CHAPTER 3: AQUATIC ECOSYSTEMS

CHAPTER 3 **EXECUTIVE SUMMARY**

The waterways of the southern Washington Cascades contain vital habitat for a wide array of aquatic species. Increasing water temperatures, propelled by rising air temperatures and depleting snowpacks, are causing thermal stress to species, disrupting migratory patterns and impacting the physiological health of several anadromous species. These impacts are compounded by alterations in streamflow patterns, such as diminished summer flows and increased high flows in winter and spring, which will exacerbate habitat fragmentation, intensify competition, and increase mortality rates for fish. The extent and severity of current and expected impacts underscores the pressing need for accelerated conservation and restoration strategies to improve future conditions of aquatic habitats and their dependent species.

Specific strategies include:

- **Outstanding Resource Waters (ORW) designation:** The ORW designation under the Clean Water Act provides an extra layer of protection to unique, ecologically-important, and high-quality waters. We have identified high priority sections of three waterways—Upper Lewis River, Wind River, and Washougal River—that are potential future candidates for ORW consideration.

- **Wild and Scenic designation:** The National Wild and Scenic Rivers System was set up to protect the free-flowing nature of select river systems. Through a multi-step selection process considering past designation efforts, current risks, and amount of protection gained, we created two tiers of recommendations. Our Tier 1 recommendations include sections of: Clear Fork Cowlitz River, Cispus River, Yellowjacket Creek, Lewis River, and Wind River—all of which, except Yellowjacket Creek, are waterways that have already been formally recommended by the Forest Service for Wild and Scenic designation. Tier 2 includes sections of: Quartz Creek, Smith Creek, Siouxon Creek, Muddy River, and Clear Creek—which includes waterways that have been identified as eligible but not yet formally deemed suitable. Public support and community engagement will play crucial roles in elevating priority waterways through to designation.

- **Expand no-cut buffers for headwater streams on state and private lands:** We recommend a no-cut buffer of at least 75 feet on headwater streams to protect water quality and the health of imperiled aquatic systems.

- **Involvement in federal timber sales:** By actively participating in timber sale planning processes, the public can help mitigate degradation of aquatic habitats by advocating for increased no-cut buffers, reduced use of ground-based logging machinery near waterways, and harvest prescriptions that retain higher canopy cover percentages in critical areas.

- **Remove passage barriers and address habitat fragmentation:** Dams and under-sized culverts present passage barriers that reduce the distribution and quality of habitat for fish and put many species at risk. Dam removal is critical for improving the vitality of native fish species. Culvert upgrades are discussed alongside road survey recommendations in Chapter 2 where we highlight connectivity work that can benefit both terrestrial and aquatic species.

- **Road surveys to prioritize road restoration and reduction opportunities:** Conducting on-the-ground surveys of roads to prioritize them for closure or restoration can help the Forest Service address negative impacts from forest roads, such as habitat fragmentation and sedimentation issues.

- **Support and improve the Legacy Roads and Trails program:** The strategic use and continued funding of the Legacy Roads and Trails program can aid in addressing water quality problems stemming from the backlog of maintenance needs on road systems on national forest lands. This program would benefit from increased transparency and public involvement in project prioritization.

- **Enhanced monitoring for pollutants and plant and wildlife species:** Addressing the lack of monitoring of pollutants, temperature, sediment, and species distributions necessitates an increase in focus and funding for state-level monitoring programs.

- **Supporting beaver co-existence and carrying out beaver reintroduction:** We recommend strategic reintroduction of beavers to suitable river and wetland habitats, combined with community education and engagement to foster human-beaver coexistence. Surveys for instream restoration suitability can be tailored to capture information for future reintroduction potential.

- **Implementing low-tech, process-based restoration in low-gradient waterways:** In addition to engineered logjams and other large instream restoration projects, we recommend the use of low-tech, process-based restoration, such as beaver dam analogs (BDAs) and post-assisted log structures (PALS). This type of restoration is meant to mimic natural fluvial processes, slow flows, spread water laterally across the landscape, reconnect floodplains and side-channels, and create refugia for imperiled salmon, steelhead, and various amphibian species. Considering factors such as slope, floodplain width, land ownership, access, and the presence of at-risk species, we identified 26 sites in the southern Washington Cascades that are priority candidates for survey and potential implementation.

- **Strategic reed canarygrass treatment:** Strategic efforts to combat invasive reed canarygrass must involve collaborations focused on early detection and rapid response as well as continued attention in previously treated areas to keep regrowth at bay.

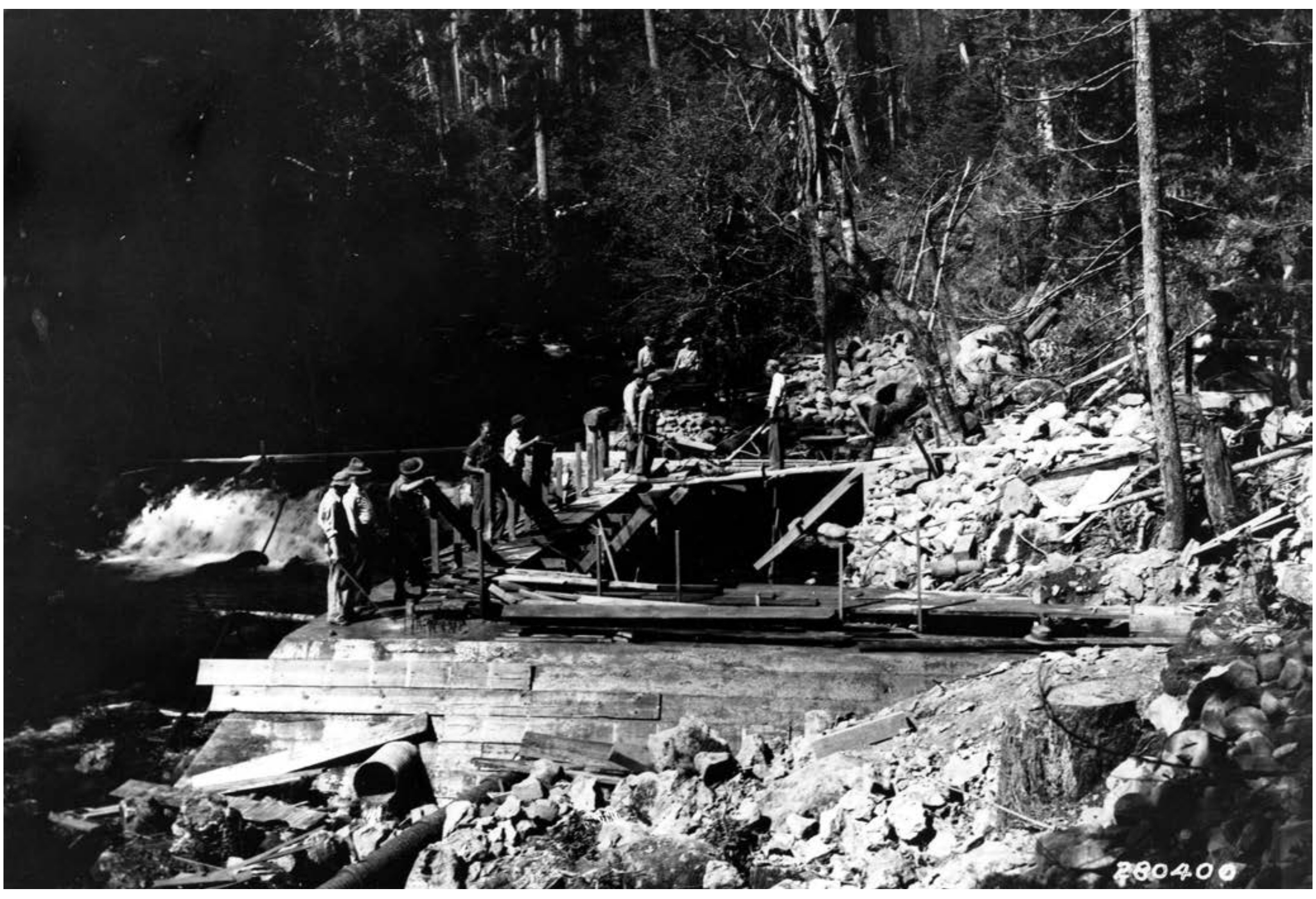
- **Volunteer engagement:** Community volunteers play a pivotal role in helping us capture important on-the-ground information and carry out hands-on restoration projects for a wide array of conservation initiatives.

Aquatic Ecosystems

Rising temperatures and altered streamflow patterns will affect many aquatic systems in the southern Washington Cascades. In the next section, we delve into expected climate impacts for aquatic systems, with a particular focus on anadromous fish species, such as coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss*). We also outline policy and restoration recommendations to protect critical habitats and improve resilience for aquatic ecosystems and species.

Historical framework

The Lower Columbia River and the streams flowing into it from the forests of the southern Washington Cascades once hosted runs of a million or more anadromous fish, but these runs now average closer to 30,000 annually.[1] Indigenous communities have a deep connection to the aquatic systems of the region. For thousands of years, they depended on fish for sustenance and have stewarded the aquatic resources of the region to maintain healthy populations of different species. Many spiritual traditions revolve around the harvest of salmon, smelt, lamprey, and others. As explorers, trappers, and settlers expanded into these lands, fish populations began to suffer. The health and resilience of aquatic systems was further degraded by dam building, timber extraction near waterways, draining of wetlands, land and road development, channel manipulation, and the removal of instream wood to facilitate the downstream transportation of timber to mills. As a consequence, many waterways now exist in a fragile state, rendering them even more vulnerable to severe impacts from climate change. In addition to passage barriers and a lack of instream wood, riparian trees, and overall aquatic habitat heterogeneity, many rivers and streams are incised and isolated from their floodplains, a situation which accelerates water transport and flushes juvenile fish out of the cooler, headwater reaches before they complete their freshwater life cycle. Anadromous fish, due to their long migrations, varied life stages, and their reliance on both ocean and freshwater systems, are in a particularly precarious position and face a number of compounding threats.



Members of the Civilian Conservation Corps building a dam on Trout Creek in 1933

Meadow Creek flowing through Lone Butte Meadows

AQUATIC ECOSYSTEMS, SPECIES, AND **EXPECTED IMPACTS**

Temperature and stream flow

The combination of increasing air temperatures and decreases in snowpack is predicted to warm water and impact aquatic and riparian habitats.[2,3] August stream temperatures (a metric used for comparing differences in peak temperatures) are expected to warm approximately 0.4 to 0.5 °F (0.2 to 0.3 °C) per decade, with a 2.3 °F (1.3 °C) increase between 2000 and 2040 and a 4 °F (2.2 °C) increase between 2000 and 2080.[1] Moreover, many fish are already living close to the upper range of their thermal tolerance.[4] According to the Washington State Department of Ecology, the Gifford Pinchot National Forest (GPNF) has 30 streams (and over 88 miles) that are currently temperature-impaired.[1]

High water temperatures can impact summer upstream migrations, forcing salmon and steelhead to delay or stop their upward migration in an effort to seek cold water refugia and avoid thermal stress.[1] It can also impact egg incubation, spawning, rearing, cardiorespiratory activity, and swimming performance.[1,3,5]

Altered streamflow patterns

Altered streamflow patterns—from changes in the amount of snow and timing of snowmelt and rain—are also expected to impair the function of aquatic ecosystems and decrease the quantity and quality of aquatic habitat.[6] In the Columbia Basin, we can expect to have less snow, earlier snowmelt, less rain in summer, and more rain in winter and spring.[7] Snowmelt-dominated watersheds are expected to shift to mixed rain-snow, mixed rain-snow watersheds are expected to become mostly rain-dominated, and rain-dominated watersheds may experience an increase in winter precipitation.[8,9] The reduction in snow levels and

Washout on route 504 near Mount St. Helens. Photo courtsey of Nickolett Uhler and KGW

shift from snowfall to rainfall will be most pronounced in mid-elevation areas.[7] Increased rain in the winter and spring months is expected to result in higher peak flows during these seasons.

In the southern Washington Cascades, the frequency of days with high winter flows may rise from 11 days in the 1980s to 13 in the 2040s or 14 in the 2080s, and peak flows (the highest flow in a given year) may be 9.6 to 17.3% higher during the same comparison period.[1] These increases will be higher in the mountainous terrain of the GPNF. A rise in high flows can cause an increase in sediment and can scour riverbeds, destroy redds (spawning areas for fish), and lead to higher levels of mortality for newly-emerged alevins, fry, and parr, particularly for winter and spring spawning species.[8] High flows also increase channel incision, disconnecting creeks and rivers from their floodplains, side-channels, wetlands, and other refugia.

Salmon moving upstream to spawn

Summer flows may decrease by 40 to 65% as a result of extended dry periods, decreased snowpack, and earlier runoff.[1] This has a direct impact on many species. Coho salmon, for instance, are expected to experience a parallel reduction in habitat (40 to 65%) over the next several decades.[1] Reduced summer flows—especially in simplified river systems lacking suitable water storage capacities—create barriers for migrating fish, increase competition in smaller habitat areas, and cause young fish to be stranded in small isolated pools that dry up before the rains return.[8] These impacts are exacerbated by roads and culverts, which further fragment habitat.

Impacts from wildfires, dams, and changes in the marine environment

High intensity forest fires, although a natural part of a watershed's evolution, can cause added strain on aquatic systems. They can create pulses of sediment in streams and can reduce riparian shade. Burnt soil is unable to absorb rainwater and instead causes water to flow downslope and gather other sediment, with this material ultimately ending up in stream systems, burying redds and impacting levels of dissolved oxygen in the water.

Climate-related changes in the marine environment also impact salmonids. Some of the primary changes in the marine environment affecting salmonids are 1) changes in ocean temperature, current, and upwelling patterns; 2) persistent and large anoxic "dead" zones; 3) reduced abundance and distribution of forage fish, invertebrates, jellyfish, and planktons; and 4) ocean acidification that impacts the growth and survival of important salmonid food sources, such as krill and amphipods.

The multitude of overlapping impacts paints a dire picture for salmon and steelhead. While reductions in populations are almost certain, these species have historically been known for their phenotypic plasticity and resilience, and anadromous species may adapt and move to new suitable habitats as long as there is a wide array of options.[1] Passage barriers (dams and large waterfalls) will preclude this option along some waterways, but as energy sectors are diversifying and awareness about the substantial impact of dams on aquatic health increases, we may see at least some of the impact of dams reduced through time.

Hudec et al. (2019) highlight the adaptation potential of anadromous fish:

> "Where barriers do not impede movements, species may adapt by shifting their distributions in space or time to track suitable habitats or to recolonize previously disturbed habitats from nearby refugia if a diversity of landscape conditions exist (Reeves et al. 1995, Sedell et al. 1990). Many of the species considered here also have diverse life histories, which may change based on how climate change affects metabolic rates, water temperature, stream productivity, and habitat connectivity. Development of adaptive responses associated with phenology may also bolster population resilience in ways that allow species to persist in dynamic environments subject to long-term climate trends (Crozier et al. 2008, Kovach et al. 2012)."

Streamflow is projected to increase at all locations in winter and spring. Summer streamflow is, on average, projected to decrease owing predominantly to an earlier shift in snowmelt onset accompanied by a reduction in summer precipitation and increases in evaporation due to higher temperatures.

Chegwidden et al. 2019

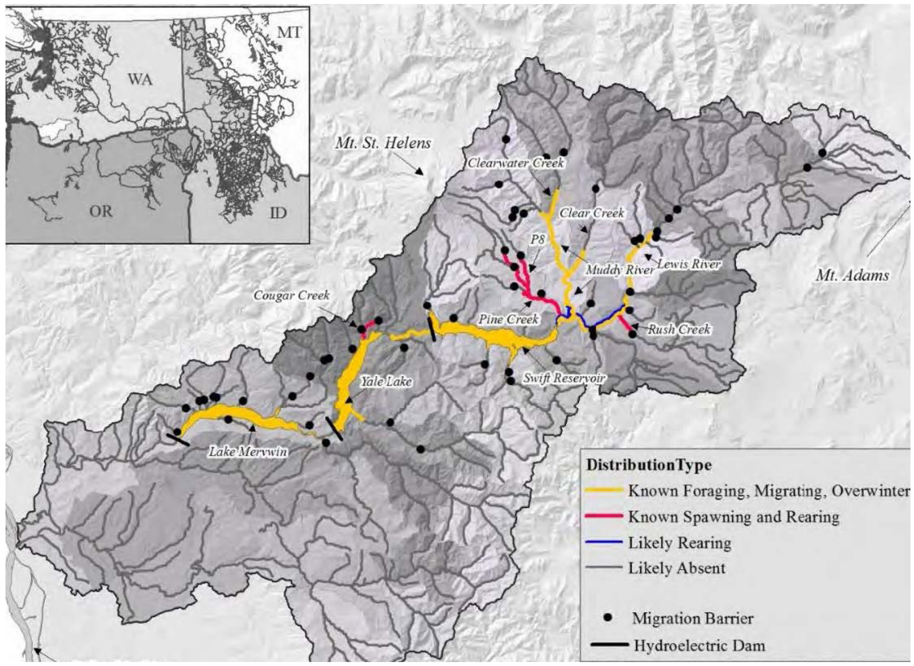
Other species-spesific impacts

Cutthroat trout (*Oncorhynchus clarkii*) are less sensitive than salmonids to rising water temperatures, but low summer flows can severely impact the species.[10,11] Low summer flows can impact foraging and cause stranding, reductions in genetic diversity, and direct mortality as pools dry up.[12,13]

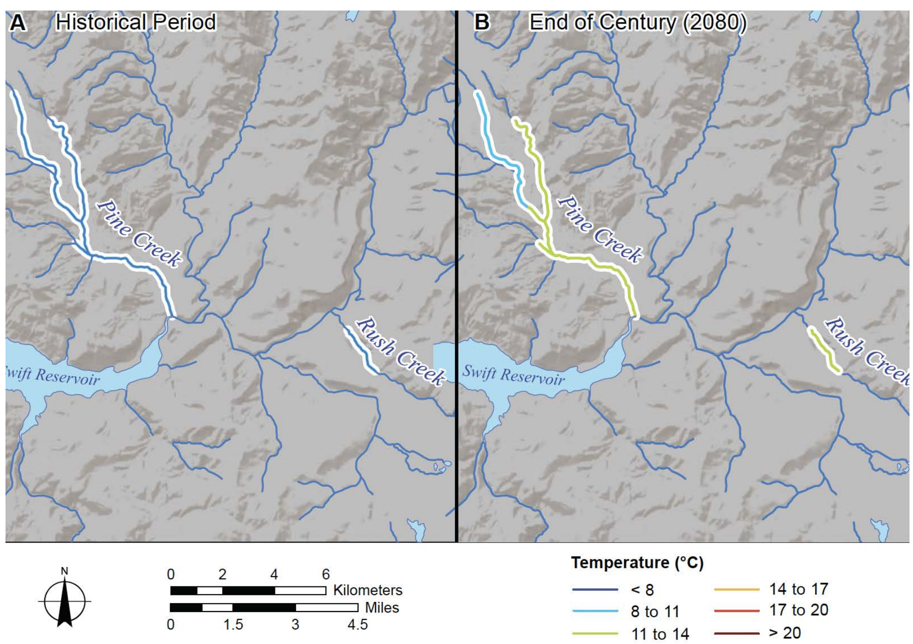
Bull trout (*Salvelinus confluentus*) are expected to be severely impacted by warming water temperatures.[14] They rely on cool water for spawning (with average summer water temperatures less than 52 °F or 11 °C). They are "one of the most thermally sensitive coldwater species in western North America." [15,16] Bull trout habitat is expected to shrink, with thermal bottlenecks limiting access to cooler upstream habitats. Bull trout are relatively rare, but there are two known natal streams in the GPNF, Pine Creek and Rush Creek, that contain a combined total of approximately 12.4 miles (20 km) of habitat.[1] Spawning and juvenile rearing also occur in Cougar Creek, which feeds into Yale Reservoir.[17] Stream temperature increases in portions of these creeks are expected to significantly shrink the amount of area suitable for spawning and rearing.[1]

Pacific lamprey (*Entosphenus tridentatus*) play a vital ecological role and are important to many Indigenous groups. As an anadromous species, it navigates between freshwater and the ocean, facing similar threats as salmon, including passage barriers, lack of suitable habitat, and climate impacts associated with extremes in both low and high flows.

Our region is home to a variety of aquatic and terrestrial amphibians that rely on particular habitat types and seasonal cycles due to their intricate life stages. The northwestern salamander (*Ambystoma gracile*) and Cope's giant salamander



Map from Hudson et al. (2019) showing bull trout distribution in the Lewis River subbasin using field data from 1979 to 2016



Map from Hudec et al. (2019) showing "[s]ummer temperatures (°C) in two streams (outlined in white) that support spawning and rearing by bull trout in Gifford Pinchot National Forest in: (A) the 1980s, and (B) the 2080s, based on NorWeST and the A1B emission scenario. Stream reaches shown in green may become too warm for spawning and rearing in the future."

(*Dicamptodon copei*), which utilize both in-channel and riparian habitat, may be impacted by low summer flows and increased temperatures, which can disrupt their development cycle.[18] The Cascade torrent salamander (*Rhyacotriton cascadae*) is likely sensitive to climate change due to 1) its reliance on specific microhabitats, such as cool, forested streams and low-flow habitats for egg deposition; 2) sensitivity to temperature variations; 3) limited dispersal ability; and 4) vulnerability to altered water availability and sedimentation resulting from changes in precipitation, snowpack, and stream discharge.[19] Ponded meadows provide breeding habitat for species like the northern red-legged frog (*Rana aurora*) and western toad (*Anaxyrus boreas*).[20] Drought, invasive plants, and altered hydrologic patterns can impact the health and viability of these habitats.

CFC volunteer measures a western red-backed salamander

Northern red-legged frog

ADVOCACY AND LEGAL PROTECTIONS FOR **WATERWAYS**

There are several avenues to protect aquatic ecosystems and improve resilience in the Gifford Pinchot National Forest and surrounding state and private lands. The first step is to curtail further degradation and lay the foundation for future improvements. Legal requirements within the Clean Water Act, the federal and state endangered species acts, the Northwest Forest Plan, Washington State's Forest and Fish Law, and other policies and regulations present opportunities to protect aquatic systems and increase climate resilience.

The Clean Water Act

The original goal of the Clean Water Act (CWA) was to totally eliminate pollutants entering waterways over time. In practice, the CWA is generally used to prevent the "discharge of pollutants without a permit." The CWA was the impetus for a water quality program now in place that requires states to identify waters that are not meeting quality standards, such as those with high temperatures or sediment issues, and to create plans to clean them up. Waters that are not meeting standards are placed on the impaired waters list, the 303(d) list, and are effectively in the queue to receive a targeted clean-up plan, the primary of which is called a Total Maximum Daily Load (TMDL). The GPNF and surrounding state and private lands have several waterways listed as impaired yet without a clean-up plan. Getting these impaired waters onto a clean-up plan, such as a TMDL, is one powerful way to improve aquatic habitats in southwestern Washington. Unfortunately, there is insufficient staffing and funding to keep up with demand.

Utilizing this process to improve waterways in southwest Washington will require submitting official comments and coordinating with the Department of Ecology to increase funding and include more previously-identified priority waterways on the work plan for the state.

Outstanding Resource Waters

The Clean Water Act also enables states to designate unique, ecologically-important, and/or high-quality waters as Outstanding Resource Waters (ORW). This state-level designation provides an extra layer of protection to waterways to ensure these values are protected. An ORW protection prevents new sources of pollution, such as from mining or excessive riparian logging, except in very limited circumstances like emergencies. New activities proposed in the ORW area would need to prove they were not impacting water quality, and if the new activity could not prove a lack of impacts, that activity would not be allowed.

To be designated as an Outstanding Resource Waters a waterway must meet at least one of the following criteria:

a. "The water is in a relatively pristine condition (largely absent human sources of degradation) or possesses exceptional water quality, and also occurs in federal and state parks, monuments, preserves, wildlife refuges, wilderness areas, marine sanctuaries, estuarine research reserves, or wild and scenic rivers;

b. The water has unique aquatic habitat types that by conventional water quality parameters (such as dissolved oxygen, temperature, or sediment) are not considered high quality, but that are unique and regionally rare examples of their kind;

c. The water has both high water quality and regionally unique recreational value;

d. The water is of exceptional statewide ecological significance; or

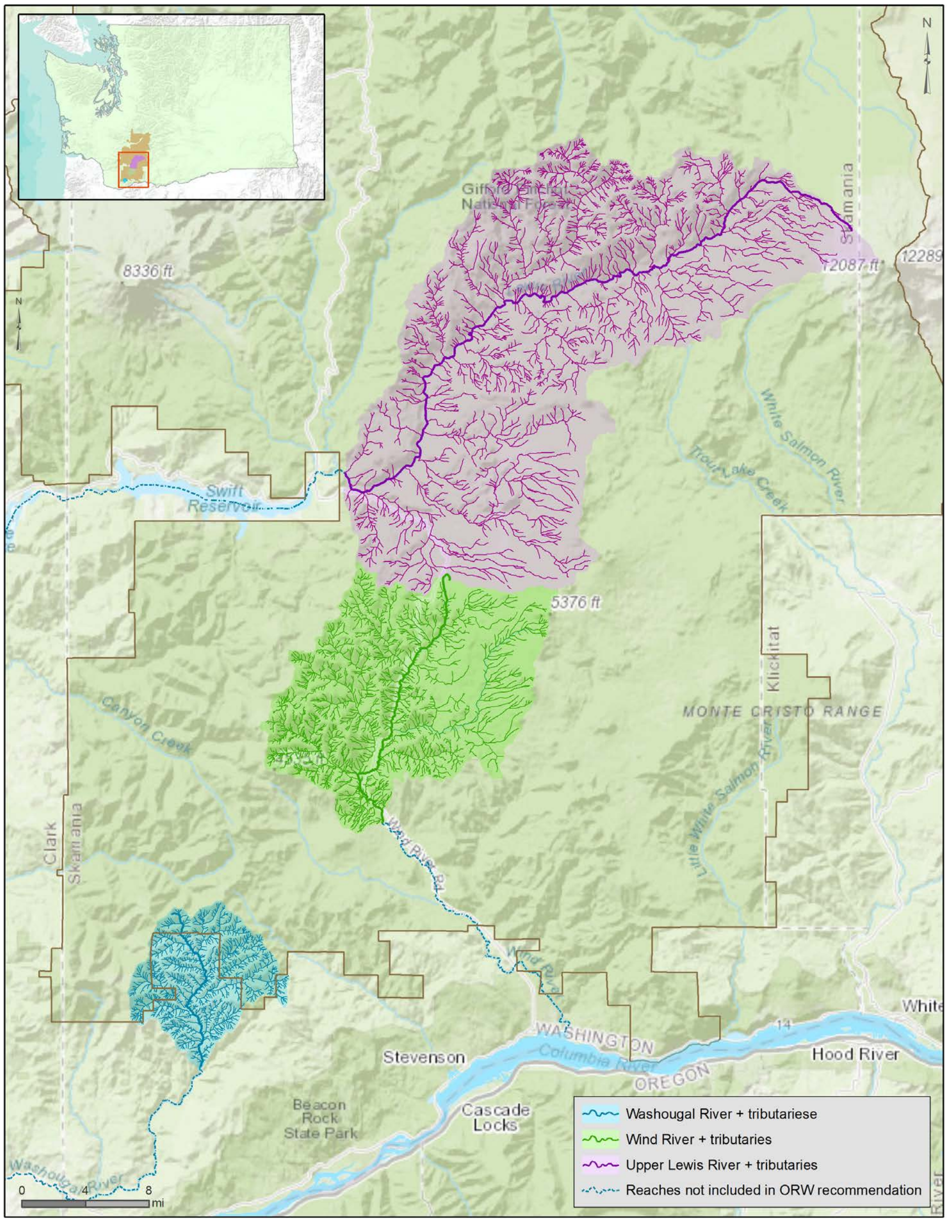
e. The water has cold water thermal refuges critical to the long-term protection of aquatic species. For this type of outstanding resource water, the nondegradation protection would apply only to temperature and dissolved oxygen." [21]

A historic first: The Green River, Napeequa River, and Cascade River are Outstanding Resource Waters

The upper portions of the Green River were among the first three waterways to be designated as Outstanding Resource Waters in Washington state

The Green River flows from headwaters near the slope of Mount St. Helens into the North Fork Toutle River, later joining the Cowlitz and Columbia Rivers. It is a designated genebank for wild steelhead and is beloved by backcountry hikers, cyclists, foragers, horseback riders, and anglers. It has also been considered one of Washington's most-threatened waterways, due to recurring attempts by mining corporations to prospect for gold, copper, and other minerals in the area.

On December 18, 2023, portions of the Green River, Napeequa River, and Cascade River were designated as Washington state's first Outstanding Resource Waters, granting them new protections under the Clean Water Act.

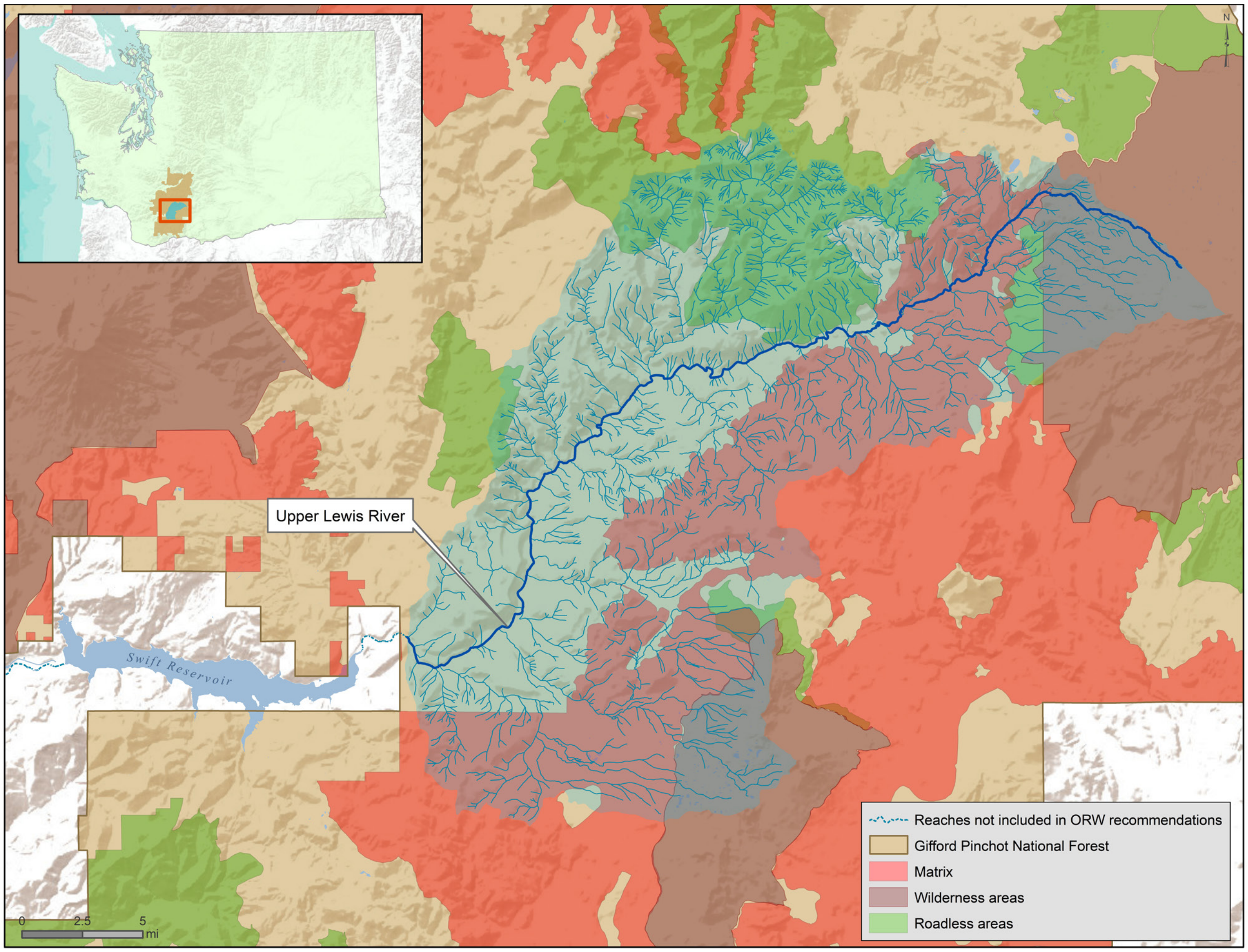


Recommended waterways for future Outstanding Resource Waters consideration

Recommendations for new Outstanding Resource Waters

In this section, we identify three waterways (Upper Lewis River, Wind River, and Washougal River) in the southern Washington Cascades that are suitable candidates for future ORW designation. These recommendations are an initial step to help prioritize local efforts, acknowledging that pursuing an ORW designation requires extensive collaboration, stakeholder buy-in, and a long-term campaign involving multiple groups.

To create this list, we prioritized waterways on public lands that are A) in relatively good ecological condition, B) home to threatened aquatic species, and C) at-risk, i.e., they are located in areas where we could expect impacts from logging, development, or degradation. We also took into account the state requirements previously mentioned for ORW designation. Although meeting just one of the criteria is sufficient for a waterway to be considered for ORW status, we have chosen waterways that fulfill multiple criteria to ensure a more compelling case for designation. To investigate suitability, we referenced documentation and spatial data from the WA Department of Ecology, Environmental Protection Agency (EPA), Lower Columbia Fish Recovery Board, U.S. Forest Service, WA Department of Natural Resources, county data repositories, and watershed action plans, with particular attention paid to Department of Ecology's Current Water Quality Assessment, the GPNF Land and Resource Management Plan, Lower Columbia Fish Recovery Board's SalmonPORT, and the Washington State Scenic River Assessment.[22–26]



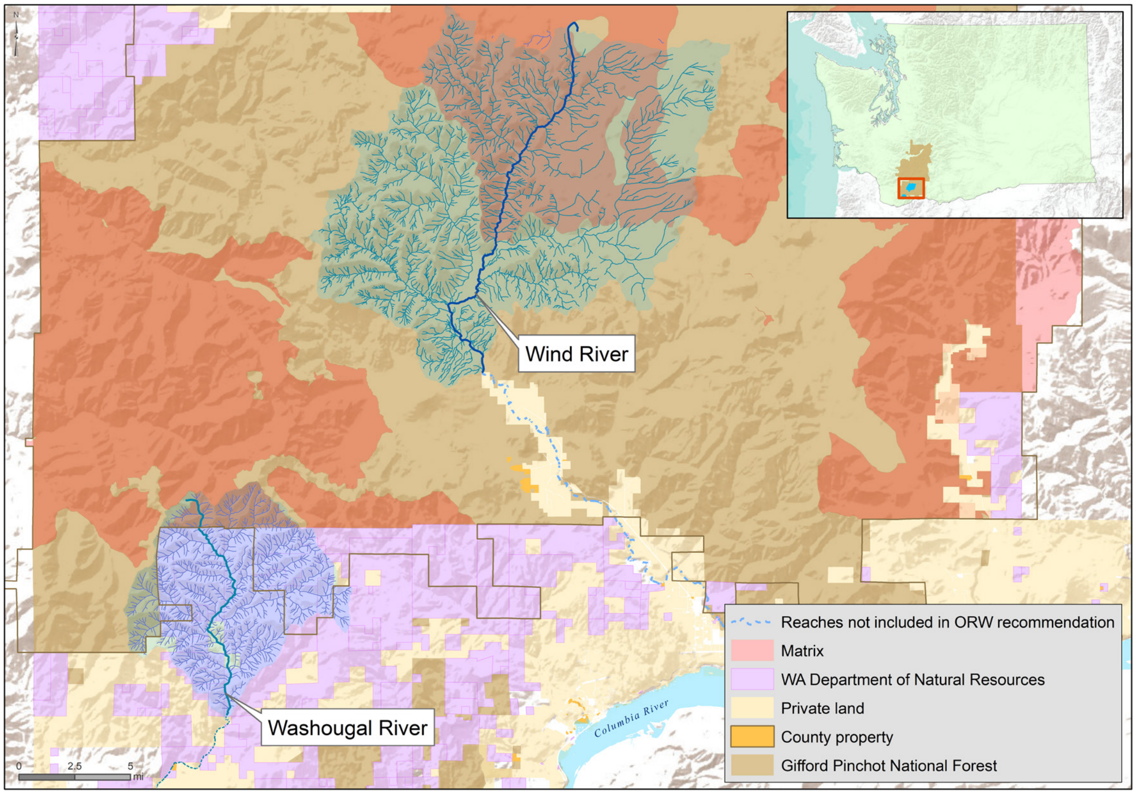
Map of the Upper Lewis River watershed highlighting reaches of the mainstem and tributaries that could be protected through the ORW process

Recommendation 1: Upper Lewis River

The Upper Lewis River flows from its source in the Mount Adams Wilderness through stretches of old-growth, past massive rocky cliffs, and into Swift Reservoir. This area is a popular recreation destination for its scenic beauty, fishing opportunities, hiking trails, and renowned waterfalls. There are also prehistoric villages along the river that are listed in the state's Register of Historic Places. The river contains valuable habitat for coho, steelhead, and bull trout and has been identified by the EPA as one of twelve primary thermal refuges for the Columbia River. This stretch of the Lewis River is almost entirely in the GPNF.

The Upper Lewis River meets three ORW criteria: 1) relatively pristine condition, with much of it in Wilderness and Late-Successional Reserves, 2) high water quality and regionally-unique recreational value, and 3) exceptional statewide ecological significance. Aligning with this finding, Pew Charitable Trusts commissioned a third-party analysis in 2021 to examine and highlight priority waterways in Washington for ORW designation.[27] This watershed, referred to therein as "Headwaters Lewis River," ranked 8 of 20, highlighting its relative importance in a state-wide list of priority waterways.

A waterfall on the Upper Lewis River



Wind River and Washougal River mainstem reaches and tributaries that could be protected through the ORW process

Recommendation 2: Wind River

Wind River was designated as a wild steelhead gene bank by the Washington Department of Fish and Wildlife in 1980 due to its status as a stronghold for summer-run steelhead.[28] The river is undammed and has been identified by the EPA as one of twelve primary thermal refuges for the Columbia River. The Wind River watershed does have an improvement plan for temperature due to some areas exceeding the temperature standard, but it is not exceeding any other water quality standards and otherwise has high water quality. Its diverse riparian corridor provides vital habitat for a wide variety of species, both aquatic and terrestrial. Moreover, the Wind River corridor boasts a distinctive landscape, characterized by deep, cliff-lined gorges, thermal mineral springs, and other geologic and scenic attributes. Additionally, the river and its riparian areas serve as a popular destination for various recreational activities, such as fishing, hiking, boating, and cross-country skiing. The recommended reach originates in Matrix lands of the GPNF and then flows through a stretch of Late-Successional Reserves to the boundary of the national forest.

The Wind River meets three of the ORW criteria: 1) high water quality and regionally-unique recreational value, 2) exceptional statewide ecological significance, and 3) cold water thermal refugia.

Recommendation 3: Washougal River

This upper section of the Washougal River originates within Matrix lands of the GPNF and runs through state lands before passing through a small aggregation of private lands. There are scenic falls on the upper mainstem and varied recreational destinations throughout the watershed, including whitewater kayaking.[29] The Washougal River is undammed and has been identified by the EPA as a thermal refugia for the Columbia River. None of the reaches we are considering for nomination are listed on the 303(d) impaired waters list.

The Washougal River meets three of the ORW criteria: 1) high water quality and regionally-unique recreational value, 2) exceptional statewide ecological significance, and 3) cold water thermal refugia. A small number of private landowners own properties on the lower portion of the recommended reach; therefore, designating the entire mapped area would require outreach and coordination with these stakeholders.

CFC staff and volunteer conducting lamprey surveys in the Wind River

The Washougal River

Wild and Scenic designation

The National Wild and Scenic Rivers System was created by Congress in 1968 to protect the free-flowing nature of some of the country's river systems, particularly those that retained a primitive character. This effort was a response to the prolific alteration of waterways across the U.S., including damming for hydropower and redirection of water for agriculture use.

The act encompasses three different designations:

1. Wild rivers: free from impoundments, remaining primitive, and inaccessible by road
2. Scenic rivers: free of impoundments, largely primitive, and partially accessible by road
3. Recreational rivers: accessible by road, with possible developments along the shoreline, and with potential past impairments

A key element of the designation process involves determining Outstanding Resource Values (ORVs) for any river being considered. The managing agency, generally the Forest Service, must then create a plan aimed at protecting those identified ORVs.

Notably, while safeguarding waterways, the Wild and Scenic Rivers Act acknowledges the potential for appropriate use and development. It encourages a balance between protection and utilization. The legislation encourages a management approach that transcends political boundaries and actively involves public participation in shaping protection goals.

As of 2022, the National Wild and Scenic Rivers System, implemented under this act, protects 13,467 miles of 228 rivers across 41 states and the Commonwealth of Puerto Rico.[30] Remarkably, this coverage accounts for less than one-half of one percent of the nation's rivers.

Although Congress has the final say in designating most Wild and Scenic Rivers, the Forest Service or other federal agencies can nominate rivers or sections of rivers for this designation. If the Forest Service determines a river or section is "eligible" and/or "suitable" for a designation then the agency has to apply interim protections to ensure the resource values of that river are protected until Congress decides whether or not to officially designate the waterway under the Wild and Scenic Rivers Act. These interim protections are limited and easier to overturn than official designation.

There is also a pathway for designation through the state. If a state designates a river through its own Wild and Scenic program, the Governor can then make a request to the Secretary of Interior that the river be included in the national system. The Secretary will determine whether the river meets the criteria, and after notice to relevant federal agencies and the public, as well as ample opportunity for public comment, the Secretary will make a final determination on whether to include the river in the national system.

Before Congress can vote on adding particular rivers to the Wild and Scenic Rivers System, both a determination of eligibility and suitability must be done. Eligibility is a determination that the river segments are free-flowing and includes a consideration of whether the waterway and the adjacent land area have at least one ORV. Suitability, in turn, looks to determine whether an eligible river should be included in the Wild and Scenic Rivers System and considers factors such as existing land uses along the studied segment(s), whether the ORVs would actually be protected through the designation, and whether there are other important uses that weigh against designating the segment(s).

Rivers that are deemed eligible and/or suitable receive protection against water resource projects (including water supply dams, diversions, and flood control work) and hydroelectric projects, as well as protection measures related to impacts from transportation infrastructure, utilities, recreation development, motorized travel, vegetation management, and domestic livestock grazing. When and if rivers move from an eligible stage to suitable, wherein it is formally recommended to Congress for protection, the waterway gains a higher level of protection.

Once a river is designated, a management plan is crafted, including resource inventories, monitoring, and task force development. Its classification (wild, scenic, or recreational) will dictate the extent of protection afforded to the waterway. Wild designations offer the most protection. For example, wild designation offers a quarter mile mineral withdrawal, which prohibits mining on either side of the waterways banks. For scenic and recreation designations, mining would still be allowed, but the mining activities would have to be carefully evaluated to ensure there is no pollution and no unnecessary impairment of the scenic or recreational values. Scenic designation offers the second highest level of protection, and recreational designation offers the lowest level of protection.

Many rivers on the GPNF were studied in the 1990s for possible inclusion in the National Wild and Scenic Rivers System. In total, 14 were found eligible and four were found suitable and formally recommended to Congress by the Forest Service for inclusion in the Wild and Scenic Rivers System. However, these were never formally designated by Congress. The four that were found suitable and recommended for inclusion are the Cispus River, Muddy Fork Cowlitz River, Clear Fork Cowlitz River, and North Fork Lewis River (sometimes called Upper Lewis River or Headwaters Lewis River). The following 14 waterways were found to be eligible but have yet to receive a suitability determination. These are: Lewis River, Clear Creek, Green River, Ohanapecosh River, Quartz Creek, Siouxon Creek, Smith Creek/Muddy River, Toutle River, White Salmon River, Yellowjacket Creek, Cowlitz River, East Fork Lewis River, and Wind River.

Public support can and has influenced the Wild and Scenic designation process in the past. Several waterways which were found eligible in the 1990 study were not initially proposed for study by the Forest Service and were only studied and included after members of the public submitted them for consideration. Some of the waterways submitted and eventually found eligible due to public submission include Clear Creek, Quartz Creek, Siouxon Creek, Yellowjacket Creek, Ohanapecosh River, and White Salmon River.

Recommendations for new Wild and Scenic designations

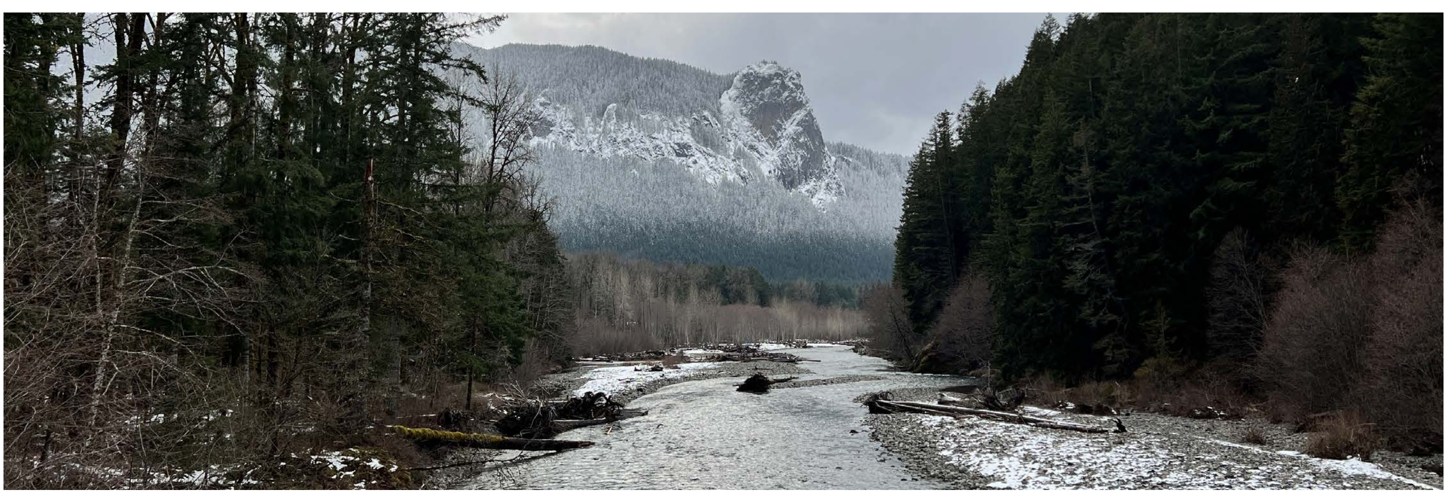
In this section, we identify a set of waterways that we recommend be prioritized for Wild and Scenic consideration. Similar to ORW designations, pursuing Wild and Scenic status is a multi-group effort requiring group buy-in, and in this case, a congressional campaign. We view these recommendations as an initial step to better understand which waterways in the southern Washington Cascades would be suitable candidates for future Wild and Scenic discussions.

Our recommendations include waterways that have already been found to be eligible by the Forest Service. We then considered other factors to refine our recommendations and to create a two-tiered ranking of priority. These factors included: importance for anadromous fish species, land allocation as it relates to suitability for designation, land allocation as it relates to logging and development risks, and recreational value.

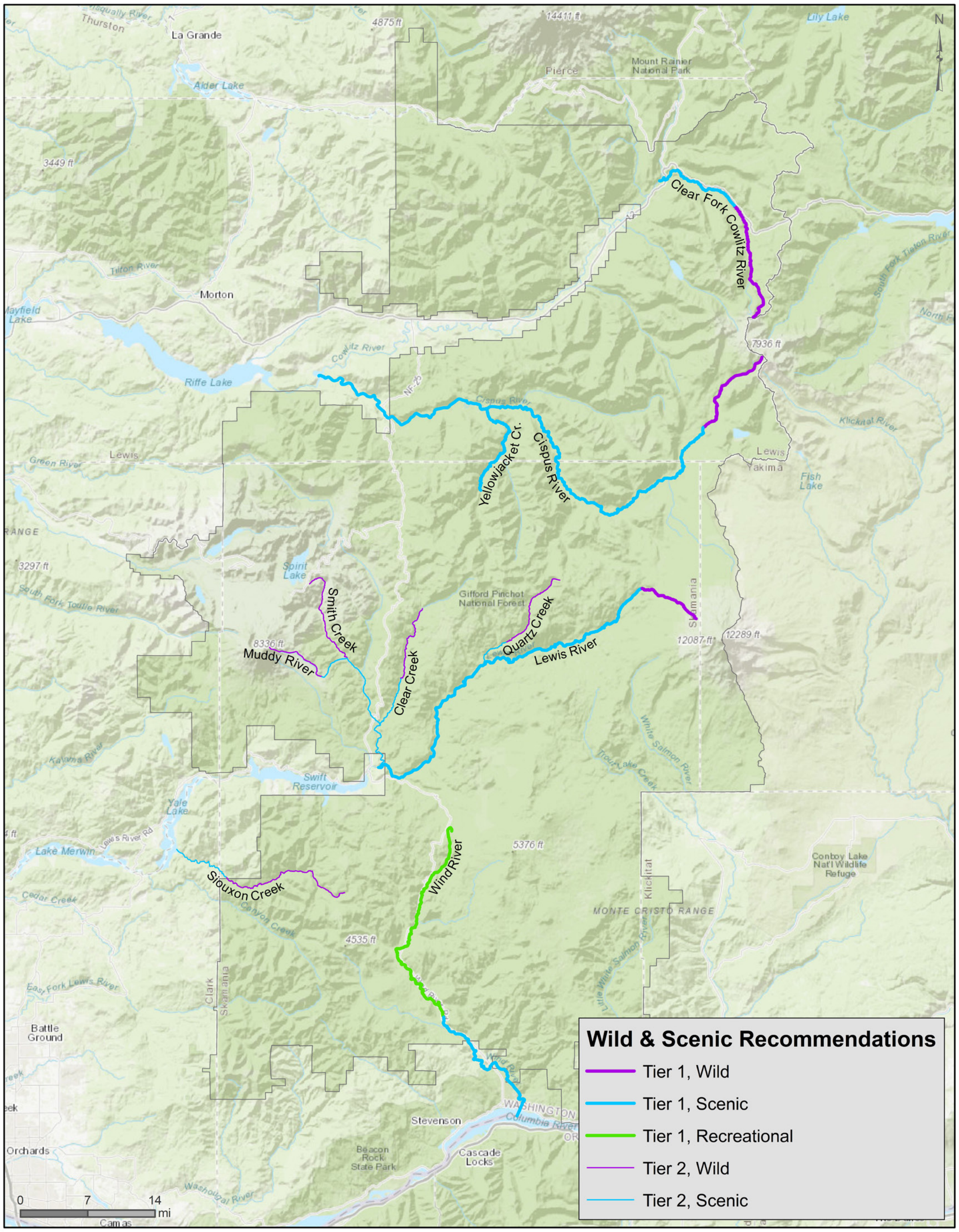
Tier 1 Recommendations
Clear Fork Cowlitz
Cispus River
Upper Lewis River
Yellowjacket Creek
Wind River

Tier 2 Recommendations
Quartz Creek
Smith Creek
Siouxon Creek
Muddy River
Clear Creek

Our Tier 1 recommendations are waterways that, in most cases, have been formally recommended by the Forest Service for inclusion in the Wild and Scenic System, with the exception being Yellowjacket Creek, which was found eligible but not recommended. Our Tier 2 recommendations include waterways that have been



Tower Rock towering over the Cispus River



identified as eligible for Wild and Scenic designation but were not yet deemed suitable by the Forest Service. These Tier 2 waterways could rise in priority if substantial community support emerges for the designation of a particular waterway.

We refined the previous 1990 Forest Service list, utilizing new information on factors such as fish, risk, recreation, impact of designation, and likelihood of success. For instance, Muddy Fork Cowlitz River was found suitable but not included in either tier because it falls almost entirely within wilderness or national park boundaries and therefore already has high levels of protection. Yellowjacket Creek, on the other hand, was found eligible but not yet deemed suitable, and was included in our top tier because of risks associated with its placement within Matrix lands and potential impacts from mining. The remaining waterways previously found eligible but not included in our Tier 2 list were discounted for reasons such as: a low risk of logging, development, or pollution; a minimal increase in protection level from what already exists; or a large overlap with private land, where designation success would be lower and where there would be fewer viable enforcement mechanisms.

No-cut buffers for headwater streams on state and private lands

The Forest and Fish Rules dictate timber harvest regulations and stipulations on state and private lands, and they offer a framework for protection of waterways and riparian zones. In comparison to federal lands, these rules generally provide less protective measures for riparian areas.

Currently, with some exceptions, headwater streams receive little protection from logging. Type Np waters, a class of headwater streams, are perennial streams reaches that are not currently fish habitat or they are intermittent reaches that are downstream of a perennial section. Type Ns waters, another class of headwater streams, are seasonal, intermittent, currently non-habitat streams reaches that are connected by a surface channel to a downstream perennial stream. What does exist is a limit on heavy equipment within 30 feet of the stream, which is an insufficient width to protect the stream from serious negative impacts. Moreover, logging of riparian trees is often allowed all the way up to the waterway in these headwater streams. At this point, we know the severity of the damage that is caused by logging activity near streams. The loss of stream shade causes higher water temperatures in downstream reaches and the increase in sedimentation negatively impacts downstream habitats. We should be adjusting our management methods to better protect aquatic habitats and drinking water.

Because of this, we recommend a no-cut buffer of at least 75 feet on all headwater streams, especially perennial ones, to protect water quality and the health of imperiled aquatic systems.

We are working to address these deficiencies through timber sale comments, and we will also be working within the Adaptive Management Program (part of the Forest and Fish Rules) to discuss this issue and determine whether the rules put in place many years ago are sufficient to retain habitat values and maintain water quality standards under the Clean Water Act.

Staying involved in federal timber sales

Opportunities to improve aquatic habitats or curtail degradation will often arise during the federal timber sale planning process. Logging prescriptions can be adjusted to improve protections for particular waterways, such as increasing no-cut buffers. Also, public support for restoration work can be demonstrated, which improves the chances that this type of work is integrated into upcoming management plans.

During the timber sale planning process, the agency will plan on-the-ground activities under the guidance of various land management allocations such as Late-Successional Reserves, Matrix, Congressionally Withdrawn Areas (such as Wilderness), Riparian Reserves, and others. For this section, we will focus on Riparian Reserves, which is a federal land management designation intended to offer heightened protections for areas around waterways. This usually includes wetland areas, the adjacent floodplain of a waterway, and lands directly upslope from creeks, rivers, and wetlands. Riparian Reserves do not prevent logging outright, but typically there is a no-cut buffer delineated within subsections of these areas and there is an overriding management direction guiding the agency to focus timber management toward harvest actions that, at a minimum, will not negatively impact the nearby aquatic system. But, there are widely varied interpretations of these harvest guidelines.

When ecologically-harmful logging activities are proposed within these areas, the Riparian Reserve designation offers a mechanism for outside entities, such as non-profits or community members, to advocate for more protective measures. On-the ground surveys and investigations of spatial data can help elucidate areas where heightened protection should be advanced through comment letters and/or direct dialogue with the Forest Service. This can include requests for larger no-cut buffers, reductions in the use of ground-based logging machinery near the waterway, and harvest prescriptions that retain higher canopy cover percentages or employ a fell-and-leave strategy rather than extracting trees.

CFC staff and volunteers collecting data along a stream in a timber sale stand

Road surveys

On-the-ground surveys of roads can help in prioritizing roads for closure or restoration, the latter of which can consist of culvert upgrades or the installation of aquatic organism passage structures. Information gleaned from surveys can be shared directly with the Forest Service and can influence future management efforts.

While many national forest roads are needed for timber harvest or to access established recreation sites, others may be less necessary and may be suitable candidates for closure or seasonal closure due to their potential negative impacts on terrestrial or aquatic habitats. Roads can fragment habitats, increase sediment issues in aquatic systems (from erosion or malfunctioning culverts), and increase the introduction and spread of invasive species.[31–35] High road densities have also been shown to negatively impact a variety of terrestrial wildlife species.[34,36]

The funding allocated to the GPNF is insufficient to effectively manage the existing road network and keep up with the maintenance needs required to fix washouts, address road failures, control encroaching vegetation, minimize erosion, and keep culverts open and functioning. The Forest Service acknowledged this in its 2015 Travel Analysis Plan and slowly works to address this issue by implementing road restoration and reduction efforts during timber harvest projects.[37] Unfortunately, these efforts address only a fraction of the vast need, and by being limited to timber sale areas, needs in other parts of the national forest often remain unaddressed.

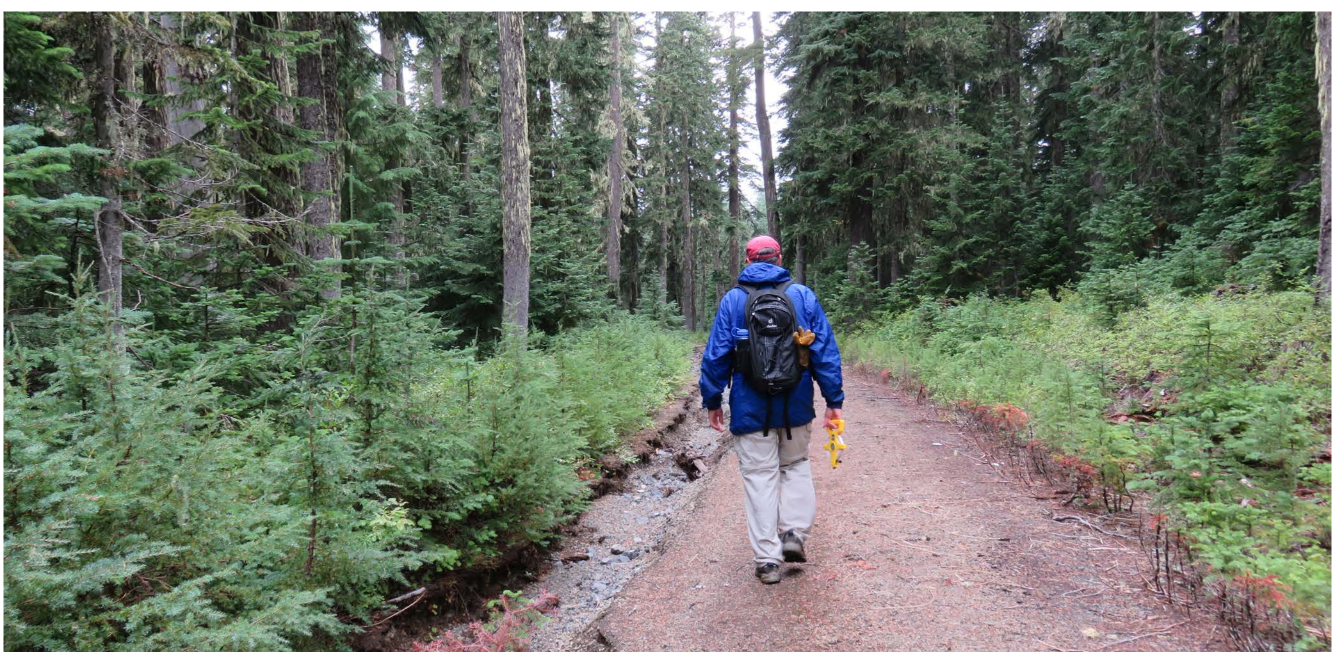
In Chapter 4, we outline two priority areas where we recommend a dedicated investigation of road restoration and closure potential.

Retain and improve the Legacy Roads and Trails program

The Legacy Roads and Trails (LRT) program began in 2008 as a targeted temporary funding program to address the serious water quality problems stemming from the backlog of maintenance needs on the road systems on national forest lands. In 2021, the Infrastructure Law made this program permanent and authorized $250 million for fiscal years 2022-2026. While this creates opportunities for habitat improvement locally, there has been a lack of clarity on how the Forest Service prioritizes LRT projects and how the public can be involved in advancing publicly-driven recommendations. We recommend that the regional office of the Forest Service establishes a process for annually ranking and selecting LRT projects and including opportunities for public input in this process. We also advocate for the continued funding and strategic use of the LRT program.

Monitoring for pollutants, sediment, temperature, and species

A key component to protecting water quality is ensuring there is sufficient monitoring of pollutants, sediment, temperature, and species distributions. Both federal and state agencies have monitoring responsibilities under various laws, but they are chronically underfunded and



A CFC volunteer conducts erosion assessment along a forest road to address excess sedimentation concerns understaffed and often unable to adequately meet these requirements. For instance, a tributary flowing into the Green River just upstream from the Green River Horse Camp had previously been found to have high levels of copper, potentially from old mines in the area.[38] This information was collected in 2001, yet there has been no update of the data since. Without access to updated on-the-ground information, conservation and restoration efforts may overlook important needs and areas of degradation.

Conservation groups and other entities can play a role in these efforts by communicating with the WA Department of Ecology and the Forest Service and advocating for increased attention to known issues and funding for monitoring programs. Frequently, lack of attention to a particular problem is related to staffing and funding issues. Stakeholders can advocate through the state legislatures' biennial budgetary process to ensure Ecology has sufficient funding for monitoring. If areas with particular monitoring needs remain unaddressed after communication with Ecology and the Forest Service, concerns can be elevated to EPA Region 10, the entity responsible for administering the Clean Water Act and which offers federal oversight of Washington State's Department of Ecology's water quality program.

RESTORATION RECOMMENDATIONS FOR **AQUATIC SYSTEMS**

There is a great deal of work taking place across the region to recover threatened aquatic species and improve the resilience of riverine ecosystems. Partner groups such as Lower Columbia Fish Enhancement Group, Underwood Conservation District, Yakama Nation, Cowlitz Indian Tribe, and the Forest Service represent a handful of the entities that are carrying out large wood placement on rivers and creeks across the southern Washington Cascades. Lower Columbia Fish Enhancement Group, for instance, has been chipping away at a years-long effort to restore habitat along the South Fork Toutle River. This work has consisted of a variety of restoration approaches, ranging from large engineered logjams to smaller, low-tech projects along tributaries. The Cowlitz Indian Tribe has been working for the past several years on improving habitat for salmon at the confluence of Yellowjacket Creek and Cispus River. Through this effort, the Tribe has built a series of large logjams that have already begun creating new habitat and significantly expanding aquatic complexity in the area. Partner groups have also played vital roles in removing dams that have been blocking fish passage for decades. Dam removal is one of the most important steps that can be taken to improve the health and resilience of anadromous fish populations.

An engineered logjam on the Cispus River

Thanks to region-wide entities like Lower Columbia Fish Recovery Board coordinating project priorities and federal- and state-level funding enabling millions of dollars' worth of work to move forward each year, we can expect to see many new projects come online over the next several years to address habitat degradation and resilience needs.

In this section, our aim is to delve into restoration recommendations that are tuned to the work of groups like CFC, with a focus on low-tech, process-based restoration and other efforts that can be employed widely and that can directly benefit from the help of community volunteers.

Beaver recovery

Beavers have been helping shape aquatic and riparian landscapes throughout the Pacific Northwest since they first arrived in the area 7 to 7.3 million years ago.[39] Before European colonization, beaver populations in the United States were estimated to be between 60 and 400 million.[40] The subsequent period of intensive trapping nearly extirpated beavers from the Pacific Northwest, but their numbers have rebounded in some areas, with estimates ranging from 6 to 12 million.[41] Despite their partial recovery, beaver populations are a fraction of what they once were, and they are still absent from many headwater systems.[41,42] Recolonization in upper headwater systems is often difficult to achieve because beaver colonies can be hindered by stretches of unsuitable habitat, culverts, and waterfalls, all of which were previously passable when downstream populations were abundant, healthy, and forcing upward dispersal. Recolonization in lowland systems is generally easier as beaver colonies have access to more contiguous suitable habitats and can more easily disperse to find a mate when they leave their home.

Beavers actively modify stream channels and floodplains by building dams and digging channels. The sediment and wood structure that is retained behind a beaver dam can raise the stream bed, expanding riparian areas laterally and creating larger areas of saturation.[43–45] Beavers can help forge new side-channels and reconnect relic wetland areas. With increased pooling and water storage above ground, it can increase hyporheic exchange—the movement of water between the surface and the water that moves underground. With increased moisture and a lateral spreading of water, beaver-impacted riparian areas can become more resistant to fires, drought, and channel incision from high flow events.[46–48]

Fairfax and Whittle (2020) compared the greenness of vegetation in riparian areas that were beaver-dammed before, during, and after a wildfire. Stream reaches with no beavers saw a loss of 51% of the riparian vegetation, while reaches with beavers had a reduction of 19%.[48] The results suggest that the presence of beavers can help keep the soil moist and vegetation green and fire resistant even in a period of drought.

Other research has shown that beaver dams can capture the influx of sediment and contaminants that are present after a fire.[49] Burned landscapes are typically less able to hold moisture due to changes in soil composition and vegetation; consequently, the runoff will send fine sediments and pyrogenic contaminants into the streams below, negatively impacting the aquatic community. A beaver dam or similar instream feature can retain these sediments, reducing degradation of downstream habitat and water quality.[49]

For several years now, Cascade Forest Conservancy has been releasing beavers into headwater systems in the GPNF. The beavers are sourced from urban or near-urban areas where they are causing problems for landowners, such as flooding or damage to trees. Our release sites were identified through a spatial analysis we carried out in 2018. This spatial analysis was followed by on-the-ground surveys to collect more refined data on habitat viability.

As beavers have been absent from most headwater systems for many decades, channel structure in many places has become too simplified and incised to support their return without foundational changes to floodplain function. Also, survival may be limited in some areas by a lack of forage (favored hardwoods such as cottonwood or willow) or deep pools to allow beavers an escape from predators. Due to these factors, much of our future beaver recovery efforts will be focused on improving beaver habitat through instream restoration and riparian planting, especially in areas near and above current beaver populations where this work can attract beavers into the higher reaches of waterways. In the next section, we highlight areas where on-the-ground surveys can be carried out to gauge suitability for low-tech, process-based restoration. These surveys serve the dual function of also capturing information for beaver reintroduction suitability.

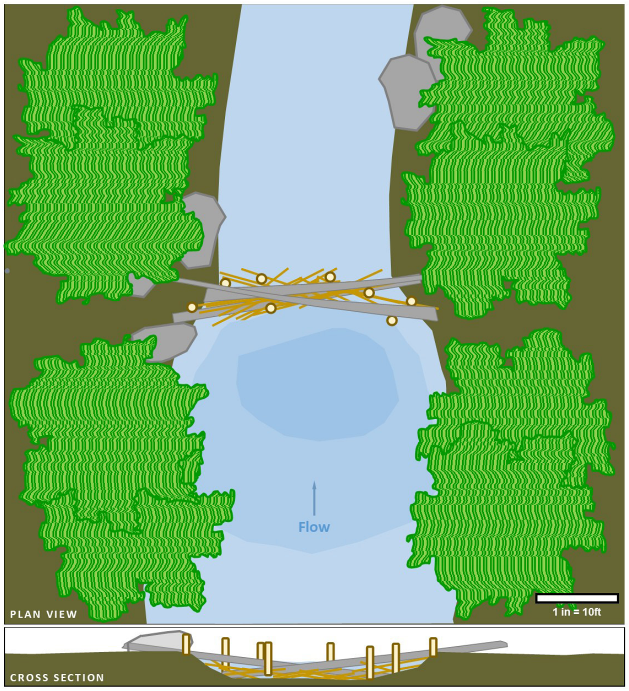
Releasing beavers to areas of historic occupancy and current suitability is a potential restoration strategy, but it must be accompanied by a thorough consideration of co-existence opportunities at the source site. In other words, are there methods or devices that can be employed to allow "nuisance" beavers to remain where they are found so that they can continue to persist and expand without relocation? In some cases, this will not be possible, but in others we have found success by educating landowners on ways to mitigate the issues that beavers are causing, such as devices that limit a beaver's ability to plug a culvert. In most cases, even after relocation, other beavers will occupy the source site and continue to cause issues for these landowners who are residing in areas where beavers used to live. In Appendix A, we list resources for landowners and organizations hoping to advance co-existence strategies for beavers.

On the policy side of things, there has been a recent initiative to create and implement a statewide beaver ecosystem management plan in Washington. This move reflects a commitment to recognizing and harnessing the vital role beavers play in maintaining ecosystem health and biodiversity. By defining beavers as a keystone species, the plan would prioritize providing resources and services to address human-beaver conflicts, emphasizing outreach, education, coexistence, relocation, and, only as a last resort, lethal removal services. We see this as a positive step forward in beaver conservation and recovery efforts in Washington and will be participating in the legal efforts to ensure beavers are protected.

Low-tech, process-based restoration

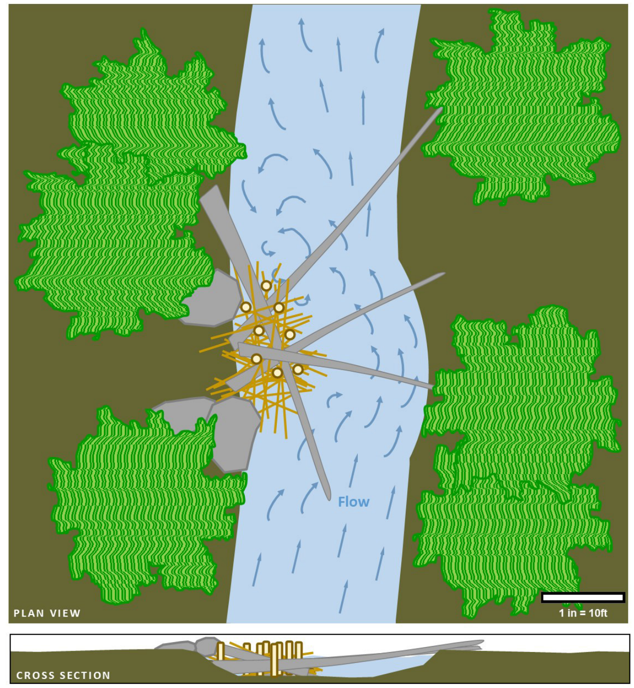
In this section, we will discuss low-tech, process-based restoration (LTPBR). This type of restoration can consist of handbuilt beaver dam analogs (BDAs), post-assisted log structures (PALS), individually placed large logs, or strategically-felled riparian trees (with riparian felling work, it is important to ensure that sufficient canopy cover is retained). Some structures are channel spanning (creating pools above the structures); some are flow

Four types of instream structures for low-tech, processed-based restoration



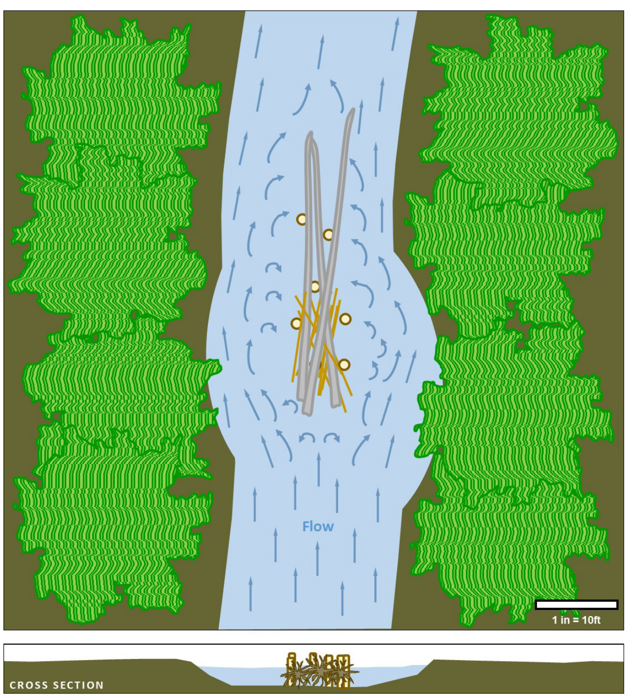
Beaver Dam Analog

Captures sediment, slows stream flow, and creates a pool



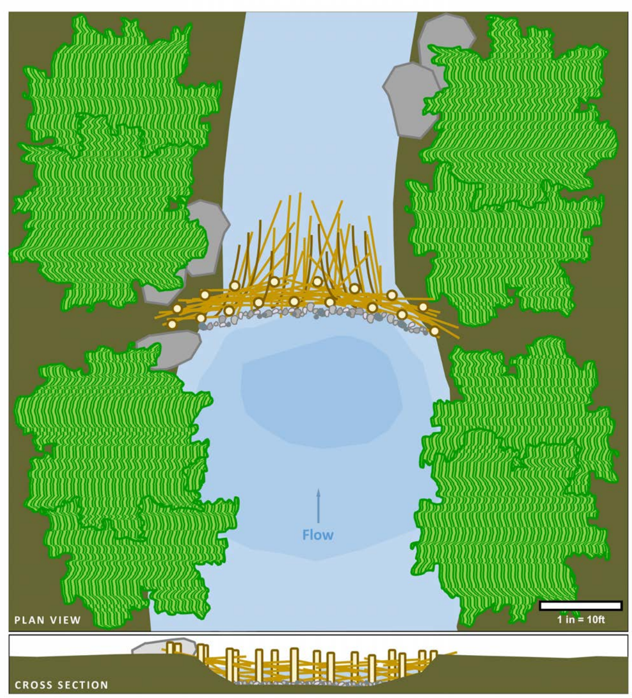
Channel Process Structure

Impedes flow on one side of the stream, creating hydraulic diversity that erodes banks and stores sediment



Flow Splitting Structure

Splits flow into multiple channels and increases aquatic complexity



Channel Spanning Structure

Captures sediments, slows stream flow, and creates a pool

Beaver dam analogs installed by CFC and volunteers along Stump Creek

splitting (these are smaller and positioned in the middle of the streambank to encourage new side-channels and channel complexity); and others are positioned on one side of the waterway to both direct flows to the opposite bank and create pooling. BDAs are generally similar to channel-spanning structures yet are intended for lower gradient reaches and areas where the substrate allows the installation of posts.

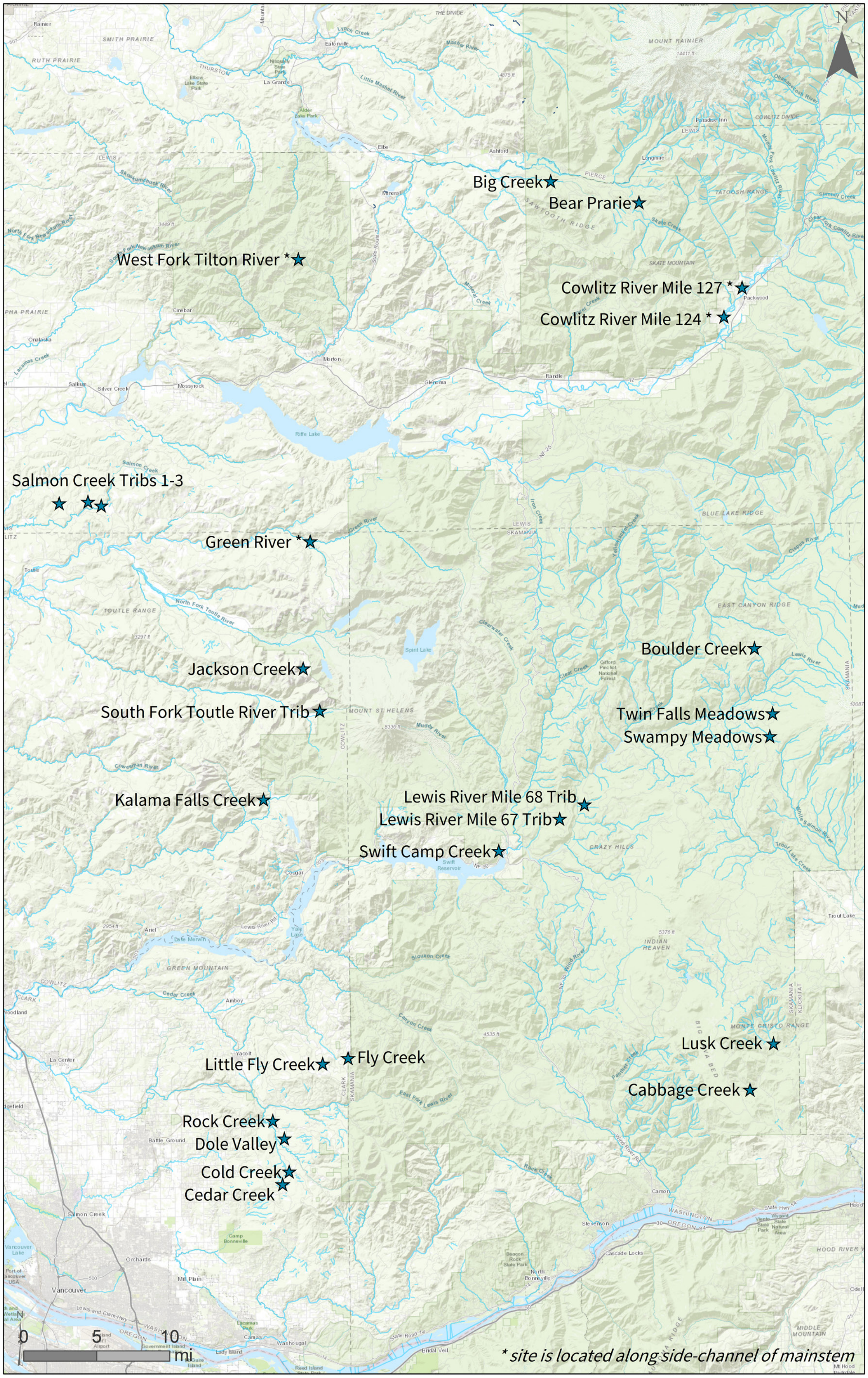
LTPBR creates new microhabitats within a stream channel and also serves as structure to slow flows and spread water laterally across the landscape (out of incised channels). This re-engages floodplains and side-channels that can persist longer into the dry season, creating refugia and access to rich foraging grounds for a variety of aquatic and terrestrial species. As these structures change the flow, they create new habitats and flow patterns, furthering the cycle of change and re-establishing aquatic complexity. As new channels are forged, the change begets future changes and increased floodplain connectivity. This work can also help reduce water temperature, as water is redirected into newly connected riparian floodplains that provide more shade (from vegetated riparian areas) and as groundwater exchange increases connection between the above-ground water and the cool waters that flow below. All these factors interact to improve habitat quantity, quality, connectivity, and complexity for salmon and many other species. While climate change threatens aquatic systems in multiple ways, instream wood is able to respond in-kind. This work also complements beaver recovery by creating new beaver real estate ("beaverhoods") and attracting beavers to new or formerly occupied habitats.

In this next section, we highlight 26 potential LTPBR sites in and around the GPNF. We selected these sites based on the following factors:

- Fish presence and habitat uplift potential: Will this work improve or expand habitat for at-risk species?
- Slope: Is it flat enough to be suitable for low-tech, non-engineered restoration?
- Land ownership: Is landowner support likely?
- Access: Can restoration materials such as logs, wood posts, and post-pounders be reasonably imported to the site?

For areas on federal land, we gave preferential consideration to areas where we know the Forest Service will soon be focusing their planning efforts and associated funding and permitting.

We know the on-the-ground dynamics of some of these areas better than others. This list is a first step in highlighting potential future project areas, with the requisite next step being thorough on-the-ground investigation and refined prioritization.



Potential LTPBR sites in southwest Washington

Considerations for resident trout species

Most current-day instream restoration efforts are focused on recovering habitat for salmon and other anadromous fish due to the multitude of risks faced by these species, but a pinpointed assessment of vulnerability of resident rainbow or cutthroat trout in certain areas will be a valuable step for ensuring at-risk populations are set on a path toward recovery. When instream restoration projects targeting resident species are implemented above barriers that prevent the passage for anadromous fish (such as work carried out above waterfalls), downstream species can still reap benefits through the attenuation of high and low flows. Such upland initiatives can also benefit amphibians dependent on damp riparian environments, as well as birds that prey on these resident trout.

Strategic treatment of reed canarygrass

Reed canarygrass (RCG) poses a significant threat to riparian habitats and biodiversity, spreading rapidly and outcompeting native vegetation species. Moreover, it exacerbates drought issues by absorbing substantial amounts of water from waterways and wetlands. The negative impact on water storage, biodiversity, and tree abundance affects a wide array of species, including fish, amphibians, and beavers. Tackling an RCG infestation is a time-consuming process, requiring diligent monitoring and follow-up. Therefore, it becomes crucial to strategically target locations where eradicating RCG will have the most substantial positive impact on habitat and resilience.

While chemical treatment is often a part of the restoration process, we must also emphasize native revegetation, which can aid in the process of outcompeting and shading out RCG, reducing the need for repeated treatments. Regular monitoring of priority wetland locations is vital, and we recommend the employment of an early detection, rapid response methodology to keep future infestations at bay before they become entrenched.

Volunteers can play a pivotal role in this conservation effort, surveying wetlands to identify areas where RCG is starting to take hold. They can also assist in monitoring previously treated areas, promptly identifying and reporting any resurgence of RCG. By engaging the community, we can build a collective effort to protect our waterways and wetlands from the encroachment of this particularly pernicious invasive plant.

Reed canarygrass at Woods Creek Watchable Wildlife Area

A call to action from Wheaton et al. 2019: select passages from the Low-Tech Process-Based Restoration of Riverscape Design Manual

A channel spanning structure constructed at Stump Creek

"Scaling restoration to match the scope of degradation will require a re-imagination of what's possible and an expansion of the restoration toolbox to include low-tech process-based approaches that get more people off the sidelines and into riverscapes restoration. In the American West alone, it is estimated that conservatively between 50,000 to 100,000 miles of perennially flowing riverscapes are degraded (USEPA, 2016), depending on definitions of degradation, choice of indicators of stream health, or the bar we set for stream recovery. The impairments to riverscapes are well understood and documented (Allan, 2004; Montgomery and Wohl, 2003), but the sobering scope of this degradation is often not emphasized enough. The grand challenge is what to do about it. As practitioners, scientists, landowners, and resource managers, do we standby, continue to observe and accept this degradation? Or do we re-imagine what these riverscapes could be and invest in re-establishing sustainable and resilient riverscapes and, in turn, the communities and ecosystems that depend on these riverscapes?"

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"Current stream restoration practice costs an average of $65,000 to $450,000 per mile (median: $270K per mile), and the median length of restoration projects is < 0.5 mile (Bair, 2004; Bernhardt et al., 2007). These are respectable per project monetary investments, but the size of the projects is far too small to reverse over 200 years of riverscape degradation, land use impacts, and systematic structural starvation – in short, the scale of restoration does not match the scale of degradation. We need to make restoration investments that are smarter, and 'partner' with the natural processes to let the system do much of the work required to restore riverscapes (Restoration Principle 7). This approach is far more likely to lead to self-sustaining riverscapes (Restoration Principle 10). This requires a process-based perspective and an honest look at the bigger picture. We cannot afford to continue to disproportionately overspend on small projects (i.e., spatial extent of < 2 miles of riverscapes), ignore the scope of the problem (i.e., 50-100,000 miles of degradation), or expect measurable increases in populations of imperiled fish and wildlife – our approach needs to change."

***

"The overarching goal of low-tech restoration is to improve the health of as many miles of riverscapes as possible and to promote and maintain the full range of self-sustaining riverscape processes."

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"The restoration approach (i.e., low -tech process-based restoration) described in this manual is intended to be implemented primarily in wadeable streams. Approximately 90% of the perennial streams and rivers in the United States are considered wadeable (EPA, 2006). The importance of wadeable streams, also often referred to as low-order or headwater streams, has been well-documented. Wadeable streams contribute to the biodiversity of river networks (Meyer et al., 2007), are important carbon-storage zones (Beckman and Wohl, 2014), contribute allochthonous inputs (nutrients, litter, etc.) to lower, larger depositional rivers (Bellmore and Baxter, 2014), and are important controls on water quality and quantity (Alexander et al., 2007)."[50]

Appendix A: Beaver Co-existence Resources

https://coexistwithbeavers.org/

https://awionline.org/content/coexisting-beavers

https://www.oregonzoo.org/news/2022/01/living-beavers-tips-and-tools-coexistence

https://www.beaversolutions.com/

https://www.beaverinstitute.org/

https://beaversnw.org/

Chapter 3 Reference List

1. Hudec JL, Halofsky JE, Peterson DL, Ho JJ. *Climate Change Vulnerability and Adaptation in Southwest Washington*. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; 2019:PNW-GTR-977. doi:10.2737/PNW-GTR-977

2. Rieman BE, Isaak D, Adams S, et al. Anticipated Climate Warming Effects on Bull Trout Habitats and Populations Across the Interior Columbia River Basin. *Trans Am Fish Soc*. 2007;136(6):1552-1565. doi:10.1577/T07-028.1

3. Dalton MM, Mote PW, Snover AK, eds. *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*. Island Press/Center for Resource Economics; 2013. doi:10.5822/978-1-61091-512-0

4. Beechie T, Imaki H, Greene J, et al. Restoring Salmon Habitat For A Changing Climate. *River Res Appl*. 2013;29(8):939-960. doi:10.1002/rra.2590

5. Zhang X, Li HY, Deng ZD, Leung LR, Skalski JR, Cooke SJ. On the variable effects of climate change on Pacific salmon. *Ecol Model*. 2019;397:95-106. doi:10.1016/j.ecolmodel.2019.02.002

6. Tohver IM, Hamlet AF, Lee SY. Impacts of 21st-Century Climate Change on Hydrologic Extremes in the Pacific Northwest Region of North America. *JAWRA J Am Water Resour Assoc*. 2014;50(6):1461-1476. doi:10.1111/jawr.12199

7. Chegwidden OS, Nijssen B, Rupp DE, et al. How Do Modeling Decisions Affect the Spread Among Hydrologic Climate Change Projections? Exploring a Large Ensemble of Simulations Across a Diversity of Hydroclimates. *Earth's Future*. 2019;7(6):623-637. doi:10.1029/2018EF001047

8. Wu H, Kimball JS, Elsner MM, Mantua N, Adler RF, Stanford J. Projected climate change impacts on the hydrology and temperature of Pacific Northwest rivers: Climate Change Impacts on Streamflow and Temperature. *Water Resour Res*. 2012;48(11). doi:10.1029/2012WR012082

9. Elsner MM, Cuo L, Voisin N, et al. Implications of 21st century climate change for the hydrology of Washington State. *Clim Change*. 2010;102(1-2):225-260. doi:10.1007/s10584-010-9855-0

10. Ma C, Morrison RR, White DC, Roberts J, Kanno Y. Climate change impacts on native cutthroat trout habitat in Colorado streams. *River Res Appl*. 2023:rra.4122. doi:10.1002/rra.4122

11. Anlauf-Dunn K, Kraskura K, Eliason EJ. Intraspecific variability in thermal tolerance: a case study with coastal cutthroat trout. Cooke S, ed. *Conserv Physiol*. 2022;10(1):coac029. doi:10.1093/conphys/coac029

12. Wofford JEB, Gresswell RE, Banks MA. Influence of Barriers to Movement on Within-Watershed Genetic Variation of Coastal Cutthroat Trout. *Ecol Appl*. 2005;15(2):628-637. doi:10.1890/04-0095

13. Sheldon KA, Richardson JS. Season-specific survival rates and densities of coastal cutthroat trout across stream sizes in southwestern British Columbia. *Ecol Freshw Fish*. 2022;31(1):102-117. doi:10.1111/eff.12616

14. Falke JA, Flitcroft RL, Dunham JB, McNyset KM, Hessburg PF, Reeves GH. Climate change and vulnerability of bull trout (Salvelinus confluentus) in a fire-prone landscape. Marshall CT, ed. *Can J Fish Aquat Sci*. 2015;72(2):304-318. doi:10.1139/cjfas-2014-0098

15. Isaak DJ, Young MK, Nagel DE, Horan DL, Groce MC. The cold-water climate shield: delineating refugia for preserving salmonid fishes through the 21st century. *Glob Change Biol*. 2015;21(7):2540-2553. doi:10.1111/gcb.12879

16. Jones LA, Muhlfeld CC, Marshall LA, McGlynn BL, Kershner JL. Estimating Thermal Regimes of Bull Trout and Assessing the Potential Effects of Climate Warming on Critical Habitats: Bull Trout Thermal Regime and Climate Change. *River Res Appl*. 2014;30(2):204-216. doi:10.1002/rra.2638

17. Hudson JM, Doyle J, Lamperth J, Al-Chokhachy R, Robertson G, Wadsworth T. Lewis River Bull Trout: A Synthesis of Known Information. Published online April 4, 2019. https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/hydro/lewis-river/license-implementation/acc/LR_BT_Synthesis_Final_20190404.pdf

18. Blaustein AR, Walls SC, Bancroft BA, Lawler JJ, Searle CL, Gervasi SS. Direct and Indirect Effects of Climate Change on Amphibian Populations. *Diversity*. 2010;2(2):281-313. doi:10.3390/d2020281

19. WDFW. Cascade torrent salamander. Accessed July 12, 2023. https://wdfw.wa.gov/species-habitats/species/rhyacotriton-cascadae

20. Abney C, Balzer S, Dueckman A, Baylis A, Clements D. Early Spring and Early Vanishing Wetlands as Harbingers of the Future? The Climate Change Trap for Ephemeral Pond-Breeding Frogs. *Northwest Sci*. 2019;93:52. doi:10.3955/046.093.0105

21. Water Quality Standards for Surface Waters for the State of Washington. Washington State Legislature. https://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A

22. USFS. *GPNF Land and Resource Management Plan*. 1990. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5444081.pdf

23. Washington State Parks and Recreation Commission. *Washington State Scenic River Assessment*. 1998.

24. Department of Ecology - State of Washington. Washington State Water Quality Assessment 303(d)/305(b) List. Published July 6, 2023. https://apps.ecology.wa.gov/ApprovedWQA/ApprovedPages/ApprovedSearch.aspx

25. Lower Columbia Fish Recovery Board. SalmonPORT. Published July 6, 2023. https://www.lcfrb.org/salmon-resource-map

26. U.S. Environmental Protection Agency Region 10. *Columbia River Cold Water Refuges Plan*. 2021.

27. *Washington State of Our Rivers Report*. *Final Report*. Conservation Science Partners, Inc.; 2021.

28. Dry Creek and Headwaters Wind River Watershed Restoration Action Plan. Published online December 3, 2021. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1017942.pdf

29. River Index. American Whitewater. Published 2023. https://www.americanwhitewater.org/content/River/view/river-index#

30. The National Wild & Scenic Rivers System. Accessed August 21, 2023. https://www.rivers.gov/about

31. Adhikari A, Rew LJ, Mainali KP, Adhikari S, Maxwell BD. Future distribution of invasive weed species across the major road network in the state of Montana, USA. *Reg Environ Change*. 2020;20(2):60. doi:10.1007/s10113-020-01647-0

32. Trombulak SC, Frissell CA. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. *Conserv Biol*. 2000;14(1):18-30. doi:10.1046/j.1523-1739.2000.99084.x

33. Kastridis A. Impact of Forest Roads on Hydrological Processes. *Forests*. 2020;11(11):1201. doi:10.3390/f11111201

34. De Rivera CE, Bliss-Ketchum LL, Lafrenz MD, et al. Visualizing Connectivity for Wildlife in a World Without Roads. *Front Environ Sci*. 2022;10:757954. doi:10.3389/fenvs.2022.757954

35. Perkin JS, Acre MR, Graham J, Hoenke K. An integrative conservation planning framework for aquatic landscapes fragmented by road-stream crossings. *Landsc Urban Plan*. 2020;202:103860. doi:10.1016/j.landurbplan.2020.103860

36. Thiel R. Relationship between Road Densities and Wolf Habitat Suitability in Wisconsin. *Am Midl Nat*. 1985;113(2):404-407. doi:https://doi.org/10.2307/2425590

37. *Travel Analysis Report*. Gifford Pinchot National Forest; 2015. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd486103.pdf

38. Raforth RL, Norman DK, Johnson *A. Second Screening Investigation of Water and Sediment Quality of Creeks in Ten Washington Mining Districts, with Emphasis on Metals*. Washington State Department of Ecology; 2022.

39. Samuels, Joshua X., and John Zancanella. An Early Hemphillian Occurrence of Castor (Castoridae) from the Rattlesnake Formation of Oregon. *J Paleontol*. 2011;85(5):930-935.

40. E.T. Seton. *Lives of Game Animals*. Vol 4. Doubleday, Doran & Company; 1929.

41. Naiman RJ, Johnston CA, Kelley JC. Alteration of North American Streams by Beaver. *BioScience*. 1988;38(11):753-762. doi:10.2307/1310784

42. Giese LAB, MacDougall D. The Beaver: Natural History of a Wetlands Engineer. *Wetlands*. 2004;24(2):480-482. doi:10.1672/0277-5212(2004)024[0480:R]2.0.CO;2

43. Pollock MM, Beechie TJ, Jordan CE. Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. *Earth Surf Process Landf*. 2007;32(8):1174-1185. doi:10.1002/esp.1553

44. Pollock LJ, Thuiller W, Jetz W. Large conservation gains possible for global biodiversity facets. *Nature*. 2017;546(7656):141-144. doi:10.1038/nature22368

45. Polvi LE, Wohl E. The beaver meadow complex revisited - the role of beavers in post-glacial floodplain development. *Earth Surf Process Landf*. 2012;37(3):332-346. doi:10.1002/esp.2261

46. Pollock MM, Heim M, Werner D. Hydrologic and Geomorphic Effects of Beaver Dams and Their Influence on Fishes. Published online 2003. https://www.researchgate.net/publication/231218389_Hydrologic_and_Geomorphic_Effects_of_Beaver_Dams_and_Their_Influence_on_Influence_on_Fishes

47. Hood G, Bayley S. The effects of high ungulate densities on foraging choices by beaver (Castor canadensis) in the mixed-wood boreal forest. *Can J Zool*. 2008;86:484-496. doi:10.1139/Z08-029

48. Fairfax E, Whittle A. Smokey the Beaver: beaver-dammed riparian corridors stay green during wildfire throughout the western United States. *Ecol Appl*. 2020;30(8). doi:10.1002/eap.2225

49. Whipple AA, Viers JH. Coupling landscapes and river flows to restore highly modified rivers. *Water Resour Res*. 2019;55(6):4512-4532. doi:10.1029/2018WR022783

50. Wheaton JM, Bennet SN, Bouwes NW, Maestas JD, Shahverdian SM. *Low-Tech Process-Based Restoration of Riverscapes: Design Manual*. Utah State University Restoration Consortium; 2019.