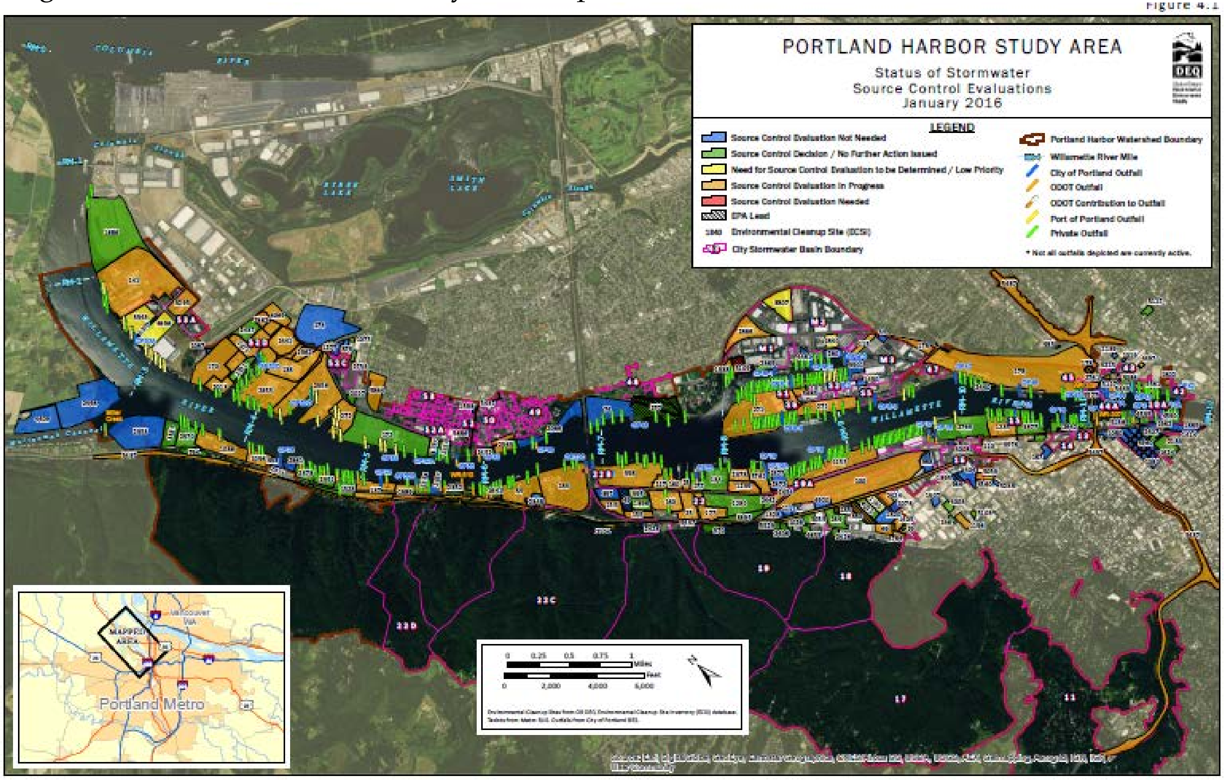
Figure 24: Alternative I from the EPA Feasibility Study

Figure 2. Footprint of the sediment management areas in Alternative I.

After a 60-day public review of the plan, EPA will issue the ROD identifying the final cleanup goals and the sediment management areas (SMAs) within the river. After the ROD, additional sampling will be conducted to design the remedy (i.e., a specific cleanup method, or combination of methods such as dredging and capping) for each SMA. Only after approval of the remedial design, will implementation of the cleanup begin.

Also since preparation of the GSI 2014 summary, Oregon DEQ has released an updated *Portland Harbor Upland Source Control Summary Report* (March 25, 2016). This report provides the most recent DEQ work to identify and assess potential upland sources of contamination to Portland Harbor. This report concludes that DEQ has completed its determinations of the need for source control measures at all upland sites within the study area; and is on track to implement needed measures prior to implementation of the final in-water remedy, in order to prevent likely future adverse effects on water or sediment quality (i.e., recontamination). DEQ indicates "As of the date of this report, final actions, demonstration of effectiveness and decisions for 60% of upland sites have been completed. Controls are in place for all pathways and effectiveness demonstration is underway for 26 of the remaining 57 sites[22], with source control decisions anticipated by 2016 and 2017, which will confirm control of 75% of the sites evaluated. Plans are in place or under development to complete implementation of controls at the remaining 23% of sites evaluated by DEQ prior to or in conjunction with the in-water remedy. The three upland sites with uncontrolled pathways that EPA is leading make up the final 2% of sites and also need completed investigation and implementation of any needed controls." Furthermore, "when viewed on a Harbor-wide basis, these conclusions strongly support a low potential for recontamination of remediated sediment and represent acceptable risk to Willamette River receptors, provided that all planned source control measures and bank remediation to be integrated with the in-water remedy are completed and demonstrated to be effective."

Figure 4.1



22 More detail about each of these sites is provided in Table 5.1 of the DEQ document.

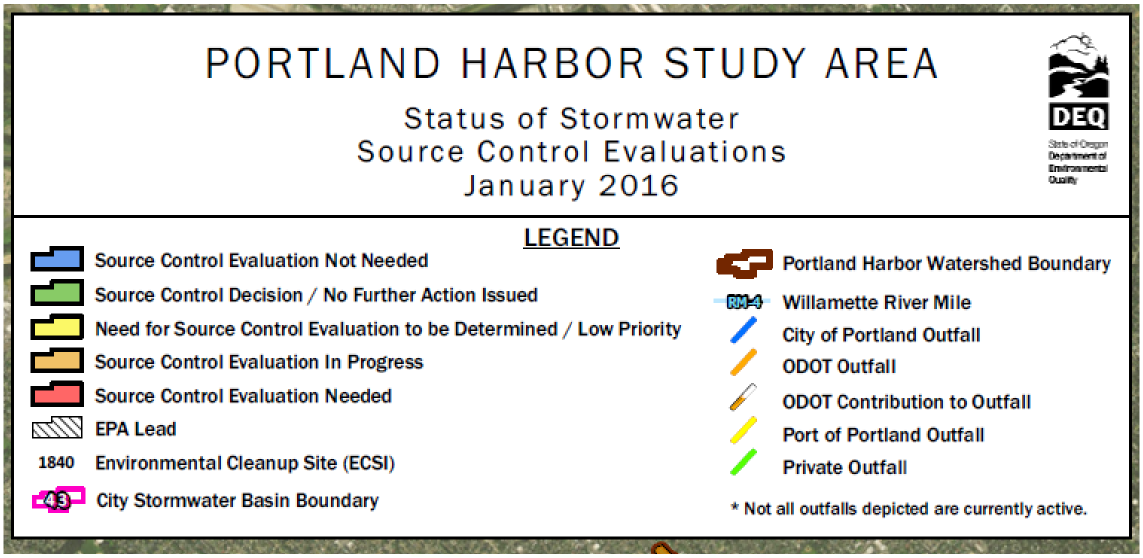
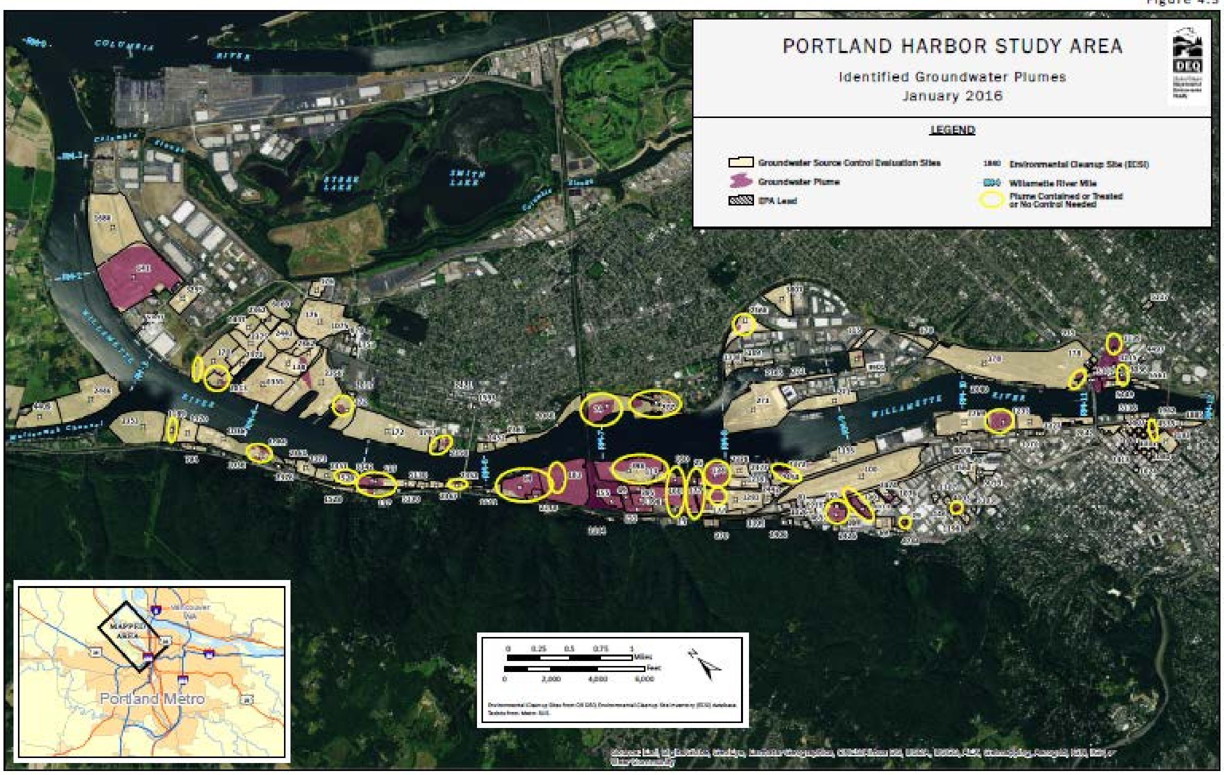
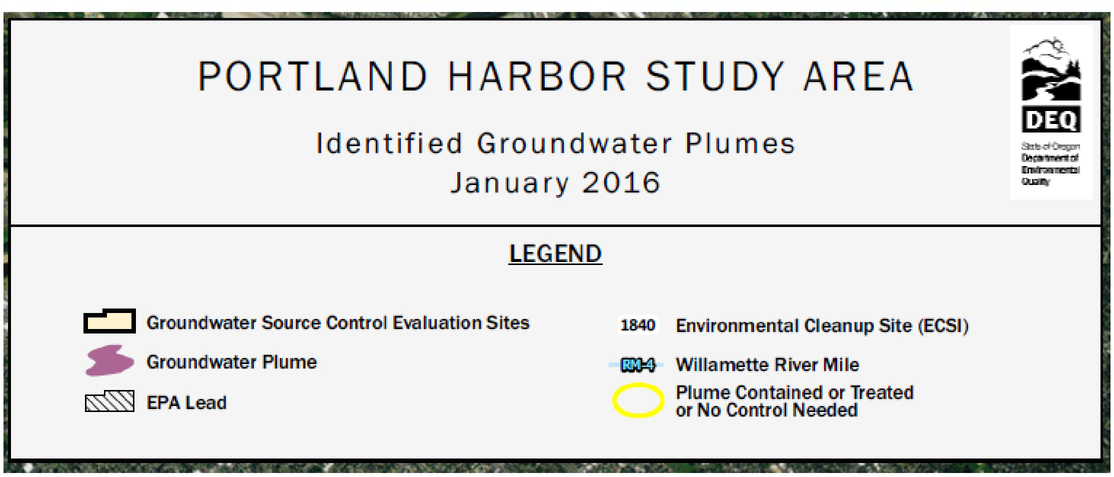

PORTLAND HARBOR STUDY AREA
Status of Stormwater
Source Control Evaluations
January 2016
DEQ
State of Oregon Department of Environmental Quality
LEGEND
Source Control Evaluation Not Needed
Source Control Decision / No Further Action Issued
Need for Source Control Evaluation to be Determined / Low Priority
Source Control Evaluation In Progress
Source Control Evaluation Needed
EPA Lead
1840 Environmental Cleanup Site (ECSI)
City Stormwater Basin Boundary
Portland Harbor Watershed Boundary
Willamette River Mile
City of Portland Outfall
ODOT Outfall
ODOT Contribution to Outfall
Port of Portland Outfall
Private Outfall
* Not all outfalls depicted are currently active.

Figure 4.3


PORTLAND HARBOR STUDY AREA
Identified Groundwater Plumes
January 2016
LEGEND
Portland Metro


PORTLAND HARBOR STUDY AREA
Identified Groundwater Plumes
January 2016
DEQ
State of Oregon Department of Environmental Quality
LEGEND
Groundwater Source Control Evaluation Sites
Groundwater Plume
EPA Lead
1840 Environmental Cleanup Site (ECSI)
Willamette River Mile
Plume Contained or Treated or No Control Needed

ii) Downtown Reach Study

GSI 2014: "DEQ compared the Downtown Reach data to the Portland Harbor Superfund Project Area data, and found that, with the exception of mercury and lead, "surface sediment data shows that concentrations of contaminants of concern are significantly lower than those found in the Portland Harbor". As a result, DEQ concluded that the Downtown Reach is unlikely to be a significant, ongoing source of contamination to the Superfund Project Area." (pg. 1-12).

iii) Other Water Quality Data

The City of Portland is evaluating additional monitoring data available on the lower Willamette River. These analyses are not complete and available for this technical memo, but will be included in the full lower Willamette characterization.

D. Biological Communities

Several studies have focused on fish or wildlife communities specific to the lower Willamette River (i.e., north, central, and south reaches). Fish communities have been documented through the Willamette River Fish Study (ODFW 2001; 2002), and through a series of Lower Willamette River studies over the years (e.g., EPA 2016). Aquatic communities and their habitats from the lower river through Portland are described reach-by reach in the *Willamette River Inventory* (Bureau of Planning, 2000). This document also provides a detailed description of wildlife communities along the Lower Willamette River.

i) Fish Communities

Altman et al. (1997)[23] report that ODFW (1988) identified 54 species as being present within the Willamette Basin, and identified 7 additional species from other sources (see Table 3, pp. 22-23 in Altman et al. 1997). Forty-eight percent of these were introduced species. Within the Lower Willamette, Farr and Ward (1993) found a total of 39 fish species from 17 families, with 19 of the species from seven families being exotic species introduced. Ward and Nigro (1991) and Farr and Ward (1993) characterized fish communities from the Lower Willamette River through Portland. They found that the native northern pikeminnow was the most abundant species, followed by a number of non-native species including black crappie, white crappie, largemouth bass, smallmouth bass, and walleye.

The listings of many native populations under the Endangered Species Act (ESA), and the large numbers of exotic species present, are indicators of the poor health of fish populations in the Lower Willamette River. In March 1998 and March 1999, NOAA Fisheries issued final rules to list four evolutionarily significant units (ESUs) of steelhead (*Oncorhynchus mykiss*) and Chinook salmon (*O. tshawytscha*) as threatened under the federal ESA (Table 2).

This represented one of the first listings of an aquatic species in an urban area under the ESA, and because the Willamette River flows through the heart of the downtown and industrial cores, the first application of the ESA in a densely developed and industrialized landscape. Since then, nine additional ESUs that spawn, rear or migrate through Portland streams and

[23] Although not discussed at length in this document, Altman et al. provide an extensive description of aquatic communities throughout the Willamette Basin. This is an important background document for understanding regional scale patterns in Willamette River biological communities and the factors that affect them. It is, a comprehensive analysis of existing studies summarizing specific information on algae, macroinvertebrates, fish, amphibians, reptiles and mammals in the basin.

rivers, for a total of 13 Columbia River salmon stocks (ESUs), have been listed that use the Lower Willamette River (Table 2). In addition, aquatic species such as lamprey, sturgeon and eulachon; and terrestrial species including the streak-horned lark and the yellow-billed cuckoo, have been listed as federal species of concern or threatened species.

Table 2: ESA-listed fish species found in Portland streams and rivers.

Portland, Oregon: ESA-Listed Species				Listing	Year Listed
ESU/DPS	Race	Species			
Upper Willamette	Spring	Chinook Salmon	*Oncorhynchus tshawytscha*	FT	1999
Upper Willamette	Winter	Steelhead Trout	*Oncorhynchus mykiss*	FT	1999
Upper Columbia	Spring	Chinook Salmon	*Oncorhynchus tshawytscha*	**FE**	1999
Lower Columbia	Sp,Fa	Chinook Salmon	*Oncorhynchus tshawytscha*	FT	1999
Upper Columbia		Steelhead Trout	*Oncorhynchus mykiss*	FT	1997
Middle Columbia		Steelhead Trout	*Oncorhynchus mykiss*	FT	1999
Lower Columbia	Su,Win	Steelhead Trout	*Oncorhynchus mykiss*	FT	1998
Columbia River		Chum Salmon	*Oncorhynchus keta*	FT	1999
Lower Columbia		Coho Salmon	*Oncorhynchus kisutch*	FT	2005
Columbia River		Bull Trout	*Salvelinus confluentus*	FT	1998
Snake River		Sockeye Salmon	*Oncorhynchus nerka*	**FE**	1991
Snake River	Fall	Chinook Salmon	*Oncorhynchus tshawytscha*	FT	1992
Snake River	Sp-Sum	Chinook Salmon	*Oncorhynchus tshawytscha*	FT	1992
Snake River		Steelhead Trout	*Oncorhynchus mykiss*	FT	1997
Southern DPS		Pacific Eulachon	*Thaleichthys pacificus*	FT	2011
Southern DPS		Green Sturgeon	*Acipenser medirostris*	FT	2006
Northern DPS		Green Sturgeon	*Acipenser medirostris*	FSoC	2004
		White Sturgeon	*Acipenser transmontanus*	SoC	
		Pacific Lamprey	*Entosphenus tridentatus*	SoC	
		W. Brook Lamprey	*Lampetra richardsoni*	SoC	
		River Lamprey	*Lampetra ayresii*		
		Streaked Horned Lark	*Eremophila alpestris strigata*	FT	2013
Western DPS		Yellow-billed Cuckoo	*Coccyzus americanus*	FT	2013

(a) ODFW Fish Study

ODFW conducted the most extensive fish study of the Lower Willamette through Portland in 2000 - 2004. Using electrofishing, beach seines and radio telemetry, biologists documented nearshore habitat use, outmigration, timing, size structure, growth, migration rate, and residence time. Results indicated extensive use of the lower river by juveniles. Most (87%) of the juvenile salmonids captured were Chinook salmon, 13% were steelhead, and nine percent were coho salmon. Occasionally observed were mountain whitefish, sockeye salmon, and cutthroat trout.

Hatchery-produced salmon dominated the catch, composing more than half of the Chinook salmon (54%), coho salmon (66%), and steelhead (91%). Large (>100 mm fork length) hatchery Chinook salmon dominated the electrofishing catch; Small (<100 mm fork length) unclipped Chinook salmon dominated the beach seine catch.

Juvenile salmonids were present in every month sampled from May 2000 to July 2003. Outmigrating juvenile Chinook, both hatchery and unmarked, often increased in late autumn and persisted into the next summer. Coho salmon and steelhead were generally present only during winter and spring.

Fish feed and grow as they move through the lower river. ODFW found that median fork lengths and weights of hatchery and unmarked Chinook salmon were often significantly greater at downstream sampling sites than at upstream sites, suggesting that they are feeding to sustain growth as they outmigrate.

Regarding migration rate, ODFW found small juvenile salmonids move relatively quickly through the lower river. However, of 186 juveniles, the median migration rates for steelhead (12.5 km/d) and Chinook salmon (11.3 km/d) were significantly faster than for coho salmon (4.6 km/d). Median residence times in the study area were 8.7 days for coho salmon, 3.4 days for Chinook salmon, and 2.5 days for steelhead. ODFW concluded that river flow and fish size explained much of the variation in Chinook and coho migration rates. Release day and river flow explained much of the variation in coho salmon migration rates. No significant relationships were observed for steelhead.

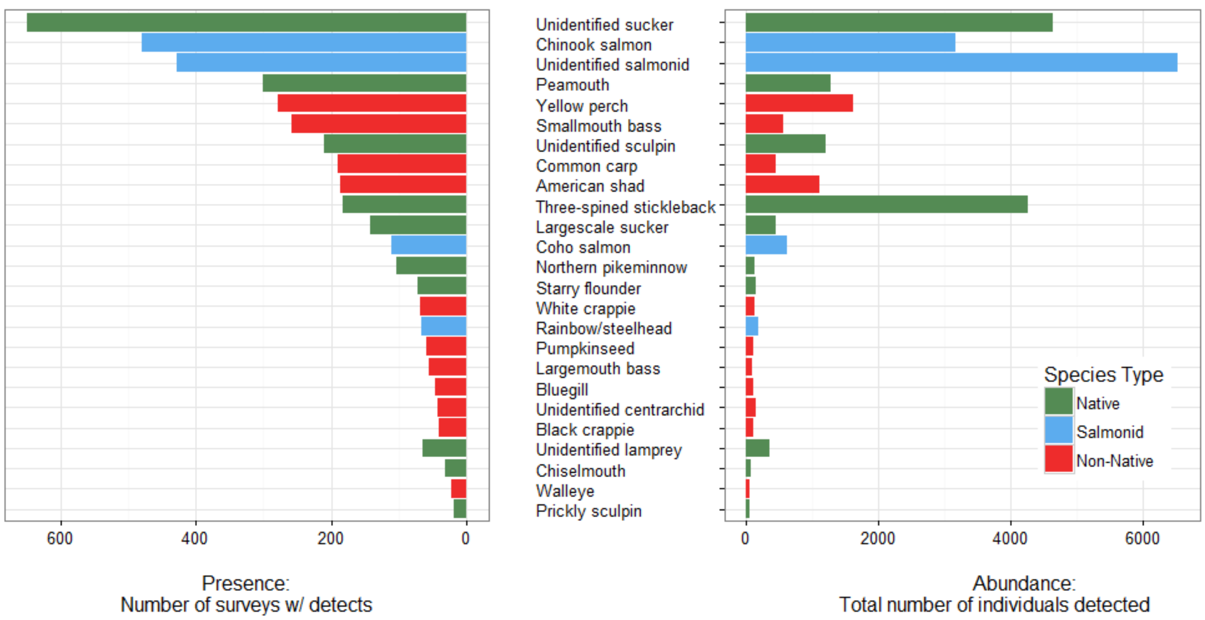
Regarding near-shore habitat use, radio-tagged juvenile Chinook salmon were not highly associated with nearshore areas; about 76% of the recoveries occurred offshore (>10% of the channel width). Steelhead were rarely (25%) associated with nearshore areas. Most fish that were recovered near shore generally did not show clear selection for (or avoidance of) particular habitats. However, coho salmon were found near shore more often (43%), appeared to prefer beaches, and avoided riprap and artificial fill.

ODFW also evaluated fish presence across generalized habitat categories (e.g., beach, riprap, rock outcrop) and into clustered groups based on similarities in physical and chemical parameters. Results for large juvenile salmonids indicated presence varied significantly among habitat types, but differences were almost always associated with low catches of fish at seawall sites (possibly due to sampling at depth only in these areas). ODFW also found no indication that yearling salmonids were associated with specific habitats or groups of habitats, with one exception. The presence of coho salmon in spring at rock outcrops was significantly higher than at other habitats, suggesting these areas have a particular value. High catches sometimes occurred more frequently in off-channel areas (alcoves, backwaters, side channels), but were not significantly different from those in the main river channel. Juvenile Chinook salmon catches were lowest at sites with low (0-10%) vegetative cover, and higher with sand substrates, shallow water, and moderate amounts of bank vegetation during winter.

Data collected to evaluate diet indicated that Chinook and coho salmon have specialized, selective feeding behaviors. Daphnia were the most important prey item for these two species, occurring in 65% of the samples and composing >80% of their diets by weight. The amphipod Corophium spp. and insects (both aquatic and terrestrial) were also common prey. Conversely, fish and crayfish composed nearly all (97%) of smallmouth bass diet by weight. Yellow perch, bass, and sunfish generally had more diverse diets than juvenile salmonids, and unlike salmonids, did not specialize on particular taxa. Diets of unmarked and hatchery Chinook salmon overlapped significantly, though unmarked fish exhibited a more selective feeding behavior and consumed larger amounts of prey.

For the overall species composition, ODFW found in electrofishing surveys that suckers, Chinook (and unidentified) salmonids, and peamouth were the most commonly present native species; yellow perch and smallmouth bass were the most commonly present non-native species (Figure 14). Native three-spine stickleback were not encountered in as many surveys as other species, but were present in large numbers at the sites where they occurred, and had more total number of individuals captured than all other species except unidentified suckers and salmonids.

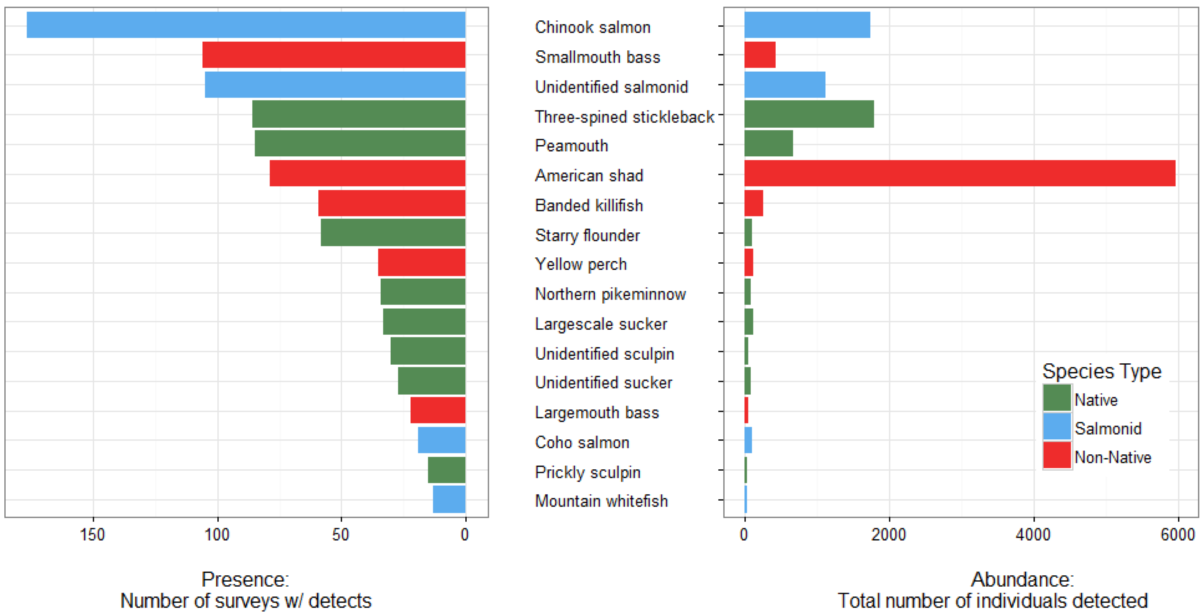
Figure 25: Species composition from the ODFW Willamette Fish Study (ODFW 2005) electrofishing surveys.



ODFW also conducted beach seine surveys (Figure 15). Beach seines can only be conducted on wadeable beach shorelines, and are ineffective in sampling habitats such as riprap, seawalls or rocky or deep shorelines. They therefore cannot be used to compare fish communities in these different habitat types, but they provide other valuable insights, such as on the value of beach habitats, and are often effective at capturing smaller fish.

In the beach seines, Chinook were by far the most commonly captured species, collected in a third more surveys than any other species. The non-native American shad was captured in fewer surveys, but was highly abundant where present (with over three times the total numbers of any other species). Smallmouth bass was the most commonly encountered non-native species, but was far less numerous than shad.

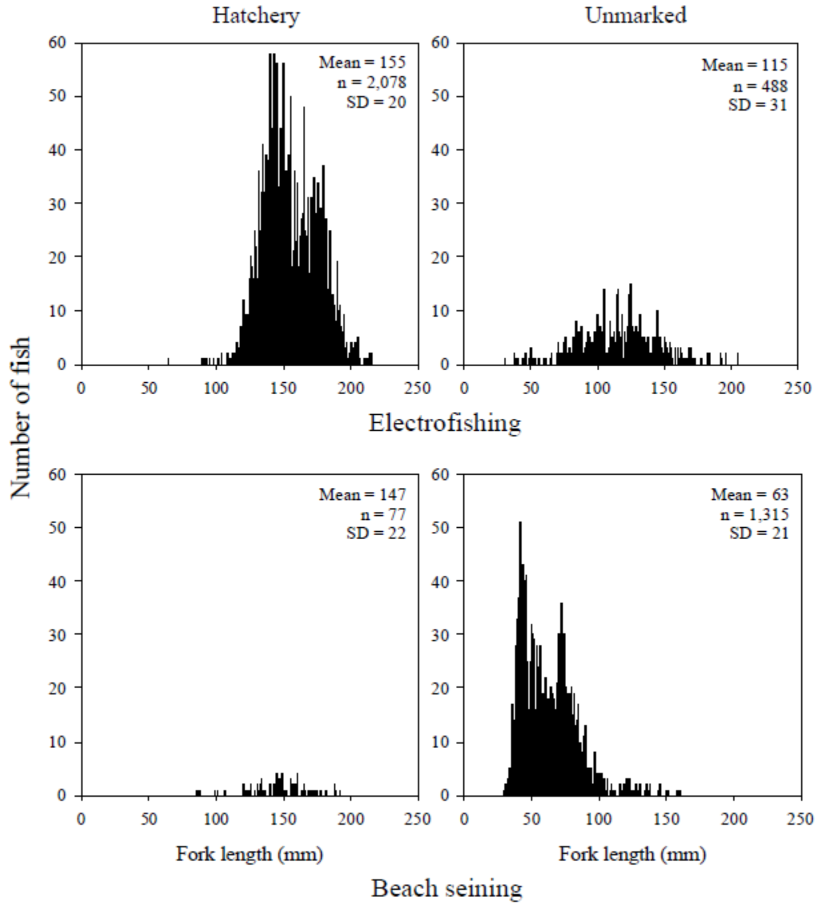
Figure 26: Species composition from the ODFW Willamette Fish Study (ODFW 2005) beach seining surveys.



ODFW found a distinct difference in the size and type of Chinook salmon captured by electrofishing and beach seining. The electrofishing typically captured larger, hatchery fish, whereas the beach seines typically captured smaller, wild fish (Figure 16)[24]. The results also show that subyearling Chinook life stages are common in the lower Willamette through Portland. Although the extent to which they are present in other habitat types is not known, they clearly make extensive use of available beach habitats.

[24] Electrofishing typically caught juvenile Chinook larger than 100 mm – suggesting that they were yearling fish, and were mostly fin-clipped - indicating they were of hatchery origin. In contrast, the beach seined Chinook were predominantly less than 100 mm and unclipped suggesting that they were wild-origin subyearlings.

Figure 27: Figure 4 from Friesen and others (2005). Fork length distributions for hatchery and unmarked juvenile Chinook salmon captured by electrofishing (top panels) and beach seining (lower panels) in the lower Willamette River, 2000-2003. SD = standard deviation.

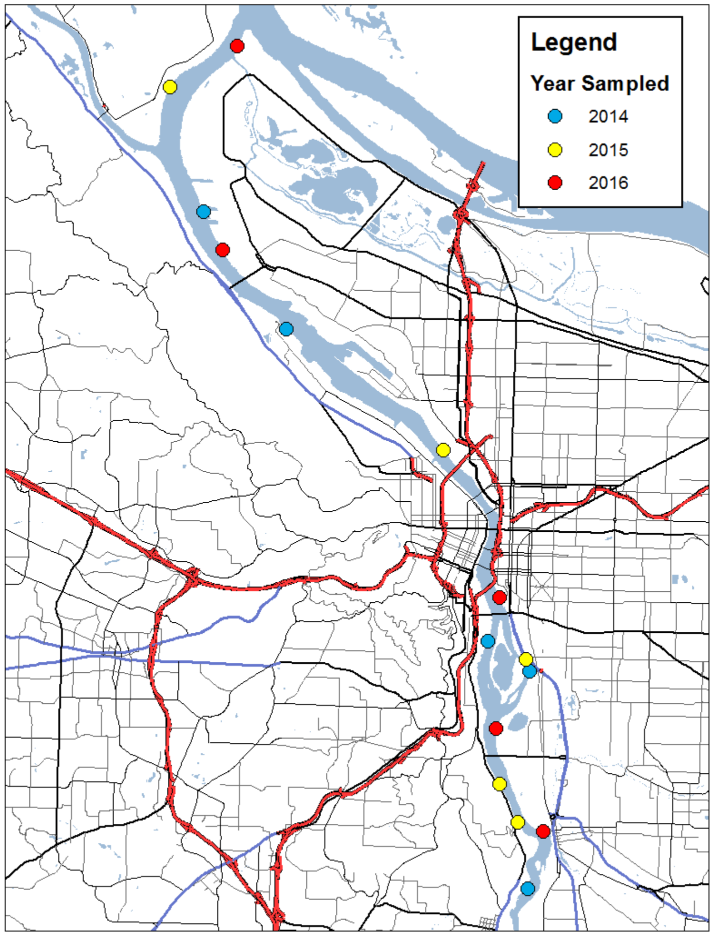


(b) PAWMAP fish data

The City of Portland evaluates watershed health through the Portland Area Watershed Monitoring and Assessment Program (PAWMAP), which is based on the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP)[25]. PAWMAP monitoring efforts are primarily focused on the tributaries to the Willamette River since the mainstem has been thoroughly characterized by a wide range of studies, including the Portland Harbor Remedial Investigation (EPA 2016), the Willamette Fish Study (ODFW 2005), and city water quality monitoring efforts. In order to complement but not duplicate these existing efforts and data on the mainstem, PAWMAP only samples fish communities in the Willamette. The city samples five sites along the Willamette mainstem quarterly for fish species composition. Stations are rotated – with new stations each year for four years, at which point the stations are repeated.

[25] PAWMAP and its design are described here: https://www.portlandoregon.gov/bes/article/489038. EMAP's Field Protocols are described here: https://www.epa.gov/sites/production/files/2013-11/documents/nrsa_field_manual_4_21_09.pdf

Figure 28: PAWMAP Stations sampled for fish communities along the lower Willamette River.

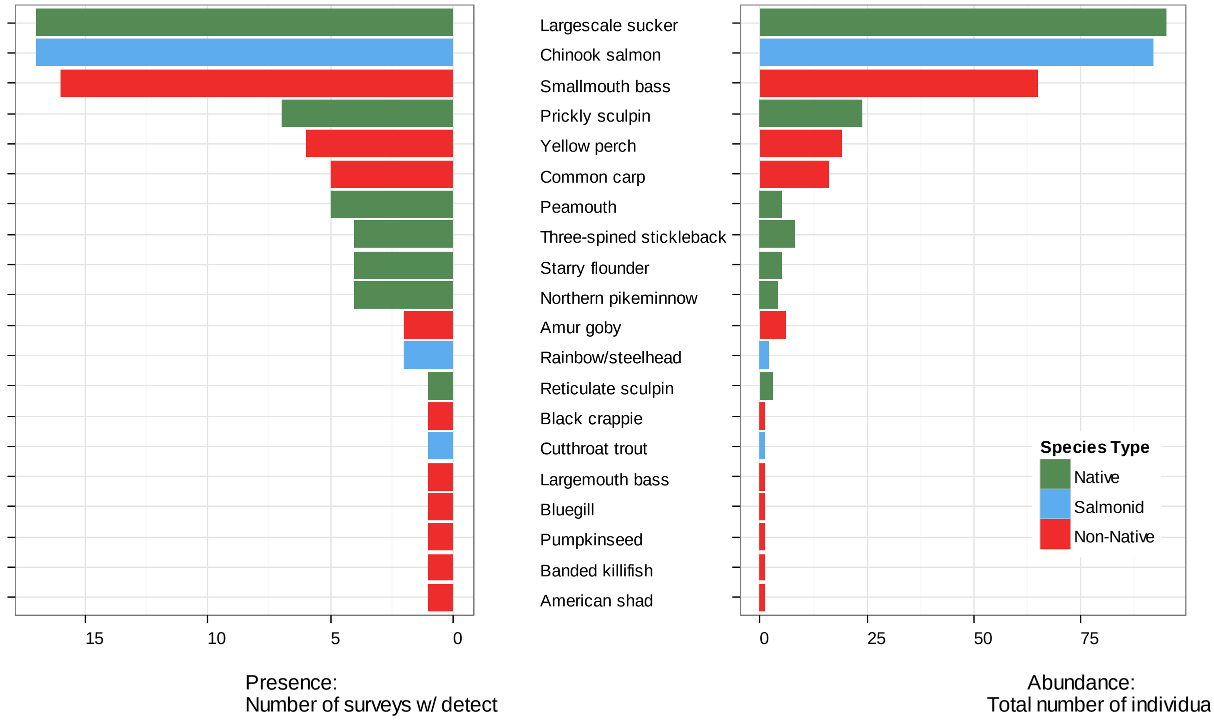


Results indicated that largescale sucker and Chinook salmon were the most commonly detected species from 2014 – 2016 (Figure 29). Prickly sculpin (a native species) was more commonly found than in the ODFW surveys. Consistent with the ODFW study, smallmouth bass, yellow perch and carp were the most commonly encountered and abundant non-native species. Overall, slightly more than half of the ten most commonly encountered species are native.

The PAWMAP fish data in the lower Willamette mainstem have a higher prevalence of non-native fish than the PAWMAP tributary surveys. In the tributaries flowing to the lower Willamette (excluding the Columbia Slough), the ten most commonly captured species were all native, and two of the five most commonly encountered species were salmonids (BES, In prep.[26])

[26] Bureau of Environmental Services. In preparation. Portland Area Watershed Monitoring and Assessment Program (PAWMAP): Report on the First Four Years of Data (FY 2010-11 to FY 2013-14).

Figure 29: Species composition from PAWMAP surveys from 2014 – 16.



(c) NPCC Willamette Subbasin Plan

The Northwest Power and Conservation Council conducts subbasin planning to support Columbia River salmon recovery efforts. Using Ecosystem Diagnosis and Treatment modeling, NPCC conducted as assessment that indicated that conditions in the Portland area of the Lower Willamette are an important bottleneck for upriver populations, and that restoration of these conditions had the potential to contribute to tributary populations such as those from the Clackamas. For all six Clackamas populations combined, the Portland area was the second-ranked restoration priority. It had a moderate overall restoration ranking and relatively high rankings for Clackamas Spring Chinook (restoration rank 2 out of 13), Fall Chinook (restoration rank 3 out of 7), and upper Clackamas steelhead (restoration rank 3 out of 8).

The assessment found that salmon and steelhead currently use the area almost entirely as a migration corridor because of the lack of habitat to support rearing. (This is consistent with other studies that found that most juvenile salmonids move through the area in less than two weeks (Friesen and others, 2002). However, under a restored condition, the lower Willamette adds considerable rearing habitat that would be used by juvenile fall Chinook as they move toward the estuary (pg. 3-441). This rearing habitat would be particularly important for Clackamas fall Chinook, as well as for Clackamas spring Chinook adult and juvenile migration.

Restoration of water quality and shallow water habitat in the Portland area would greatly increase the rearing capacity for Clackamas coho and steelhead as well. However, chemicals (pollutants), and lack of habitat diversity and quantity continue to limit production of upper river coho. (3-445). Restoration of the lower Willamette would add considerable capacity to all Clackamas populations (3-448, 9).

Overall, the NPPC found that "Conditions in the lower Willamette River affect the performance of all six populations in the Clackamas River. This assessment showed that conditions in the lower Willamette can contribute significantly to the potential biological performance of fish in the Clackamas River. In fact, it is apparent that the Clackamas River and the lower Willamette River form a contiguous habitat unit. This expanded view of the Clackamas can form a useful focus for restoration and management of coho, Chinook, and steelhead in the Clackamas River." (3-454 – 455):

Current habitat conditions in the Portland (lower Willamette) area are highly degraded, so the area had almost no protection value for the six Clackamas populations. Limiting conditions included: chemical pollutants, loss of habitat diversity, pathogens, predation (the result of large numbers of introduced fish species), and loss of key habitat.

(d) Teel et al. (2009) study

Teel et al (2009) conducted genetic analyses of 280 subyearling fish collected in winter and spring 2005–2006 from wetland and main-stem Lower Willamette River sites. One site (Ramsey Refugia) was a City of Portland restoration project that restored new off-channel habitat.

The study found that fish from throughout the Columbia Basin were using lower Willamette habitats. Genetic stock identification analysis indicated that Willamette River spring Chinook made up a substantial proportion of the samples overall but that Lower Columbia fall Chinook, Lower Columbia spring Chinook, and subyearlings from the middle and upper Columbia River summer–fall-run populations were present in river and wetland samples over the study. "The results suggest that floodplain restoration projects intended to improve fish habitats during winter and spring periods in the lower Willamette River may benefit Chinook salmon populations from the upper Willamette River, lower Columbia River, and upper Columbia River summer–fall evolutionarily significant units." (pg. 211)

ii) Wildlife

Lewis and Clark noted the abundant wildlife in the lower Willamette area:

> "I [s]lept but verry little last night for the noise Kept [up] during the whole of the night by the Swans, Geese, white & Grey Brant Ducks &c… they were emensely noumerous, and their noise horid." (*The Journals of Lewis and Clark* p. 277).

The *Willamette River Inventory* (Adolfson 2003) provides a comprehensive assessment of wildlife across the lower Willamette. It inventories existing resources and sites and characterizes habitat types and their use by wildlife. Since then, the city's 2011 Oregon Terrestrial Ecology Enhancement Strategy (TEES) completed a more updated assessment of special status wildlife, plants, and habitats.

The bottomland forests of the river offer wintering and/or breeding habitat for waterfowl, shorebirds, and Neotropical avian migrants and are part of a large lower Columbia River lowland ecosystem. Wetlands associated with bottomland forest (cottonwood riparian forest) are preserved on Sauvie Island and in the Smith and Bybee Lakes area. Kelley Point Park and Smith and Bybee Lakes provide critical breeding and nesting habitat for declining populations of neotropical birds. Fish and amphibians are also strongly associated with aquatic, wetland, and riparian habitats. At least seven native amphibian species inhabit Forest Park, including five salamanders and two frog species. Bald eagle, blue heron, osprey, and other raptor species depend on the upland forest, bottomland riparian forest, and emergent wetlands. The Harborton wetland area presents viable habitat for amphibians, reptiles, birds, and mammals, and off-channel fish habitat during high water conditions. Miller Creek provides a partial passageway between these wetlands and the upland forest for salmonids, amphibians, reptiles, and small mammals.

The travel corridors along Columbia Slough are important for dispersion of mammalian species such as deer, coyote, fox, and beaver, as well as reptilian (e.g., turtles, snakes) species. Bobcat, coyote, deer, and occasional bear are known to make use of the proximity of shelter in the upland forests and forage along the river. Between the Linnton area and the St. Johns Bridge, the dominant large scale habitat context is the looming presence of the Tualatin Mountains (Forest Park section) immediately adjacent to the river. The linkage for terrestrial species is largely blocked by Hwy 30, a four- to five-lane roadway. There are few broadscale terrestrial habitat linkages on the eastern river shore in this reach.

In-water habitat is used by salmonids primarily for passage (upstream and downstream) and rearing, although the Columbia Slough channel and other embayments provides refuge areas. In the Linnton area, the Multnomah Channel provides an important linkage and resting area for salmonid species. Miller Creek, the Tualatin Mountains, Harborton wetlands, Burlington Bottoms, and Sauvie Island are part of a diverse habitat complex linked to the Channel. The open water habitat also provides feeding areas for birds such as ducks, cormorants, gulls, herons; and mammals such as river otter and mink. Kelley Point Park and the Harborton wetlands increase the importance of the reach as a corridor for terrestrial species migrating from wildlife refuges in Southern Washington and Sauvie Island. Insectivores such as swallows and bats also forage over the water.

At the north end of the lower river, water birds include double-crested cormorant, great blue heron, herring gull, mallard, hooded and common mergansers, and gadwall. Raptors detected include northern harrier, merlin, red-tailed hawk, osprey, bald eagle, and peregrine falcon. A wide variety of song birds use the reach, including black-capped chickadee, bushtit, Bewick's and winter wrens, American robin, starling, Hutton's vireo, song sparrow, dark-eyed junco, purple finch, golden-crowned kinglet, and various other sparrows (i.e., house, white-crowned, golden-crowned, and fox sparrows). Other birds identified are downy woodpecker, northern flicker, mourning dove and rock dove (domestic pigeon), western scrub-jay, and American crow. Painted turtle, northwestern garter snake, common garter snake, long toed salamander, western red-backed salamander, red-legged frogs, Pacific chorus (tree) frog, and bull frog are present. Mammal species noted include mink, deer, beaver, river otter, and raccoon (Adolfson 2003).

The Tualatin Mountains form a topographic constraint that defines the western limit of the lower Willamette floodplain. The Tualatin Mountains are a different level III ecoregion from the rest of the lower river (Figure 1). The *Forest Park Wildlife Report* (Deshler 2012) provides a comprehensive inventory of wildlife use of this area, and documents habitat characteristics, threats and information gaps important to managing its unique resources.

In the Central Reach, a number of raptor species (red-tailed hawks, peregrine falcons, etc.) have adapted to the urban setting and limited habitat, such as are provided by riverside park/promenade. Habitat diversifies again in the South Reach. Complexes around River View Cemetery, Ross Island and Oaks Bottom are frequent stopover and forage sites for many wildlife species. In this area, numerous large and small holes at or above the ordinary high water mark indicate the presence of river otter, bank swallows, and/or kingfishers. Barn swallows and violet-green swallows feed and collect nesting materials, and kingfishers were observed foraging. Other river bird species detected include cormorant, widgeon, bufflehead, Canada goose, and numerous pairs of mallards. Passerine and other bird species observed include golden crowned kinglet, song sparrow, winter wren, American goldfinch, bushtit, black-capped chickadee, and American crow. Purple martins are seasonal visitors.

To identify plant and animal species and terrestrial habitats needing protection, conservation, and/or restoration, TEES listed Special Status Species[27] to help land managers and planners identify actions for implementation. As of 2011, TEES has identified 76 wildlife Special Status Species in Portland: 2 amphibians, 2 reptiles, 58 birds, and 14 mammals (https://www.portlandoregon.gov/bes/article/354986, pages 4-6) (Table 2).

Table 2: Wildlife - Special Status Species in Portland

	Federal Status	**State Status**	**NWPCC Focal Spp.**[28]
Amphibians			
Northern red-legged frog	Species of Concern	Sensitive-Vulnerable	X
Clouded salamander		Sensitive-Vulnerable	
Reptiles			
Northwestern pond turtle	Species of Concern	Sensitive-Critical	X
Western painted turtle		Sensitive-Critical	
Birds			
American bittern			
American kestrel			X
American white pelican		Sensitive-Vulnerable	
Bald eagle	Delisted[29]	Delisted[30]	X
Band tailed pigeon	Species of Concern		
Black throated gray warbler			
Brown creeper			
Bufflehead			
Bullock's oriole			
Bushtit			
Chipping sparrow		Strategy Species	X
Common nighthawk		Sensitive-Critical	
Common yellowthroat			X
Downy woodpecker			
Dunlin			X
Great blue heron			
Green heron			X
Hammond's flycatcher			

[27] Special Status Species were identified as those wildlife species whose range includes Portland and that are officially listed or identified by various named entities.
[28] Identified in the Northwest Power and Conservation Council Willamette Basin Subbasin Plan as Focal Species. These include species that are: listed or that are current candidates for listing as threatened or endangered by federal agencies; listed as threatened, endangered, sensitive—critical, or sensitive—vulnerable by ODFW; declining in the basin or region as indicated by Breeding Bird Survey (BBS) data; endemic to the Willamette Basin; or perform ecological functions quite different from those performed by other species that regularly occur in the same habitat type.
[29] http://www.fws.gov/pacific/ecoservices/BaldEagleDelisting.htm
[30] http://www.dfw.state.or.us/conservationstrategy/news/2012/2012_may.asp

	Federal Status	State Status	NWPCC Focal Spp.[28]
Hermit warbler			
Hooded merganser			
House wren			
Hutton's vireo			
Loggerhead shrike		Sensitive-Vulnerable	
Long-billed curlew		Sensitive-Vulnerable	
Merlin			
Nashville warbler			
Northern harrier			X
Olive-sided flycatcher	Species of Concern	Sensitive-Vulnerable	X
Orange crowned warbler			
Pacific slope flycatcher			
Peregrine falcon	Delisted[27]	Delisted[31]	
Pileated woodpecker		Sensitive-Vulnerable	X
Purple finch			
Purple martin	Species of Concern	Sensitive-Critical	X
Red crossbill			
Red-eyed vireo			X
Red-necked grebe		Sensitive-Critical	
Rufous hummingbird			
Short-eared owl		Strategy Species	
Sora			X
Streaked horned lark	Candidate	Sensitive-Critical	X
Swainson's thrush			
Swainson's hawk		Sensitive-Vulnerable	
Thayer's gull			
Varied thrush			
Vaux's swift			X
Vesper sparrow	Species of Concern	Sensitive-Critical	X
Western meadowlark		Sensitive-Critical	X
Western sandpiper			
Western wood pewee			X
White-breasted nuthatch		Sensitive-Vulnerable	X
White-tailed kite			
Willow flycatcher - Little	Species of Concern	Sensitive-Vulnerable	X
Wilson's warbler			
Winter wren			
Wood duck			X
Yellow warbler			X
Yellow-breasted Chat	Species of Concern	Sensitive-Critical	
Mammals			
American Beaver			X
California myotis		Sensitive-Vulnerable	
Camas pocket gopher	Species of Concern		

[31] http://www.dfw.state.or.us/conservationstrategy/news/2010/2010_april.asp

	Federal Status	State Status	NWPCC Focal Spp.[28]
Fringed myotis	Species of Concern	Sensitive-Vulnerable	
Hoary bat		Sensitive-Vulnerable	
Long-eared myotis	Species of Concern		
Long-legged myotis	Species of Concern	Sensitive-Vulnerable	
Northern river otter			X
Red tree vole	Species of Concern	Sensitive-Vulnerable	X
Silver-haired bat	Species of Concern	Sensitive-Vulnerable	
Townshend's big eared bat	Species of Concern	Sensitive-Critical	X
Western gray squirrel		Sensitive-Vulnerable	X
White-footed vole	Species of Concern		
Yuma myotis	Species of Concern		

Other criteria used to identify Special Status Species (and not included in the table) include: Oregon Natural Heritage Information Center (ORNHIC) data, the *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (2000) or *Conservation Strategy for Landbirds in Coniferous Forests of Western Oregon and Washington* (1999), Oregon Watershed Enhancement Board priorities, and the Audubon watchlist.

A searchable TEES database provides information about their habitats, life histories, and limiting factors, where known. The database also lists 32 Special Status plant species (page 7). Habitat types considered as having special significance were identified as Special Status Habitats, and were discussed in Section B.5 of the TEES document.

Environmental elements that limit the growth, abundance, or distribution of a population are known as limiting factors. For example, the absence of old, hollow trees is a limiting factor for some bat species. TEES developed a list of limiting factors, grouped by major categories and numbered (Attachment G of the TEES document), that are linked to species and habitat tables, matrices, and databases. The main categories of limiting factors are:

- Biological Stressors
- Climate Change
- Disruption of Natural Disturbance Regimes
- Habitat Change
- Degradation and Loss
- Habitat Fragmentation and Access
- Human Disturbance
- Pollution

Each factor has a list of more detailed factors. For example, biological stressors include 13 subfactors, such as competition for nesting cavities, and invasive aquatic animal species. All of the limiting factors (Attachment G) are here: http://www.portlandoregon.gov/bes/article/354993

i) Macroinvertebrates

There has been very limited evaluation of benthic macroinvertebrates in the Lower Willamette River. Tetra Tech (1994) found no families of Ephemeroptera, Plecoptera, Trichoptera (EPT)[32]

[32] Aquatic insects that are sensitive to degraded water quality and habitat. They are typically found in healthy tributary watersheds.

present in the lower reaches of the river. However, this is true for most of the middle and upper river also, and the lack of these families may not be unusual in large low gradient rivers dominated by fine-grained substrate. Altman et al. (1997) concurs, finding that macro-invertebrate assemblages in the lower main stem are dominated by pollution tolerant organisms and those adapted to low dissolved oxygen levels. Typical invertebrates in the lower river are oligochaetes (segmented worms), cladocerans (water fleas), amphipods (scuds), odonates (dragonflies and damselflies), and chironomid midges (Ward and others, 1988)." (pp. 18-19).

Windward Environmental (2003) collected some initial baseline information on benthic invertebrates settling on artificial substrates as part of the Portland Harbor study. They found that chironomids (midges) were the most abundant and diverse taxa. Oligochaete worms were the second most diverse taxa, while amphipods were the second most abundant taxa. Other taxa included isopods, ostracods, caddisflies, mites, and flatworms. Interestingly, they found the highest abundance of organisms in a backwater section of the Swan Island Lagoon, while the least abundant site was nearby at the mouth of the lagoon. These data fill an important data gap and will be helpful in evaluating changes in the community through the lower river.

However, the challenge with evaluating the health of macroinvertebrate communities in the Lower Willamette River is the lack of information on reference conditions for which to compare unimpacted macroinvertebrate populations in large low-gradient rivers. For example, it will be hard to utilize the Windward data to define the health of the impacted Lower Willamette until information is obtained for invertebrate communities on artificial substrates in comparatively unimpacted reference reaches.

(a) ODFW Macroinvertebrate study

ODFW also sampled macroinvertebrates in the Lower Willamette as part of the Willamette Fish Study (ODFW 2005). They sampled macroinvertebrates and zooplankton at 26 different habitat sites during spring 2003 using drift nets, Hester-Dendy multiple-plate samplers, and ponar dredges. ODFW "… identified approximately 38,000 organisms from 44 taxa. Cladocerans (bosminids and daphnia), copepods, and aquatic insects dominated the water column "drifting" taxa. Daphnia and chironomids dominated the taxa that attach to substrates (95% of all organisms); and oligochaetes and chironomids dominated the sediment dwelling taxa.

ODFW noted few differences in the distribution of major taxa groups among habitats, suggesting a generally homogenous macroinvertebrate community structure: "Density and community metrics varied among gear and habitat types. Beaches tended to have relatively high species diversity, taxa richness, and sensitive taxa richness; seawalls had comparatively low densities and taxa richness. Rock outcrops and floating structures appeared to be preferred habitats for adult aquatic insects. Riprapped sites had very high densities of aquatic organisms and, except for multiple-plate samples, relatively high taxa richness. "

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