2. AQUATIC ECOSYSTEMS

Higher water temperatures

- Impacts to fish phenology, survival, productivity, and habitat, particularly salmon, steelhead, and bull trout
- Thermal barriers preventing migration and genetic interchange for aquatic species
- Altered structure and abundance of aquatic invertebrates, plants, microbes, and nutrients

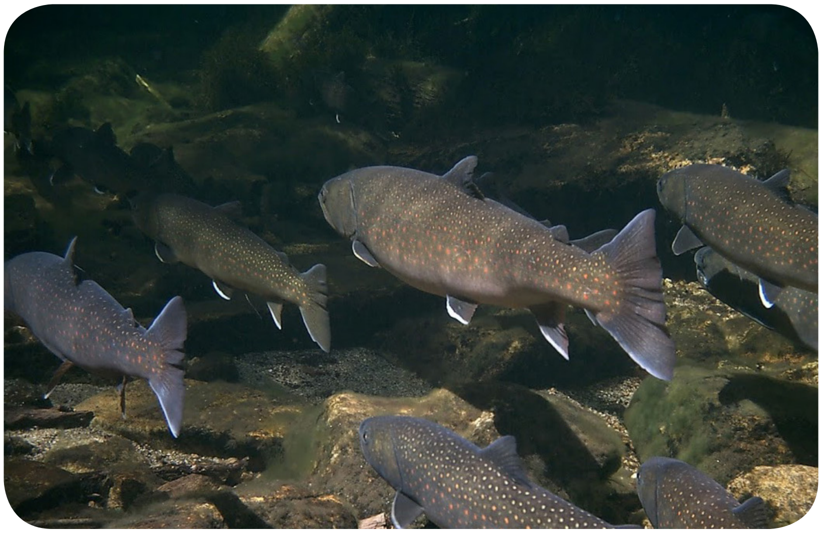
Altered streamflow patterns and timing

- Impacts to life stages of salmonids, including eggs, juveniles, and adults
- Decoupling of seasonal interactions

AQUATIC ECOSYSTEMS, SPECIES, AND EXPECTED IMPACTS

Aquatic systems in the southern Washington Cascades are expected to be affected by climate change in several ways. Increasing air temperatures, changing soil moisture contents, and shifts to riparian vegetation are predicted to warm waters and impact aquatic and riparian habitat for an array of fish, amphibians, and terrestrial species (6, 24). In addition, many aquatic and riparian species are already relying on fragmented and degraded habitat. Some aquatic species are already living close to the upper range of their thermal tolerance and therefore even small shifts in temperature can have dramatic effects on populations (15). Increases in water temperature can cause salmonids to become more susceptible to disease, which can affect population viability and can increase predation. The increase in water temperature also causes a decrease in dissolved oxygen, which can impede survival for various aquatic species (6).

Altered streamflow patterns are also expected to degrade aquatic ecosystem function and decrease the quantity and quality of spawning habitat (9). Increased precipitation falling in the form of rain rather than snow in the winter and spring months is expected to result in higher peak flows during these months and in lower base flows in the summer months. These shifts can cause an increase in sediment introduction, scouring of stream substrates and salmonid redds, and downcutting of the stream channels, thereby disconnecting them from their floodplains and fish refugial areas. In addition to negatively affecting salmonid redds, these shifts would also lead to higher levels of mortality for newly-emerged fry, particularly for winter and spring spawning species, as well as parr and adults (7). Lower streamflows during the summer months are expected to decrease habitat and population connectivity, increase water temperatures, and create thermal barriers for fish.



Bull trout - one of the many aquatic species threatened by the changing water cycle and warming water temperatures. Photo by USFWS

Aquatic systems are in a particularly precarious position due to the multiple stressors created by shifting water temperatures, altered flow patterns, and the inability of many aquatic species to move and adjust to new habitat (10). The main concerns relate to the cumulative effects of these anticipated stressors, the already degraded condition of many aquatic habitats, and the variability of habitat and species responses.

The shift to decreased snowpacks, peak flows, and earlier spring thaws is expected to affect the survival and timing of migration, spawning, incubation, and rearing of salmonids throughout the year. These shifts will also affect other aquatic species that have adapted to certain temperature and flow regimes. Climate-related changes in the marine environment are already resulting in negative effects to anadromous salmonids, thereby also affecting the freshwater aquatic and riparian ecosystems where they spawn and rear. Some of the primary changes in the marine environment that are affecting salmonids are (1) ocean temperature, current, and upwelling patterns; (2) persistent and large dead/anoxic zones; (3) abundance and distribution of forage fish, invertebrates, jellyfish, and planktons; and (4) ocean acidification that is impacting the growth and survival of important salmonid food sources, such as krill and amphipods.

In many instances, as water temperatures rise, suitable stream

Increased frequency of high flow events

- Scouring of spawning substrate and eggs, affecting winter and spring spawning salmonids
- Reduced overwinter fish survival, especially juveniles
- Road failures
- Increase in sediment delivery

Low summer flows

- Habitat and population fragmentation
- Reduction in available habitat
- Drought impacts in surrounding floodplains
- Exacerbated instream and riparian microclimate warming

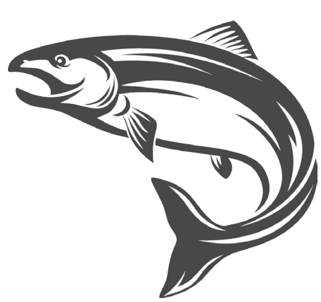
habitat will shift upstream or, in the case of lakes and reservoirs, to lower strata (6). Isaak and Rieman (2012) estimated that stream temperature gradients in the Pacific Northwest may shift upstream 5-143 km (3-89 miles) by 2050. Complicating this wide-ranging dynamic is the expectation that altered hydrologic regimes, changing channel structure, and culverts can impede access to new habitat areas.

In the Gifford Pinchot National Forest, a decrease in mean summer **stream flow** is expected to impact many stream reaches, with significant shifts in the streams listed below (31). Many of these streams are highlighted as project area priorities on pages 26 and 27 where restoration and conservation priorities are outlined.

CISPUS AREA	Big Creek	Cabin Creek
Pumice Creek	Little Creek	Woods Creek
Squaw Creek	Wakepish Creek	Ferrous Creek
Fourmile Creek	Hemlock Creek	Lower reaches and tributaries of Quartz Creek

LEWIS RIVER, MUDDY RIVER, AND PINE CREEK AREAS	Upper reaches and tributaries of Clearwater Creek	Upper reaches and tributaries of Elk Creek
Wright Creek	Tillicum / Lower Tillicum Creek	Copper Creek
Chickoon Creek	Strawberry Creek	(An increase in Pepper Creek)

WIND RIVER AND EAST FORK LEWIS RIVER AREAS	Big Hollow Creek	Panther Creek	Cedar Creek
Trout Creek	Dry Creek	Green Fork	
East Fork Trout Creek	Oldman Creek	McKinley Creek	



An increase in **temperature** is also expected to impact many streams, with significant shifts in the streams listed below.

CISPUS RIVER AREA	The confluences of Cispus River with Quartz Creek, Woods Creek, Iron Creek, and Greenhorn Creek	Yellowjacket Creek

LEWIS RIVER, MUDDY RIVER, AND PINE CREEK AREAS	Smith Creek	Pine Creek
Clear Creek	Clearwater Creek	Rush Creek
Muddy River	Lewis River	

WIND RIVER AND EAST FORK LEWIS RIVER AREAS	Brush Creek	Trapper Creek	Anaconda Creek
Wind River	Layout Creek	Big Hollow Creek	Snass Creek
Little Wind River	East Fork Trout Creek	Panther Creek	Side Creek

Salmonids will be particularly sensitive to shifts resulting from climate change, and it has the potential to affect all their life stages (23). Dalton et al. (2013) highlight how evolutionary challenges relate to the current threats to salmon:

> "As different salmon species and populations within species evolved over time, they acquired diverse spawning and migratory behaviors to take advantage of variations in temperatures, streamflow, ocean conditions, and other habitat features (Mantua et al. 2010); these characteristics now shape their vulnerability to climate change. For example, steelhead (*Oncorhynchus mykiss*), "stream-type" chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), and coho salmon (*O. kisutch*) are particularly sensitive to changes in stream conditions as young fish remain in freshwater habitats for a year or more after hatching before migrating to the sea. The adults then return in the spring and summer, often taking several months to migrate upstream to high-elevation headwater streams to spawn (Mantua et al. 2010). For these populations, higher stream temperatures and altered streamflows due to climate change are likely to be significant limiting factors."

As noted in the previous pages, the impacts to spawning, rearing, and adult survival of salmon are significant concerns for the region. Conservation and restoration efforts to increase the species resilience is one of the primary objectives we considered when identifying and prioritizing aquatic projects.

Crozier and Zabel (2006) found that Chinook salmon in the Snake River of Idaho that inhabited wider and warmer streams were more sensitive to higher summer temperatures than those inhabiting narrower and cooler streams. However, they found that the salmon in these narrow and cool streams were more sensitive to reduced fall streamflows than their wide stream brethren.

Steelhead and other **rainbow trout** (*Oncorhynchus mykiss*), as well as **cutthroat trout** (*Oncorhynchus clarkii*), will likely be more sensitive to the changes in hydrology than the warming of waters. An increase in high flow events can disrupt spawning and rearing habitat, causing eggs to wash away or stream beds to downcut, which can further alter healthy flow dynamics. Low summer flows can impact survival by causing stranding and heat mortality. Low flows can also negatively impact foraging and genetic diversity.

Bull trout (*Salvelinus confluentus*) are expected to be heavily impacted by climate change, particularly due to warmer water temperatures. Bull trout are sensitive to temperature shifts and rely on cool water for spawning. Without proper mitigation, bull trout habitat is expected to shrink and thermal bottlenecks will make access to upstream habitat limited. Bull trout are relatively rare, but there are populations currently found in several streams in the region, including Pine Creek, Rush Creek,

Pacific tree frog. Photo by Michael Sulis

Cougar Creek, Lewis River, North Fork Tieton River, Klickitat River, Bumping River, and Rattlesnake Creek. There are also likely still remnant populations in stream reaches located in the foothills on the north side of Mount Rainier. Spawning areas are, however, more limited and will be greatly affected by warming waters. Fortunately, restoration efforts can be implemented to mitigate some of the more extreme impacts. Efforts to support and expand bull trout habitat (mainly through instream restoration and planting for shade) are outlined in the subsequent section of the guidebook.

"Steelhead will be most sensitive to the changes in hydrology, while salmon and bull trout will be impacted by both temperature increases and hydrologic shifts."

Amphibian species that may be affected by shifts to riparian systems, such as impacts from fragmentation, drying, and altered flow regimes, include: Cascades frog, chorus frog, garter snake, long-toed salamander, northwestern salamander, Van Dyke's salamander, Larch Mountain salamander, and western toad.

As ectotherms, amphibians are especially susceptible to the environment and at risk to changes in air and water temperatures. Toxic contaminants from pesticides, herbicides or fungicides can further impact amphibians by killing them directly or affecting their behavior and reducing their growth rates (32). Considering the potential cumulative impacts to amphibians in shifting riparian systems, it is important to reduce this added impact by reducing the use of damaging aquatic chemicals on state and federal lands. In addition, it will be important to work with private land owners to ensure cross-boundary collaboration that supports broad ecosystem health.

Road washouts from high flow events can quickly destroy potentially critical patches of habitat for Van Dyke's salamanders (*Plethodon vandykei)* and other amphibians that reside near waterfalls and in high gradient systems. Lastly, ephemeral ponds at higher elevations, which support various amphibian populations, may disappear as a result of lower snowpacks.

The Southwest Washington Adaptation Partnership identified **bird species** that are expected to be particularly vulnerable to climate impacts in riparian systems. These are: hairy woodpecker, red-breasted sapsucker, American dipper, harlequin duck, wood duck, and hooded merganser. Other birds impacted by climate change are discussed in the Forest Ecosystems chapter.

"Van Dyke's salamanders and other amphibians that reside near waterfalls and other high gradient systems will be sensitive to high flow events from climate change."

STRATEGIES AND RECOMMENDATIONS FOR AQUATIC ECOSYSTEMS

The threats to aquatic ecosystems are significant, but there are strategies that can be implemented to lessen and even counteract many of the negative impacts (15, 24, 25, 33–38).

"Reducing fragmentation and removing barriers can provide flexibility for fish populations to shift as climate pressures increase and new habitat areas are required"

In this section, we will outline recommendations for protecting and restoring aquatic habitat and building resilience to climate change effects. Ultimately, the best approach will be a mix of different strategies, plans that take local and fine-scale issues into consideration while maintaining focus on the broader, regional context. In addition to input from local biologists and hydrologists, the work of Johnson (2004), Battin et al. (2007), Beechie et al. (2012), and Dalton et al. (2013) was instrumental in helping us outline these restoration and conservation strategies.

• **Floodplain and side-channel reconnection** can can reduce the negative consequences of high peak flows by dissipating streamflows through more natural and varied routes, storing flood water, and increasing the availability of refugia. This work can also mitigate temperature increases by increasing the length of hyporheic flow paths beneath the floodplain, which can cool water during the summer (15). Examples of this type of project include the creation of side channels and sloughs, removal of levees/dikes, and re-meandering of dredged or straightened channels.

STRATEGIES AND RECOMMENDATIONS

- Floodplain and side-channel reconnection
- Road reduction
- Dam removal and stream crossing structure upgrades
- Expansion of Wild and Scenic River designations
- Management and expansion of riparian buffers to restore natural function
- Reintroduction of beavers
- Reduction in grazing and restoration of areas currently impacted by grazing
- Planting of trees
- Control of invasive plants
- Addition of large wood
- Restoration of incised channels
- Increase in surveys and monitoring with improved data sharing

Logging and stream "cleanout" activities of the 1970s and 1980s, which disrupted natural flows and depleted the amount of large wood in and around streams, caused the mainstems of many of the streams to downcut and become disconnected from the side-channels. The building of roads exacerbated and expanded this problem.

Floodplain and side-channel reconnection projects are often large-scale and accompanied by significant initial hurdles, but when organizations and agencies are working from a similar blueprint and a common strategy, new opportunities can more easily develop, and benefits are more encompassing than when independent actors are working disparately. Additionally, stream channel projects benefit local communities by decreasing road maintenance costs, improving fish habitat and water quality, and oftentimes employing local contractors for the work.

Floodplain and side-channel reconnection in the southern Washington Cascades can help re-establish natural flow regimes that were altered by the loss of large instream wood structures. Focus areas are outlined below and on the maps on pages 26 and 27.

o In **Trout Creek** and its tributaries (Compass, Crater, Layout, East Fork, Planting, and Martha Creeks), the disconnection of mainstems from historic side-channels poses a significant risk to fish survival due to expected increases in temperature and high streamflow events. Loss of channel complexity, as well as high and low flow refugia, are primary limiting factors for Lower Columbia River steelhead trout. These fish are currently listed as "Threatened" under the Endangered Species Act (ESA) so the need to increase their resilience to expected changes is imperative. Side-channel restoration along these stream reaches will expand future rearing habitat and will increase the availability of spawning habitat and adult steelhead "holding" habitat that will be critical during summer low flow and winter/spring high flow periods. The site-specific restoration areas along Trout Creek and its tributaries are areas where historic side-channels existed, as evident from the presence of river gravel, old scour, and deposition features.

o **Wind River** is also at risk due to past timber harvest activities and will require restoration to build sufficient climate resilience. Climate impacts include habitat fragmentation, instream and riparian habitat degradation, and reduced productivity and distribution of fish and other aquatic species. Currently, side-channel and other refugial habitat is scarce throughout the Wind River watershed. An increase in side-channel habitat here will increase the amount of important refugia for both juvenile and adult steelhead during high and low flow events. Spawning gravels and over-summer pools are also scarce, so side-channel restoration efforts along Wind River should be tailored to address these aspects as well.

o The coho and winter steelhead that reside in **Little Wind River** will benefit from floodplain and side-channel reconnection. The initial stretches of this river are the priority areas for restoration.

o In the **North Fork of the Cispus River**, past management has affected channel complexity and the amount of large wood structures in the waterway. With expected warming due to climate change, nine miles of anadromous fish distribution, and Clean Water Act 303D listing in the lower reaches for temperature, this river is a priority focus area for floodplain reconnection.

o The ESA-listed fish in the **Cowlitz River** are currently persisting in degraded habitat and will be further impacted as climate change alters habitat function. Side-channel and floodplain reconnection will improve future resilience. Establishing agreements with local landowners to comprehensively improve fish habitat and water quality is an integral part of the restoration strategy of the Cowlitz River.

o The multitude of fish species in the upper reaches of **Lewis River** are at risk from warming waters and changes to streamflow. Side-channel restoration is one of the primary methods for improving habitat for aquatic and riparian species here. Although not currently a spawning area for bull trout, these fish do occur in the Lewis River and will benefit from these restoration actions.

o Side-channel restoration and floodplain reconnection along **Greenhorn Creek** and its tributaries would benefit anadromous and resident fish that depend on this waterway and are at-risk from low summer flows and impacts from high flow events due to loss of channel complexity. Populations of coho, spring Chinook, and winter steelhead currently reside here.

Recently decommissioned forest road

• The **reduction of road density** improves aquatic and terrestrial systems, decreases stressors to wildlife, and also brings jobs to local communities (39–49). The maps on pages 52, 53, and 54 highlight the specific roads we have identified for closing or decommissioning due to ecological risk, including aquatic impact factors such as the number of stream crossings, particular topographic qualities, and erosion potential. As a general rule, we believe that reducing the amount of road miles should be one of the restoration activities associated with each timber harvest project. This could be cost- and time-effective because the NEPA, ESA, and Heritage Resource consultation for both timber harvest and road projects could be combined into one effort. Also, it is a time when road work would be occurring concurrently with other actions, thereby lessening the span of impact from active management. Road closures and decommissionings should also be considered for stand-alone road management projects.

"The reduction of unneeded forest roads can improve aquatic ecosystems, decrease stressors to wildlife, reduce the impacts of invasive species, and bring jobs to local communities"

• **Dam removal** can dramatically change river flows and riparian areas in a short period of time. By removing barriers that once prevented native salmon and steelhead from reaching miles of habitat, dam removal efforts have helped to restore native fish populations and improve future resilience. The Condit Dam on the White Salmon River prevented fish passage from 1913 until it was breached in October 2011. Dam removal was completed in December 2012, and anadromous fish species have successfully recolonized the historically accessible tributaries and mainstem reaches upriver from the former dam site (33). Removal of the Hemlock Dam on Trout Creek in 2009 has had similar success by allowing ESA-listed steelhead trout and other species unimpeded access to 15 miles of stream habitat, with additional miles being added as side-channel reconnection projects are implemented.

Future opportunities to improve connectivity through dam removal should focus on restoring aquatic habitat connectivity. Even if certain dams provide some level of fish passage, they should be

The Condit Dam on the White Salmon River prevented the passage of fish and other aquatic wildlife since it was constructed in 1913. Since its removal in October of 2011, native fish species and kayakers have recolonized upstream of where the dam once stood. Photos by Ben Knight

considered for removal where feasible in order to improve fish population viability, enhance water quality, and restore streamflow, large wood cycles, and sediment routing regimes. Dams that degrade water quality and impact sensitive species through abnormally high or low temperatures should also be top considerations for removal. Throughout southern Washington, dams still exist that negatively impact fish populations and fish habitat, including those on the Columbia, Nisqually, Cowlitz, Cispus, and Lewis Rivers. All of the dams on these rivers are located outside of federal lands. There are also dams located on smaller streams, many of which are no longer serving any purpose, yet are fragmenting fish populations and disrupting natural stream processes. Feasible means to amend this issue vary widely with land designation and current political environments. Some of these dams are listed in the National Inventory of Dams prepared by the U.S. Army Corps of Engineers. The Colvin Dam, located on Colvin Creek and affecting fish habitat along the North Fork of the Lewis River, has been proposed for removal by the Cowlitz Tribe. We support the removal of this dam to benefit the health and resilience of salmon and steelhead. Other existing dams should be prioritized for removal based on their impacts to fish habitat and life cycles, continued utility, and potential long-term ecosystem benefits resulting from their removal.

• **Expansion of Wild and Scenic River designations** should include the Green River, Cispus River, Wind River, Lewis River, and East Fork Lewis River. These rivers, as well as some of their tributaries, have been evaluated by the Gifford Pinchot National Forest and found to be eligible for inclusion in the National Wild and Scenic River System. These proposed Wild and Scenic Rivers are often already managed to maintain their outstanding recreational, fisheries, historical, cultural, geological, and scenic values. However, we believe it is important to permanently protect these values from harmful management and development activities via their Congressional designation as Wild and Scenic Rivers, especially where these rivers run through non-federal land ownerships. This permanent protection would contribute to their long-term resilience in the face of increasing climate change-related stressors. This legislative step prohibits dams and other federally-assisted projects that would impair the river's free-flowing character, water quality, or outstanding values. Wild and Scenic River designation further protects the river and riparian areas from degradation by establishing a protected corridor extending ¼ mile from the ordinary high water mark on both sides of the river. Also, the acreage of the Congressionally-designated corridor can be reallocated to protect connected waterways. For example, corridor acreage within already highly protected areas, such as wilderness areas, may more effectively restore connectivity of riparian areas if it is allocated elsewhere. These particular rivers are noted for designation because they have outstanding values that could be threatened by disruptive projects. Once a river is designated, the resulting management plan for the river would exclude uses that are inconsistent with the maintenance of the river's outstanding and remarkable values.

"Riparian no-cut buffers help protect streambank stability, water quality, stream temperatures, soil moisture, downed wood, and large instream wood sources"

While organizations can work to promote Wild and Scenic River designation, community support is vital because only Congress can make these designations. Citizens should write or call their representatives to express support for this type of watershed protection.

• **The preservation and broadening of riparian buffers** on federal, state, and private lands is a needed step to ensure that riparian functions and values are protected (50–52). Riparian buffers are areas along streams that are designated as off-limits to commercial timber harvest and heavy equipment incursions in order to protect streambank stability, water quality, stream temperatures, soil moisture, downed wood, and large instream wood sources. Much of the focus of these buffers has been on protecting species listed as Sensitive, Threatened, or Endangered. Now that the Forest Service's 2012 Planning Rule highlights the need to consider climate change in forest management planning, we hope to see the size of buffers increase in some areas and to specifically consider climate change aspects, such as microclimate impacts (53).

Laws governing federal, state, and private forest lands in southern Washington require varying levels of protection for riparian areas. On federal lands, the Northwest Forest Plan designated Riparian Reserves for the protection of land bordering lakes, streams, rivers, and wetlands. The Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan is designed to prevent further degradation of watershed condition and protect high-quality fish habitat and populations. Within the Riparian Reserves, a no-cut buffer is established and is intended to eliminate commercial harvest within its borders. The size of the riparian no-cut buffer is based on the type of waterbody and whether it is fish-bearing. We believe that attainment of the ACS Objectives demands a precautionary approach to forest management within Riparian Reserves, and harvest within the reserves should

Quartz Creek in the Gifford Pinchot National Forest only occur when necessary for riparian health. This is a high standard of proof, and considering recent justifications for logging in Riparian Reserves, conservation groups and citizens should be diligent with oversight to keep the microclimate of these areas undisturbed and to support the retention of suitable levels of large trees for instream wood. Since riparian thinning can easily cause negative impacts to aquatic species, it should be limited to areas where the benefit is clear and significant and where the management efforts are supported by a broad set of research (35, 52, 54, 55).

On state and private lands, riparian buffers are broken down into three Riparian Management Zones (RMZs) – the Core Zone, Inner Zone, and Outer Zone. The Core Zone excludes all timber harvest and extends 30-50 feet from the ordinary high water mark, depending on the type of stream. The Inner Zone allows some harvest, if harvest allows for adequate shade and meets the desired future condition. Harvest in the Outer Zone requires leaving 20 conifer trees at least 12” dbh per acre (WAC 222-30-040). Decreasing destructive harvesting within the RMZ, especially the Inner Zone, will benefit aquatic and riparian systems.

To further protect riparian areas, alternative ways to retain riparian areas on private forest lands under the Forest Practices Rules should be pursued. For example, on private forest lands there is a small forest landowner riparian easement program offering small landowners money in exchange for retention of their forested lands. This program is intended to prevent the reduction of habitat available for the restoration of salmon and other aquatic resources (WAC 222-21-005). Riparian areas on other private lands may also be protected through conservation easements, or encouraging the landowner to develop a management plan in cooperation with the Washington Department of Natural Resources, other agencies, and impacted tribes (WAC 222-23-010).

• **Surveying** stream culverts and erosion on forest roads is important for prioritizing where restoration efforts should be focused (35, 39). Obtaining up-to-date information is essential for maintaining suitable aquatic habitat connectivity and lessening negative impacts from high flow events. Each year, and increasingly likely with climate change, forest roads are failing and causing harm to aquatic habitat and hindering access for forest users (56). Many of these failures can be mitigated by maintaining current condition data on culverts and erosion. Current data on fish presence is also very beneficial for biologists and planners to help identify current distribution, conservation needs, and priority restoration areas. Through partnerships between state agencies, federal agencies, local organizations, and the public, forest resource specialists can help prioritize focus areas for monitoring.

Severe erosion found on a citizen science road survey

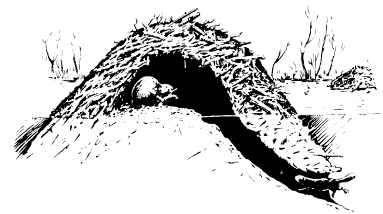
• The **reintroduction of beavers** (*Castor canadensis*), as well as increasing the abundance and distribution of beavers in watersheds where they are already present, can have a multitude of positive impacts on riparian and aquatic ecosystems. These include decreased water temperatures and peak flows, increased streamflow retention, improved access to floodplain habitat, and increased abundance and biodiversity of aquatic- and riparian-dependent flora and fauna (57, 58). With relatively little expense or controversy, beaver reintroduction can be a holistic way to improve aquatic resilience while also re-establishing an important piece of the trophic cascades. Due to trapping, grazing (which depletes the natural stock of hardwoods), and loss of channel complexity due to logging and other management activities, beaver populations have decreased in many parts of the southern Washington Cascades. New regulations on body-gripping traps, set in place in 2000 by the Washington State Legislature, have significantly reduced beaver trapping. Livestock grazing has been reduced in many areas and with new climate pressures suggesting a need to reduce this influence even further, we hope to see grazing continue to be focused away from sensitive and valuable stream systems. The simplification of stream systems will be addressed through restoration projects, which can often be coupled with beaver reintroduction efforts. Moreover, reintroduction, if not carried out in conjunction with side-channel improvements, should be focused on areas where reduced channel complexity will not be a limiting factor for new beaver populations.

Our recommendation is to coordinate ahead of time with state and county agencies, as well as companies that work with wildlife on private land, to set up agreements for the transfer of beavers that have been trapped as "nuisance" animals (likely found impacting culverts or chewing on trees). These animals would be kept in holding ponds for pairing and then transferred to appropriate reintroduction locations on state and federal lands. The site-specific locations along the priority creeks outlined below will be identified by the presence of suitable forage for beavers, site-specific restoration needs, appropriate stream velocities, and the existence of past lodges or dams. Priority beaver reintroduction locations in the southern Washington Cascades were identified with the help of local wildlife and aquatic specialists and include:

o Hampton Creek
o Woods Creek
o Big Creek
o Bee Tree Ponds
o Lone Butte

A map of these areas can be found on pages 26 and 27. Some of these areas are completely lacking in extant beaver populations while others have small populations that need to be enhanced.

"Beavers can have a multitude of positive impacts on riparian systems"



• **Planting** native trees for shade and bank stability can help decrease stream temperatures, improve biodiversity, and reduce erosion and sedimentation by strengthening bank stability, increasing riparian shade, enhancing nutrient delivery, and decreasing the spread of non-native plants (26, 35, 59, 60). Planting and seeding in strategic locations will enhance both short-term and long-term ecosystem health for riparian areas and the species that depend on these areas. This work is best focused along waterways that are not only degraded but also at risk and important for overall ecosystem integrity in the face of a shifting climate. The priority tree species are cottonwood, willow, cedar, aspen, and Douglas-fir. In the southern Washington Cascades, areas in need of planting are shown on pages 26 and 27, and they include Rush Creek, Pine Creek, Yellowjacket Creek, Cispus River, North Fork Cispus River, Cowlitz River, Wind River, Little Wind River, Panther Creek, Trout Creek, Muddy River, and several tributaries of Wind River and Trout Creek.

o **Rush Creek and Pine Creek** are the two main spawning streams for ESA-listed Columbia River bull trout in the southern Washington Cascades. These two creeks, which are in close proximity to each other also provide habitat for coho, Chinook, steelhead, cutthroat, and rainbow trout. Expanding the "reach" of bull trout habitat along these creeks is critical to ensuring the species' long-term viability as waters warm and current habitat becomes less suitable. Local fish biologists have identified riparian planting as a priority to mitigate stream temperature increases. Since some reaches of Pine Creek extend into private property, we suggest working with the local landowners to set up coordinated restoration strategies and agreements. Non-profit organizations are in a good place to bridge these gaps, and we plan to work in this realm accordingly.

o Cottonwood and aspen trees are needed along **Yellowjacket Creek** to increase shade, enhance bank stability, and sustain future beaver populations. These efforts will support spring Chinook, fall Chinook, coho, winter steelhead, and overall aquatic resilience.

"Planting cottonwood, willow, cedar, and Douglas-fir trees in riparian areas can improve resilience in aquatic ecosystems"

o In addition to channel configuration needs in the **Cispus River** and **North Fork of the Cispus River**, riparian planting will significantly build the resilient capacity of this critically important area. Currently home to steelhead, Chinook, and coho, the Cispus waterways have suffered from past sediment deposition and logging, and they are currently impacted by heavy recreation on their shores. Due to expected warming along the Cispus River, planting will be an important mitigation measure that should be enacted soon.

o **Cowlitz River** is one of the Gifford Pinchot National Forest's largest rivers and is home to Chinook, coho, steelhead, and an array of species that rely on this large, winding waterway. Riparian planting along the river will benefit many different aquatic and terrestrial species. Much of this river flows through private land, so cross-boundary efforts will be needed to effectively improve long-term resilience.

o Invasive reed canary grass has become a problem along the **Muddy River** and is expected to become an even larger issue as climate change further threatens bank stability and impacts native riparian plant communities. Native riparian plants are intrinsically tied to the health of fish and aquatic invertebrates they protect, yet they are severely threatened by the likely increase in the spread of invasive plants due to changing weather patterns, which can sometimes introduce an added stressor for native plant populations. One of the main ways to wipe out reed canary grass is to crop it low and plant trees that will shade it out (61). This has the added benefit of decreasing stream temperatures, which, according to climate models, will be important for the Muddy River (31).

o Planting and seeding along **Wind River** will be an important restoration step for improving climate resilience for salmon and steelhead in the region. These efforts should be focused on areas that were heavily logged in the past, are infested with weeds (especially reed canary grass), have low tree species diversity, have high solar impact, and have low levels of instream wood.

o Planting efforts along **Little Wind River** should be coupled with floodplain or side-channel reconnection to improve habitat resilience for coho and winter steelhead.

o Planting along **Panther Creek** should be focused between Jimmy Creek and Cedar Creek to support bank stability and to decrease stream temperatures for an array of aquatic species and for the ESA-listed fish downstream in Wind River.

o **Trout Creek** and many of its tributaries contain fish populations that will be impacted by climate change, especially ESA-listed Lower Columbia River steelhead trout. These impacts include higher stream temperatures for longer periods of the year and altered peak and base flows (higher flows in late fall-spring and lower flows in summer-early fall). This creek, its tributaries, and downstream rivers will benefit greatly from riparian planting of conifers and hardwoods. In addition to a fine-scale focus on areas impacted by past management and invasive species, this work should also be carried out at the old Hemlock Dam site (where the vegetation has not recovered).

• **Removing and controlling invasive plants** can help mitigate temperature increases by decreasing competition and supporting native trees and shrubs (51). Controlling invasive plants also supports biodiversity since non-native plants will often take over large areas and displace different species that would normally comingle. Care should be exercised to make sure that invasive control efforts do not bring unintended impacts such as negative impacts on water quality from herbicides or sediment delivery from active management. Approaches such as early-detection rapid-response, similar to what is currently underway along hiking trails, could aid in the early adoption of mitigation measures in riparian areas, which could then be enacted through small-scale, manual treatment efforts. If invasive plant populations in certain areas are too large to control with manual treatment, aquatically-appropriate herbicides should be used to ensure that efforts are not causing more harm than good. As outlined in the planting section above, invasives treatment should be focused along **Trout Creek and its tributaries, Wind River,** and **Muddy River**, and they should be coupled with riparian planting to improve the long-term benefit.

Reed canary grass (*Phalaris arundinacea*) - an invasive plant in riparian areas. Photo by Roger Banner

• **Eliminating mining** along most waterways, especially those important to fish, will improve the habitat viability of fish populations by minimizing harmful mining pollution, sedimentation, and physical impacts, enhancing their ability to survive the stressors from climate change.

o Hard rock mining threatens water quality and fish habitat through acid mine drainage, increased copper levels, and sedimentation commonly associated with hard rock mines. Salmonids are particularly sensitive to copper, and it is toxic to them even at low concentrations. Additionally, hard rock mines often require large tailings ponds to contain mining waste, and failure of tailings ponds can be catastrophic to the watershed. Hard rock mining proposals within the Gifford Pinchot National Forest have historically been located along the Green River, a Wild Steelhead Gene Bank and proposed Wild and Scenic River. The Green River provides important habitat for native steelhead, which needs increased protection to counteract the expected decreases in steelhead habitat due to climate change.

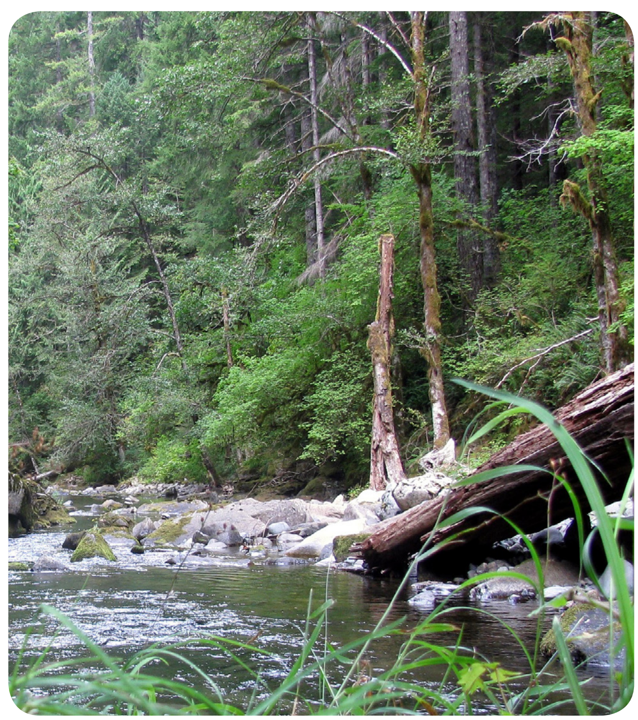
o Suction dredge mining is a process where miners use a motorized suction pump and hose to vacuum the sediments on the river bottom in search of gold. The sediment is then released in a plume that flows downstream, along with toxic heavy metals that were previously settled in the river bottom. In addition to polluting the water column, suction dredge mining destroys redds and degrades spawning substrate and water quality, thereby reducing quality spawning areas and harming salmonid eggs and alevins that rely on clean and appropriately-sized substrate for incubation and rearing. As warming waters reduce suitable habitat for salmonids, it is essential that suction dredge mining be eliminated or significantly reduced in waterways important for their life cycles.

• **A reduction in livestock grazing** near riparian areas will directly reduce sediment delivery to streams and will aid in the restoration of vegetation, which traps sediment and increases stream shade. In the southern Washington Cascades, the amount of private grazing on public land has decreased in the past decade, but impactful grazing areas still remain in sensitive ecological zones.

The number of grazing allotments in the GPNF has decreased from four to one in the last ten years. The remaining allotment, encompassing approximately 30,000 acres, is located on the south side of Mount Adams and intersects 132 linear miles of streams, all of which flow south and into the White Salmon and Columbia Rivers. While the current primary focus of management concerning this allotment is the effect on local wildlife and terrestrial vegetation (aspens and shrubs), the effects on aquatic systems are significant and will likely increase as climate change brings new and different pressures. In lieu of removing this private allotment, there are steps that can be taken to minimize the negative effects on the local aquatic environment and downstream communities. These steps include (1) maintaining proper fencing and adjusting (and enforcing) appropriate timing of grazing activities, such as limiting grazing during important times of perennial growth; (2) adjusting boundaries to avoid important riparian areas, such as shrinking the western portion of the allotment to avoid the Riparian Reserve of the White Salmon River and/or Cascade Creek; (3) constructing and maintaining plentiful, alternative water sources for the cattle in the form of troughs and guzzlers; and (4) reducing the size of the allotment where it intersects perennially flowing streams such as Gotchen Creek and Morrison Creek. The grazing allotment currently encompasses the following waterways: Buck Creek, Cascade Creek, Crofton Creek, Gotchen Creek, Hole in the Ground Creek, Morrison Creek, Salt Creek, Shorthorn Creek, Wicky Creek, and the White Salmon River.

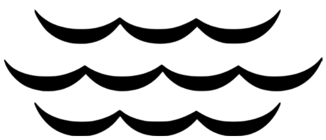
•**The addition of large wood structures** can provide benefits to aquatic systems and fish populations (57). This approach can be quite effective in adding valuable habitat features to aquatic environments (15). These types of habitat features are expected to be increasingly needed as climate refugia. Unfortunately, though, they are expected to become less abundant due to lower summer flows and disrupted channel configuration through high flow events. Due to logging, which removed most large trees in riparian areas, there is a shortage of large wood structures in some creeks and rivers of the region. In the southern Washington Cascades, there are several priority areas for large wood addition, including **Cispus River, North Fork of the Cispus River, Trout Creek and its tributaries,** and **Wind River and its tributaries**. Wood addition projects in these waterways should occur both during and independent of timber harvest projects, taking care to

“Instream wood structures provide habitat areas and refugia for aquatic species.”

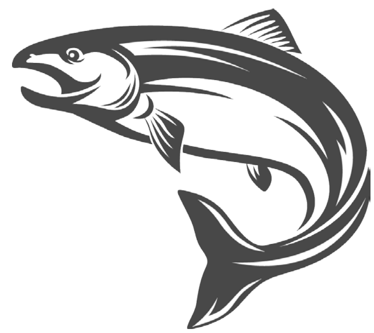


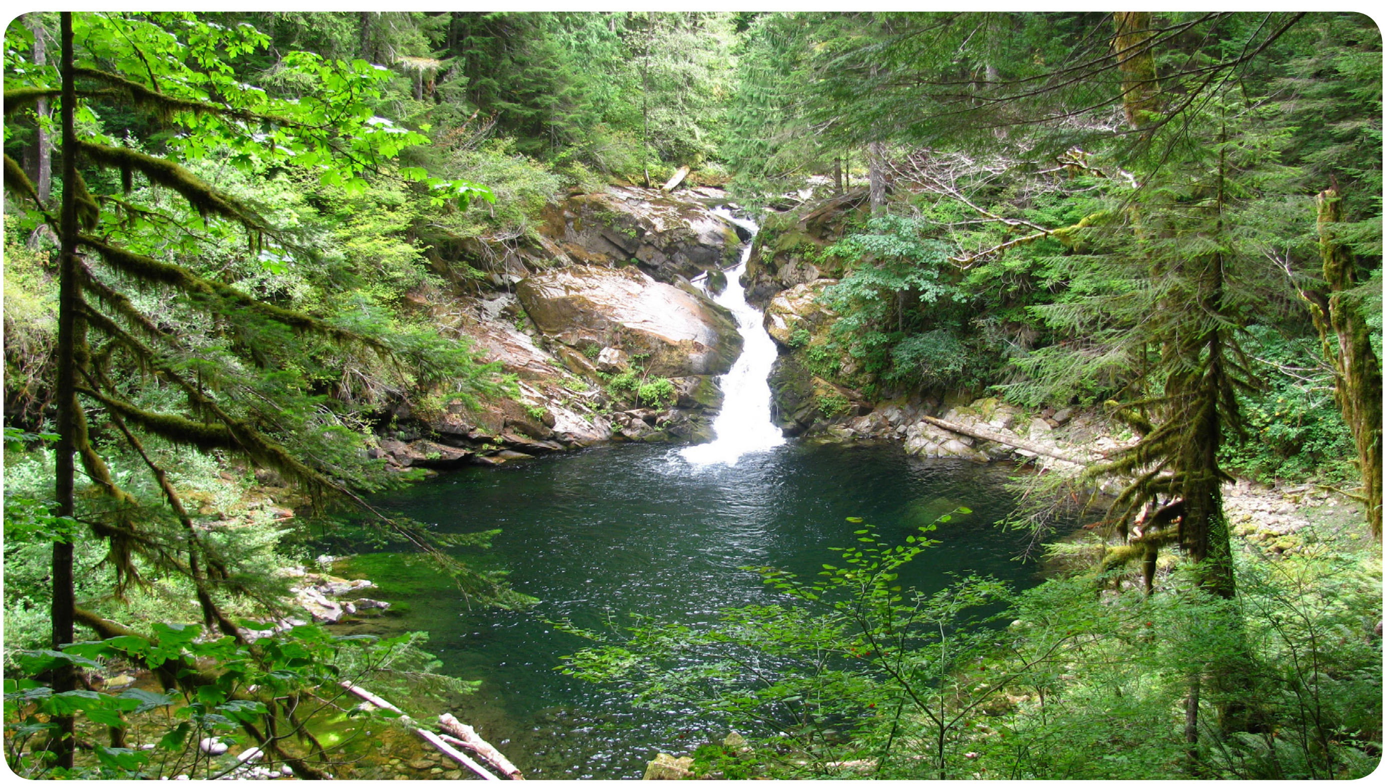
minimize harm to the existing riparian environment. Trout Creek, in particular, needs more deep pools for spawning and rearing habitat for steelhead. And, Lower Trout Creek and Wind River mainstems need large wood in the main channel and in its re-opened/reconnected relict side-channels that are currently being restored with a multi-year Lower Trout Creek Habitat Enhancement Project.

Conservation groups and restoration planners should establish community partnerships ahead of time to use fallen timber from surrounding lands. Agreements put in place with power companies, reservoirs, state lands, and private land owners can benefit both parties by increasing project efficiency, decreasing costs, and helping landowners in the removal of fallen large trees.



- **Other aquatic restoration improvements** include (1) reducing water withdrawals along different ownership classes; (2) supplementing depleted streams with fish carcasses or analogues for seasonal nutrient additions; (3) restoring incised channels; (4) increasing flood storage allocations and connected reductions in hydropower production that would help in the maintenance of instream flows for salmon and steelhead; and (5) infrastructure and human-use shifts such as upgrading to more efficient water application systems and changing to crops that require less water, which can mitigate the negative effects of a reduced supply (6, 15, 35, 62, 63).





PRIORITY AREAS FOR AQUATIC RESTORATION

Part I: North

Cispus River
- Side-channel restoration to re-establish sinuosity and improve resilience
- Planting to reduce temperature impacts
- Addition of large wood to increase habitat pools
- Expanding Wild and Scenic River designation efforts to decrease impacts from logging

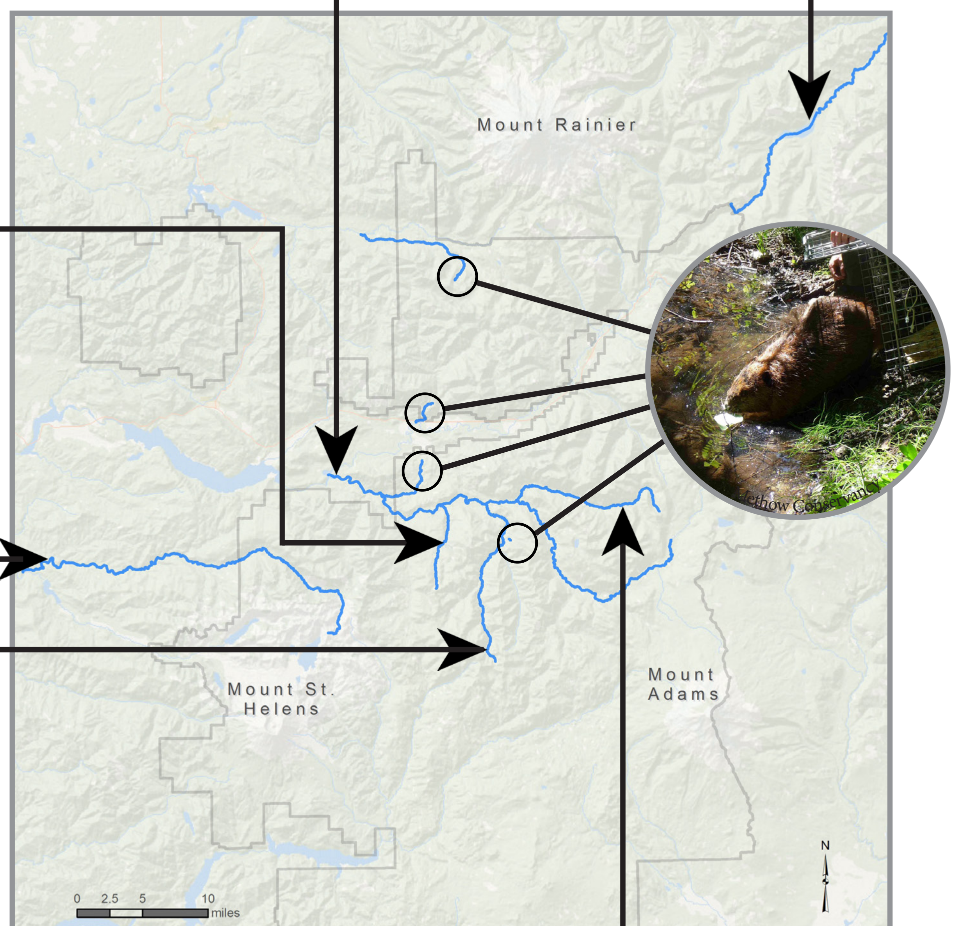
Bumping River
- Planting for shade to support existing bull trout habitat
- Side-channel restoration to improve aquatic resilience

Greenhorn Creek
- Side-channel restoration and floodplain reconnection to enhance channel complexity and reduce impacts from high flow events

Green River
- Eliminate mining to support fish habitat, water quality, and the role of the Green River as a Wild Steelhead Gene Bank.
- Wild and Scenic River designation

Yellowjacket Creek
- Planting cottonwood, cedar, and aspen to decrease temperature impacts for anadromous fish

North Fork of the Cispus River
- Addition of large wood to increase habitat features for fish
- Planting conifers and hardwoods to mitigate temperature increases



PRIORITY AREAS FOR AQUATIC RESTORATION

Part II: South

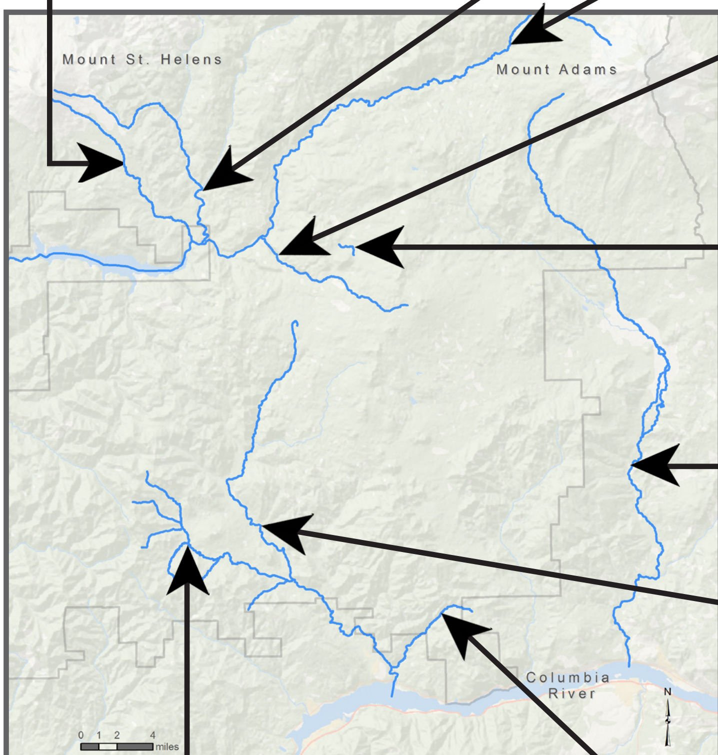
Pine Creek
- Planting for shade and erosion control to support existing bull trout habitat and improve water quality
- Work with private land owners of private in-holdings to expand restoration outside the GPNF

Muddy River
- Invasives control to decrease spread of reed canary grass
- Planting to shade out invasives and maintain bank stability

Lewis River
- Floodplain and side-channel reconnection to improve habitat for salmon, steelhead, and bull trout

Rush Creek
- Planting for shade to expand suitable bull trout habitat upstream

Lone Butte
- Beaver reintroduction to improve wetland and riparian habitat



White Salmon River
- Promote continued expansion of Wild and Scenic River designation
- Reduce grazing impacts by adjusting buffers and seasonal schedules and ensuring proper fencing

Wind River
- Side-channel restoration to increase channel complexity, decrease temperature impacts, and mitigate impacts from high flow events
- Planting for shade
- Large wood addition and beaver reintroduction to create more pools and habitat features

Trout Creek
- Side-channel restoration to improve steelhead habitat and resilience
- Planting for shade
- Invasives control to mitigate future impacts from reed canary grass
- Large wood addition to increase number of habitat features
- Beaver reintroduction to enhance aquatic health and resilience

Little Wind River
- Planting for shade to mitigate expected instream warming
- Large wood addition to increase habitat features