# Designing a Complex of Low-Tech Structures at Sapp Road Park to Restore Floodplain Connectivity and Enhance Beaver Habitat

By
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## Acknowledgements

This report would have been impossible without the help and support of so many people over the last academic year and I will here attempt to name as many as possible. Thank you to practicum coordinator and WSM instructor Grant Gilmore for originally suggesting to a small group of students that Sapp Road Park would be a great place to learn more about beavers in an urban setting. The quality of this research is a product of that same group of enthusiastic students including Chaz Hastings, Phil Harris, Nick Baker, and Casey Sowers, whose outstanding work contributed to this and other studies on the site's potential for beaver related restoration. I would also like to thank my practicum advisor Kristen Numata for her help with copy editing, Jen Vanderhoof for providing information on beaver habits and vegetation preferences, and my parents, Eddie Paulson and Susie McCune for their support and interest in my research. Finally, I would like to thank my amazing wife, Maggie Witt, for her patience and avid support throughout the project.

# TABLE OF CONTENTS

# EXECUTIVE SUMMARY

The purpose of this practicum report will be twofold. First to characterize the wetland in Sapp Road Park along Percival Creek, Tumwater, WA, given current site conditions. Second, to investigate the feasibility, design, and potential impacts of installing a complex of low-tech, low-cost, biodegradable structures along Percival Creek in order to enhance floodplain connectivity and encourage beaver colonization of the site.

The majority of the wetland is a palustrine persistent emergent wetland dominated by reed canary grass (*Phalaris arundinacea*) and yellow-flag iris (*Iris pseudocarorus*). The wetland includes about two acres of more biodiverse palustrine forested wetland; one acre dominated by red alder (*Alnus rubra*) in the upstream, southern reach of the Creek near Sapp Rd SW, and another forested acre dominated by western redcedar (*Thuja Plicata*) in the downstream, northern end of the parcel. A sedge and reed meadow on the west side of the parcel in a shallow depression hosts a mix of Slough sedge (*Carex obnupta),* small-fruited bulrush (*Scirpus microcarpus),* and other plant species.

The wetland has a riverine, geomorphic setting with channelized flow, evidence of small oxbows, and continuous flow. The water source for Percival Creek, a first order perennial stream, is the groundwater-fed Trosper Lake approximately 1 river mile south of Sapp Road Park. Percival Creek is an incised stream with several sharp, almost 90 degree turns along its channel through Sapp Road Park. There is also evidence of medium to high base flows and groundwater inputs from Mt Bush to the northwest. The wetland's hydrodynamics are unidirectional flow from south to north over a middle gradient, alluvial floodplain dominated by non-hydric sandy glacial outwash soils.

According to Water Resource specialist Grant Gilmore, enhancing beaver (*Castor canadensis*) habitat along Percival Creek advances several City of Tumwater goals regarding water storage, water quality, and biodiversity. To further these goals, this research aims to provide evidence based recommendations for implementing a complex of beaver dam analogs (BDAs) and/or post-assisted log structures (PALs) along Percival Creek.

The ultimate goal of a low-tech complex is to increase connectivity between Percival Creek and its floodplain on Sapp Road Park and attract beavers into the site so they may accelerate restoration of wetland functions on site including water quality improvement, flood storage, and biodiversity. In order to promote discussion of the best possible solution, this study proposes two different complex designs for consideration by the City of Tumwater. First, a design utilizing PALs and BDAs to force channel avulsions, disrupt the reed canary grass meadow, trap sediment, aggrade the stream, and enhance floodplain-channel interconnectivity. Second, a design of just BDAs to force ponding, drown reed canary grass, trap sediment, and increase water capacity.

# 1.0 INTRODUCTION

*1.1 Purpose*

This practicum explores the feasibility and possible impacts of restoring natural landscape processes in the wetland at Sapp Road Park, Tumwater, WA with low-tech Process Based Restoration (PBR) techniques (Wheaton et al. 2019). This approach would involve the installation of a complex of hand-built, biodegradable structures along Percival Creek within the bounds of Sapp Road Park (SRP). The project goals are to increase water storage and residence time, boost aquifer recharge, promote riparian plant growth and recruitment, and enhance suitable habitat for beavers. This project has the potential to convert the site from a degraded wetland with an incised stream dominated by invasive reed canary grass (*Phalaris arundinacea*) into a depressional wetland with high channel-floodplain connectivity that contributes to aquifer recharge, reduces downstream flooding, and provides attractive habitat for beavers and many, many other species.

*1.2 Site location*

The study site is an 11.87 acre parcel called Sapp Road Park (SRP) at 2332 SW Sapp Drive, Tumwater, WA, 98512, in Thurston County (Figure 1) Section 28, Township 18, Range 2W (Parcel #: 76910100000).

SRP is on the west side of Tumwater, WA, where Percival Creek flows through a culvert under Sapp Road SW, a two-lane surface road cutting west-east that defines the southern edge of the parcel and imposes a habitat barrier (Figure 1). The east side of the site rises steeply in elevation beyond the stream and includes a problematically restored upland with a walking trail that parallels the north-south oriented Antsen St SW and its associated dense residential properties. The northwest corner of the site is dominated by the forested Mt Bush and includes Klahowya Lane SW and scattered residential properties.

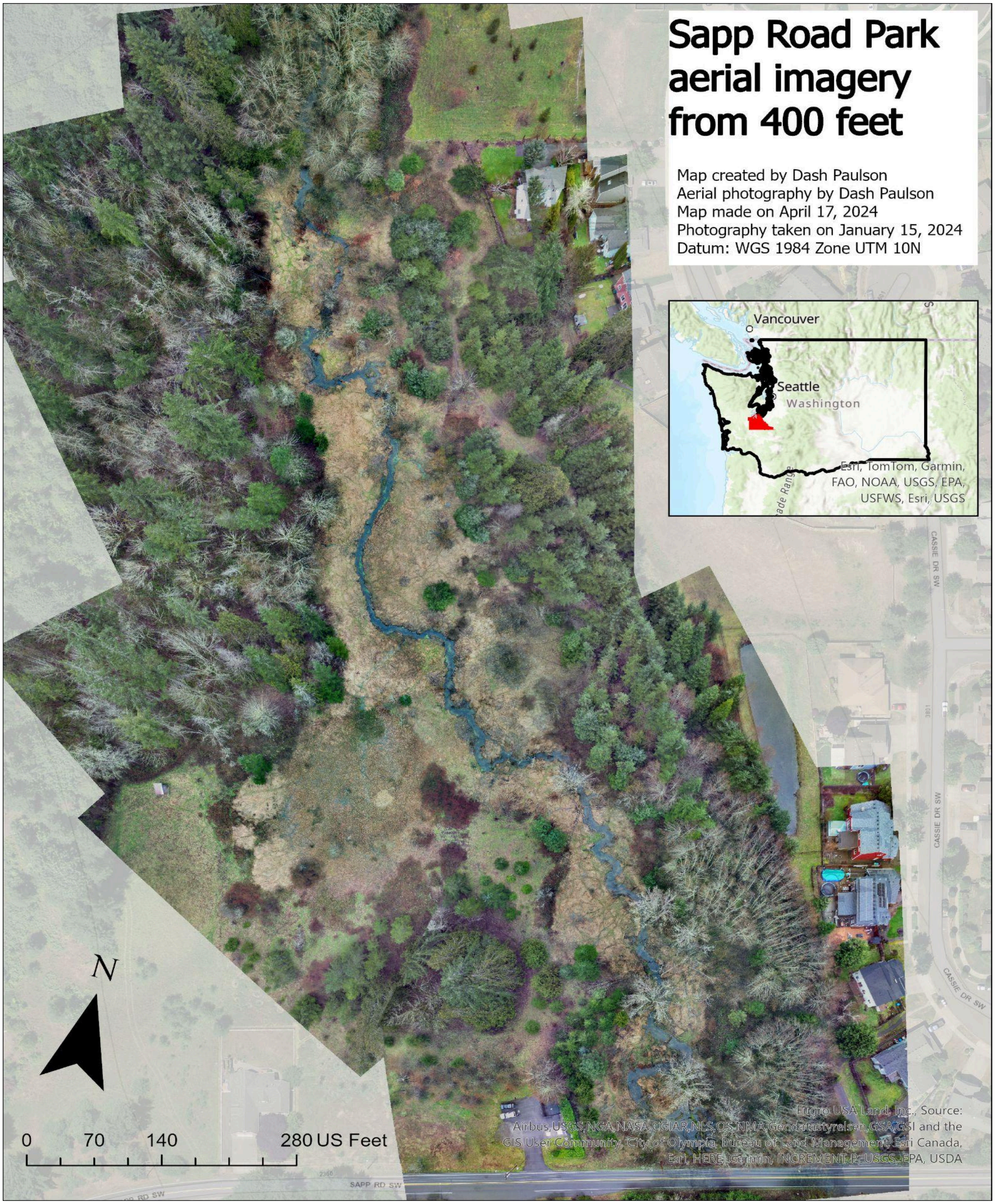


Figure 1: Sapp Road Park as seen from 400 feet above. Aerial photography taken with a DJI Mini 3 Pro UAV (drone) on January 15, 2024.

*1.3 Geology*

SRP lies within the southern Puget Lowlands, a tectonic depression between the Cascade and Olympic Mountain ranges that extend from the Puget Sound to Eugene, Oregon (PBS 2022). The depression is parallel to the Cascadia Subduction Zone, where the Juan de Fuca Plate subducts beneath the North American Plate and causes uplift of the Olympic Mountains and volcanism in the Cascade range. The rapidly growing population in the Puget Lowlands, commonly referred to as the Puget Sound, is vulnerable to rare but extremely violent earthquakes.

The region has been repeatedly glaciated over the last 2 million years, most recently during the Vashon glaciation around 14,000 years ago. The local topography reflects the cyclic advance and retreat of the Puget Ice Lobe, which formed compacted, undulating ridges underlain by glacial till (drumlins) and surficial layers of well sorted sand and silt deposited during glacial melting. SRP is situated near surface deposits of Mesozoic volcanic rocks and quaternary alluvium (Figure 2).

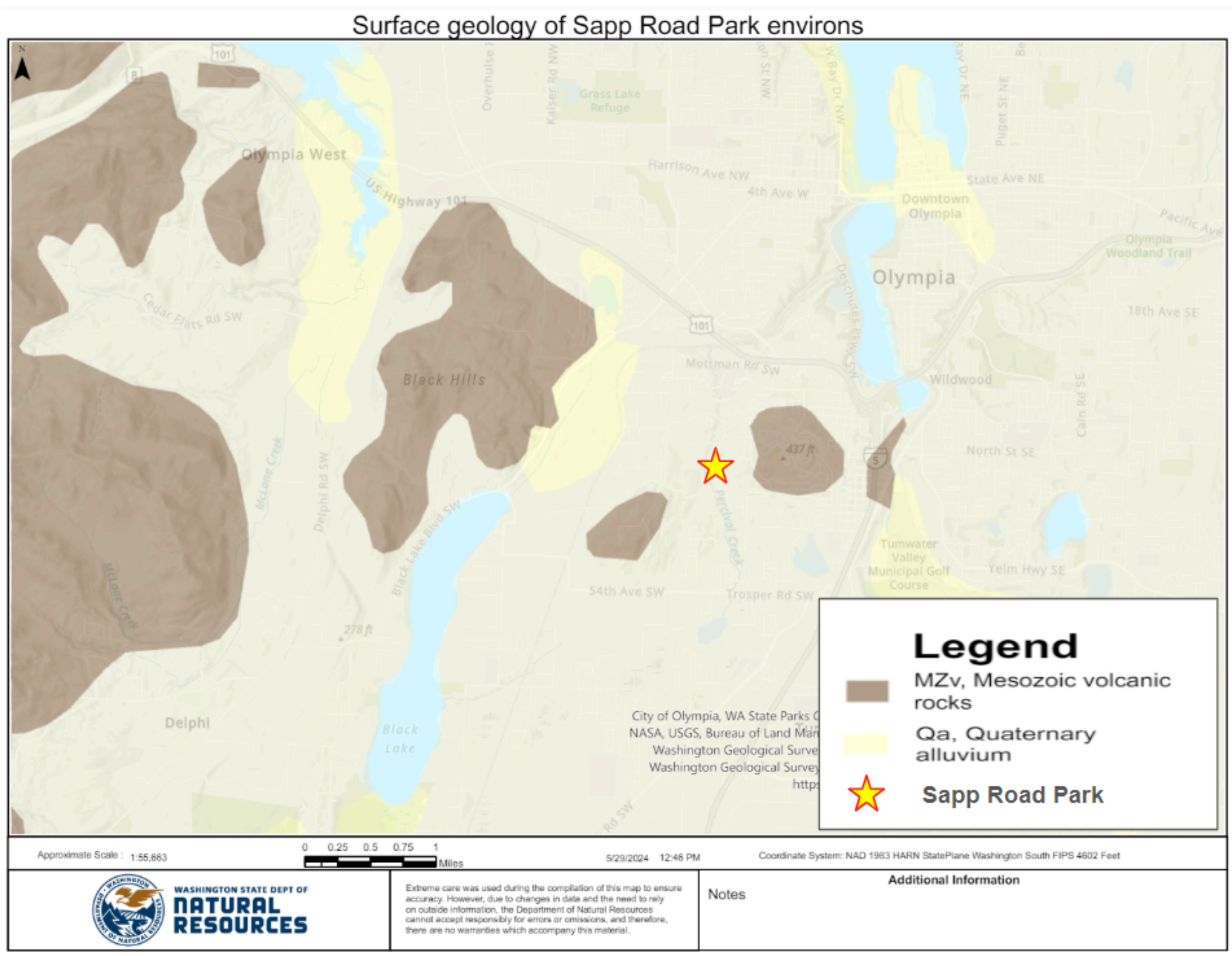


Figure 2: Surface geology around Sapp Road park from the Washington Department of Natural Resources. The park itself is mapped as lying on Pleistocene continental glacial drift, which can include a

wide array of substrate materials that can include till and outwash clay, silt, sand, gravel, cobbles, and boulders deposited by or originating from continental glaciers.

*1.4 Watershed*

SRP is located in Water Resource Inventory Area (WRIA) 13 (HUC: 12-1711-0016-0202), also known as the Deschutes watershed (Figure 3).

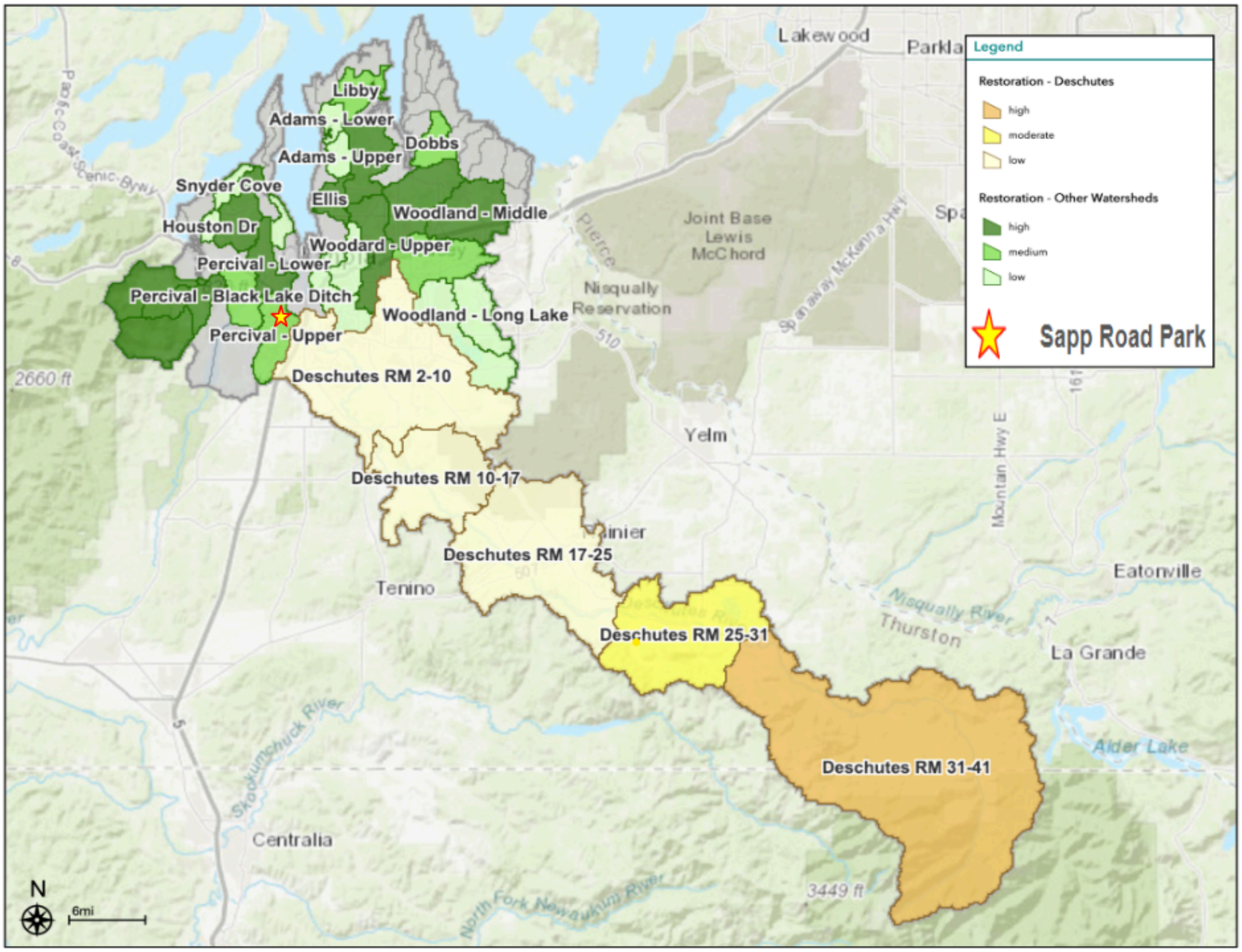


Figure 3: An overview of WRIA 13 and the Percival Creek sub-basin. Map adapted from Thurston Regional Planning Council, 2021.

The SRP parcel is bisected by Percival Creek, a 1st order stream in the Deschutes lower subbasin that flows south to north on the parcel from a culvert under Sapp Road. The Creek's source is Trosper Lake, a freshwater kettle lake approximately 1 river mile south of the parcel and the site's contributing basin is approximately 4.35 square miles according to USGS StreamStats web application (Figure 4).

Percival Creek is a 1st order stream with less than 20 CFS/year on average that drains into Budd Inlet

**StreamStats Report on Sapp Road Park drainage basin**

**Region ID:** WA
**Workspace ID:** WA20240407171457026000
**Clicked Point (Latitude, Longitude):** 47.01574, -122.93287
**Time:** 2024-04-07 10:15:26 -0700

› Basin Characteristics

| Parameter Code | Parameter Description | Value | Unit |
| --- | --- | --- | --- |
| BSLDEM30M | Mean basin slope computed from 30 m DEM | 3.71 | percent |
| CANOPY_PCT | Percentage of drainage area covered by canopy as described in OK SIR 2009_5267 | 37.8 | percent |
| DRNAREA | Area that drains to a point on a stream | 4.35 | square miles |
| ELEV | Mean Basin Elevation | 195 | feet |
| PRECIP | Mean Annual Precipitation | 52.6 | inches |
| PRECPRIS10 | Basin average mean annual precipitation for 1981 to 2010 from PRISM | 49.3 | inches |
| RELIEF | Maximum - minimum elevation | 357 | feet |

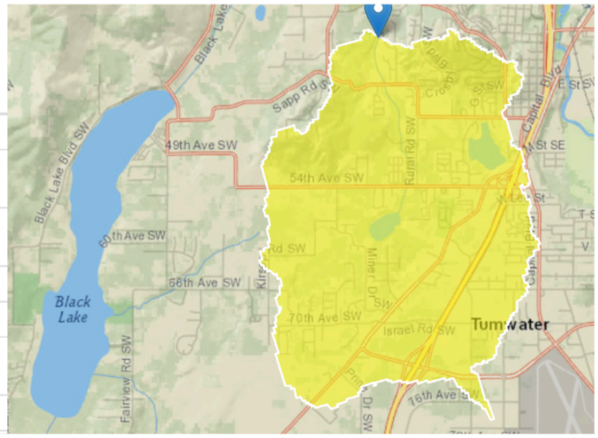


Figure 4: Information on the Percival Creek sub-basin compiled from USGS StreamStats web application.

The Creek's mouth is Black Lake ditch to the north, which flows directly into Capitol Lake, an artificial freshwater lake within the Budd Inlet estuary. Percival Creek is listed as an impaired waterway by the EPA via the "How's my Waterway?" web application, which reports persistently elevated water temperatures and low dissolved oxygen levels that impair aquatic life. Capitol Lake is slated by Washington State for restoration into an estuarine system within the next ten years. This enormous project, which will likely cost between $150-250 million, has focused attention on restoring, rehabilitating or otherwise improving the handful of tributaries that drain into Capitol Lake, such as Percival Creek.

*1.6 Site history and land use*

Like much of the land around Tumwater in the late 1800s, the old growth forests that dominated the area were clear cut. Percival Creek is named after Samuel Percival, an early settler who built the first sawmill in Olympia on Budd inlet. Historic documentation is sparse on the creek or Trosper Lake, but given the almost straight south-north disposition of the creek before it connects with black lake ditch, it is possible the stream was channelized to float timber downstream to the Percival Timber mill. After clearcutting, SRP was drained and converted into agricultural land. It may have been farmed for food crops but was definitely used as pasture for cattle; A decaying cattle tie up is still evident on the northeast corner of the parcel (Photo 1) and the lumpy, bumpy microtopography along the creek also suggests extended use as pasture.

Since the 1990s, SRP has been owned by the City of Tumwater and restoration efforts were made in the early 2000s. A variety of conifers encroaching on the riparian corridor, thickets of rose bushes, and plastic landscaping fabric mark the outcome of this restoration. The plastic fabric around the southern perimeter of the wetland is especially concerning as it isolates the soil from nutrients and prevents new vegetation. The latest round of restoration work in the immediate area has focused on removing as much of this fabric as possible.

Photo 1: Remains of a cattle tie on northeast corner of Sapp Road Park.

*1.7 Climate change*

The Puget Sound is characterized by a mediterranean climate, with wet winters and dry summers. Average precipitation is slightly higher in the South Puget Sound than the rest of the region.

Climate projections for Thurston County suggest the region will see even higher precipitation in the next century and elevated temperatures. This may raise the possibility of more frequent flooding events in the watershed (Figure 5). Stream temperatures may also rise over time, reducing dissolved oxygen and threatening aquatic organisms.

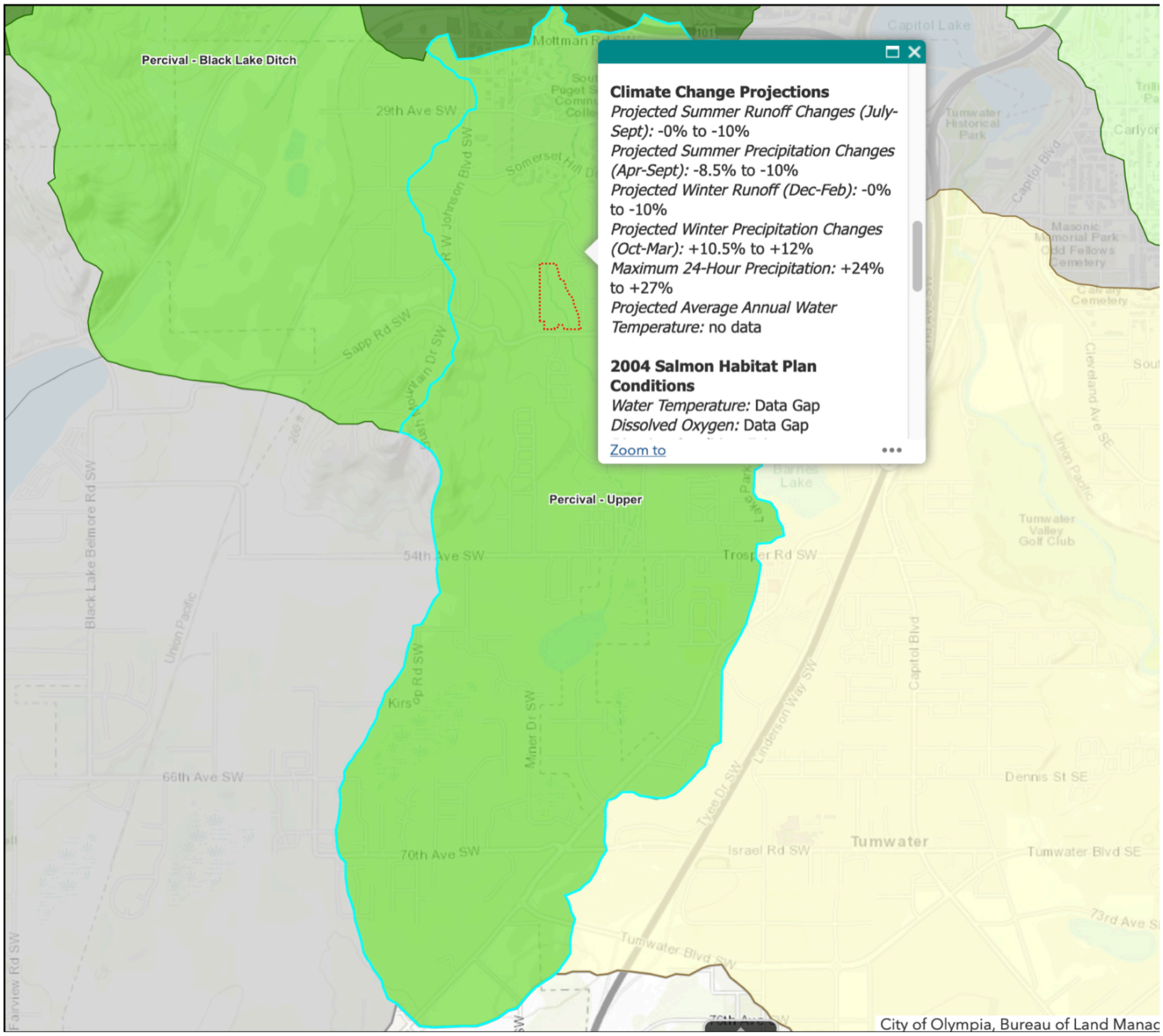

Figure 5: Climate change projections for the upper Percival Creek sub-basin. Data from Thurston Regional Planning Council, 2021.

# 2.0 METHODS

*2.1 Desktop Review*

This study analyzed maps and data from a variety of online services including:

- The Thurston County iMap platform
- The US Fish and Wildlife Service (USFWS) National Wetlands Inventory Mapper (NWI)
- The USFWS Information for Planning and Consultation tool (IPaC)
- The National ESA Critical Habitat Mapper from USFWS
- The Natural Resources (NRCS) Conservation Service Web Soil Survey
- The Agricultural Applied Climate Information System from NRCS for WETS table
- The US Geological Survey Streamstats web application
- The Essential Fish Habitat Mapper from National Marine Fisheries Service (NMFS)
- Salmonscape web application from WA Department of Fish and Wildlife (WDFW)
- The WDFW Priority Species on the Web Map application

A variety of technical reports on site history, local hydrology, and local geomorphology were also consulted, including reports from and prepared for Thurston County, the City of Tumwater, the Washington Department of Fish and Wildlife (WDFW), and the Washington Department of Ecology (WECY). See references for a full accounting.

Site topography was analyzed with built and bare environment LiDAR imagery and 2 foot topographic contours from the Thurston County iMap platform. The NRCS Web Soil Survey was consulted for predicted soil series on site, which was ground truthed with multiple soil samples during field investigations.

*2.2 Wetland Delineation Methods*

Field observations were made to confirm or update off-site research and were conducted on multiple site visits between December 15, 2023 and May 3rd, 2024. The field team included Dash Paulson, Chaz Hastings, Nick Baker, Phil Harris, and Casey Sowers.

The field investigation utilized rapid assessment methods detailed in the US Army Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987) and relied on indicators described in Regional Supplement to the Corps of Engineers Wetlands Delineation Manual: Western Mountains, Valleys, and Coast Region (Environmental laboratory 2010).

Plant species were identified using A Field Guide to the Common Wetland Plants of Western Washington & Northwestern Oregon (Cooke 1997) and Flora of the Pacific

Northwest: An Illustrated Manual (Hitchcok and Cronquist 2018). When plant names varied between sources, we defaulted to the name used in Hitchcock and Cronquist. The site vegetation was classified using the Cowardin classification system (FGDC 2013).

Soil pits were dug on site to a minimum depth of 18 inches. Soil horizon colors were characterized with use of a Pantone Munsell Soil Color Book. Soil textures and hydric soil indicators were identified with methods from the NRCS Field Guide to Hydric Indicators Version 8.2. Soils found on site were compared to predictions from the Web Soil Survey.

The hydrogeomorphic (HGM) classification for the site was determined using the Hydrogeomorphic Classification System for Wetlands (Smith 1995). The dimensions of Percival Creek were measured using methods from Hydrology and the Management of Watersheds (Brooks et al. 2013).

On multiple site visits, a DJI Mini 3 Pro Unmanned Aerial Vehicle (the drone) was flown over the site to capture imagery between 50 and 400 feet above the surface. The images were stitched together using ArcGIS Pro software to create a high resolution field map (figure 1) that shows the site during winter conditions in a process known as photogrammetry.

*2.3 Low-tech PBR suitability assessment*

Not all sites are suitable for low-tech process based restoration. Sometimes a site may be a good candidate for low-tech PBR, but not ideal for beaver colonization or vice versa. Existing infrastructure, flood risks, soil contamination, and other conditions may recommend that the site be restored with an eye to keeping beavers away from an area. If beavers enter these high risk sites, relocation may be an acceptable option.

The authors of the Design Manual present their suitability assessment process within the context of the established USDA's Natural Resource Conservation Service's Conservation Planning Process (Figure 6). This contemporary planning framework promotes the use of adaptive management i.e. methods for implementing uncertain, novel management practices while managing for risk and increasing understanding of how the actions perform (Wheaton et al. 2019). Site managers must carefully consider the site conditions, project goals, and stakeholder willingness before embarking on a low-tech PBR strategy (Figure 7). A series of trials may be the best way for landowners to begin working with the approach, which allows them to find efficiencies, develop expertise with the techniques, test new ideas, and assess outcomes within their specific, local context. An adaptive management framework can help structure and accelerate the learning process during these trials.

USDA United States Department of Agriculture

CONSERVATION
ROAD MAP

The Natural Resources Conservation Service (NRCS) uses a 9-step planning process to provide assistance to our customers and develop a conservation plan.

1. **Identify Problems and Opportunities** - Initial opportunities and problems are first identified while working with the customer.
2. **Determine Objectives** - The customer identifies their objectives, while the planner guides the process so that it includes the customer's needs and values, the resource uses and on-site and off-site ecological protection.
3. **Inventory Resources** - Natural resource, economic, and social information for the planning area is collected to further define problems and opportunities, develop alternatives, and evaluate the plan.
4. **Analyze Resource Data** - The planner studies the resource data and defines existing conditions for all the identified natural resources, including limitations and potentials for the desired use.
5. **Formulate Alternatives** - Alternatives are formulated that achieve the customer's objectives, solve identified concerns, and take advantage of opportunities to improve or protect resource conditions.
6. **Evaluate Alternatives** - Alternatives are evaluated to determine their effectiveness in addressing the customer's problems, opportunities and objectives.
7. **Make Decisions** - The customer selects their preferred alternatives and works with the planner on practice implementation.
8. **Implement the Plan** - The customer implements the selected alternatives. The planner provides the land manager with detailed practice implementation information.
9. **Evaluate the Plan** - The planner evaluates the effectiveness of the plan in solving the resource concerns and works with the customer to make adjustments as needed.

USDA is an equal opportunity provider, employer and lender.

Figure 6: The 9-step planning process advised by the NRCS for assessing and planning resource problem solutions. Adapted from USDA website.

The Design Manual also includes several worksheets that allow for a rapid assessment of site suitability (Box 3) and should be carefully reviewed by landowners before moving ahead with this restoration strategy.

| |
|---|
| **Areas Adjacent to Riverscape Land Use** |
| Areas adjacent are in an undeveloped range or forest land setting |
| Areas adjacent are in a crop, pasture, or hay land setting |
| Areas adjacent are in a developed setting |
| **Valley Bottom Land Use (e.g., roads, bridges, culverts, buildings, diversions)** |
| Valley bottom and adjacent area (up and downstream) does not contain infrastructure of concern |
| Valley bottom or adjacent area (up and downstream) contains some infrastructure, but would not be negatively impacted by processes of wood accumulation or beaver dam activity, or consequences of impact would be low |
| Valley bottom or adjacent area (up and downstream) contains infrastructure that may be negatively impacted by low-tech structure failure and consequences would be unacceptable |
| **Stream Order & Wadeability** |
| 1st through 3nd order wadeable stream |
| 3rd – 5th order wadeable stream |
| 5th order non-wadeable stream or greater |
| **Channel Change and Floodplain Reconnection** |
| Landowner/manager willing/able to give the stream space to adjust in the valley bottom and understands this may include lateral erosion, deposition, change of stream channel position, and inundation |
| Landowner/manager willing/able to give the stream space to adjust in some portions of the valley bottom but not all of it |
| Landowner/manager unwilling/unable to give the stream space to adjust in the valley bottom |
| **Willingness to allow processes of wood accumulation and/or beaver dam activity** |
| Landowner/manager willing/able to allow dynamic processes & no concerns with nearby landowner/managers. |
| Landowner/manager willing/able to allow some processes (but maybe not all) and/or concerns of or with nearby landowner/managers |
| Landowner/manager unwilling/unable to allow processes of wood accumulation and/or beaver dam activity |
| **Adaptive Management** |
| Landowner/manager understands multiple treatments through time may be needed and is committed to follow-up monitoring, maintenance, and adaptive management |
| Landowner/manager understands multiple treatments through time may be needed but resources to do follow-up may limit the ability to adjust or correct problems |
| Landowner/manager wants a single intervention; no monitoring, maintenance, or adaptive management will occur |

Figure 7: Adapted from the Low-Tech Process Based Restoration of Riverscapes: Design Manual. The authors write that “For each factor, select the characteristic that best describes the project site. If answers vary within the project area, consider breaking the site into multiple reaches and assessing each separately. This is not a comprehensive list, but rather, represents some basic considerations related to assessing potential risks to property, infrastructure, and public safety to discuss with the landowner/manager and stakeholders (green = lower risk, yellow = moderate risk, red = higher risk). For factors rating yellow or red, project planners may need to engage other technical specialists for additional review and analysis.”

However, where PBR is a suitable strategy and beaver colonization is desirable, the next steps are to 1) hypothesize why beavers are not already present in the site 2) decide how beavers might be enticed to colonize the site 3) Identify the best placement, type, and number of low-tech structures that would serve site goals 4) what management strategies are available to keep beavers from damaging local property

*2.4 Wetland Rating methodology*

The Sapp Road Park wetland was functionally assessed and rated according to the Washington State Wetland Rating System for Western Washington, (Hruby & Yahnke 2023), which assesses wetlands by their potential value for improving water quality, reducing flooding, and providing habitat for wildlife.

The WA Wetland Rating System does not pass comment on the economic values in a wetland; it aims to identify and categorize a wetland's sensitivity, significance, rarity, and functions. This report used the Washington Department of Ecology Tool for Online Rating (WATOR) to map one-acre map units of site vegetation, surrounding habitat, hydroperiods, and other attributes.

# 3.0 SITE CHARACTERIZATION

*3.1 Site overview and wetland boundary*

Our team conducted several field investigations at SRP on December 15, 2023, January 19, 2024, February 15, 2024, March 15, 2024, and May 3, 2024. One riverine wetland unit, approximately 6 acres, was delineated within the study area (Figure 8).


Figure 8: Sapp Road Park parcel boundary marked in yellow and the extent of the delineated wetland highlighted in green. The extent of the wetland is much larger than the NWI reports, but approximately the same as mapped in Thurston County iMap.

The Sapp Road Park wetland can be characterized as a palustrine emergent wetland on the narrow floodplain enclosed by steep sides. At either end of the wetland, the emergent vegetation gives way to palustrine forested wetland. At two points along the reach of Percival Creek the floodplain narrows significantly, roughly separating the long parcel into three distinct sections. The north downstream section has abundant willows (*Salix spp.)* growing immediately along and within the Creek, enclosed by a reed canary grass meadow, a fringe of Yellow-flag Iris (*Iris pseudacorus),* and scattered sedges (*Carex spp.)* and Skunk Cabbage (*Lysichiton Americanus*). The adjacent uplands on the west side of the Creek are dominated by Western-red cedar (*Thuja plicata*) and big leaf maple (*Acer macrophyllum*). By contrast, the east side of the creek hosts blue spruce (*Picea pungens*), Ponderosa pine (*Pinus ponderosa*), and red alder (*Alnus rubra*).

The mid-stream section, and the widest part of the floodplain, is an emergent wetland where the floodplain bulges out to the west. The reed canary grass and yellow-flag iris that co-dominate the riparian edge along Percival Creek give way here to a meadow of slough sedge (*Carex obnupta*) and other emergent sedges and rush species. The meadow is bordered to the south by a dense patch of Nootka Rose (*Rosa nutkana)*.

The upstream section to the south is narrow and steep sided, closest to Sapp Road SW, lined with alders, Himalayan blackberry (*Rubus bifrons)* and reed canary grass. Groundwater in the upstream section is listed as hazardous (Figure 9) and this section of SRP will be most heavily affected by the planned culvert replacement in 2025.

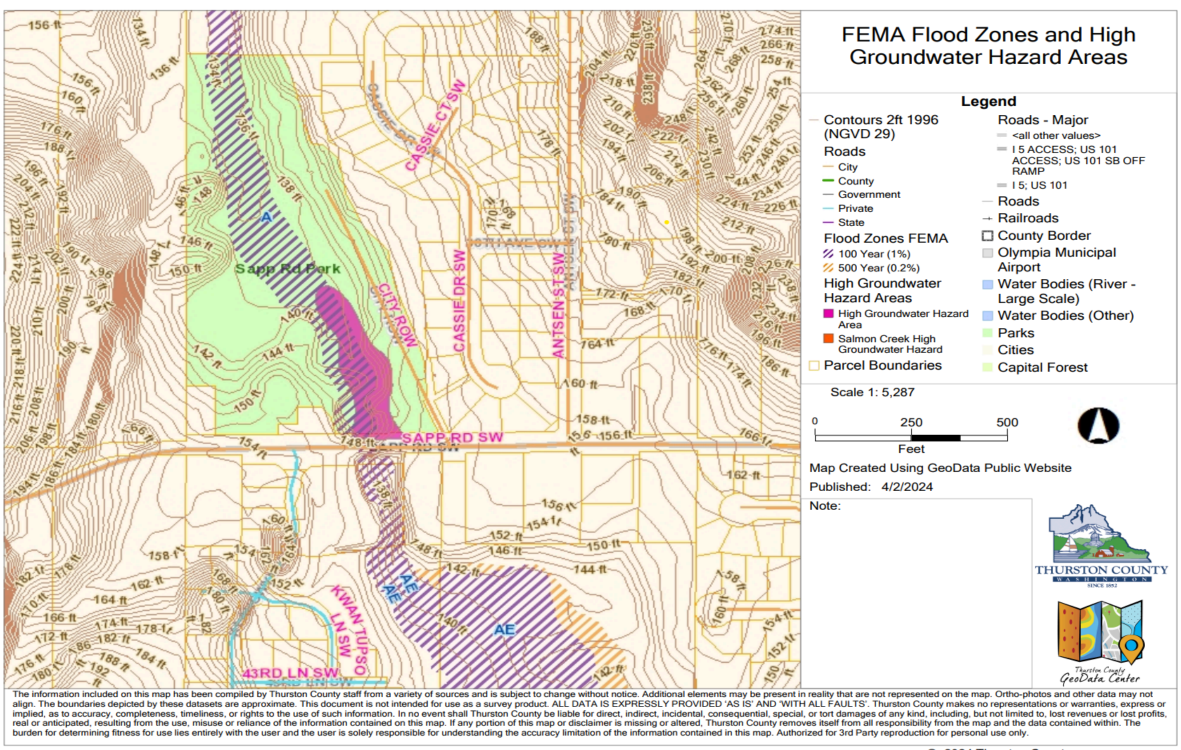




Figure 9: FEMA flood zones at SRP. The 100-year floodplain is shown and a groundwater hazard area in the upstream section of the site is marked out.

*3.2 Vegetation results*

Reed canary grass and yellow-flag iris dominate the terraces on either side of Percival Creek and occupy much of the overall floodplain. NWI maps the streamside as a palustrine emergent vegetation community with seasonal inundation (Figure 10). This may partly explain the prevalence of the reed canary grass, since the spreading grass is well known to thrive in flashy hydroperiods where the water table fluctuates rapidly throughout the year. Yellow-flag iris disperses floating seed pods and is one of only a few invasive species robust enough to compete with reed canary grass, which might explain how it has taken over the streambanks.

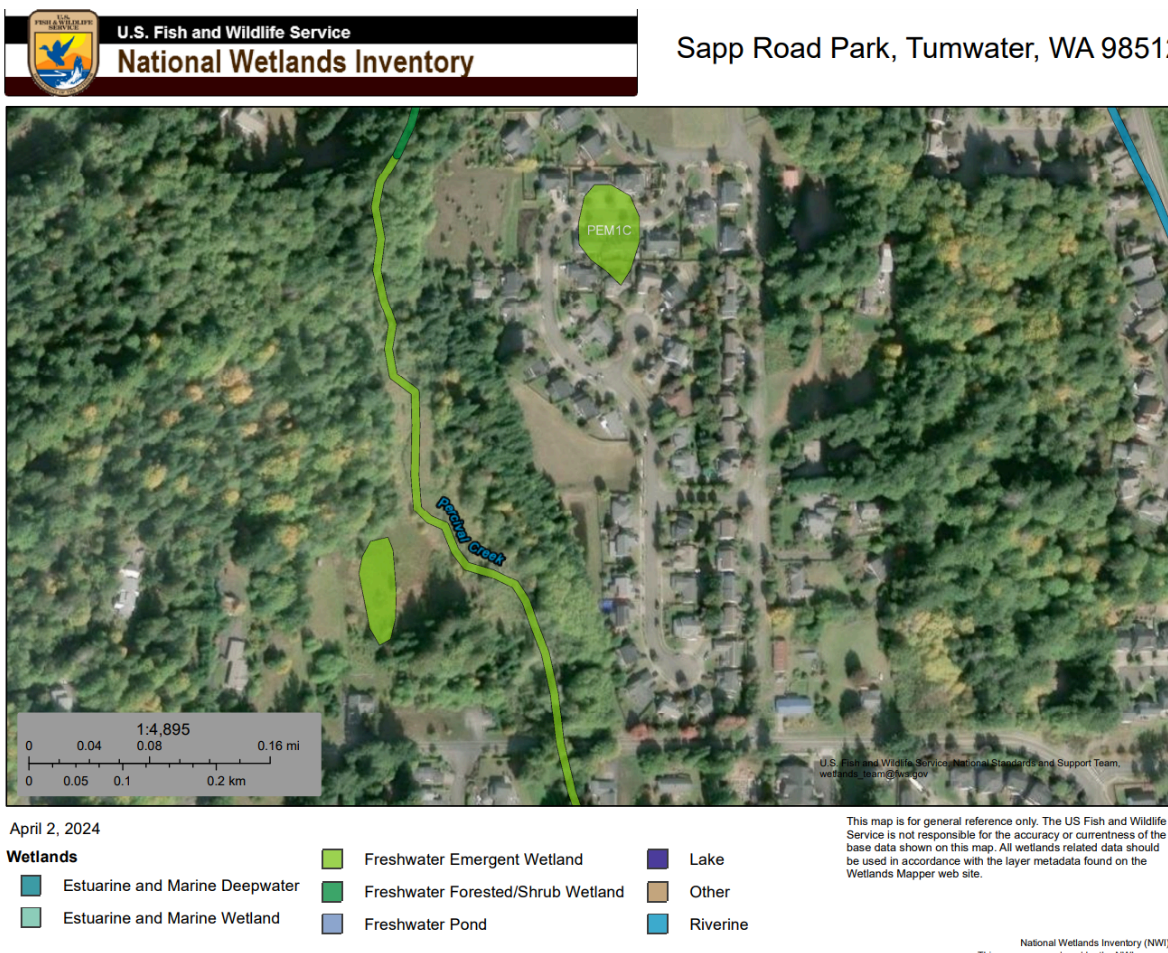


Figure 10: View of SRP through National Wetlands Inventory (NWI) mapping application. The wetland classification shown is out of date, one example being that wetlands are indicated where there is now clearly residential development. Furthermore, the mapping sharply underestimates the extent of the wetland at Sapp Road Park and divides it into two units, which is not supported by our field investigation.

Outside the invasive, co-dominant species along the creek, Sapp Road Park has diverse vegetation along the sides of the parcel and on either end (Appendix A: Vegetation Inventory), particularly on the northwest. The south end of the parcel near the culvert under Sapp Rd SW is forested wetland dominated by red alder with an understory of blackberry and reed canary grass (Figure 11). The west and northwest parts of the wetland are the most biodiverse, possibly because of the steady hydrology flowing off Bush Mountain(Figure 12).

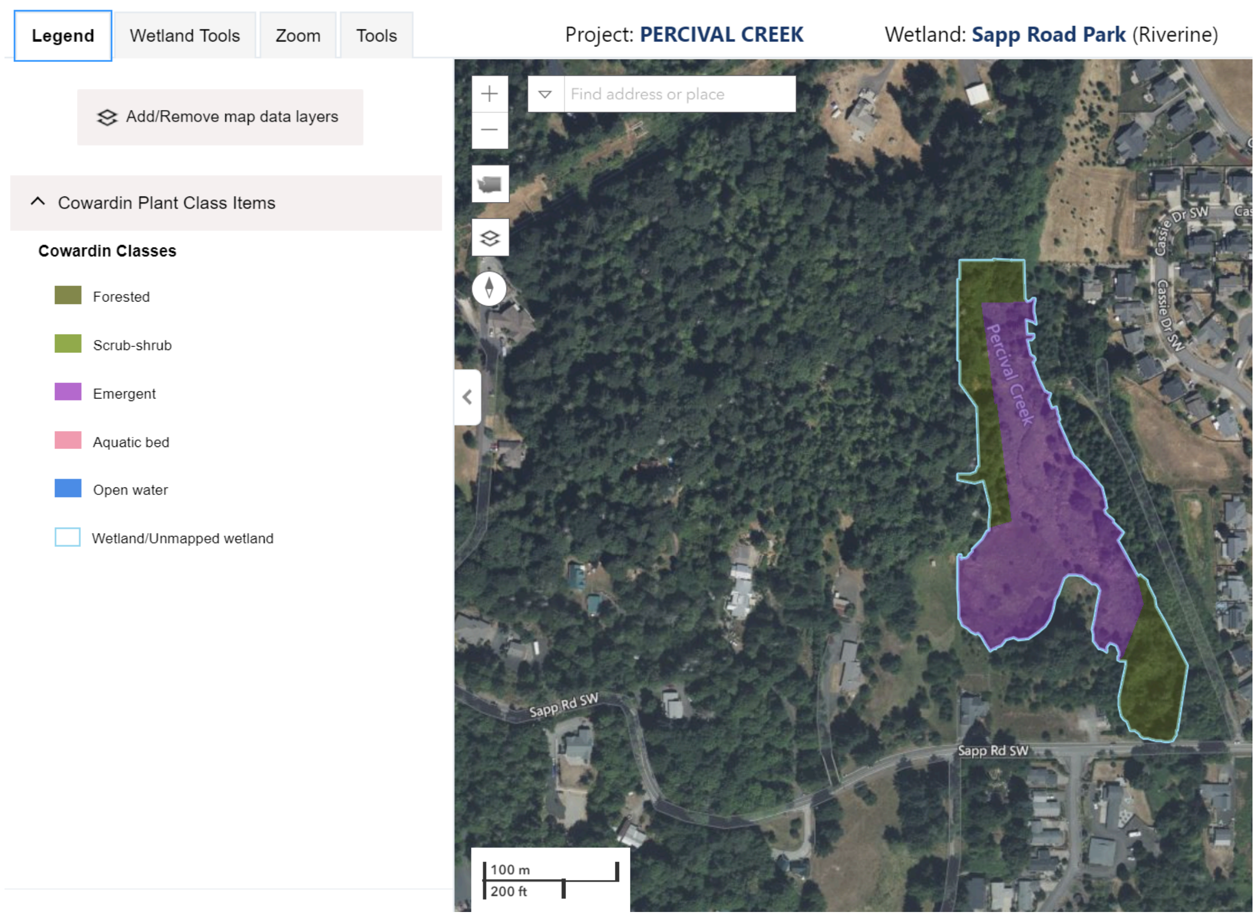


Figure 11: Cowardin plant classes in the wetland at Sapp Road Park. The midstream section is palustrine emergent vegetation dominated by reed canary grass and an isolated meadow of slough sedge. The downstream section to the north and upstream section to the south are both palustrine forested.

The northwest palustrine forested wetland is dominated by western red cedar and has a complex understory of Hardhack (*Spiraea douglassi*), Salmonberry (*Rubus spectabiliis),* Skunk cabbage, slough sedge, and other species. The cedars in this section are mature, with average trunk diameters of more than 30 inches.

The western sedge meadow hosts a variety of Carex species, soft rush (*Juncus effusus)*, Brooklime (*Veronica americana)*, Skunk cabbage, and small-fruited bulrush (*Scirpus microcarpus*). The meadow's biodiversity stands in sharp contrast to the streamside and could be explained by the presence of underlying soils.

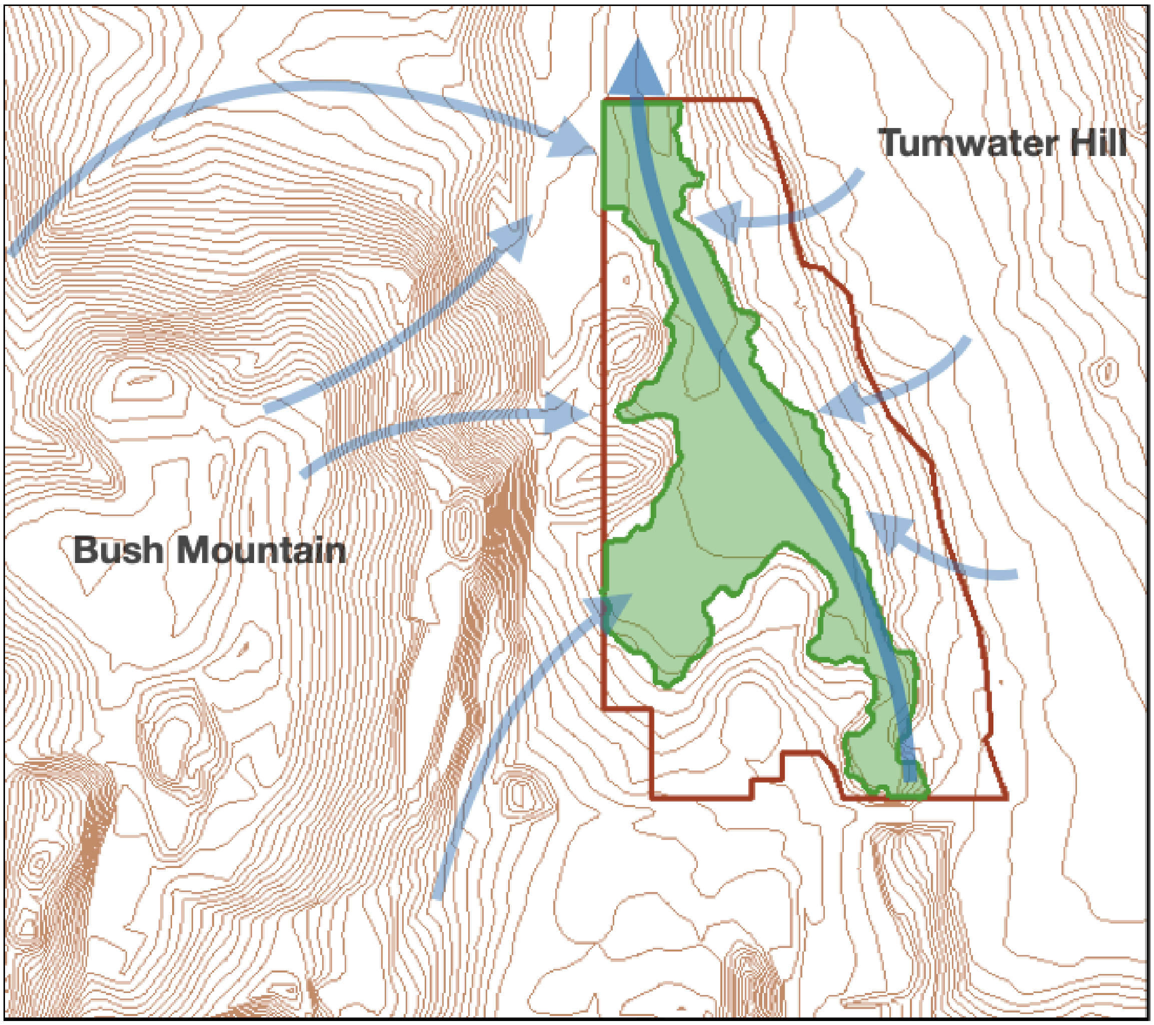


FIgure 12: Mid-scale topography and hydrology of SRP. Bush Mountain supplies a steady stream of surface and subsurface water to the wetland. The primary water input from the east is subsurface water from stormwater infiltration infrastructure. Figure adapted from Hastings 2024.

*3.3 Soil results*

According to the NRCS Web Soil Survey, the site is dominated by non-hydric Giles silt loam of various slopes along the course of Percival Creek and to the east of the parcel while hydric McKenna gravelly silt loam, 0 to 5 percent slopes, dominates the west and northwest corner of the parcel (figure 13).

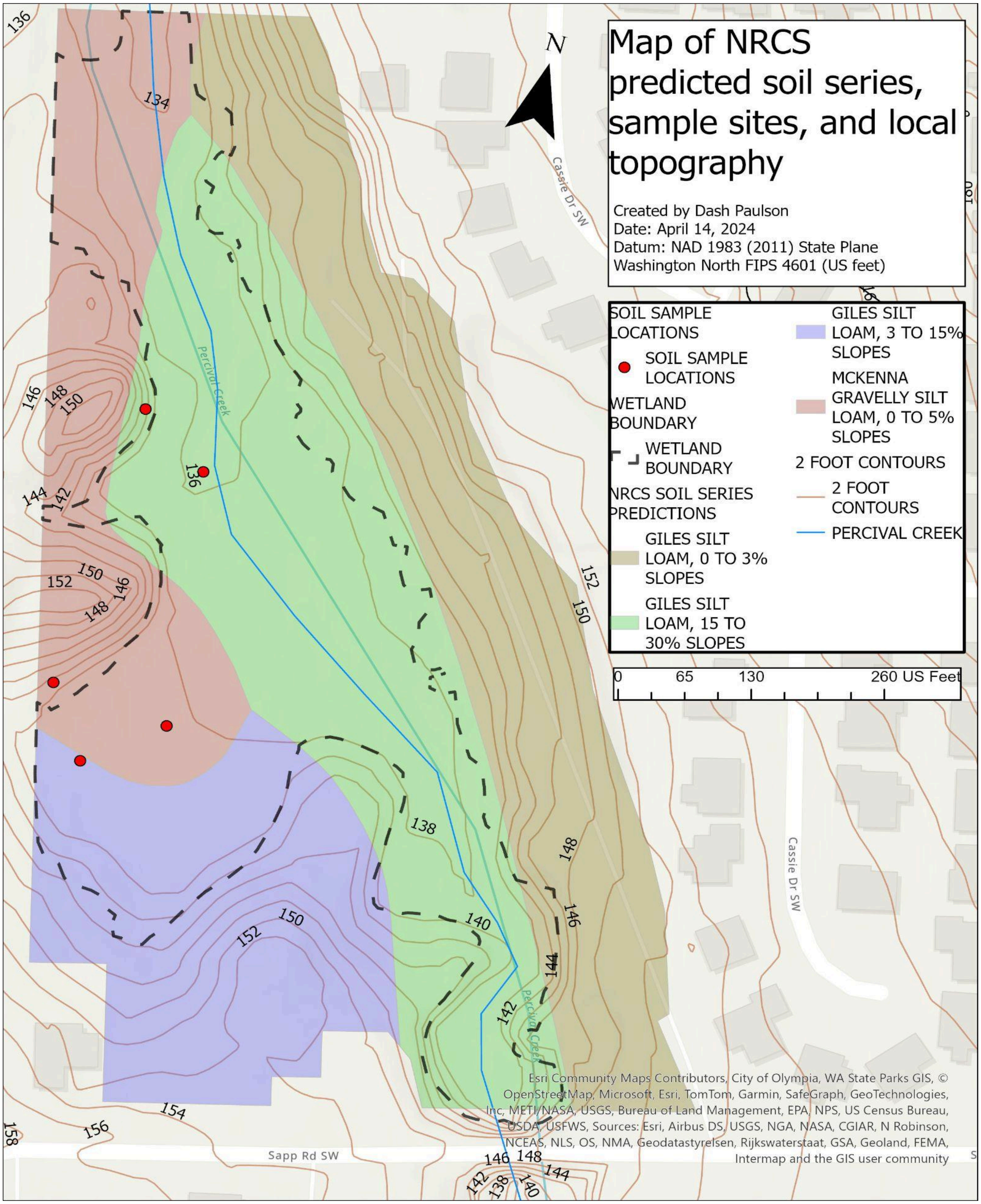


Figure 13: NRCS mapped soil series at Sapp Road Park and the wetland boundary. Soil sample pits marked in red. Soil pits revealed a sandier than expected top layer along the stream and in the sedge meadow.

NRCS describes the McKenna gravelly silt loam as “having a very slow infiltration rate (high runoff potential) when thoroughly wet” compared to the Giles silt loam, which is predicted to have “a high infiltration rate (low runoff potential) when thoroughly wet” i.e. high and rapid transmission of water. These properties may help to explain the surface water flowing from the northwest into Percival Creek. Water from seeps along the hillsides flow overland before saturating the west streamside.

The sedge meadow is underlain with McKenna gravelly silt loam and is largely isolated from overbank flooding because of a gentle rise in the land between the meadow and the Creek. This may be evidence that the streamside of Percival Creek is aggraded, probably from logging activity in the mid through late 1800s.

Numerous soil pits were dug throughout the site over the course of repeated field visits (Appendix B: USACE data forms).
Overall, the streamside soils were found to be surprisingly sandy with a layer of organics on top. The soils under the sedge meadow and between the forested to emergent transition zone were higher in silt with a much lower content of sand. Redox features were observed in all pits determined to be in the wetland.

*3.4 Beaver habitat analysis*

The site is packed with evidence of previous beaver activity. Relic beaver features, including piles of beaver chewed woody material, downed trees with beaver chew marks on stumps and logs, and deep, narrow canals emerging at right angles from Percival Creek (Photo collage 1). Previous studies of the site suggest the area was actively colonized by beavers in the early 2000s (2000-2005),This evidence strongly suggests beavers actively colonized the site at some point and under the right circumstances SRP would be good beaver habitat again.

Perhaps the most encouraging finding during site investigations that beaver may again colonize SRP was confirmation that beavers from upstream are already visiting the site on a regular basis.  Fresh beaver chew (several days to several weeks old) was identified throughout the site on every visit, particularly at the south end of the parcel in the stream near the culvert. Shrubs and trees had clear evidence of beaver herbivory up and down the parcel. It appears beaver are actively foraging at Sapp Road Park, but we found no evidence of an active den. The foragers are likely from wetlands south of the site that support a colony of beavers known to the City of Tumwater and confirmed by drone photography (photo 2).

Photo 2: Aerial photograph of wetland immediately south of Sapp Road Park. The yellow arrow indicates what may be a beaver lodge. Percival Creek runs through this site as well, but has been impounded and redirected, resulting in a beaver meadow where most flat ground has been inundated with shallow water. The beavers foraging at Sapp Road Park are likely coming from this site.

This nearby colony could be related to the beavers who once occupied SRP and they are the most likely source of juvenile beavers in the area who could migrate to the site and adopt any low-tech structures installed on the site. Another scenario could be that the whole upstream colony might add SRP to their territory, particularly if the culvert replacement slated for 2025 leads to better stream connectivity under Sapp Road SW.

Photo collage 1: Evidence of past beaver activity and current herbivory. Beginning with bottom left image and moving clockwise: a felled tree near Percival Creek possibly from the early 2000s, a large pile of sticks near the stream, possibly remains of a dam, another pile of beaver chew near the stream, recent herbivory by beavers on the site near the culvert.

*3.5 Low-tech PBR suitability assessment*

SRP is a good candidate for a low-tech restoration strategy. The steep sides of the valley can hold large quantities of water in the case of a flood event; low relief along the stream reduces the chance of blowouts; evidence of previous beaver herbivory indicates the area has been colonized before and could be again; site managers (the City of Tumwater) have indicated an openness to experimenting with the techniques detailed in the Design Manual and they have experience monitoring and managing beaver activity.

There are some caveats to the suitability of the site: Percival Creek has relatively low stream power (less than 20 cubic feet/second flow) so any design to harness channel bank erosion may be limited most of the year. Flood events in this case would be important drivers of channel complexity. Furthermore, the creek may not be incised so much as the floodplain is aggraded (Chris Jordan, NOAA, personal communication), which would complicate the restoration process. Further site assessments should prioritize digging several pits to at least 3-feet deep along the stream on the east and west sides and determine if the sandy silt loam in the upper layers was deposited on hydric soils which lie further down.

WIth these limitations in mind, trial installation of one to several beaver dam analogs (BDAs) and or post-assisted log structures (PALs) at Sapp Road Park is recommended as a low cost method for restoring wetland functions. The general principles behind this method and two possible complex designs are described further in this report in sections 6 and 7.

# 4.0 WETLAND RATING

*4.1 Summary of results*

The wetland was characterized according to the Washington Wetland Rating System for Western Washington. Sapp Road Park (SRP) was determined to be a Category II wetland with high scores (both 8/9) for improving water quality and hydrologic functions and demonstrated a medium score for habitat (6/9) due to local habitat fragmentation. A copy of the completed rating forms can be found in Appendix E. Copies of the WATOR figures used to complete the rating can be found in Appendix F.

The wetland at SRP scored notably high for improving water quality because of its listing within the Thurston County TMDL for the Deschutes River and tributaries to Capitol Lake and the level of pollutants likely to enter the stream. The hydrologic score was high because of the potential for overbank storage in the case of flood event and the density of vegetation that can slow down water and capture sediment. The habitat score was relatively lower than the other attributes because of serious habitat fragmentation within 1 km of the wetland.

## RATING SUMMARY - Western Washington

**Name of wetland (or ID#):** Sapp Road Park **Date of site visit:** 12/15/2023

**Rated By:** Dash Paulson **Trained by Ecology? Yes** [ ] **No** [X] **Date of Training:** N/A

**HGM Class used for rating:** Riverine

**Wetland has multiple HGM classes? Yes** [ ] **No** [X]

**NOTE: Form is not complete without the figures requested** *(figures can be combined).*

**Source of base aerial photo/map:**

**OVERALL WETLAND CATEGORY:** [**Category II**] (based on functions [X] or special characteristics [ ])

**1. Category of wetland based on FUNCTIONS**

[ ] **Category I** - Total score = 23 - 27
[X] **Category II** - Total score = 20 - 22
[ ] **Category III** - Total score = 16 - 19
[ ] **Category IV** - Total score = 9 - 15

| FUNCTION | Improving Water Quality | Hydrologic | Habitat | |
|---|---|---|---|---|
| Site Potential | M | H | M | |
| Landscape Potential | H | M | L | |
| Value | H | H | H | **Total** |
| **Score Based on Ratings** | 8 | 8 | 6 | 22 |

**Score for each function based on three ratings**
(order of ratings is not important)

| | |
|---|---|
| 9 = H,H,H | 6 = M,M,M |
| 8 = H,H,M | 5 = H,L,L |
| 7 = H,H,L | 5 = M,M,L |
| 7 = H,M,M | 4 = M,L,L |
| 6 = H,M,L | 3 = L,L,L |

Table 2: Wetland Rating and function scores for Sapp Road Park. Figure produced by the Washington Department of Ecology's WATOR Web Application on March 3, 2024.

## 5.0 REGULATORY SETTING

*5.1 Federal regulations*

Percival Creek discharges into Capitol Lake, located in the Puget Sound's Budd Inlet, a clear surface connection to Waters of the United States (WOTUS). According to the Sackett Decision, wetlands are part of WOTUS when they exhibit a "continuous surface connection to bodies that qualify as 'waters of the United States' in their own right, so that there is no clear demarcation between 'waters' and 'wetlands'." (Sackett v. EPA, 598 U. S. (2023). Many activities, including construction, development, or restoration on or near wetlands connected to WOTUS will be regulated under the Clean Water Act (CWA 1972) section 404 (33 U.S.C. § 1341 SEC. 404), which regulates the discharge of dredged or fill material into WOTUS. Therefore SRP, which contains delineated wetland over more than half its surface area and abuts Percival Creek is likely under the jurisdiction of the United States Army Corps of Engineers (USACE) and any action resulting in dredge or fill in Percival Creek will require a 404 permit from USACE.

According to the National Marine Fisheries Service (NMFS) web-based mapping tool, the Creek provides Essential Fish Habitat (EFH) for harvestable Chinook (*Oncorhynchus tshawytscha*) and Coho salmon juveniles (*Oncorhynchus kisutc*h). NMFS oversees EFH nationally under § 2. 104-297. (7) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). Since Coho and Chinook are both listed under MSA and the site is mapped for EFH, SRP is likely under the jurisdiction of NMFS, otherwise known as NOAA. Under the Coastal Zone Management Act (CZMA), NMFS must coordinate with state agencies in WA concerning projects in counties with a marine shoreline, which includes Thurston County, and in practice the CZMA is administered by the Washington Department of Ecology (WECY) on behalf of NOAA.

If a project on site requires a federal permit like the 404, it also requires an investigation to determine the presence or absence of federally listed species as set forth in the Endangered Species Act (ESA). SRP does not directly overlap observed habitat for any threatened or endangered terrestrial species, according to the US Fish and Wildlife (USFWS) IPaC web application map. However, the parcel is within the range and could provide habitat for several ESA listed species including Chinook salmon, Taylor's Checkerspot butterfly (*Euphydryas editha taylori*), Oregon spotted frog (*Rana pretiosa*), Yellow-billed cuckoo (*Coccyzus americanus*), and Olympia Mazama pocket gophers (*Thomomys mazama pugetensis*).

The presence of various salmonid species in Percival Creek also implies that the local Squaxin Island Tribe, the Nisqually Tribe, and the Puyallup Tribe should be consulted before any project proceeds at Sapp Road Park given their treaty rights to fish and hunt within their usual and accustomed grounds (Figure 14). Tribal expertise can also prove hugely beneficial to overall project design and for reviewing potential impacts.

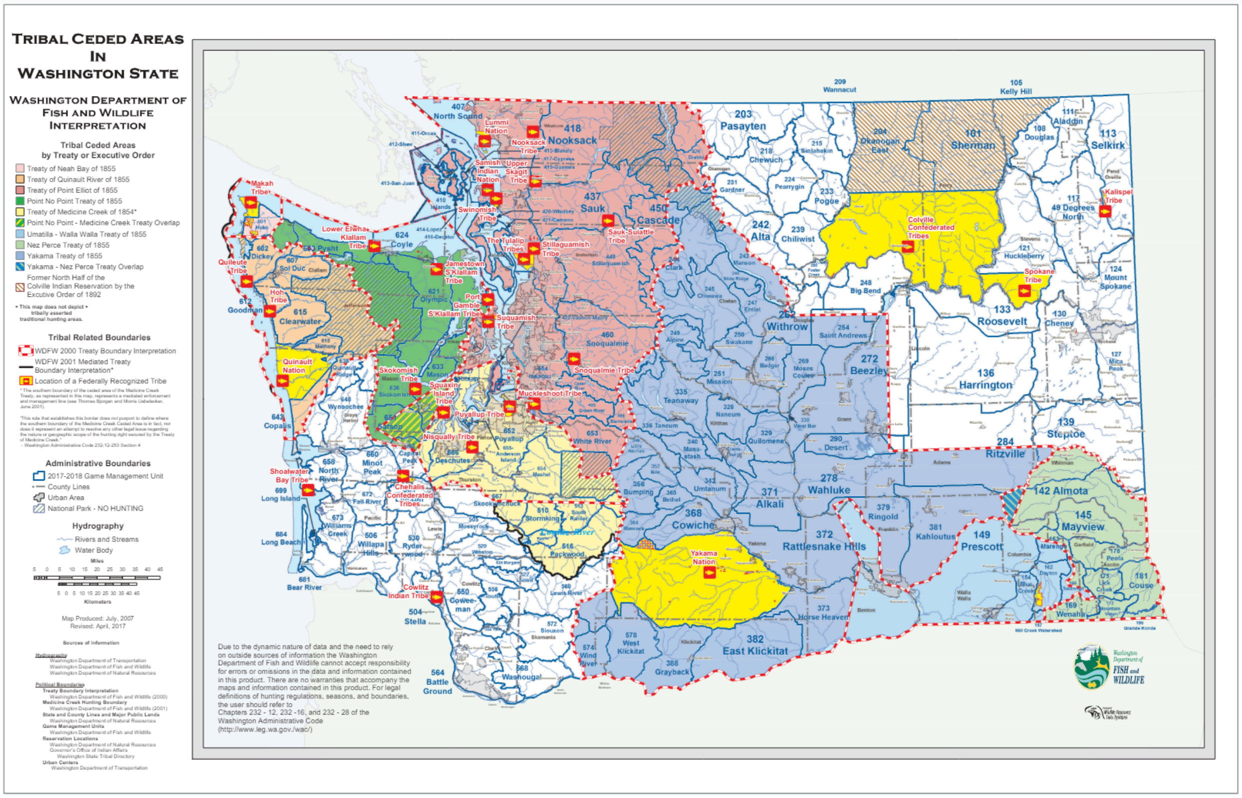


Figure 14: North Creek Park lies within land ceded by the Tribes party to the Treaty of Medicine Creek in 1854. The park may lie within the usual and accustomed fishing and hunting grounds of the Squaxin Island Tribe, the Nisqually Tribe, and the Puyallup Tribe. Percival Creek, as a salmon bearing stream, represents a traditional resource for the Tribes, as established in the treaty and upheld in the 1974 Boldt Decision.

### *5.2 Washington State regulations*

Any project that requires a 404 permit from USACE will also require a Water Quality Certification under CWA section 401 (33 U.S.C. § 1341 SEC. 401) from the Washington Department of Ecology, which administers section 401 in Washington.

Percival Creek and associated wetlands are considered waters of the state under the Water Pollution Control Act (Revised Code of Washington [RCW] 90.48.020), which is administered by WECY. Percival Creek is also regulated as a water of the state under the Hydraulic Code (RCW 77.55), which means the Washington Department of Fish and Wildlife (WDFW) is authorized to approve or deny projects within, under, or over waters of the state in order to protect aquatic species and their habitat through a Hydraulic Project Approval (HPA).

SRP is mapped by WDFW as providing habitat for big brown bats (Eptesicus fuscus) and little brown bats (Myotis lucifugus) which are listed in WDFW's Priority Habitat and Species Program (WAPHS).  There are no state PHS regulations, so this is not a source of regulatory obligations for SRP, but WAPHS is a valid source of best available science for the Washington Growth Management Act (GMA) and thus relevant to any site project.

Any action affecting environmental quality at SRP will require a comprehensive review of impacts as set forth in RCW § 43.21 under the State Environmental Protection Act (SEPA). The SEPA review process provides necessary information for agency decision-makers, applicants, and the public regarding any impacts to the environment from actions taken at the site.

*5.3 Local jurisdiction*

SRP is zoned within the City of Tumwater as a mixture of open space (TMC § 18.31) and residential/sensitive resource (RSR, TMC § 18.08) and any development on the site would be subject to these zoning ordinances. Further, the presence of wetlands on SRP, fish habitat, and its position in a special flood hazard zone mean the City of Tumwater is beholden to its own Wetlands Protection Standards Ordinance (TMC §16.28), Fish and Wildlife Habitat Protection Ordinance (TMC § 16.32), and Floodplain Overlay Ordinance (TMC § 18.38). However, SRP is not within Tumwater's shoreline jurisdiction according to WAC 173-18-38 probably because the stream's average flow is below 20 cfs/sec.

According to TMC § 16.28.090, wetlands within the City of Tumwater are rated according to the Washington State Wetland Rating System for Western Washington (Hruby and Yahnke 2023) meaning local standards are in line with WECY best available science BAS. Under this rating system, SRP is rated as a Category II wetland with water quality and hydrologic scores of 8 and a habitat score of 6 for a total wetland functions score of 22. The wetland would thus be entitled to a buffer of 150 feet, according to TMC § 16.28.170(2), which is based directly on WECY Best Available Science.

| Regulation | Permit | Implementing Agency | Applicability to SRP if action would fill or alter a portion of the wetland i.e. installing low-tech structures |
|---|---|---|---|
| **US FEDERAL GOV** | | | |
| Clean Water Act (CWA) | Section 404 Permit | U.S. Army Corps of Engineers | Any discharge of fill or dredged material into a water of the U.S. (including wetlands) requires a permit. |
| Clean Water Act (CWA) | Section 401 Water Quality Certification | Washington Department of Ecology (WECY) | Any application for a 404 permit triggers a 401 Water Quality certification. |
| Endangered Species Act (ESA) | Biological Opinion | US Fish and Wildlife (USFWS) and National Marine Fisheries Service (NMFS) | SRP contains potentially suitable habitat for ESA listed species. |
| Magnuson-Stevens Act (MSA) | Letter of concurrence | National Marine Fishers Service (NMFS) | SRP is mapped as providing EFH for harvestable species. |
| Coastal Zone Management Act (CZMA) | Letter of concurrence | Washington Department of Ecology (WECY) | Site is within Thurston County, one of 15 WA counties with a marine shoreline. |
| **WA STATE**[LD1] | | | |
| WA State Hydraulic Code RCW 77.55 | Hydraulic Project Approval (HPA) | Washington Department of Fish & Wildlife (WDFW) | An HPA is required for any project that would alter any water of the state, including wetlands, and ensures fish and aquatic habitats are protected from project impacts. |
| Washington State Growth Management Act (GMA) RCW 36.70A | City of Tumwater permits (see below) | City of Tumwater | SRP is mapped as a critical area under comprehensive growth management plan developed by City of Tumwater as mandated by GMA. |
| Washington Pollution Control Act RCW 90.48 and WAC 173-201A | JARPA | Washington Department of Ecology (WECY) | SRP is waters of the state and is thus WPCA regulates any physical, chemical, or biological alterations of those waters. |
| State Environmental Protection Act (SEPA) RCW § 43.21 | SEPA Review | Washington Department of Ecology (WECY) | The SEPA review process provides necessary information for implementing agencies, applicants, and the public regarding environmental impacts from proposed actions taken on site. |
| Priority Habitat and Species program | NA | Washington Department of Fish & Wildlife (WDFW) | Provides best available science for GMA implementation and decision making. |
| **LOCAL (City of Tumwater)** | | | |
| Wetlands Protection Standards Ordinance TMC §16.28 | Critical Areas Permit | City of Tumwater | Any development on or near wetlands or their associated buffers requires a permit from the City of Tumwater. |
| Fish and Wildlife Habitat Protection Ordinance TMC § 16.32 | City approval per § 16.32.070(k) | City of Tumwater | Any development on a site that supports protected fish or wildlife habitat requires approval from the City of Tumwater. |
| FP Floodplain Overlay Ordinance TMC § 18.38 | Floodplain development permit | City of Tumwater | A floodplain development permit is required for any project undertaken in the 100-year floodplain, which includes most of SRP. |

Table 3: A summary of the federal, state, and local regulations, permits, and implementing agencies that would be involved in a proposal to fill or alter a one-acre portion of the wetland at Sapp Road Park.

# 6.0 LOW-TECH PROCESS BASED RESTORATION

*6.1 Structural starvation in American streams*

Prior to European colonization, streams and wetlands in North America were packed with woody material, home to beavers, and interconnected to their floodplains (Burchsted 2010). Obstructions in streams and prolific beaver activity created a dynamic mosaic of ponds, wetlands, marshes, swamps and braided streams. In most regions, water moved more slowly over the landscape than today and supported diverse and dynamic habitats. Along with the near extirpation of beavers in the 1800s, these complex features have been mostly removed from North American streams. Approximately 79% of 3.3 million miles of riverscapes in the contiguous US have been altered by human activity, more than 50% of wetlands have been lost since the 1780s, and less than 2% of US streams could be considered to be in pristine condition (Graf 2001; USFWS 2024).

This trend has contributed to a crisis in the health of national streams. More than one third of US streams are officially listed as polluted or impaired by the EPA. More than 70% of riparian forests have been removed or degraded, and flood-storage capacity has been severely reduced by loss of floodplain connectivity and urbanization (Wheaton et al. 2019). The poor condition of US streams has driven enormous investments in river and wetland restoration across the country. Typically, river and wetland restoration is a multi-million dollar investment requiring years of detailed planning and expert consultation. This traditional approach is critically important for restoring highly degraded wetlands and streams, particularly in urban environments, but it lacks scalability. There are too many degraded streams and wetlands in the US that cannot be prioritized for this kind of high cost, time intensive investment.

However, low-tech PBR is an inexpensive alternative built on the principle of “letting the system do the work.” The system in this case being stream power, natural processes like erosion and deposition, and biological agents like beavers. Low-tech PBR is organized around ten guiding principles (Figure 15), which are categorized by riverscape ideals and restoration philosophy. The riverscape principles inform planning and design by defining a healthy, functional riverscape as fundamentally requiring space, structure, and inefficient conveyance of water. The Restoration principles relate to specific actions that can be taken on a project to initiate and promote processes that lead to recovery and resilience (Wheaton et al. 2019).

It bears noting that central to this approach is a healthy respect for the eco-engineering benefits of beavers. In many situations, low tech PBR is most successful when the processes initiated by the initial work become self-sustaining, and the best way to ensure that is through beaver colonization of a landscape and adoption of the structures. This report’s focus precludes a deep dive into the many benefits of beavers in an ecosystem, but these aspects are covered in one of four companion papers to this report (Baker 2024; Hastings 2024; Harris 2024; Sowers 2024).

**LOW-TECH PROCESS-BASED RESTORATION PRINCIPLES FOR STRUCTURALLY-STARVED RIVERSCAPES**

**Riverscapes Principles**

1. Streams need space
2. Structure forces complexity and builds resilience
3. The importance of structure varies
4. Inefficient conveyance of water is healthy

**Restoration Principles**

5. It's okay to be messy
6. There is strength in numbers
7. Use natural building materials
8. Let the system do the work
9. Defer decision making to the system
10. Self-sustaining systems are the solution

Figure 15: Low-tech PBR's ten guiding principles, divided by riverscape assumptions and restoration philosophy. Adapted from the low-tech PBR Design manual (2019).

### *6.2 Low-tech structures: BDAs and PALs*

Historically, large wood and beaver dams were ubiquitous in North American streams, but have been systematically removed. This has led to simplified, degraded streams that provide severely limited functions for surrounding communities. One strategy for reversing this degradation may lie in returning in-stream structures to the landscape and allowing them to exist and persist. One version of this nature based approach has been condensed in the "Low-Tech Process Based Restoration of Riverscapes: Design Manual", published by Utah State. This resource strongly informs the rest of this report and will be henceforth referred to as the Design Manual or low tech PBR. The low tech structures or "recipes" documented in the Design Manual are inspired by spontaneous log jams and beaver dams. These instream structures are organic, complex, permeable, and transient. As in pristine ecosystems, they are most effective when numerous and dense within a particular reach. Therefore the design of individual structures is rapid and does not require high resolution hydraulic, hydrologic or topographic data (Wheaton et al. 2019). The complex sum of the structures is more functional than the individual parts.

The function of low-tech structures is to slow down or temporarily impound water and sediment, which forces hydraulic changes that lead to hydrologic and geomorphic impacts in and around the stream. Hydraulic change here refers to the depth and velocity of water, which drives hydrology and geomorphic responses (Wheaton et al. 2019). Hydrologic changes refers to the timing and magnitude of water movement through the landscape. Geomorphic changes include the topographic forms created from changes in erosion and deposition patterns that follow from hydraulic changes. Low-tech structures influence these processes depending on their specific form, position in the landscape, and density along a stream reach.

In general, the Design Manual recommends a mix of PALs and BDAs to achieve restoration goals at a site, if the area is judged to be a good candidate for this type of restoration. PALs typically require less time and money to build than BDAs so more PALs can be built for a given amount of funding. PALs are effective at wood accumulation, promoting channel widening, and stream aggradation, therefore halting and even reversing stream incision (Wheaton et al. 2019). BDAs can quickly increase the local water table and activate relic channels, promoting floodplain connectivity and channel avulsion. Ultimately, the particular goals of the restoration project and conditions on the ground should guide the design of individual structures, but the density of the chosen structures within a given reach should be maximized when possible to produce best results.

*6.3 How BDAs work*

Beaver mimicry is not a new concept. An early documented case of people harnessing beaver dams can be found in Eric Collier's book "Three Against the WIlderness" published in 1959, but set earlier in the 1920s and 30s. The memoir documents Collier's family's efforts to repair abandoned beaver dams on their land in British Columbia. The improved water tables attracted more game and helped the family to survive the harsh winters before beavers were reintroduced to the area and took over the dam maintenance.

BDAs are fundamentally intended to mimic beaver built structures. The Design Manual defines a BDA as "a permeable, channel spanning structure with a constant crest elevation, constructed with a mixture of woody debris and fill material to form a pond and mimic a natural beaver dam."

Beavers typically build two types of dams: tall primary dams and shorter secondary dams. From a beaver's point of view, the goal of a primary dam is to create a pond that can sustain a lodge with an underwater entrance and is ideally surrounded by water on all sides (Wheaton et al. 2019). Usually a primary dam's crest elevation is equal to or greater than the bankfull elevation. A secondary dam will often have a crest elevation at or below bankful and its purpose is to either extend deep water to new foraging locations and/or back water up to the base of the primary dam to reduce the hydraulic head. Most BDAs are built to mimic the effects of primary dams (Wheaton et al. 2019).

Beaver dams create deep, slow-moving water upstream (hydraulic process), typically known as beaver ponds. The weight of these ponds significantly increases hyporheic exchange and increases the frequency and magnitude of upstream overbank flooding. These hydrologic processes in turn force geomorphic processes like channel aggradation upstream, bar formation, bank erosion, and channel avulsion (Wheaton et al. 2019). Most of these changes increase water storage and residence time on the site, reduce downstream flooding, and provide complex, heterogeneous habitat for numerous plant and animal species (Fairfax and Jordan 2023).

The fate of a beaver dam or BDA depends on flow conditions, sediment regime, beaver activity, and/or maintenance by restoration practitioners. Typical outcomes include blowouts (complete loss of BDA), breach (failure of the mid-section or either end), sedimentation (beaver meadow), intact and holding water, or intact but not holding water (functioning more like channel spanning PAL). Each outcome represents a transformation of function that increases stream complexity and usually results in more diverse hydroperiods, and increased habitat heterogeneity.

### *6.4 How PALs work*

PALs mimic log jams and are excellent at promoting wood accumulation and increasing water roughness. These large wood structures can be designed with posts or as postless. It is common for PALs to increase in size over time as they rack up wood floating downstream and in some instances they can capture enough bedload to bury the main stem and force channel avulsion around the structure. They are usually faster and cheaper to install than BDAs while creating more variable flow patterns instream.

PALs can be categorized by their initial position in the stream: Bank-attached, mid-channel, and channel-spanning. They should be built to a height and size that is necessary to achieve project objectives. The orientation of a PAL is important; channel-spanning PALs are usually perpendicular to stream flow, mid-channel PALs can be perpendicular or parallel to stream flow, and bank-attached PALs are usually angled upstream, downstream, or perpendicular to achieve different effects.

Different PALs lead to different processes. Bank-attached PALs force convergent flow, shunting water to the opposite side of the stream and creating eddys upstream, which contributes to bank erosion, scour pool formation, sediment sorting, and channel bar formation. Mid-channel PALs force stream flows to separate, creating an eddy in the lee of the structure and promoting erosion, sediment sorting, and water roughness. Channel-spanning PALs can perform similar functions to a BDA, like backing up water and creating ponds upstream and plunge pools downstream, promoting channel aggradation and avulsion.

Different structures can be designed to affect different processes during different flow conditions, but there is no ideal LT structure. LT structures are meant to be dynamic, temporary features that initiate changes to the landscape and ultimately fragment into that landscape.

### *6.5 Designing a complex*

BDAs and PALs should be designed as part of a larger-scale project that includes many similar structures working in concert (Wheaton et al. 2019). Individual structures can have a local influence, but they are unlikely to achieve site-wide restoration goals unless they are part of an interconnected system. Building a diverse array of structures accommodates variability and uncertainty in stream flows and is more likely to promote restoration of degraded processes (Wheaton et al. 2019).

According to the PBR design manual (page 167), a complex “is a group of structures, often between 2 and 15…that are designed to work together….Like natural beaver dam complexes, [they] are more likely to influence hydrologic and geomorphic processes when built in clusters.”

Complexes can be designed to optimize different end goals. For example a collection of BDAs can maximize water storage and capture the most sediment, while a complex of just PALs will hold less water and sediment, but harness stream power more efficiently to erode channel banks and force avulsions (Figure 16).

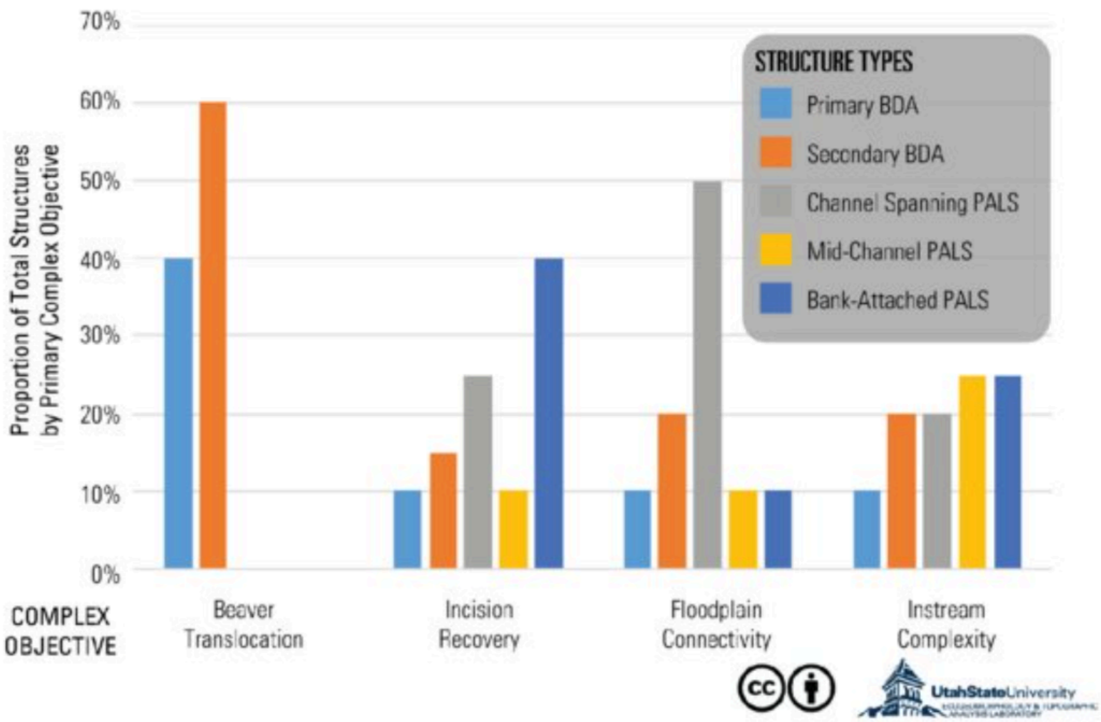


Figure 16: Conceptual depiction of how the distribution of structure types varies with complex objective. The types and number of structures relative to one another vary depending on the complex objective. Adapted from the low-tech PBR Design manual (2019).

Even with constant maintenance by beavers, dams will eventually break or blowout and be rebuilt or left to decay. This is a natural process that adds structure to streams, creates new habitat, and forces complex hydrologic and geomorphic changes.

Recognizing that the structures must function as an interdependent system, the question of where exactly to install structures and in what order must still be addressed.

This report undertook to select sites based on the same parameters that help predict dam-building behavior in beavers: watercourse depth, water depth, watercourse gradient, watershed size, valley floor width, and evidence of previous beaver structures (Rosell and Campbell-Palmer 2022). Research shows that beavers prefer to build their structures where a stream is most shallow (Hartman and Tornlov 2006) with channel width a secondary consideration. They also look for anchor points–a tree or large wood in-stream–that can give them a starting point and strengthen the dam.

In addition, topographic changes, meander bends along the current watercourse, relict beaver canals, and off-channel drainage from the surroundings were factored in, particularly with the designed placement of PALs, which are intended to force channel avulsions and change the course of the stream in contrast to BDAs which primarily function to trap water and sediment.

Furthermore, following the guidance of the Design Manual, the design process is left intentionally imprecise, since the actual structures built may be very different than the ones planned. During construction, the team installing the structures must “chase the water” as they go and modify the structure using organic, variable materials provided on-site (Chris Jordan, NOAA, personal communication). This means that any design plan is at best a suggestion that can guide but must not constrain the actual installation.

# 7.0 COMPLEX DESIGNS AND RECOMMENDATIONS

*7.1 The no intervention option*
The first option to consider for the site is the benefits and consequences of not intervening with natural processes.

Any restoration project requires ample time and money. Even a low-cost, field-based approach like PBR will still require an investment by the parcel owners, City of Tumwater.

A no-intervention approach is undesirable for three reasons: invasive RCG and Yellow-flag Iris are dominating the site and spreading their seeds downstream; channel incision is progressing and may become worse with time, which reduces the water that can be held at SRP and increases velocity downstream; beavers are less likely to recolonize the site while invasives dominate and channel incision makes dam building more difficult.

*7.2 Complex design A*
If the primary goal of of the restoration is floodplain connectivity, a mix of six to eight PALs to force channel avulsions behind three to four BDAs to trap sediment and aggrade the stream would be ideal (Figure 17).

Complex design A can be implemented piece-meal: A single BDA and one or two PALs could constitute an experimental sub-complex that could be installed in either the midstream section, downstream section or in-between. Based on results of the first sub-complex, further structures could be installed.

This design as whole or in part would benefit from implementation before the culvert replacement upstream along Sapp Rd SW because it could harness the turbulence from the work to force channel avulsions and capture the sediment released by construction, aiding site managers with their inevitable sediment capture responsibilities.

Percival Creek's low stream power is the largest source of error in this design because it may not provide enough power to force the desired channel avulsions. High flow events can ameliorate this potential problem.

For a closer analysis of the potential of this design to impound water and the GIS modeling performed in parallel to this report, see Nick Baker's "GIS Habitat Suitability Workflow for the North American Beaver (*Castor canadensis*) in the Deschutes Watershed, WRIA 13, & the City of Tumwater, WA" one of four companion papers to this report (2024).


Figure 17: Low-tech complex design A. The PALs would harness stream power to force overland flow, initiate bank erosion, channel avulsion and ultimately reverse stream incision and increase the stream's connection to the floodplain by aggrading the streambed. RCG would be disrupted and water tables would increase and stabilize.

*7.3 Complex design B*

If the primary goal is on-site water retention and enhancing beaver habitat, a series of five to eight long BDAs along the stream would be recommended (Figure 18). This design is adapted from Chaz Hastings (2024) who generously provided his own design for a low-tech complex based on his understanding of the processes and site goals.

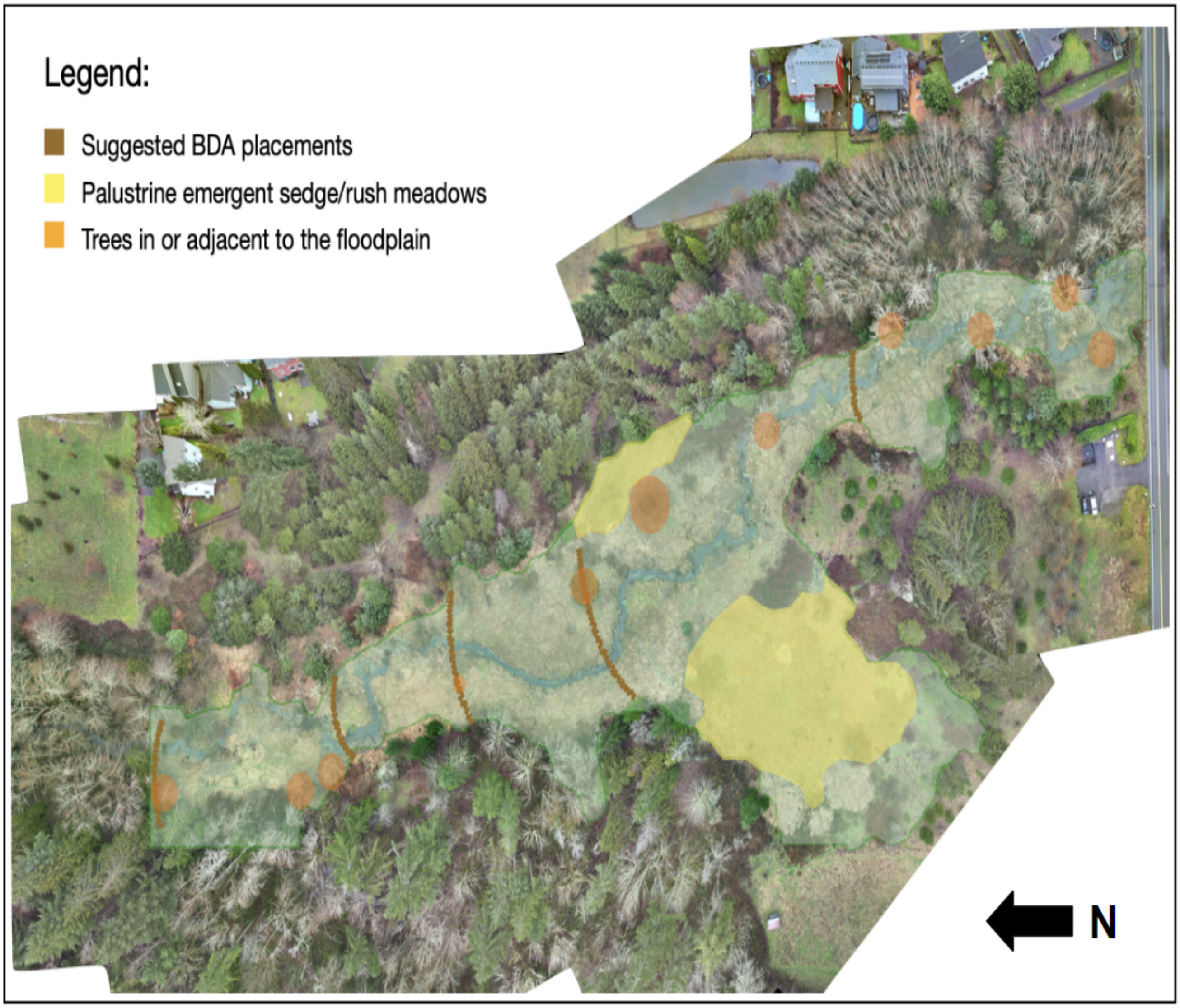


Figure 18: Low-tech complex design B. This BDA only design would increase ponding throughout the north half of the site. Adapted from Hastings 2024.

Design B resembles how beavers may eventually engineer the site to hold more water. Unlike design A, it is optimized for water storage and high water tables on site. The main challenge for this design is "chasing" the water across the floodplain with very long (hundreds of feet) BDAs that would probably have a relatively low crest elevation. This mimics how beavers may build low lying sod berms or earthen dams to create shallow ponds within their habitat.

*7.4 Design comparisons*
Design B would have the best chance of drowning out reed canary grass and attracting beaver, while Design A is optimized for channel avulsions and floodplain connectivity.

Design B is closer to a mature beaver complex, where water retention is maximized with many beaver structures. However, it may also require regular maintenance and high upfront cost in terms of labor and materials if humans undertake implementing the design. Design A is a more modest plan that can serve to initiate natural processes like bank erosion and provides a starting point for beavers who may adopt different parts of the complex and reform them. However, design A would store less water and do less to disrupt the reed canary grass on site.

The differences between the two designs help to emphasize that there is no single right way to design a PBR low-tech complex. Structure placement and density can be optimized for different end goals that incur different trade offs. Ultimately, it's hoped that a close comparison of the two designs will inspire a complex somewhere in between that is a best fit for site conditions, available resources, and stakeholder requirements.

In either case, the largest risk for any complex is upstream flooding (Figure 9) near the culvert at Sapp Road SW because of high groundwater levels. Therefore, it might be best to install structures on the upper half of the stream within the parcel. The sedge meadow depression on the west side of the parcel could serve as a valuable shallow basin for holding excess water during high flow events.

*7.5 Structure placement and design*
The guidelines for developing individual structures, both BDAs and PALs, are described in detail in the Design Manual (Chapter 4) along with schematics and instructions for basin installation procedures. This report does not attempt to dive into this process of individual design because the Design Manual itself recommends against over-engineering these individual pieces of the complex ahead of installation. The guidance recommends that "The design of individual structures is a rapid (3-5 minutes) process that does not require high resolution…data." In part, this stems from the on-site adjustments that must be made when structures are installed. The team that would be responsible for installing any structures at the site would have to work efficiently and impound the water as they go, keeping in mind that the water pressure will increase as they work and that the building process will have to respond flexibly and instantaneously to the changing conditions (Chris Jordan, NOAA, personal communication).

As stated, the intent of this report is to provide an introduction to low-tech PBR principles, evaluate their applicability to Sapp Road Park, and begin the design process (Figures 15 and 16). So it must be stressed that these plans are intentionally crude designs at crude locations in order for the treatment strategy itself to remain the principal focus, not the structures.

*7.6 Beaver adaptive management and monitoring*
People typically object to beaver activity for two main reasons: the risk of upstream flooding and damage to trees and shrubs. Simple and effective tools are available to address both of these concerns. Flood risk from beaver dams can be controlled with pond-levelers or exclusion devices (photo collage 2). These are simple, inexpensive structures that prevent beaver activity from causing hydrological damage to property, but they must be installed properly by trained individuals specializing in this type of work. Protecting vegetation is even simpler: steel fencing around the base of trees or shrubs, which can be installed by private citizens or contractors at minimal cost.

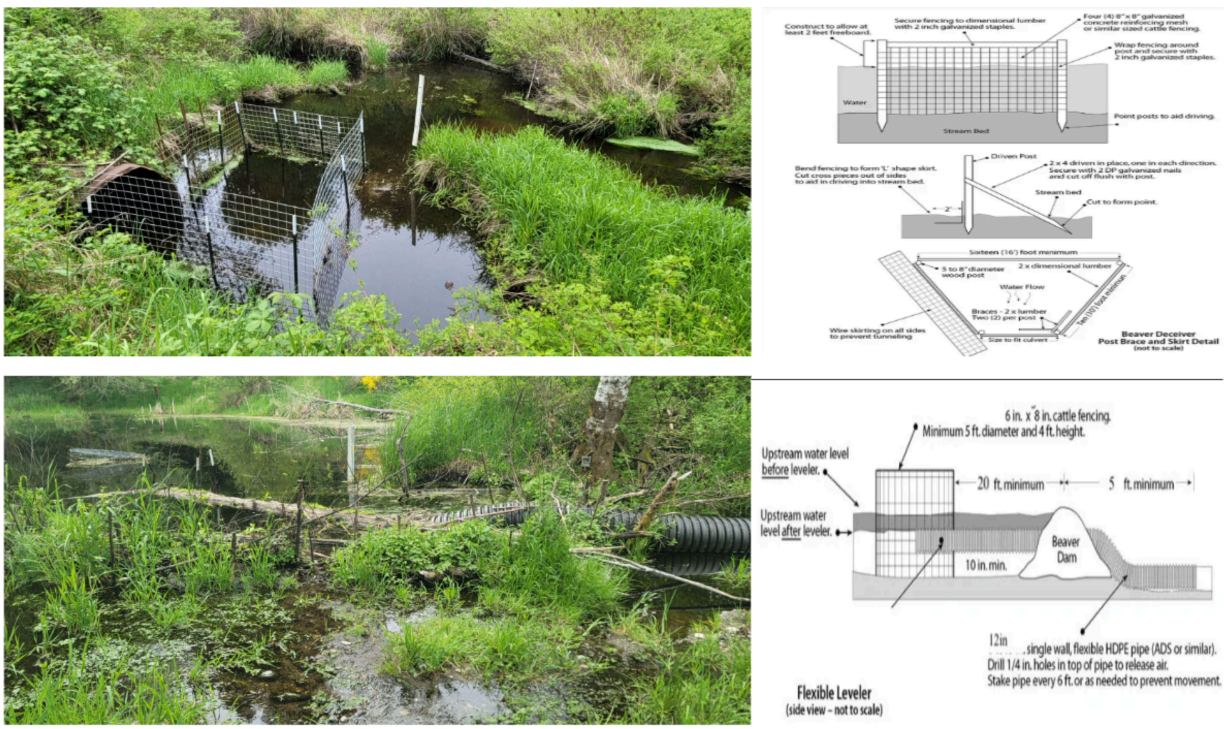


Photo collage 2: Beaver management devices. Top left: a beaver excursion device with a Z channel deployed to protect a culvert in Tumwater WA. Top right: schematics for beaver exclusion fencing adapted from BeaversNW.org. Bottom left: a pond leveler at work in Tumwater, WA o prevent flooding of private property. Bottom right: schematic of pond leveler from BeaversNW.org.

Beaver management tools and techniques can be deployed if and when there is a human-beaver conflict. SRP's steep sides on the east, south, and western sides protect infrastructure and property near the park. The main concerns would be the possibility of upstream flooding and BDA blowouts during flood events.

Therefore, consistent site monitoring will be a key component of any successful partnership with local beavers. This report recommends quick and inexpensive drone monitoring flights in both autumn and spring since these seasons coincide with beaver dam building activity and spring floods.  Beaver features (dams, lodges etc) and activity (tree felling) can be easily studied and assessed from an altitude below 400 feet and remote imagery can be acquired on a parcel like SRP in 10 minutes or less with a drone; far less time than required to walk the length of the parcel, particularly if much of the ground is inundated. Imagery acquired from drone flights will also allow land managers to document changes on the site and assess project outcomes. Signage should be considered for placement on and near the site that informs and educates residents of the beaver processes occurring. This signage should also include long-term contact information so residents can report perceived problems on site to the city.

*7.7 Bringing back the beavers*

Bringing back beavers or any wildlife species to a particular area is a complex task and success is never guaranteed. However, a common technique for encouraging beaver colonization is to recreate beaver habitat. The ponded water created by BDAs is attractive for beavers, who may take over the maintenance and expansion of the BDA. Beaver populations in western Washington have been increasing steadily since the early 2000s and the likelihood of beavers entering a site with enough water and enough food is very high (King County 2022), Once beavers colonize a site, their behavior will likely set off a cascade of ecological changes on site that will increase aquifer recharge, improve water quality, and enhance habitat, at little to no cost to landowners. The above recommendations, if implemented carefully and patiently, are likely to lead to these more ideal hydrological conditions for beavers.

It is assumed in these recommendations that the best agents to select dam sites that maximize habitat complexity and increase water water residence time are the beavers. Either complex design, and any low-tech design on the downstream section, should be intended as a temporary feature on the landscape of Sapp Road Park, meant to initiate natural processes like channel aggradation and floodplain connectivity. Ultimately, this study advocates that beavers should be allowed to take over the site's ecological fate and maintain it in perpetuity in a cycle of colonization, abandonment, and re-colonization. This approach has the potential to significantly boost the wetland's functions at a minimal cost to the city in terms of restoration design, implementation, and maintenance.

An ample food supply of native riparian vegetation would be necessary for a successful beaver colony and a highly desirable element in most riverine site restoration projects. While this paper focused on changing the hydrodynamics at Sapp Road Park, which will disrupt invasive plants and promote riparian vegetation, a specific plan for restoring vegetation at the site can be found in one of the four companion papers to this one (Harris 2024).

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