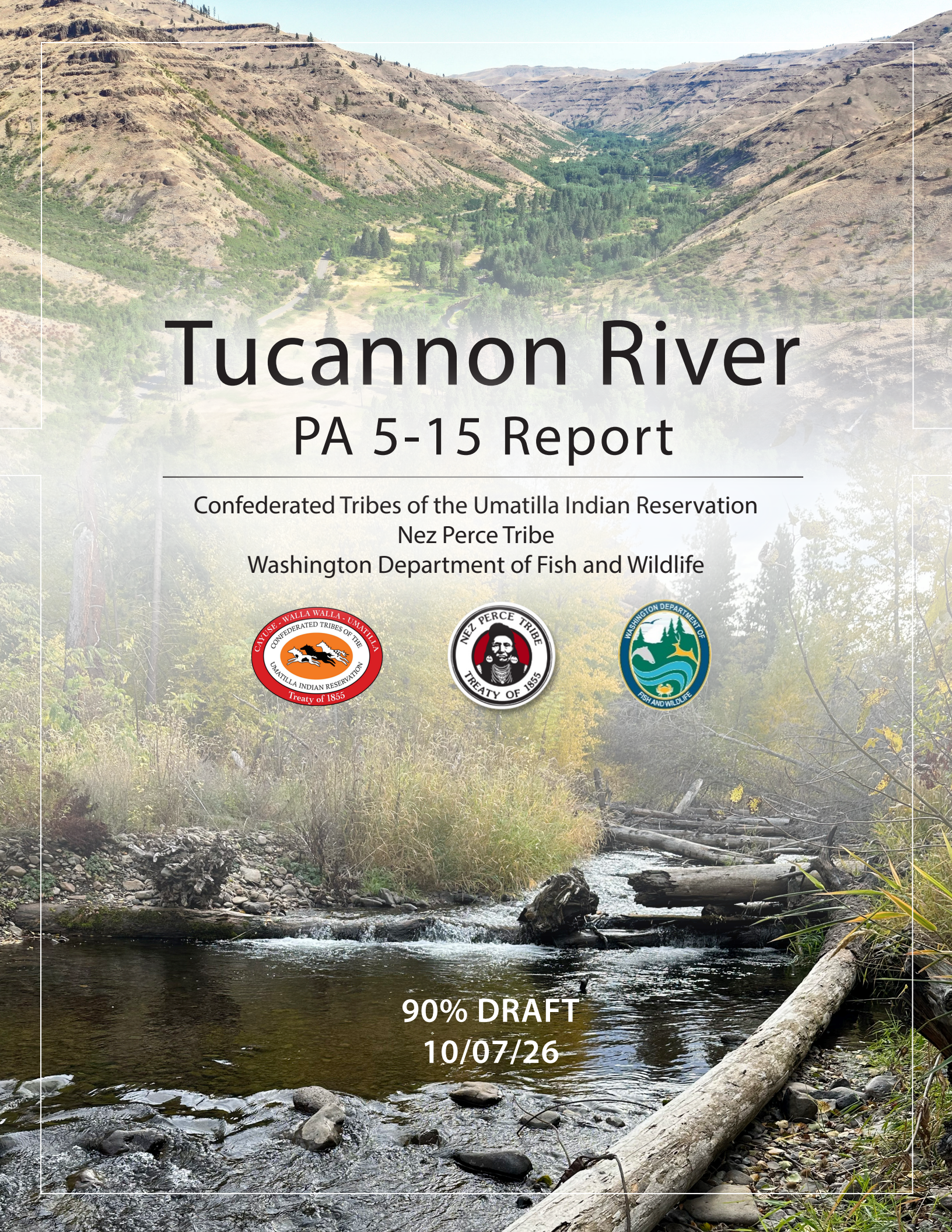


Tucannon River

PA 5-15 Report

Confederated Tribes of the Umatilla Indian Reservation
Nez Perce Tribe
Washington Department of Fish and Wildlife

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Project Area 5-15 Assessment

This Assessment builds upon previous efforts in the Tucannon River watershed, focusing on a 10-mile reach within the W. T. Wooten Wildlife Area (WTWWA). The reach extends from near the WTWWA headquarters office upstream to Camp Wooten.

Project Area (PA) 5-15 is located along the Tucannon River from below Camp Wooten (PA-5) downstream to Russell Springs (PA-15; RM 46.25–36.25). The location and boundary of PA 5-15 are shown in Figures 2, 3, and 4.

Confederated Tribes of the
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www.ecosystemsciences.com

All photographs are by the Nez Perce Tribe, CTUIR, WDFW, Wolf Water Resources, Lichen Land and Water and Ecosystem Sciences, LLC unless an alternative source is specifically identified.

■ *Cover Photos: Tucannon River; PA 5-15*



■ *W.T. Wooten Wildlife Area - Rainbow Lake*

Tucannon River PA 5-15 Report

Acknowledgements

Co-Manager Collaborators

The Confederated Tribes of the Umatilla Indian Reservation, the Washington Department of Fish and Wildlife, and the Nez Perce Tribe jointly sponsor the Tucannon River PA 5–15 Assessment and Conceptual Design. This collaborative effort brings together tribal, state, and scientific frameworks to inform restoration and management strategies. It reflects a shared commitment to integrating traditional ecological knowledge with contemporary science, consistent with the W.T. Wooten Floodplain Management Plan, updated 2014. The process emphasizes open coordination and transparent communication among all partners. Shared data and technical resources support consistent analysis and understanding across the project area. Joint decision-making ensures that outcomes are aligned with ecological goals, treaty obligations, and long-term watershed resilience.

Technical Consultant Team

Wolf Water Resources, Inc

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Resource Specialists, Inc.

Contributors

A collaborative approach was taken to incorporate ecological and fisheries recovery goals with local land management and use. The common goal was to create an action plan for improving salmonid habitat conditions and natural riverine processes while maintaining recreational opportunities in the Tucannon River PA 5-15. Contributions to the assessment and planning process were provided through a technical and scientific team, including agency representatives, fisheries and habitat specialists, restoration practitioners, land managers, and other local stakeholders.

The collaborative process brought together technical expertise, local knowledge, and existing watershed information to identify limiting factors, evaluate restoration opportunities, and develop actions appropriate to the physical and biological conditions of each project area. Technical findings and proposed strategies were reviewed and refined through an iterative process, allowing stakeholder input and practical land-management considerations to inform project priorities. The resulting action plan provides a shared framework for directing restoration efforts toward improvements in habitat connectivity, floodplain and riparian function, channel complexity, and other natural processes important to salmonid recovery while recognizing existing land uses and recreational values.



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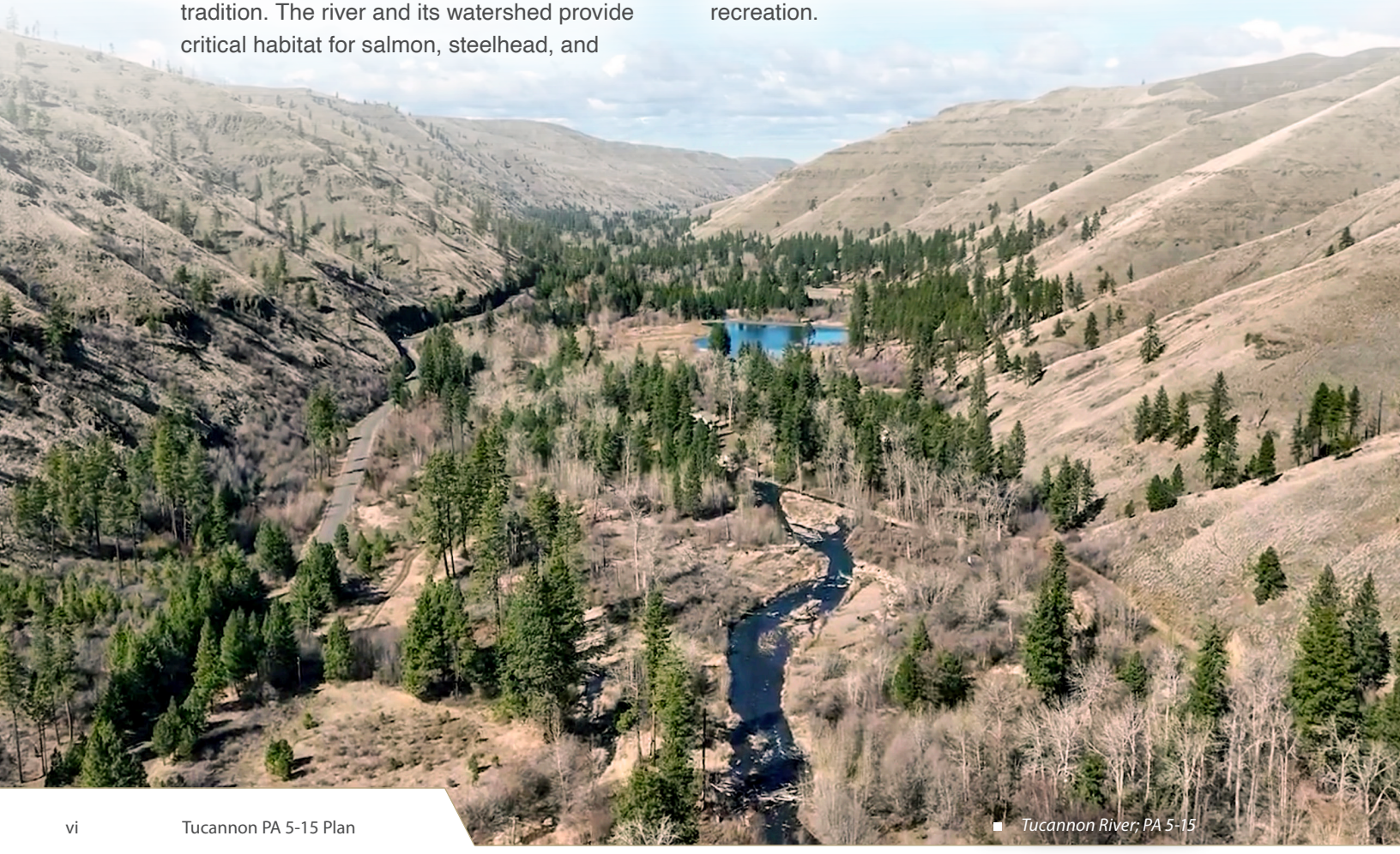
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Tucannon River

The Tucannon River watershed (Figures 1 and 2) is located in southeastern Washington, draining the west slope of the Blue Mountains before flowing into the Snake River. The watershed spans forested headwaters, mid-elevation canyons, and broader alluvial valleys, creating a diverse landscape of upland, floodplain, and aquatic habitats. This range of conditions supports a dynamic river system shaped by snowmelt, seasonal flows, and sediment processes that influence channel form and floodplain function.

For Native peoples, particularly the Nez Perce Tribe and the Confederated Tribes of the Umatilla Indian Reservation, the Tucannon River is part of a larger cultural landscape tied to treaty-reserved rights and the First Foods tradition. The river and its watershed provide critical habitat for salmon, steelhead, and lamprey—species that are central to cultural identity, subsistence, and spiritual practices. Stewardship of these resources reflects a long-standing responsibility to maintain the health of the land and water for future generations.

Today, the Tucannon River watershed is also an important recreational destination. Areas such as the W.T. Wooten Wildlife Area (Figures 2 and 3) attract anglers, hunters, campers, hikers, and wildlife viewers. The lakes and river support popular fisheries, while the surrounding forests and open lands provide year-round outdoor opportunities. Balancing these uses with ecological restoration and cultural values is central to ongoing management efforts, making the watershed both a vital natural resource and a shared landscape for conservation and recreation.



Tucannon River; PA 5-15

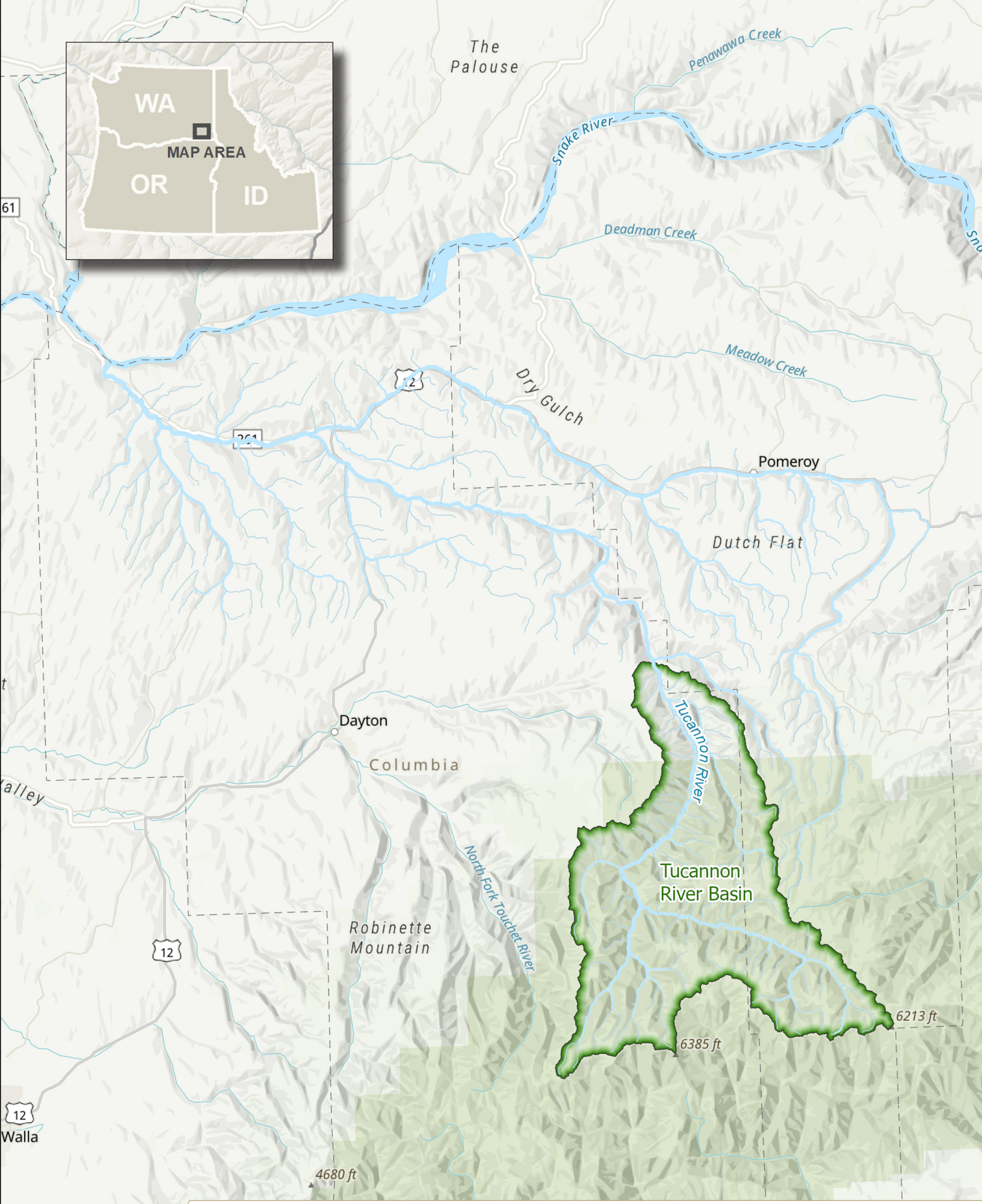
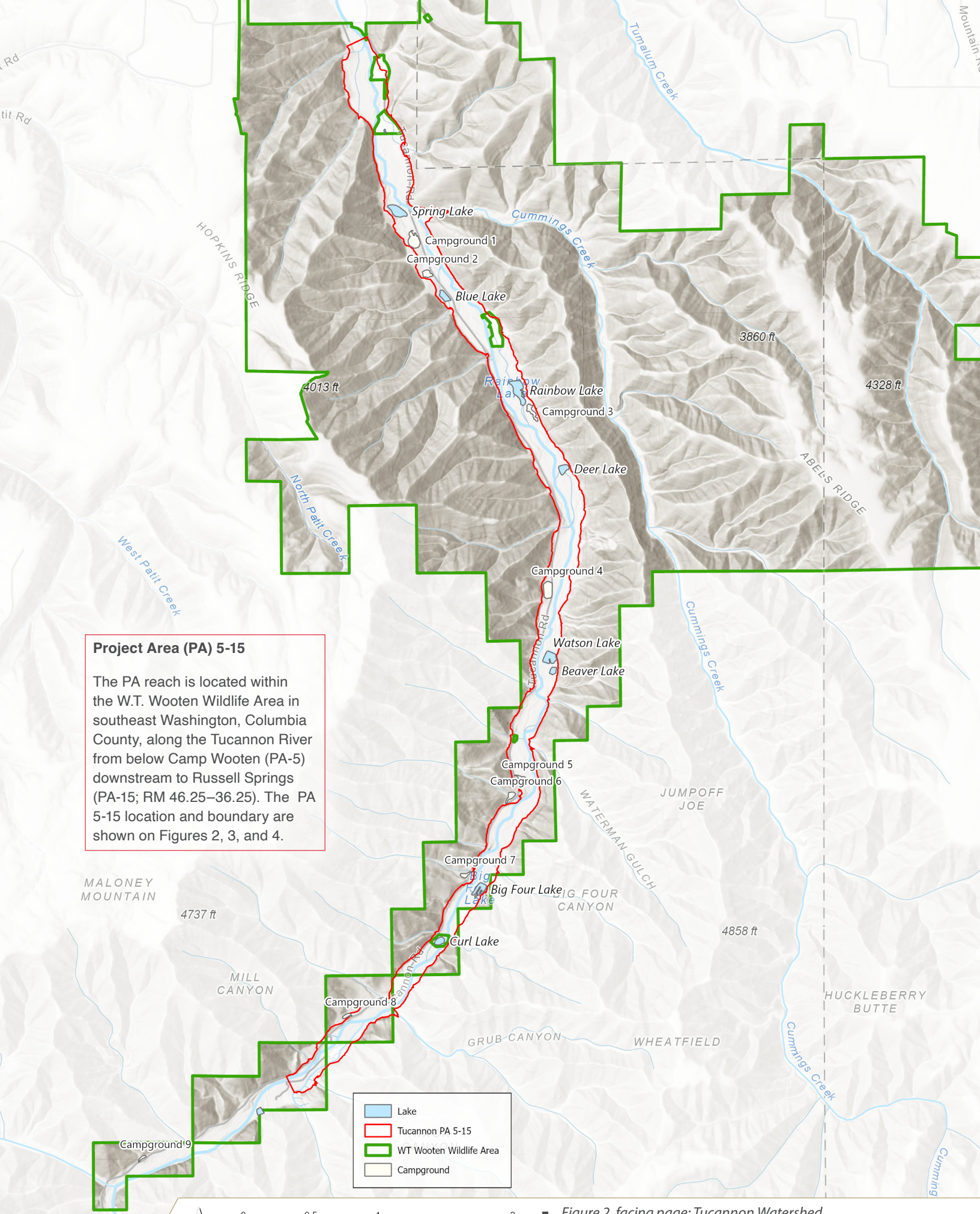
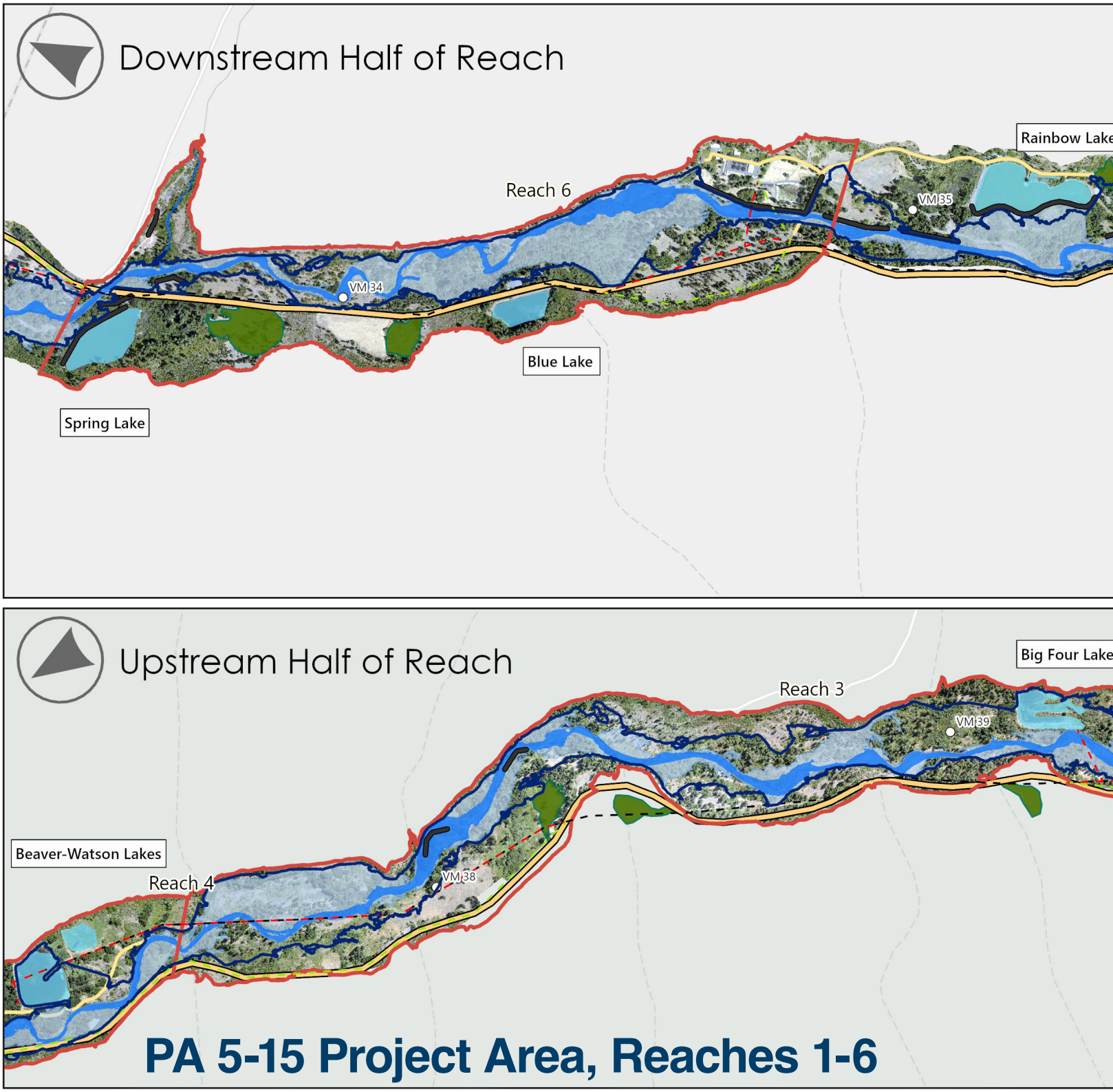


Figure 1. Tucannon River Basin Map


Tucannon River
Covello
2889 ft
LEWIS HOLLOW
3230 ft
3466 ft
CALLOWAY HILL
Sweeney Gulch Rd
Snake River
KIDWELL GULCH
STEVENS RIDGE
Tumalum Creek
North Patit Creek
STARVOUT RIDGE
Spring Lake
Rainbow Lake
ABELS RIDGE
SEOGGIN RIDGE
Peola
West Patit Creek
Watson Lake
Rose Springs
4732 ft
JUMPOFF JOE
MARTIN RIDGE
MALONEY MOUNTAIN
4667 ft
BIG FOUR CANYON
4858 ft
5252 ft
MILL CANYON
HUCKLEBERRY BUTTE
WHEATFIELD
ECKLER MOUNTAIN
Mountain Top
HIXON CANYON
Stentz Spring
LOST POINT RIDGE
BILLUPS GULCH
Jim Creek
TALLOW FLAT
SUNFLOWER FLAT
ELK POINT
North Fork Asotin Creek
COURGAR RIDGE
Tucannon River
PAIGE RIDGE
North Touchet River
MIDDLE POINT RIDGE
HORSE RIDGE
AL WILLIAMS RIDGE
5852 ft
Meadow Creek
BIG TURKEY TAIL
WEST BUTTE RIDGE
BUCKLEY RIDGE
6174 ft
6184 ft
MOUNT MISERY
6213 ft
DIAMOND PEAK
GRIZZLY BEAR RIDGE
DANGER POINT
BALD BUTTE
Tucannon PA 5-15
WT Wooten Wildlife Area
Tucannon basin
0 1 2 4
Miles
N



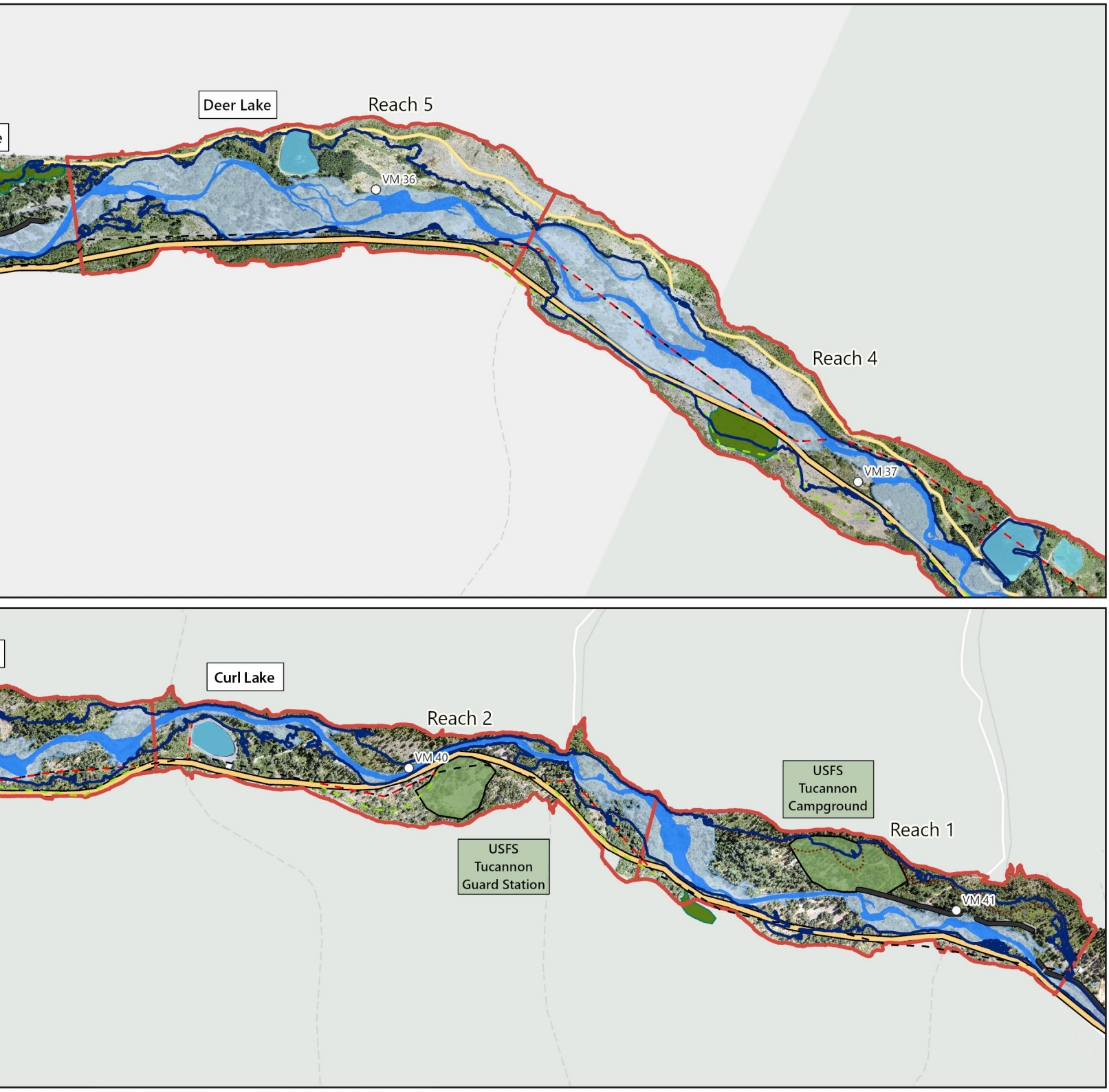
- *Figure 2, facing page; Tucannon Watershed.*
- *Figure 3, above; Project Area 5-15 Boundaries.*



PA 5-15 Project Area, Reaches 1-6

The project reach is located within the W.T. Wooten Wildlife Area in southeast Washington, Columbia County, along the Tucannon River from below Camp Wooten (PA-5) downstream to Russell Springs (PA-15; RM 46.25–36.25). The assessment quantifies the impacts of floodplain infrastructure—including roads, lakes, powerlines, and campgrounds—on channel and floodplain function within this 10-mile reach.

Infrastructure encroachment has straightened and simplified the river channel, reduced floodplain connectivity, impacted riparian vegetation and reduced large wood recruitment and retainment. These alterations have increased stream power, promoted channel incision, reduced pool formation, and diminished channel complexity and riparian habitat. The reach exhibits characteristics of degraded physical and ecological processes.



General ecological concerns associated with floodplain confinement include reduced low-velocity refuge, limited food web productivity, and increased risk of redd scour. This assessment and conceptual design prioritize restoration actions that reconnect floodplains, restore physical and ecological processes, and enhance recreational access and opportunities.

Figure 4. Project Area 5-15 Existing Conditions Map

Plan Co-Managers

The Confederated Tribes of the Umatilla Indian Reservation, the Washington Department of Fish and Wildlife, and the Nez Perce Tribe jointly sponsor the Tucannon River PA 5–15 Assessment and Conceptual Design. This process integrates tribal, state, and scientific frameworks and is guided by open coordination, shared data, and joint decision-making.

Washington Department of Fish and Wildlife

The Washington Department of Fish and Wildlife (WDFW) works to "preserve, protect and perpetuate fish, wildlife and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities." This mission guides WDFW's stewardship of healthy ecosystems, sustainable fish and wildlife populations, and public use of these resources.

WDFW balances conservation with public access and use, working collaboratively with Tribal co-managers, agencies, and stakeholders to implement science-based management, support ESA recovery, and address changing environmental conditions. A core part of WDFW's mission is providing sustainable recreational opportunities—including fishing, hunting, camping, and wildlife viewing—while ensuring these uses remain compatible with long-term ecosystem health and species conservation goals. Within the W.T. Wooten Wildlife Area, this mission is carried out through integrated management of lands, waters, habitats, hatcheries and public recreation.

Nez Perce Tribe

The Nez Perce Tribe manages natural resources through a framework grounded in cultural heritage, treaty-reserved rights, and a long-standing relationship with the land and waters of its ancestral territory. The Treaty of 1855 secured the Tribe's rights to fish, hunt, and gather across its usual and accustomed areas, forming the foundation for continued stewardship.

Management is guided by a holistic, ridge-top-to-ridge-top perspective that recognizes the interconnectedness of upland, floodplain, and aquatic systems. The Tribe emphasizes protection and restoration of native species—particularly salmon, steelhead, lamprey, and other First Foods—through restoration of watershed processes and ecosystem resilience. The Watershed Division works to protect and restore watersheds and fisheries resources throughout Nez Perce Territory, integrating traditional ecological knowledge with modern science to support healthy, harvestable fish populations for future generations.



Confederated Tribes of the Umatilla Indian Reservation

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) manage natural resources through a framework grounded in cultural traditions, First Foods responsibilities, and Treaty of 1855 rights, which ensure access to traditional foods across ceded lands and define the Tribe's long-standing stewardship role.

Management is guided by the First Foods concept—water, salmon, deer, cous, and huckleberry—and emphasizes protection and restoration of the watershed, floodplain, and aquatic processes that sustain these resources across connected upland and riverine systems. This approach recognizes the interdependence of healthy rivers, floodplains, riparian areas, fish populations, wildlife habitat, and water quality in supporting both ecological and cultural resilience.

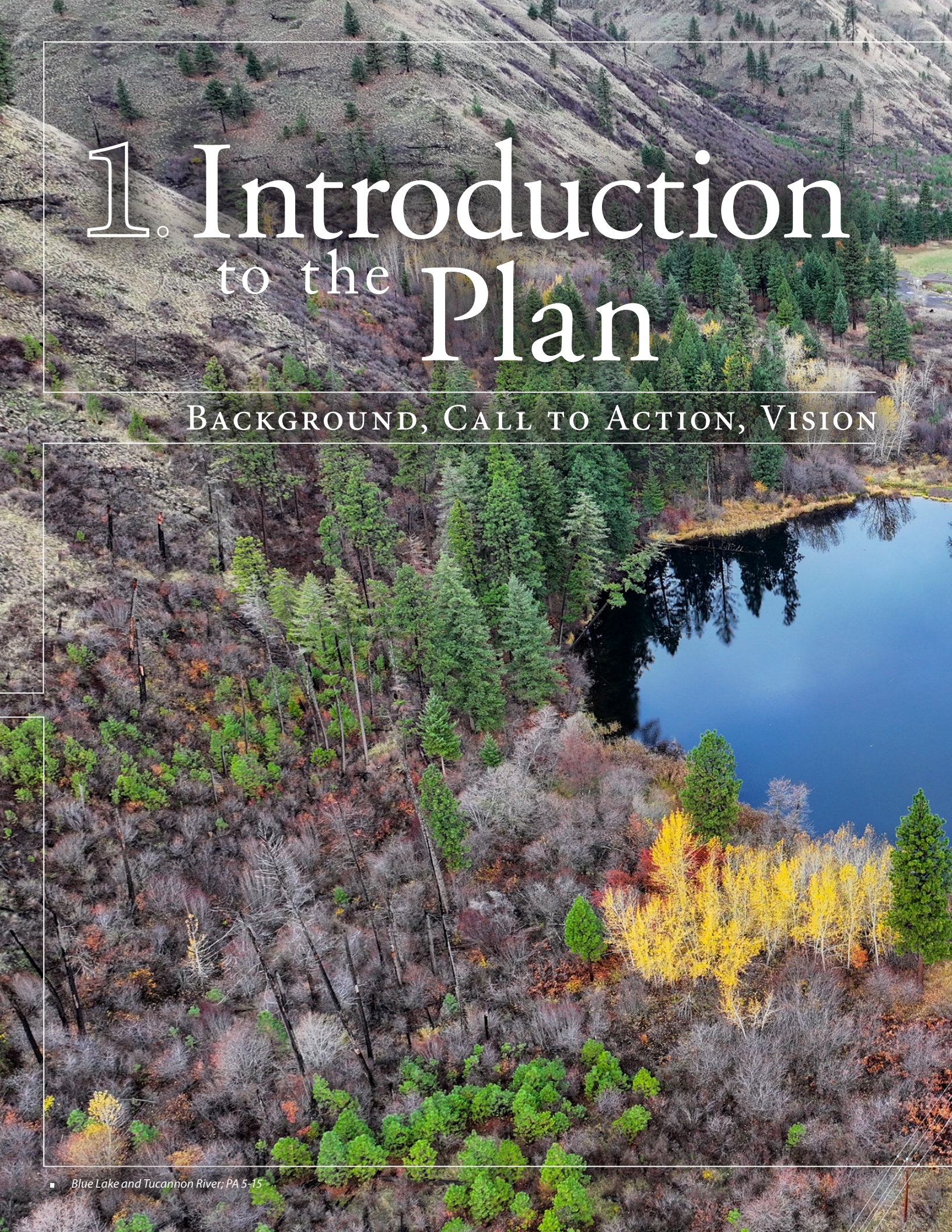
The CTUIR Department of Natural Resources integrates traditional ecological knowledge with modern science to protect, restore, and enhance healthy ecosystems, resilient habitats, and sustainable fish populations for future generations and continued cultural use. In support of this mission, the Fisheries Habitat Program works to restore functional floodplain, channel, and watershed processes; develop science-based restoration strategies and priorities; maintain current understanding of watershed function and aquatic habitat conditions; and build cooperative relationships with agencies, Tribes, landowners, and stakeholders to improve restoration effectiveness, ecosystem resilience, and long-term stewardship outcomes.



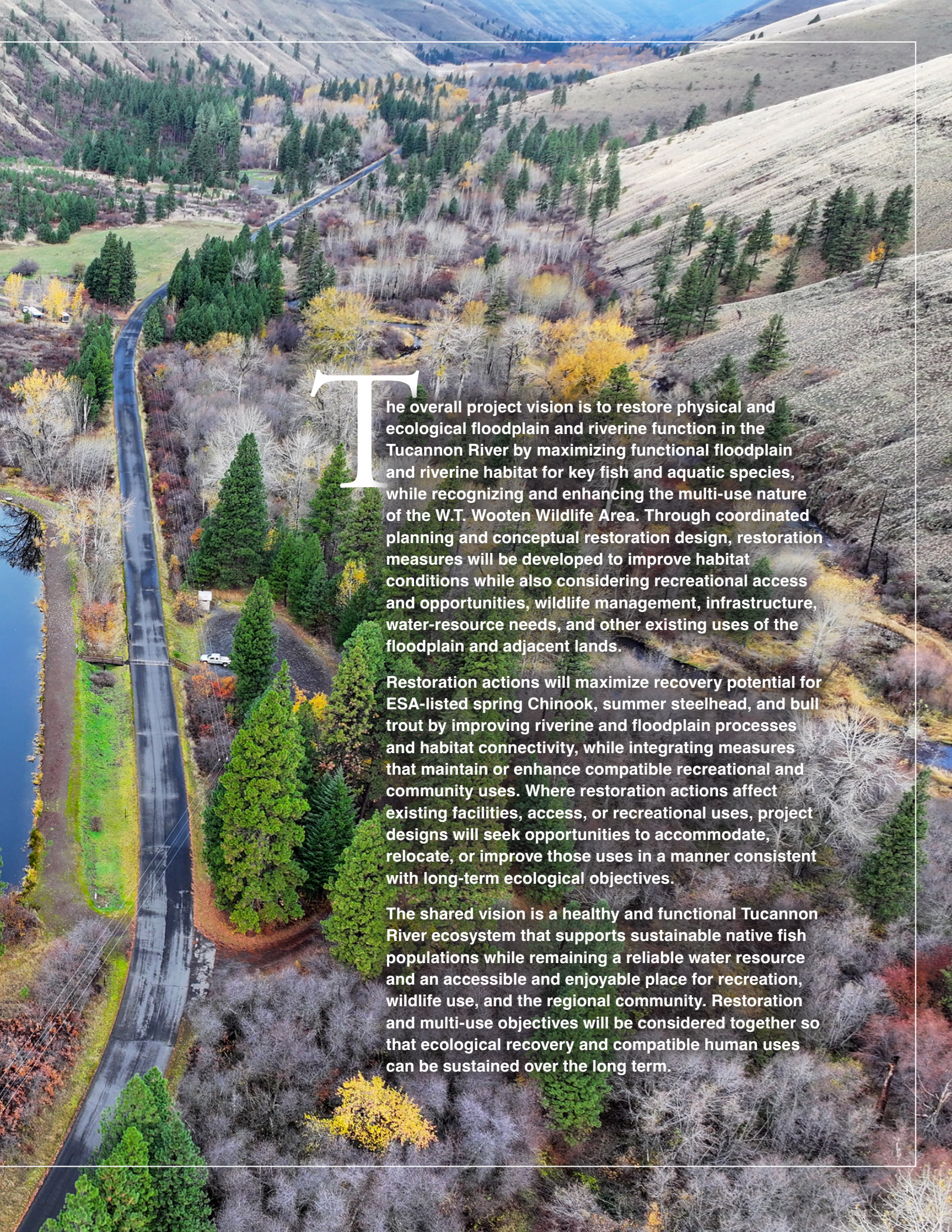
Tucannon River; PA 5-15

1. Introduction to the Plan

Background, Call to Action, Vision



Blue Lake and Tucannon River; PA 5-15



The overall project vision is to restore physical and ecological floodplain and riverine function in the Tucannon River by maximizing functional floodplain and riverine habitat for key fish and aquatic species, while recognizing and enhancing the multi-use nature of the W.T. Wooten Wildlife Area. Through coordinated planning and conceptual restoration design, restoration measures will be developed to improve habitat conditions while also considering recreational access and opportunities, wildlife management, infrastructure, water-resource needs, and other existing uses of the floodplain and adjacent lands.

Restoration actions will maximize recovery potential for ESA-listed spring Chinook, summer steelhead, and bull trout by improving riverine and floodplain processes and habitat connectivity, while integrating measures that maintain or enhance compatible recreational and community uses. Where restoration actions affect existing facilities, access, or recreational uses, project designs will seek opportunities to accommodate, relocate, or improve those uses in a manner consistent with long-term ecological objectives.

The shared vision is a healthy and functional Tucannon River ecosystem that supports sustainable native fish populations while remaining a reliable water resource and an accessible and enjoyable place for recreation, wildlife use, and the regional community. Restoration and multi-use objectives will be considered together so that ecological recovery and compatible human uses can be sustained over the long term.

CTUIR, WDFW, and NPT jointly led a collaborative, multi-use assessment of the Tucannon River PA 5–15 reach to evaluate floodplain constraints, watershed processes, recreational use, and their effects on key limiting factors. The effort develops and advances conceptual design alternatives that improve habitat for ESA-listed species while reducing flood risk and guiding long-term, multi-use management.

The multi-use assessment identifies floodplain constraints and quantifies their effects on key habitat conditions and processes, including channel complexity, floodplain connectivity, stream power, and pool development. It develops, analyzes, and advances a range of alternatives into conceptual designs aimed at improving spawning and rearing conditions for ESA-listed Snake River spring Chinook, summer steelhead, and bull trout. The resulting designs outline a pathway for multi-use management that reduces flood risk and long-term maintenance needs.

The project delivers a spatially explicit, process-based physical assessment, informed by established restoration frameworks and supported through collaboration among CTUIR, WDFW, NPT, and other federal, state, and local partners. It evaluates historical and current geomorphic and hydrologic processes, assesses land-use impacts, identifies restoration actions, and incorporates cost-benefit considerations for preferred alternatives.

The assessment informs restoration priorities to support multiple species, including Snake River spring Chinook, summer steelhead, bull trout, Pacific lamprey, and freshwater mussels. The final product establishes a defensible, watershed-specific strategy for process-based floodplain restoration, grounded in analysis of land use, vegetation, aquatic communities, and physical processes, and shaped through ongoing stakeholder engagement.

W.T. Wooten Wildlife Area

The Wildlife Area was established in the early 1940s following its recommendation in 1940 as the “Tucannon Deer and Elk Range.” Most acquisitions occurred between 1941 and 1943, creating an initial 12,000-acre area to reduce conflicts between wildlife and livestock and provide lands for wildlife and public recreation. The area has since expanded to more than 16,000 acres.

The Tucannon River originates on U.S. Forest Service lands south of the Wildlife Area and flows about 17 miles through it, joined by tributaries including Cummings Creek and the Little Tucannon River. It supports diverse aquatic life, including ESA-listed fall and spring Chinook, summer steelhead, and bull trout. Surrounding lands provide important winter range for big game and year-round habitat for wildlife. Public access improved in the 1970s with roadway upgrades, increasing visitation to approximately 120,000–140,000 visitor days annually, with peak holidays drawing 3,000–5,000 visitors, primarily from the Tri-Cities and nearby communities.

Recreation is supported by eight artificial lakes built in the 1950s by WDFW. The lakes were later deepened and improved as part of the Lower Snake River Compensation Plan (LSRCP, implemented in 1976) for mitigation of reduced recreational fishing opportunity resulting from the four Lower Snake River dams. Recreation is also supported by the Tucannon Fish Hatchery, which stocks about 75,000 catchable and 1,400 jumbo rainbow trout annually. The hatchery also supports ESA recovery and mitigation by producing steelhead and spring Chinook for the Tucannon River and regional programs.

Need for Action on the Tucannon River

The Tucannon River within the W.T. Wooten Wildlife Area represents a critical yet impaired reach for ESA-listed salmonids and other aquatic species. Restoration work has been undertaken within this 10-mile reach, but remaining infrastructure—including roads, levees, lakes, powerlines, and campgrounds—continues to confine the channel and restrict natural processes.

Decades of floodplain encroachment have reduced channel complexity, disconnected the river from its floodplain, and increased stream power, leading to channel incision, reduced pool formation, and diminished habitat quality. These conditions reflect a system constrained in a degraded and self-reinforcing state, limiting natural recovery and reducing productivity for key species. At the same time, removal of large wood, degradation of riparian vegetation, and historical channel modifications have further simplified habitat and reduced ecological resilience. Current recreational and access infrastructure also presents ongoing management challenges. Flood damage, maintenance demands, regulatory compliance issues, and ecological impacts—such as sedimentation, altered thermal regimes, and disrupted hydrology—highlight the unsustainability of existing conditions. In particular, the Tucannon Lakes and associated facilities both constrain floodplain function and require continued investment to maintain.

Biologically, the need for action is urgent. Populations of Snake River spring Chinook have declined to levels near quasi-extinction thresholds, with recent returns among the lowest observed since ESA listing. The habitat limitations identified in this assessment indicate a need for restoration to improve spawning and rearing conditions and support salmon recovery in the Tucannon River.

Salmon and steelhead populations in the Tucannon River have declined significantly due to factors outside the basin such as commercial overharvesting, hydropower facilities, and climate change. Within the assessed PA 5-15 reach, floodplain simplification, including channel straightening, floodplain smoothing, and agricultural development, along with the loss of floodplain vegetation, roughness, and loss of large wood sources due to wildfires and infrastructure changes (such as roads, levees, and lakes), has reduced the active and available floodplain by approximately 70%. This has resulted in impacted habitats that affect juvenile rearing and spawning conditions.

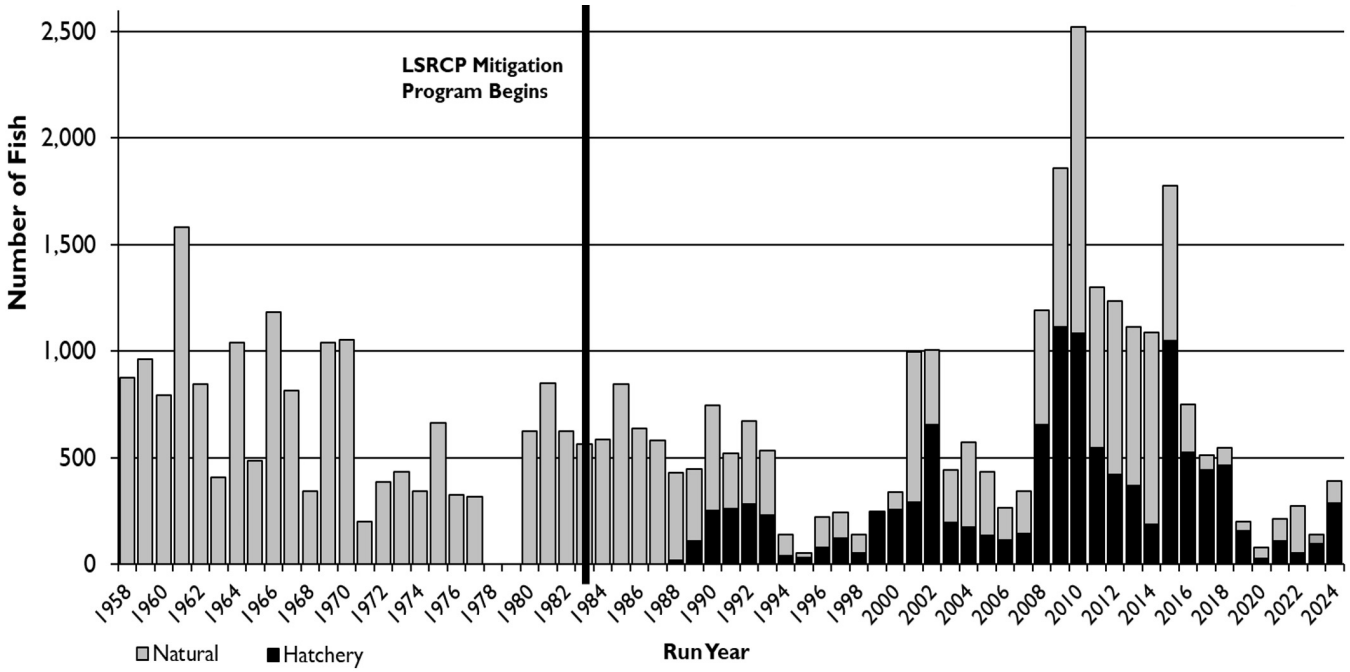


Figure 5. Tucannon River Spring Chinook Returns. Chinook Reaching Quasi-Extinction Status. NPT Ecological Goal: 22,000; Recovery Plan Goal: 750 to 3,000; Hatchery Goal: 1,152.

Setting the Stage for Restoration

This assessment builds on previous planning and restoration work within the reach and the knowledge gained through those efforts. The reach-scale geomorphic and floodplain analyses evaluate remaining constraints associated with channel incision and infrastructure and identify opportunities for coordinated restoration, infrastructure modification, and recreational improvements.

A process-based assessment and conceptual design are needed to quantify floodplain confinement impacts, evaluate infrastructure modification or removal, and identify restoration actions that reconnect floodplains, reduce stream power, and restore channel complexity. These actions are intended to support ESA-listed species recovery while reducing flood risk, improving resilience, and maintaining compatible recreational uses.

In short, the Tucannon River PA 5–15 reach requires coordinated action to transition from a constrained, degrading system to a resilient floodplain capable of supporting both ecological recovery and sustainable multi-use management.

Floodplain Management Plan

The 2014 Wooten Wildlife Area Floodplain Management Plan (FMP), developed by WDFW, provides an integrated strategy to address degraded floodplain conditions along the Tucannon River. Historic channel modification, infrastructure encroachment, loss of large wood, and riparian degradation have reduced ecological function and habitat quality.

The FMP establishes a balanced framework to restore river and floodplain processes, improve habitat for ESA-listed species and wildlife, sustain recreation, and maintain critical infrastructure. A key challenge is the location of Tucannon Lakes and associated infrastructure within the floodplain, which constrains natural processes and creates ongoing maintenance, regulatory, and ecological issues.

PA 5-15 Assessment

Building on the foundation of the Wooten Wildlife Area Floodplain Management Plan, the PA 5–15 Assessment and Conceptual Design advances this work by focusing on a critical 10-mile reach where floodplain constraints, infrastructure conflicts, and habitat limitations converge.

While the FMP establishes broad goals for balancing restoration, recreation, and infrastructure, the PA 5–15 effort provides the detailed, process-based evaluation and integrated vision needed to resolve these trade-offs, prioritize actions, and define a clear pathway toward a more functional, resilient, and multi-use Tucannon River corridor.

Vision, Goals and Objectives

The vision, goals, and objectives for the Tucannon River PA 5–15 Assessment and Conceptual Design were developed collaboratively by CTUIR, WDFW, and NPT with input from partners, stakeholders, and the public. Guided by shared data, open coordination, and joint decision-making, the process integrates tribal, state, and scientific perspectives.

The shared vision focuses on restoring floodplain connectivity, channel complexity, and riparian function to support recovery of ESA-listed species while sustaining recreation and other public uses, including fishing, hunting, and camping within the Wildlife Area. The plan also recognizes the Treaties of 1855 and the importance of maintaining healthy watersheds, floodplains, and fish populations to support Tribal treaty rights, ecological resilience, and long-term multi-use management of the Tucannon River corridor.

Vision

Restore physical and ecological floodplain function to benefit key fish and aquatic species, while broadening and enhancing recreational opportunities, through coordinated planning and conceptual restoration designs for the floodplain and adjacent lands of WT Wooten Wildlife Area.

Goals

1. Assess the impacts of floodplain confining infrastructure on listed salmonids habitat, as well as other aquatic species.

2. Identify management needs and potential alternatives for each of the Tucannon Lakes.

3. Develop an assessment and accompanying conceptual designs to prioritize the restoration of physical and ecological functions of the river, floodplain, and riparian habitats.

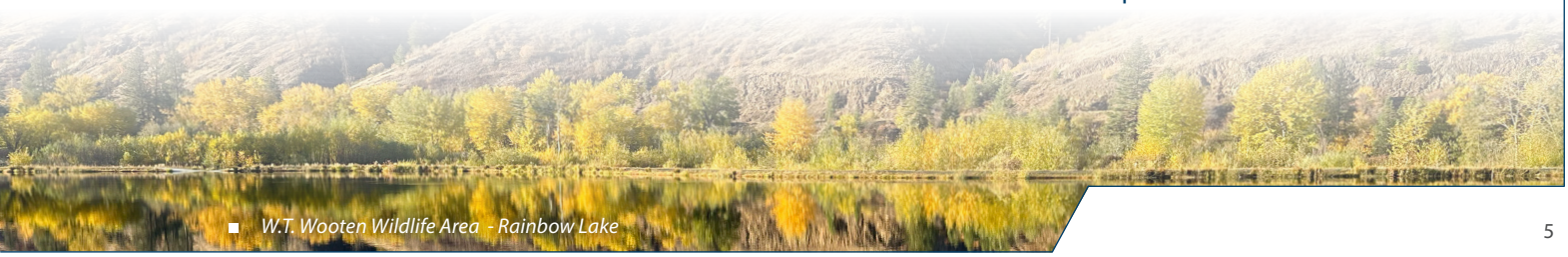
4. Restoration actions will maximize recovery potential for ESA-listed spring Chinook, summer steelhead, and bull trout on the Tucannon River.

5. Restoration actions will account for the multi-use nature of the project area.

6. Prioritized conceptual designs will provide direction to the co-managers for implementation of restoration construction projects.

Objectives

- Consider alternatives and plans for the lake areas including lake modification, relocation, or removal.
- Conduct analyses of geomorphology, riparian vegetation, and connectivity.
- Conduct analyses of fishery and productivity modeling.
- Conduct analyses of climate change effects on hydrology and water quality.
- Conduct a Lakes Management Assessment (dam safety, maintenance, spoils management, and intake/outlets).
- Use new analyses and assessments to fill remaining data gaps and inform prioritization and conceptual designs.
- Identify metrics and criteria that address the critical path items in implementing restoration.
- Identify limiting factors and processes for ecosystem recovery and restoration that are tied to River Vision touchstones.
- Identify connections to Upland Vision touchstones.
- Identify estimates of potential ecosystem and fish productivity uplift (relative to cost) for restoration actions.
- Identify potential scale of actions and their respective benefits.
- Identify potential actions that would increase safety/reduce maintenance costs.
- Identify recreational use benefits.
- Develop lists of recommended actions by Project Area.
- Restoration actions will work to improve floodplain habitat conditions by decreasing floodplain confinement and increasing overbank inundation frequency.
- Restoration actions will enhance existing fishing, hunting, camping, wildlife viewing and other recreational activities.
- Conceptual designs will identify multi-use floodplain improvements to increase floodplain availability.
- Restoration actions will benefit all salmonid life stages but will specifically focus on egg-to-fry, juvenile rearing, and adult spawning life stages of ESA-listed salmon species.



W.T. Wooten Wildlife Area - Rainbow Lake

CTUIR River Vision and Touchstones

The Tribes have a traditional and cultural connection to the foods provided by the earth. This is supported through ceremonial meals in the Tribal Longhouse and is further ingrained through the First Foods mission. The Umatilla River Vision was developed as an application of the Umatilla Tribes First Foods mission focusing on water and water quality management (Jones et al., 2008). The vision provides management context to maintain the minimum ecological requirements for the First Foods of water and salmon and requires a river that is dynamic and shaped by physical and biological processes and interaction between those processes. The vision describes the desired ecological characteristics based on fundamental touchstones that include hydrology, geomorphology, connectivity, native riparian vegetation, and native aquatic biota. As a foundational approach to organizing this Action Plan, ecological processes by touchstone provides a way to categorize and identify functional metrics and relates well to limiting factors for important species. Although this vision is developed by the CTUIR to support the First Foods mission and is directed at the Umatilla River, it is consistent with other natural resource management agency goals and is applicable to other riverine systems.

Partners and Stakeholders

Partners and stakeholders represented the broader community of interest associated with the Tucannon River and W.T. Wooten Wildlife Area. This included resource agencies, tribes, restoration organizations, land managers, recreational interests, local stakeholders, and others with knowledge of or interest in the project area. Their participation provided important perspectives on existing conditions, resource concerns, recreational uses, management needs, and opportunities for restoration. Stakeholder engagement was designed to bring these perspectives into the planning process and develop a shared understanding of the multiple uses and values associated with PA 5-15. Participants provided information and feedback on salmon recovery, ecosystem resilience, recreation, infrastructure, flood resilience, and opportunities to achieve benefits across multiple uses. These perspectives helped shape the project vision, goals, restoration priorities, and ultimately the action plan. These are the same multiple-use topics identified for discussion and prioritization during the project workshop.

Technical Team

Project oversight and technical development were provided through the Leadership and Core Team representing the principal co-managers, resource agencies, restoration partners, and technical consultants involved in the Tucannon River. The team included representatives from the Washington Department of Fish and Wildlife (WDFW), Nez Perce Tribe (NPT), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and Snake River Salmon Recovery Board (SRSRB), supported by specialists from Wolf Water Resources, Lichen Land & Water, Ecosystem Sciences, River Structures, and Mt. Hood Environmental.

The team brought together expertise in fisheries and salmon recovery, wildlife and land management, geomorphology, hydrology, habitat restoration, engineering, and stakeholder engagement. Additional technical input was provided by federal and state agencies and regional organizations with responsibilities or expertise relevant to the Tucannon River.

Throughout the assessment, the Technical Team reviewed existing conditions and data, identified limiting factors and information gaps, and evaluated restoration opportunities for PA 5-15. The team used the technical assessment together with input from partners and stakeholders to develop and refine restoration concepts that addressed salmon recovery and ecosystem processes while considering recreation, infrastructure, flood resilience, and other uses of the W.T. Wooten Wildlife Area.

Decision Making Process and Co-Manager Collaboration and Meetings

The Tucannon PA 5-15 Assessment report is the product of nearly three years (2023-2026) of collaboration between CTUIR, NPT, and WDFW personnel. This collaboration involved over 40 formal meetings with the co-managing organizations—six of which were in person, either on site along the banks of the Tucannon River, or in Walla Walla, WA, where Science and Leadership meetings were hosted. The five Science and Leadership meetings brought the project's organizational leadership and co-managers together to review and discuss potential alternatives and find agreement within a final combined preferred alternative. The list below shows the dates and key outcomes/ agreements associated with each of the five Science and Leadership meetings. Informal communication between personnel within the co-managing organizations was continuous throughout the three-year process. Two public meetings were held in Dayton and the Tri-Cities, WA, to present the assessment and solicit feedback from the public.

Science and Leadership meetings:

March 28, 2024 - The co-managers discussed initial areas of agreement and consensus and areas that would require additional work to achieve alignment. Each of the co-managers provided their preliminary preferences for future conditions within the project area.

March 11, 2025 - The co-managers reviewed the draft proposed potential alternatives and agreed to provide their respective preferred alternatives. Specific areas where the draft preferred alternatives required additional discussion/feedback to reach agreement were—Beaver/Watson Lake, Deer Lake, Curl Lake, and the Tucannon Campground.

June 13, 2025 - The co-managers presented their respective preferred alternatives and discussed areas of agreement and areas of difference. WDFW conditionally agreed to the removal of Beaver/Watson Lake if suitable replacement fishing opportunities were identified. The co-managers agreed to review an updated design for the relocation and/or reconfiguration of Deer Lake. The co-managers agreed to engage the USFS about potential restoration opportunities within the USFS-owned Tucannon Campground.

August 22, 2025 - The co-managers reviewed the updated draft combined preferred alternative and continued discussions/ negotiations, focusing on areas of agreement and differences. The co-managers provided feedback on the updated designs for Deer Lake and the Tucannon Campground portions of the combined preferred alternative.

November 21, 2025 - During this Science and Leadership Summit, the co-managers reviewed and refined the combined preferred alternative, with particular attention to proposed changes at Beaver/Watson Lakes, Deer Lake, Curl Lake, and Tucannon Campground. The resulting agreements were explicitly conditional and dependent on resolving site-specific design, access, and operational requirements.

For Beaver and Watson Lakes, WDFW conditionally agreed to removal of the existing structures, contingent upon identifying and establishing suitable alternative sites that provide replacement fishing access. Deer Lake was conditionally approved for relocation, pending confirmation of a suitable location and an ecologically sound and structurally stable design configuration. Curl Lake was conditionally approved for decommissioning, contingent upon identifying a viable downstream location for a trapping and monitoring weir. At Tucannon Campground, coordination with the U.S. Forest Service remains ongoing to determine how restoration elements can be incorporated within the campground footprint.

These conditions reflect the specific agreements reached by the co-managers and should be carried forward as requirements in the development and evaluation of the final combined preferred alternative.



Tucannon River and Rainbow Lake, Tucannon PA 5-15

Technical Assessments

This section provides a summary of technical assessments for the PA 5-15 Assessment and Conceptual Design Project within the WT Wooten Wildlife Area.

Each technical summary delves into crucial questions that will play a significant role in shaping and prioritizing the restoration strategies for the Project Area.

The reach-scale assessments uncover distinct patterns that not only link this project area to broader ecological trends but also highlight its unique characteristics.

These summary assessments provide insight into the extent and root causes of ecological degradation while outlining key processes for recovery and recommended actions. Together, they inform conceptual restoration planning by focusing on underlying causes, resulting conditions, and the actions needed for effective restoration.

These technical summaries are based on the detailed technical reports that are in the Appendices of this document.

1. Geomorphic Assessment and State of the Floodplain
2. Floodplain Space and Connectivity
3. Vegetation Assessment
4. Climate Change Impacts
5. Focal Species Production & HSI
6. Lakes and Infrastructure
7. Wetlands
8. Recreation

SUMMARY OF ASSESSMENT OUTCOMES

The assessment identified several key technical outcomes and long-term challenges within the reach.

- Approximately 70 percent of the floodplain has become disconnected due to lateral confinement from infrastructure and vertical channel incision caused by excess stream power.
- A minimum functional floodplain width of 450 feet was identified as necessary to reduce confinement pressures and improve system resilience.
- Existing conditions are further complicated by reduced riparian and floodplain vegetation, increasingly complex infrastructure constraints, and the effects of climate warming, including higher temperatures.
- These changes have contributed to a decline in overall wetland function and area.
- Aging lakes and infrastructure continue to drive increasing operation, maintenance, and replacement costs over time.
- Recreation is central to the Tucannon Valley, where artificial lakes, stocked fisheries, camping, hunting, hiking, and wildlife viewing support long-standing public use. Recreation assessments and user surveys help guide restoration and infrastructure improvements that enhance both ecological function and visitor experience.

1. GEOMORPHIC ASSESSMENT STATE OF THE FLOODPLAIN

Overview

Historical impacts to the Tucannon River floodplain within PA 5-15 include channel straightening, floodplain constriction by infrastructure, and removal of large wood. Together, these impacts have concentrated stream power and driven channel incision. The net result of lateral confinement and vertical disconnection is an active floodplain that occupies approximately 30% of its former width.

Using a new floodplain mapping approach, this study quantifies the relative factors disconnecting the floodplain from its historical extent. Confining infrastructure, which laterally disconnects the floodplain, accounts for approximately 35% of the historical floodplain extent. Lakes (18%), roads (10%), and levees (7%) make up these laterally disconnected areas. Channel incision has vertically disconnected an additional 37% of the historical floodplain extent.

As a result of this disconnection, the river has substantially increased energy and stream power. This concentration of energy creates highly erosive conditions within the river and floodplain, increasing the volume and size of sediment transported through the system. These conditions exacerbate the potential for redd scour, continued incision, and excessive wood transport.

Floodplain reconnection is the primary approach to address these erosive conditions. Reconnection efforts must address both lateral constraints and incision in concert. This can be achieved through large-scale river and floodplain reconnection actions, such as channel filling and floodplain shaping. Additional actions include removing or reducing encroaching infrastructure, reconnecting and developing side channels, increasing in-stream complexity (e.g., wood placement), enhancing riparian zones, increasing surface diversity across the floodplain, modifying or removing obstructions, and strategically relocating roads to further reduce lateral disconnection.

Technical Discussion

This assessment evaluates geomorphic floodplain connectivity along the Tucannon River (PA 5–15) to support restoration planning by quantifying how channel incision and confining infrastructure limit floodplain function. A cross-section–based geospatial analysis was

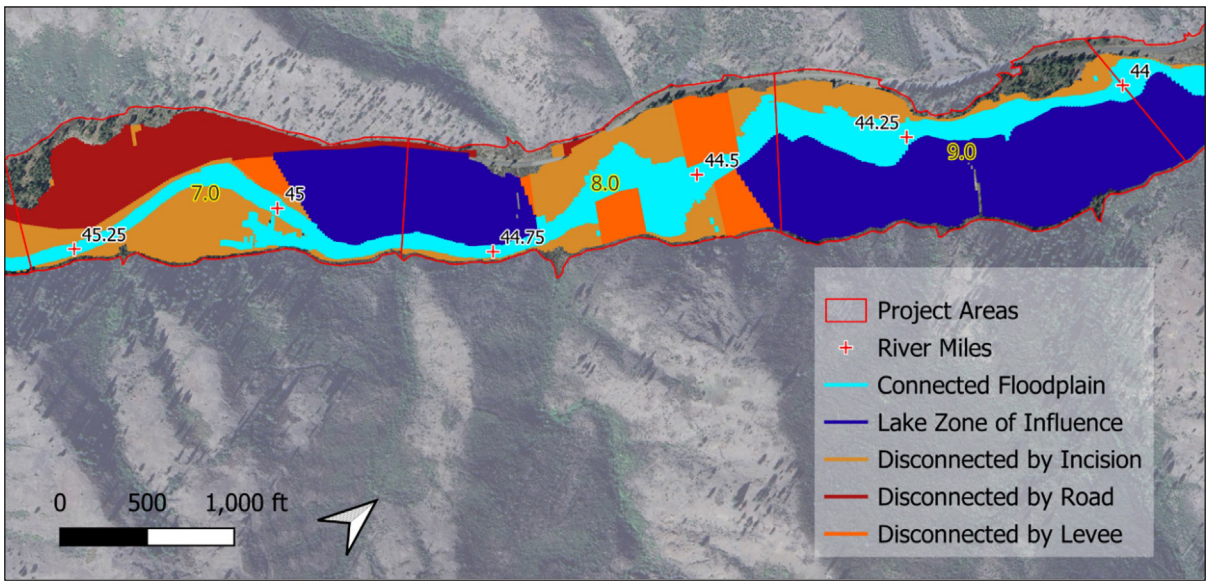


Figure 6. Example of cross-section-based connectivity analysis showing the reach from Curl Lake to Big Four Lake.

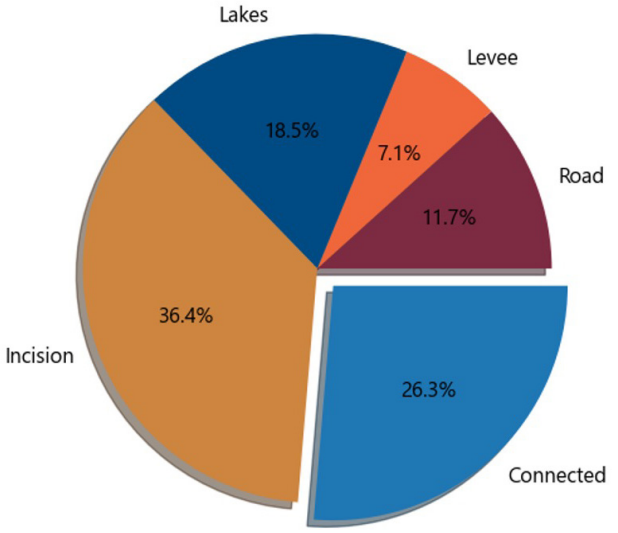


Figure 7. Area-based summary of floodplain connectivity and disconnectivity by causal mechanism.



Figure 8. Historical photograph, taken 1906, of a log mill in the Tucannon River floodplain. Source: USFS

used to measure connected and disconnected floodplain width, identifying four primary drivers of disconnection: incision, roads, levees, and artificial lakes. Floodplain width serves as a key indicator of system function, as it reflects the space available for water and sediment to disperse, reducing erosive energy and enabling natural channel processes. Results show that approximately 74% of the floodplain is disconnected to some degree, with incision representing the largest contributor, followed by infrastructure that restricts lateral connectivity and channel migration.

These constraints concentrate flow within a narrowed channel, increasing stream power and sediment transport capacity while limiting the system's ability to dissipate energy across the floodplain. Under current conditions, spawning-sized gravels are frequently mobilized during relatively common flow events, indicating an over-energetic and transport-dominated system. This imbalance reduces channel stability and inhibits the formation and persistence of geomorphic features that depend on depositional processes. Analysis demonstrates that increasing effective floodplain width directly reduces stream power, shifting conditions toward greater sediment stability and improved geomorphic function.

A floodplain width of approximately 450 feet represents a minimum functional threshold for achieving more balanced conditions, although benefits continue to increase with greater levels of reconnection.

Findings also show that incision and infrastructure act in combination, and addressing only one source of disconnection is generally insufficient to restore functional connectivity. Incision limits vertical engagement of the floodplain, while roads, levees, and lakes restrict lateral expansion, together constraining the river's ability to adjust and recover. Effective restoration therefore requires coordinated, process-based actions that expand floodplain width, reduce confinement, and reestablish connection between the channel and valley bottom. Approaches such as infrastructure modification or removal, floodplain grading, and channel adjustments to reduce incision can collectively lower stream power, promote sediment deposition, and restore more stable and dynamic geomorphic conditions.

Overall, the analysis reinforces that geomorphic connectivity is fundamentally a function of space—specifically, the ability of the river to access and interact with its floodplain. Restoring this connectivity is essential to reducing excess energy, rebalancing sediment transport, and reestablishing the processes that sustain long-term channel stability and floodplain function across the Project area.

2. FLOODPLAIN SPACE AND CONNECTIVITY

Overview

The reduction in the width of connected floodplains is influenced by both lateral constraints—such as lakes, levees, and roads—and vertical disconnection caused by channel incision. This study evaluates the resulting changes in stream power, scour potential, habitat function, wood stability, and flood inundation that have occurred due to the historical constriction of the floodplain.

This study quantifies the benefits of increasing connected floodplain width along the Tucannon River, recognizing that floodplain space can be expanded through both lateral and vertical reconnection. A series of benefit curves were developed to estimate gains in habitat quality, river function, reduced stream power, and infrastructure resilience resulting from the reestablishment of floodplain space.

A minimum "low bookend" floodplain width of approximately 450 feet was identified as a planning target for connected floodplains in the Tucannon River. This width reduces the potential for continued incision and should be applied at artificial valley pinch points. Preserving this space at critical locations enhances the long-term function and resilience of wider, well-connected floodplain segments throughout the project area. A minimum planning target of approximately 450 feet is recommended to guide future infrastructure and restoration investments.

By establishing this minimum space at critical pinch points, restored segments that exceed the low bookend threshold are more resilient to incision. The developed benefit curves provide a framework for quantifying the potential benefits associated with broader floodplain reconnection strategies.

Technical Discussion

This assessment evaluates floodplain space along the Tucannon River (PA 5–15) to support integrated restoration and multi-use planning by quantifying current floodplain conditions, the functional benefits of increased space, and the minimum space needed to sustain long-term river and floodplain processes. The study is grounded in a process-based framework that recognizes floodplain space as a primary control on hydraulic, geomorphic, and ecological function. Mapping results show that the active, connected floodplain has been substantially reduced—averaging roughly 30% of its historical extent—due primarily to channel incision, with additional reductions caused by artificial lakes, roads, and levees that constrain lateral connectivity. In many locations, these constraints have narrowed the floodplain to a fraction of its former width, limiting the river's ability to access its valley bottom and perform essential processes.

To understand the implications of this loss of space, the analysis developed reach-specific relationships—referred to as "benefit curves"—that link floodplain width to key hydraulic, geomorphic, and habitat metrics derived from modeling and field-informed data. These relationships demonstrate that floodplain width strongly influences inundation patterns, flow velocity, stream power, sediment transport, and habitat complexity. Wider floodplains consistently support greater inundation area and volume, particularly during larger flood events, while also reducing flow velocities and distributing hydraulic energy across a broader area.

This reduction in energy lowers stream power and erosion potential, promoting more stable channel conditions and reducing the likelihood of incision and infrastructure damage. In contrast, narrow and confined floodplains concentrate flow and energy, resulting in elevated erosion risk, increased sediment transport, and reduced system stability.

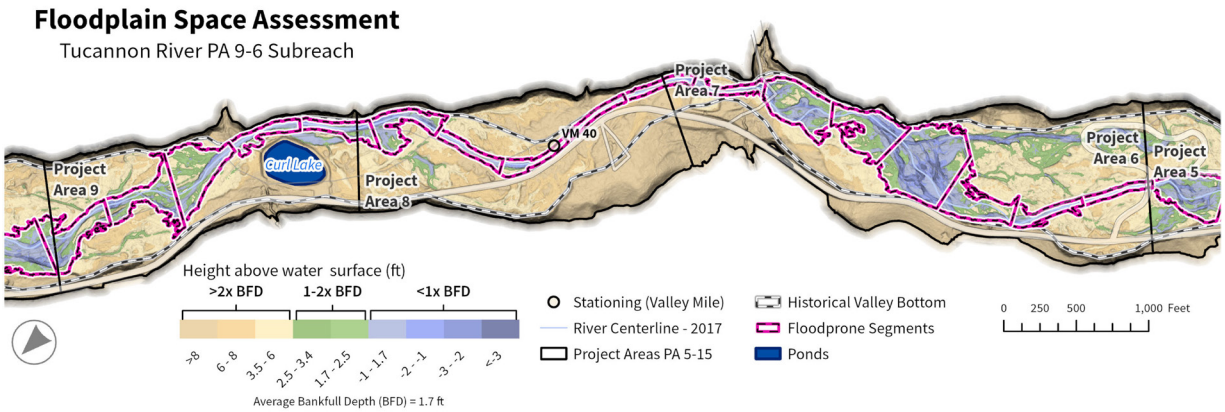


Figure 9. Mapping of contemporary and historical floodplain extents on a relative elevation model basemap. The flow direction is right to left.

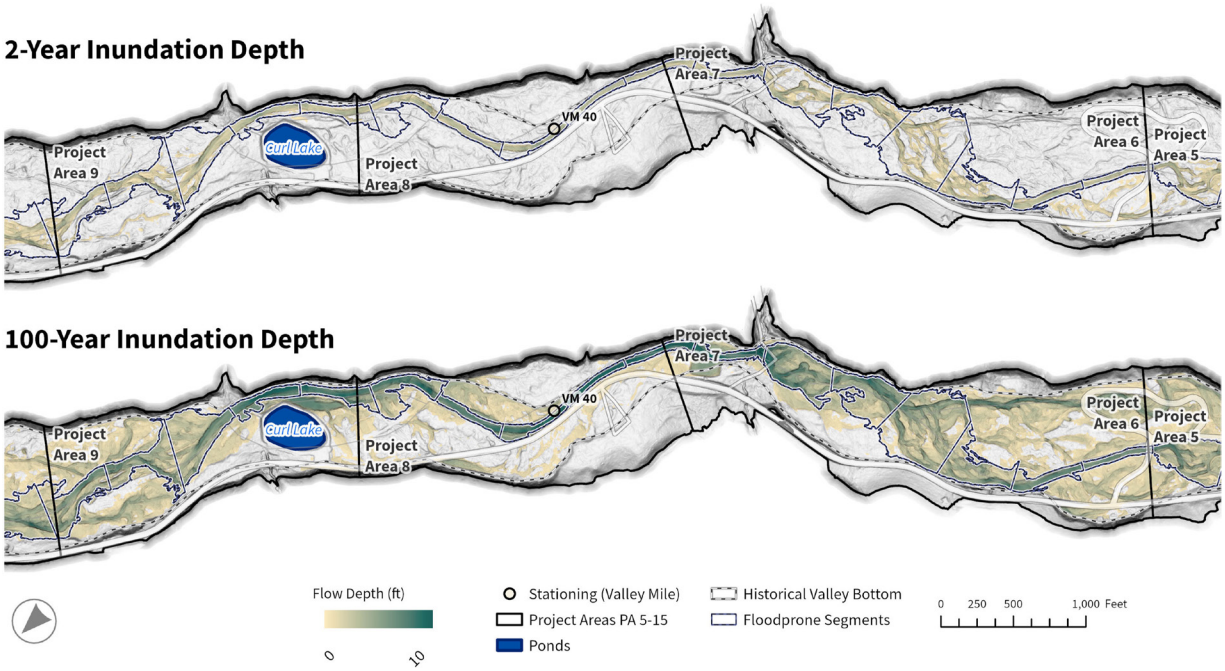


Figure 10 (above) and Figure 11 (below). Example maps of modeled inundation relative to the flood prone area.

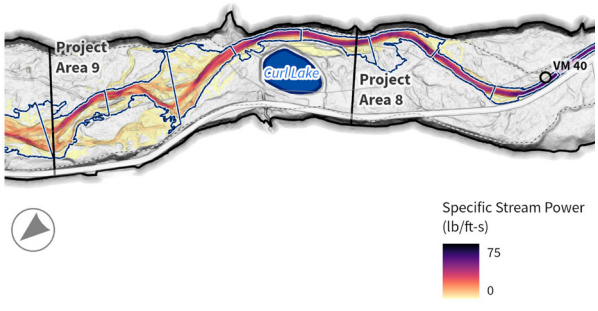


Figure 12. Map of modeled specific stream power at the 10-year flood relative to the mapped flood prone area.

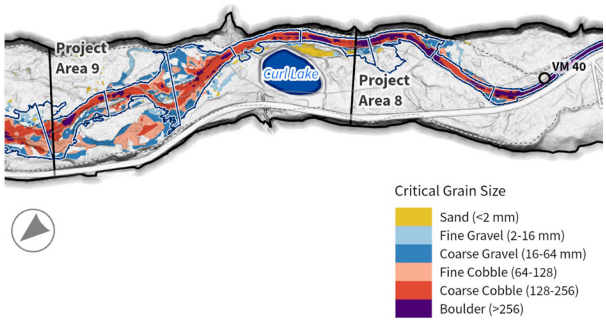


Figure 13. Map of critical diameter (mm) produced from modeled shear stresses at the 10-year flood

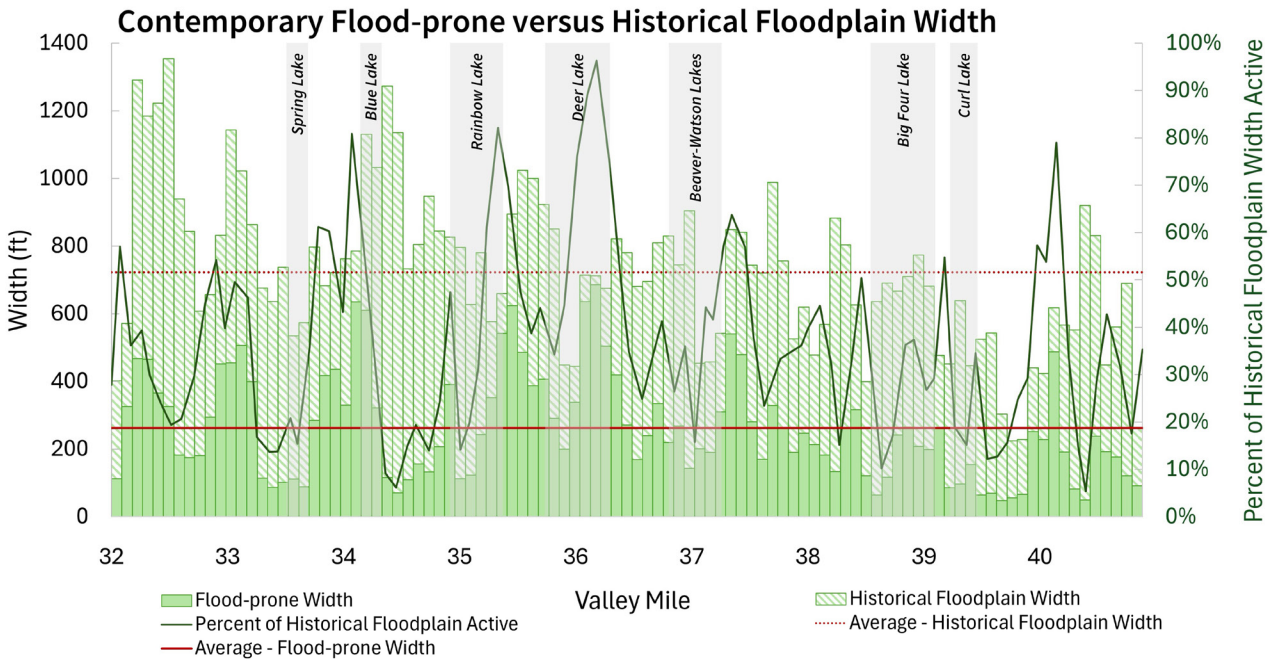


Figure 14. Historical versus contemporary (flood prone) floodplain width along the PA 5-15 Reach.

The study further demonstrates that floodplain space is closely tied to habitat function and resilience. Wider floodplains increase the availability and complexity of aquatic habitat by supporting multiple flow paths, off-channel areas, and increased edge habitat—features that are critical for juvenile fish rearing and refuge during high flows. The project's assessment indicates that wider, connected floodplains can reduce velocities and shear stresses, potentially reducing scour risk in spawning areas. Modeled scour risk is highest in the most confined segments and decreases as connected floodplain width increases. These results indicate potential improvements in conditions for incubating spring Chinook eggs, rather than measured changes in egg survival. In addition, observations from restoration sites indicate that wider floodplains enhance the retention and stability of large wood, which in turn promotes channel complexity, habitat development, and long-term restoration effectiveness.

Beyond ecological benefits, the assessment identifies important implications for infrastructure and flood risk management.

Constrained floodplains are more likely to overflow during large flood events, often directing floodwaters toward roads, campgrounds, and other developed areas. In contrast, wider floodplains provide greater capacity to store and convey floodwaters, reducing localized flood risk and potentially attenuating downstream flood peaks. These findings highlight that restoring floodplain space can simultaneously improve ecological function and reduce long-term infrastructure vulnerability and maintenance costs. The benefit curves developed in this study provide practical tools for evaluating these trade-offs, allowing planners to assess how changes in floodplain width translate into measurable improvements in system performance.

To inform planning decisions, the study also evaluates how much space the river needs to maintain long-term resilience. Using a multiple-lines-of-evidence approach, the analysis identifies three key conditions necessary to minimize incision and sustain floodplain function: bed stability, sediment deposition potential, and retention of large wood. By evaluating these factors in relation to floodplain width, the study identifies a minimum "low bookend" floodplain width of approximately 450 feet—roughly 10 times the bankfull channel width—as the threshold at which these processes

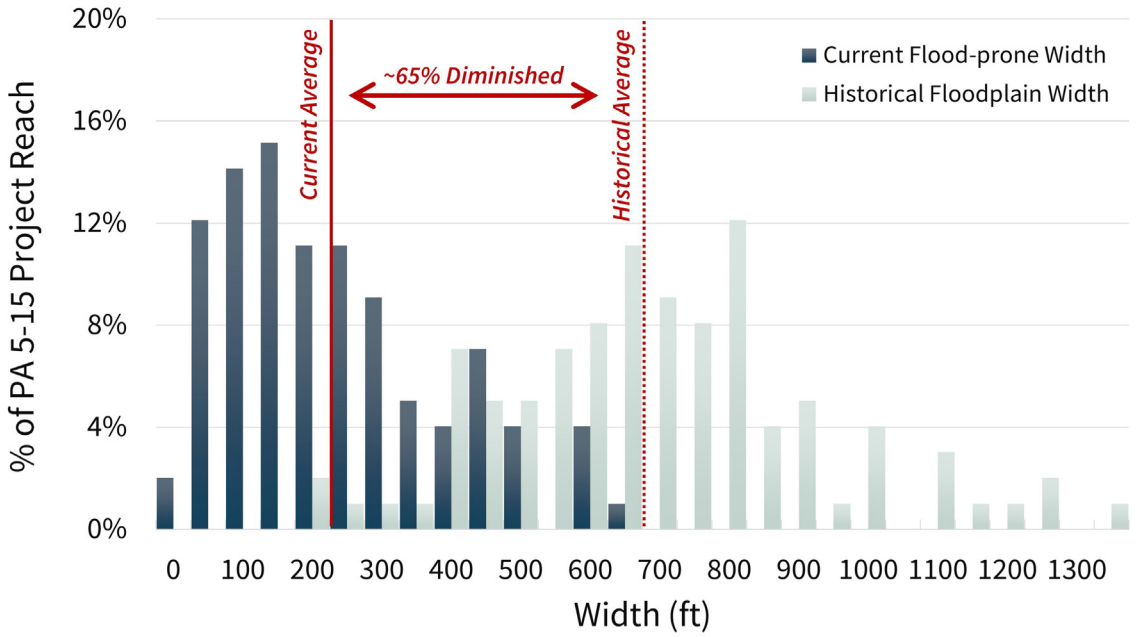


Figure 15. Histograms of existing floodplain (flood prone) widths and historical valley bottom widths.

are supported. At this width, stream power and shear stress are sufficiently reduced to stabilize the channel bed, sediment transport capacity is moderated to allow deposition, and conditions favor the retention of large wood and development of channel complexity.

This minimum width serves as a planning-level target to guide restoration design, infrastructure setbacks, and land-use decisions within the project area. However, the analysis also makes clear that this value represents a lower bound rather than an optimal condition. Benefits to floodplain function, habitat, and system resilience continue to increase with additional space, particularly as the river approaches full reconnection with its historical valley bottom. As such, restoration strategies that maximize floodplain width and connectivity—within the constraints of existing land use and infrastructure—are expected to produce the greatest long-term ecological and geomorphic gains.

Overall, the assessment demonstrates that floodplain space is the fundamental driver of river function in the Tucannon system. Loss of space has led to increased erosion, reduced habitat quality, and heightened infrastructure risk, while restoring space offers a pathway to reestablish natural processes, improve ecological outcomes, and enhance resilience to future disturbances. The findings provide a clear, quantitative framework for balancing restoration, recreation, and infrastructure needs, and for advancing a coordinated, process-based strategy for floodplain management in the Project area.

How Much Space Does the Tucannon River Need?

Based on modeling and sediment transport analyses, we developed a low bookend space target according to the estimated minimum floodplain width needed to sufficiently reduce incision potential. We analyzed space needs to support a stable streambed, promote gravel deposition, and retain large wood. Floodplains at least 450 feet wide addressed all three criteria. The 450-foot target is approximately 10 times the average bankfull channel width (44 feet) in the project reach. This low bookend target is intended for planning to support long-term resilience of the Tucannon River floodplain.

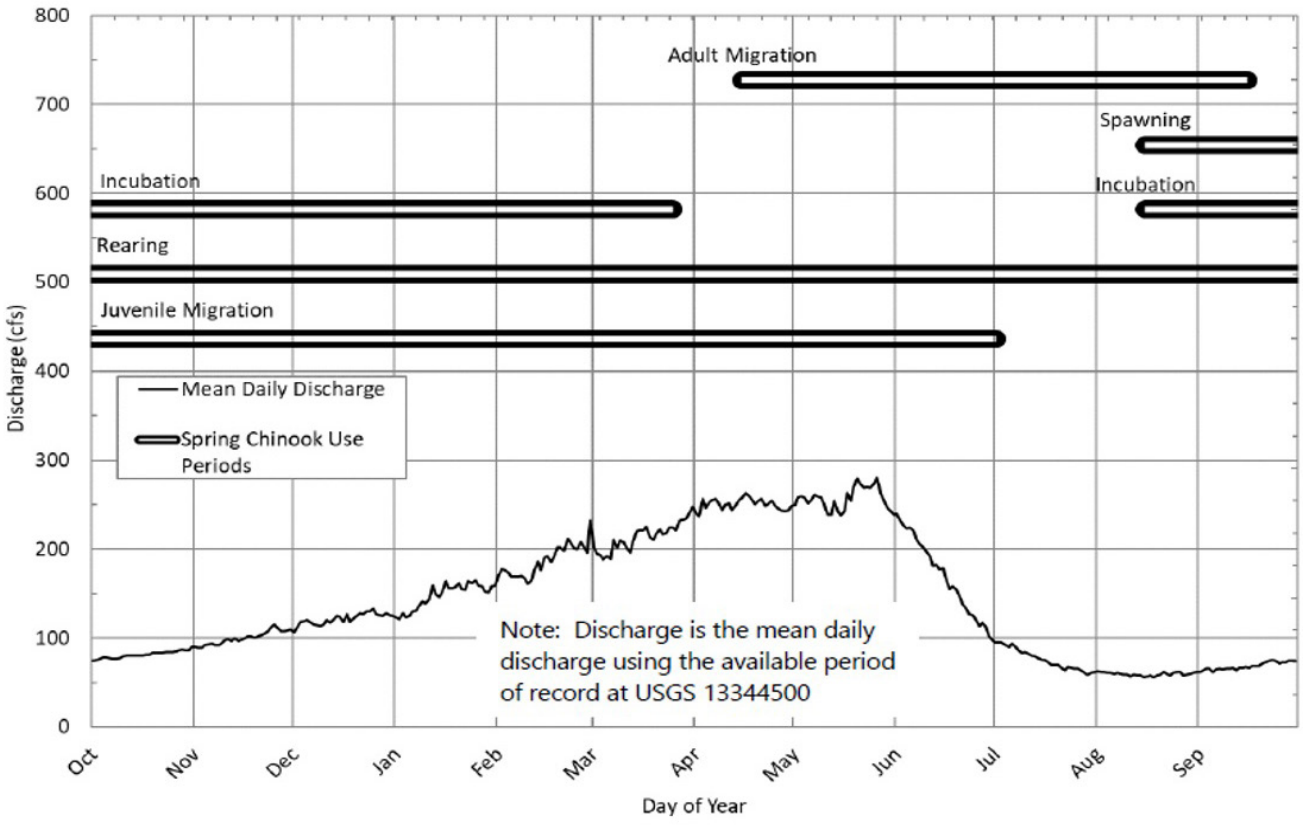


Figure 16. Mean annual hydrograph relative to use periodicity for spring Chinook (source: Anchor 2021)

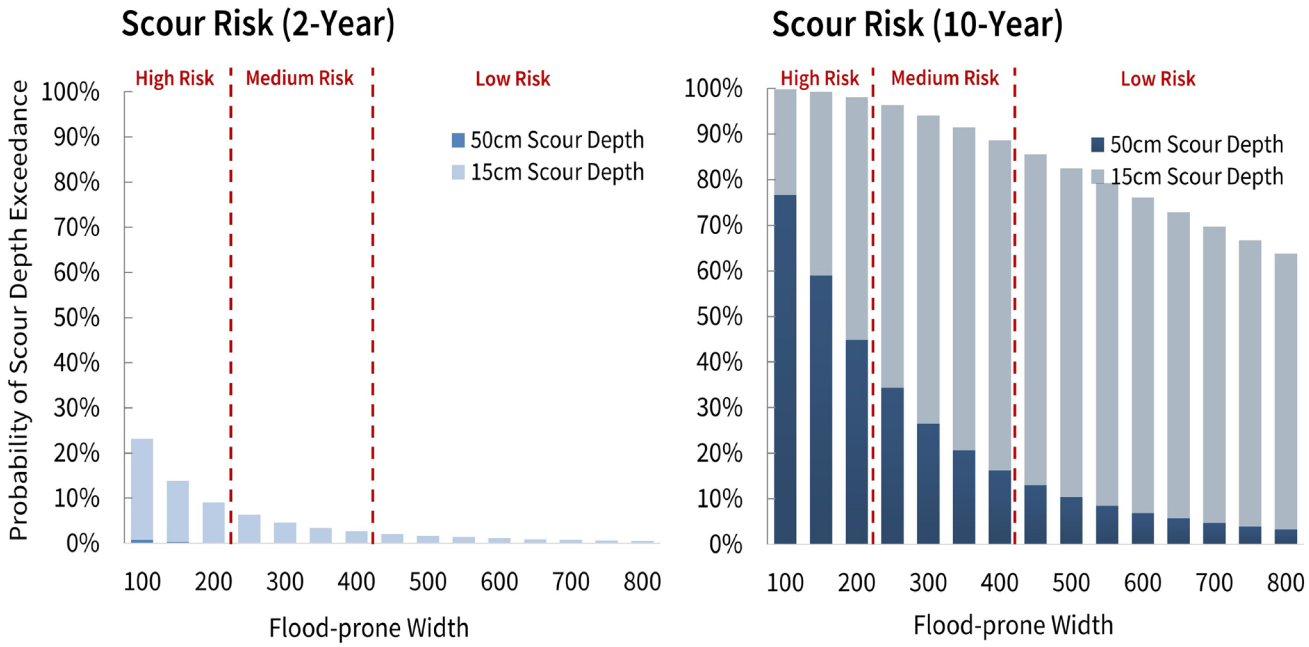


Figure 17. Probability of exceeding scour depths of 15 cm and 50 cm at the 2-year and 10-year floods. High-risk (<200 ft), medium-risk (200-400 ft), and low-risk (>400 ft) regions delineated by red bars.

3. VEGETATION ASSESSMENT

Overview

The construction of man-made lakes within the floodplain has significantly impacted vegetation communities by altering hydrology, sediment dynamics, and habitat availability. Wildfires have further contributed to the simplification of vegetation structure while increasing vulnerability to invasive species. Conversion of native floodplain forests and wetlands to agricultural lands has also reduced overall habitat complexity.

Riparian and floodplain conditions have been significantly degraded by the loss of forested systems and a broader simplification of vegetation structure. Forested and scrub-shrub communities, along with naturally occurring wetland types, have declined, reducing native plant diversity and allowing invasive species to establish and spread as monocultures. These changes have diminished habitat complexity and weakened key ecological functions across the floodplain.

Restoration should focus on reconnecting the floodplain to support the processes that sustain diverse native plant communities. Reestablishing hydrologic connectivity will help promote a wider range of vegetation types and improve overall ecosystem function. At the same time, targeted control of invasive species is necessary to prevent further displacement of native vegetation and to restore structural and biological diversity. Considering fire management with restoration efforts will also be critical to maintaining these gains, supporting long-term resilience, and sustaining dynamic, self-maintaining riparian and floodplain systems.

Technical Discussion

This assessment characterizes floodplain vegetation to support restoration planning by linking plant communities to hydrologic and geomorphic conditions. Vegetation patterns were mapped using LiDAR-derived canopy height, aerial imagery, and field observations, and categorized into general structural groups based on height and position within the floodplain. These patterns reflect gradients

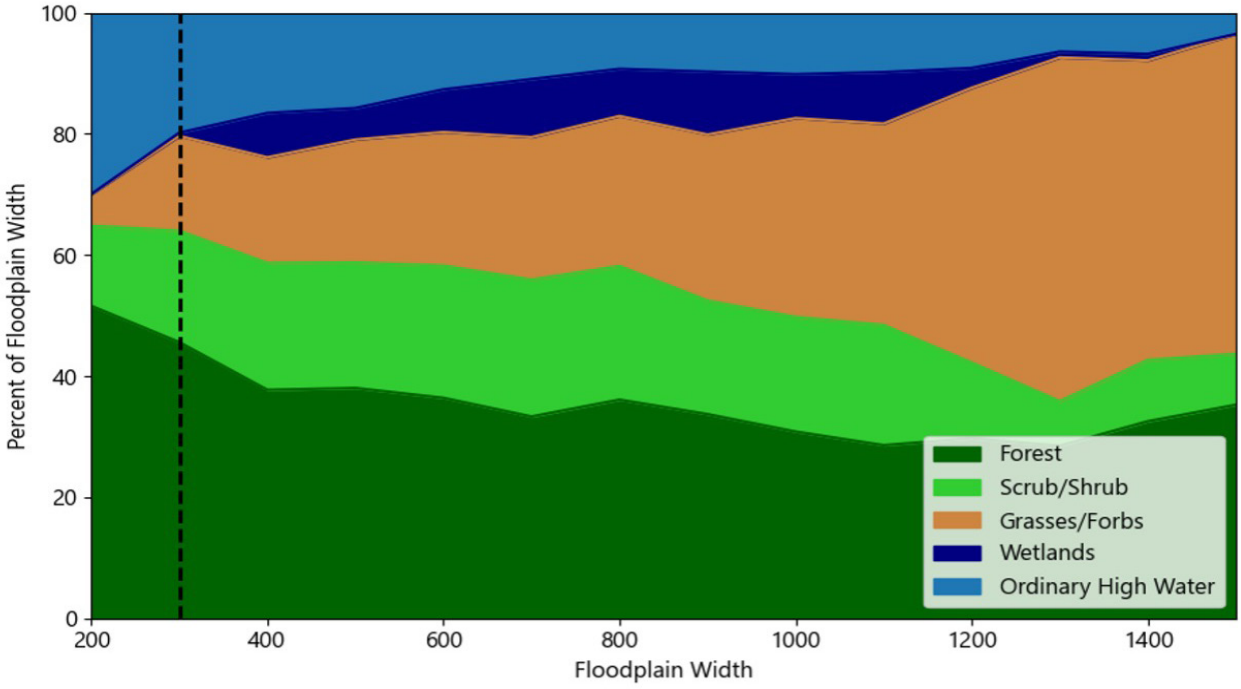


Figure 18. Summary of distribution of ecological communities by floodplain width. Results show the mean value per 100-foot floodplain width bin. Dashed black line denotes the minimum desired width of 300 feet.

in inundation frequency and groundwater influence, with vegetation structure serving as an indicator of underlying floodplain processes and site conditions.

Results show that vegetation distribution is closely tied to floodplain position, with distinct community types associated with areas of varying elevation and hydrologic connectivity. Lower, more frequently inundated areas support vegetation adapted to wetter conditions, while higher and more disconnected areas support communities indicative of reduced floodplain interaction. The analysis highlights that vegetation structure provides a useful proxy for identifying areas of functional versus impaired floodplain conditions, particularly where hydrologic connectivity has been altered.

Overall, the findings demonstrate that vegetation patterns are a direct expression of floodplain processes and can be used to assess current conditions and guide restoration. Reestablishing hydrologic and geomorphic connectivity is expected to shift vegetation communities toward conditions that reflect more frequent inundation and dynamic floodplain interaction, supporting broader ecosystem function and resilience.

4. CLIMATE CHANGE IMPACTS

Overview

Climate projections indicate warming trends, potentially resulting in higher temperatures, earlier runoff, reduced base flows, and increased stream temperatures. NorWeST recent historic (2002–2011) and projected (2040 and 2080) August mean stream temperature predictions were used in combination with life stage–specific temperature thresholds from the literature for focal species to evaluate potential habitat limitations.

The project area is expected to function as a transitional zone for suitable summer stream temperatures for key species under projected climate scenarios.

Lower and middle project areas are predicted to exceed “optimum” temperature thresholds for Chinook spawning, Chinook juvenile rearing, and all life stages for bull trout and Pacific lamprey. By late century, some portions of Project Areas 15.1 and 15.2 are anticipated to exceed maximum thermal thresholds for Chinook spawning.

Restoration and rehabilitation efforts should be prioritized in areas projected to become less thermally suitable for focal species. These actions include reducing solar exposure by enhancing riparian shading, decreasing channel width where appropriate, improving hyporheic exchange through enhanced floodplain and lateral connectivity, and increasing summer streamflows by reducing water withdrawals. Collectively, these measures are intended to mitigate the effects of a warming climate on stream temperature conditions throughout PA 5–15.2 and the broader Tucannon River watershed.

Technical Discussion

This assessment evaluates summer stream temperature conditions across the Tucannon River watershed, with a focus on Project Areas 1.1–15.2, to determine whether temperature is a limiting factor for fish productivity and how conditions may change under future climate scenarios. Results indicate that thermal conditions are already marginal in portions of the watershed, particularly in lower elevation reaches, and are projected to worsen substantially under 2040 and 2080 climate scenarios. As temperatures increase, thermally suitable habitat shifts upstream and declines across all focal species and life stages. Among these, Chinook salmon spawning is the most thermally sensitive, with the greatest extent of habitat exceeding optimal thresholds, while steelhead and Pacific lamprey exhibit higher tolerance but still experience notable reductions in suitable habitat.

Within PA 1.1–15.2, stream temperatures reflect a transitional zone between cooler headwaters and warmer downstream reaches.

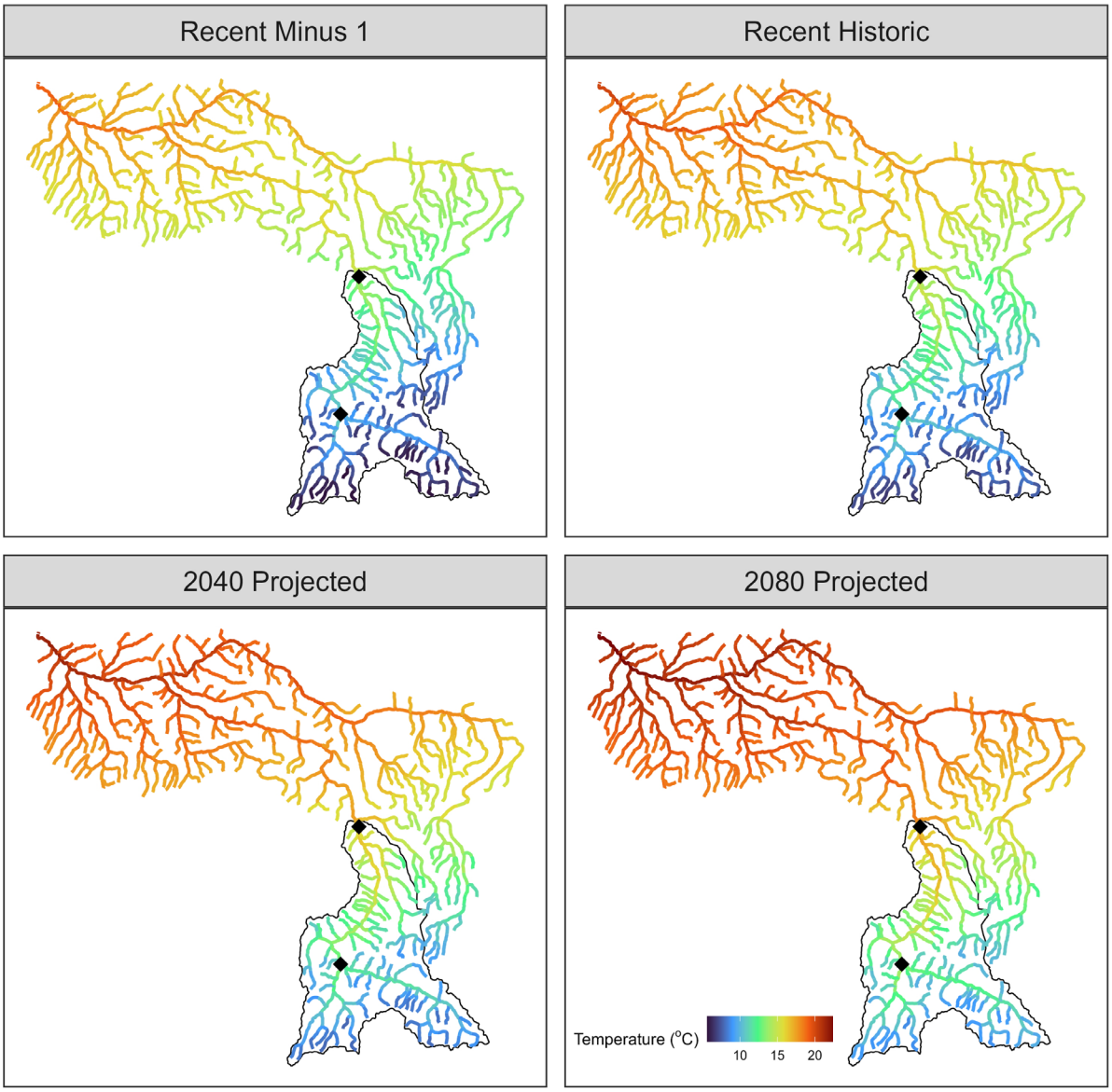


Figure 19. Modeled average August stream temperatures (Celsius) within the Tucannon River watershed for the Recent Historic, 2040 Projected, 2080 Projected, and Recent Minus 1 (Celsius) temperature scenarios. The portion of the Tucannon River watershed that is the focal area for the assessment, and includes Project Areas 1.1-15.2, is outlined in black; the black diamonds symbolize the upper and lower boundaries of the project area of the assessment.

Under current conditions, many segments remain within or near optimal thresholds for several species and life stages, but this balance degrades under projected warming. The number of reaches exceeding optimal temperature thresholds increases under both the 2040 and 2080 scenarios, with impacts expanding in both magnitude and spatial extent. By mid- to late-century, a substantial portion of the project area is projected to experience thermal conditions that limit key life stages, particularly for Chinook salmon and bull trout. These patterns highlight priority areas where thermal stress is expected to become most acute and where restoration actions may provide the greatest benefit.

A hypothetical cooling scenario involving a 1°C reduction in stream temperature demonstrates that localized improvements are possible, particularly for Chinook salmon spawning. However, the overall effect is limited, indicating that small temperature reductions alone are

insufficient to offset broader climate-driven warming trends. This underscores the need for comprehensive, watershed-scale strategies that address multiple drivers of stream temperature rather than relying on isolated actions.

Overall, the findings indicate that stream temperature is an increasingly important constraint on habitat availability and fish productivity in the Tucannon River system. Project Area 1.1–15.2 is likely to play a critical role as a transitional and potentially refugial zone, where maintaining and improving thermal conditions will be essential for sustaining cold-water species under future climate conditions. Effective restoration will require process-based approaches that reduce solar loading through increased shading, enhance hyporheic exchange and groundwater interaction through floodplain reconnection, and improve summer flow conditions. Implemented at both reach and watershed scales, these actions can help mitigate warming effects, maintain thermal refugia, and support long-term ecological resilience.

5. FOCAL SPECIES PRODUCTION & HABITAT SUITABILITY INDEX

Overview

Salmon and steelhead populations in the Tucannon River have declined significantly due to multiple factors, including commercial overharvesting, hydropower development, and climate change (Tucannon Subbasin Plan, 2004; Snake River Salmon Recovery Plan for Southeast Washington, 2011). Within the assessed PA 5-15 reach, floodplain simplification—through channel straightening, floodplain smoothing, and agricultural development—combined with the loss of floodplain vegetation, surface roughness, and large wood recruitment (due to wildfire and infrastructure such as roads, levees, and lakes), has reduced the active and available floodplain by approximately 70%. These changes have resulted in degraded habitat conditions that affect both juvenile rearing and spawning.

Juvenile winter rearing suitability for Chinook salmon, steelhead, and bull trout within PA 5–15.2 is generally low due to channel incision and reduced floodplain connectivity, which result in higher water velocities. Modeling indicates that increasing floodplain connectivity can improve hydraulic suitability for juvenile rearing.

Increasing the presence of side channels, multi-thread channel networks, off-channel habitats, and overall floodplain connectivity can improve hydraulic conditions by reducing velocities, benefiting juvenile winter rearing and other early life stages such as fry and parr. However, restoration efforts must be carefully designed to avoid excessive redistribution of flow from the main channel, as this could create barriers to upstream migration for adult Chinook salmon and bull trout during critical summer periods.

Technical Discussion

The technical analysis evaluated hydraulic habitat suitability (HHS) for juvenile winter rearing Chinook salmon, steelhead, and bull trout, as well as juvenile summer rearing and adult spawning Chinook salmon, within PA 1.1–15.2 of the Tucannon River. Across species and life stages, modeled hydraulic conditions were generally poor throughout the study area. Velocity was consistently identified as the primary limiting factor for juvenile winter rearing, with conditions typically exceeding preferred ranges, while depth suitability was also limited for most species. Depth suitability for bull trout was somewhat higher than for Chinook salmon and steelhead, reflecting their preference for slightly shallower conditions. Summer rearing suitability for juvenile Chinook salmon was also constrained, largely due to shallow depths, and spawning suitability for Chinook salmon, although higher than juvenile rearing suitability, remained relatively low overall.

Regression analyses indicated that the proportion of connected floodplain area within each project area was only weakly correlated with hydraulic suitability. Positive relationships were observed between floodplain connectivity

and winter velocity and composite suitability; however, model fit was relatively poor, and no clear relationships were identified for Chinook salmon summer rearing or spawning suitability.

These results indicate that increasing floodplain connectivity alone is not sufficient to predict improvements in hydraulic habitat conditions. Rather, floodplain connectivity provides the spatial and geomorphic context necessary for processes to occur that generate suitable hydraulic conditions over time.

Despite the relatively weak statistical relationships, reaches with limited floodplain connectivity—particularly PA 4, 7, and 13—also exhibited some of the lowest composite suitability scores across species. These reaches are largely characterized by single-thread, channelized morphology with limited side-channel or off-channel habitat.

Conversely, PA 14.3 contains relatively large areas of connected floodplain but still exhibits low suitability, highlighting that connectivity alone does not ensure the development of hydraulically suitable habitat where channel complexity remains limited. Collectively, these patterns reinforce that floodplain connectivity should be understood as a process-enabling condition rather than a direct predictor of habitat suitability.

Decades of channel simplification, floodplain disconnection, water diversion, and altered geomorphic processes have produced hydraulic conditions that are generally too fast and shallow for juvenile rearing for all species assessed and only marginally suitable for Chinook salmon spawning. Increasing floodplain connectivity expands the area available for lateral flow exchange, channel

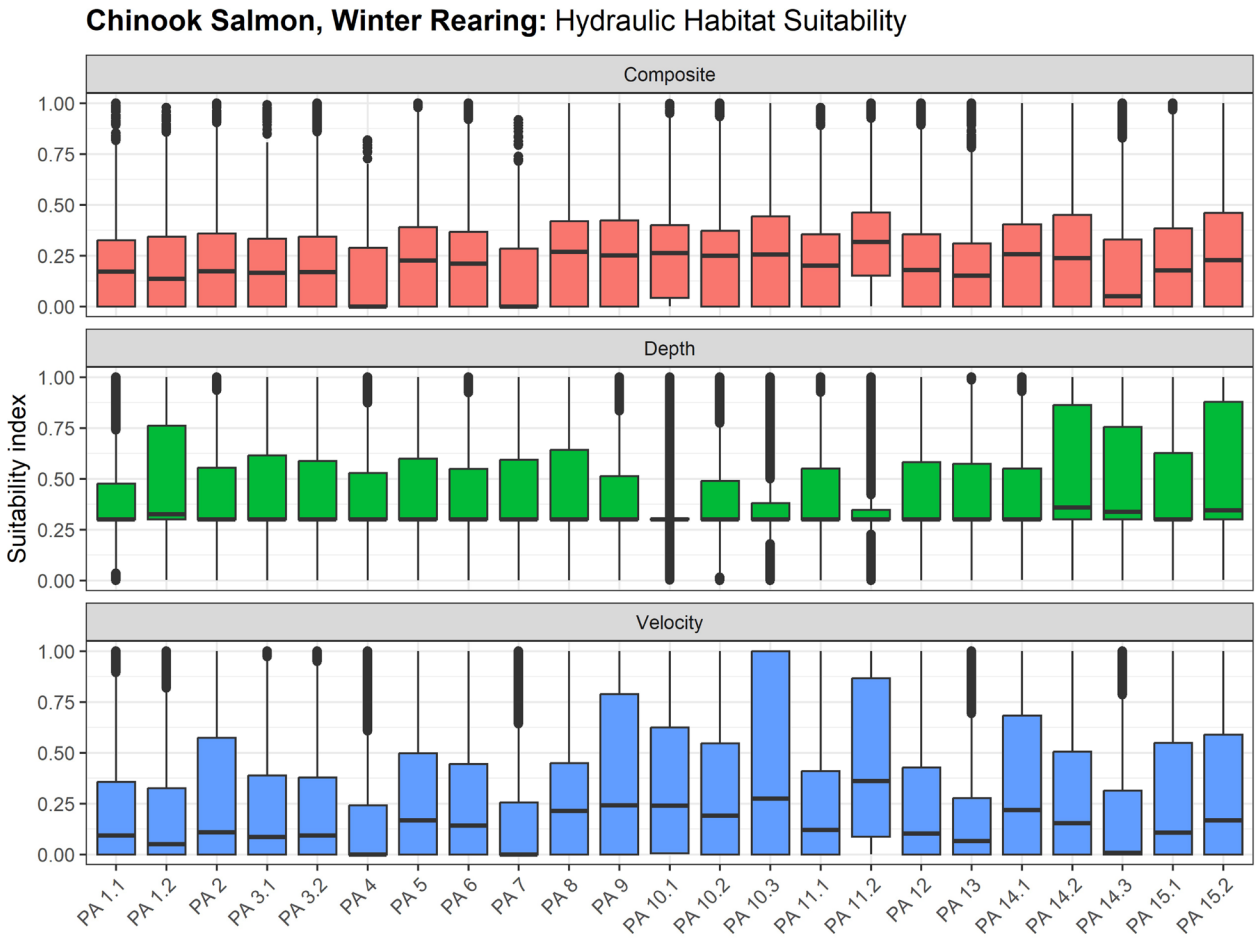


Figure 20. Box plots of composite, depth, and velocity suitability values for juvenile Chinook salmon winter rearing, summarized by project area, in PA 5-15.2 of the Tucannon River. The full Technical Report in the appendices includes box plots for Chinook summer rearing and spawning, steelhead winter rearing, and bull trout winter rearing.



Figure 21. Single and multi-thread channel complexes with relatively high habitat suitability. Exchange, channel migration, and the development of multi-thread channels, side channels, alcoves, pools, and other complex channel features create slower, deeper hydraulic environments that are more suitable for multiple juvenile life stages.

migration, and the development of multi-thread channels, side channels, alcoves, pools, and other complex channel features. These features create slower, deeper hydraulic environments that are more suitable for multiple juvenile life stages. Although these habitat types are limited within PA 1.1–15.2, they exhibit some of the highest suitability scores where they occur.

Restoration strategies that increase connected floodplain area should be implemented within a broader process-based framework that promotes channel complexity, increases channel length, reduces channel gradient, and enhances lateral habitat development, rather than relying on floodplain connectivity alone as a direct mechanism for improving hydraulic conditions.

Restoration actions that increase lateral connectivity should also prioritize the creation and maintenance of deeper, low-velocity mainstem habitats such as pools, alcoves, and backwaters, which may provide important overwintering habitat not fully replicated by side-channel environments alone. Seasonal floodplain inundation can also provide velocity refugia and favorable growth conditions for fry and early parr (Jeffres et al. 2008), life stages not explicitly evaluated in this assessment due to limited suitability data.

At the same time, restoration strategies that redistribute flow laterally must consider potential tradeoffs with adult migration conditions. Excessive reductions in mainstem depth during summer migration periods, particularly in reaches influenced by water diversion, could increase the likelihood of passage constraints for adult Chinook salmon and bull trout. Process-based restoration approaches should therefore balance increased connectivity with the need to maintain adequate migration corridors and holding habitat in the primary channel.

Beyond hydraulic conditions, increased floodplain connectivity supports a range of ecological processes that benefit salmonids across life stages (Sommer et al. 2001; Jeffres et al. 2008; Bellmore et al. 2013).

Regular floodplain inundation promotes riparian vegetation development, increases large wood recruitment, enhances channel complexity, and supports groundwater recharge and hyporheic exchange (Singh et al. 2018). These processes can moderate stream temperature extremes and create localized thermal heterogeneity that provides seasonal refugia (Poole and Berman 2001; Weber et al. 2017).

Hydraulic habitat suitability analyses provide important insight into species- and life stage–specific constraints but represent only one component of overall habitat quality. Results from this assessment should be interpreted alongside the biological and geomorphic appendices to support integrated, watershed-scale restoration planning and prioritization.

6. Lakes and Infrastructure

Overview

The existing lakes that have not been repaired or replaced present increasing concerns related to safety, structural stability, and operational functionality. Many of these features occupy more than 50% of the valley cross-section, significantly constraining flow and increasing vulnerability during high-flow events. Common deficiencies include insufficient dam crest width, elevated seepage rates, encroaching large woody vegetation on embankments, and site-specific outlet or drainpipe deficiencies. Together, these conditions elevate the risk of structural failure and reduce the ability to safely manage water levels.

Lakes with high valley occupancy are particularly susceptible to overtopping and failure during flood events, as limited conveyance capacity concentrates flow and increases hydraulic pressure on aging structures. Addressing these risks will require targeted action at each site, including repairing critical deficiencies where feasible. However, for lakes with substantial structural issues and high cross-sectional occupancy, decommissioning or relocation should be strongly considered.

These actions would reduce safety risks, improve flood conveyance, and better align infrastructure with long-term watershed function and resilience.

Technical Discussion

This assessment evaluates the operational condition, structural integrity, and floodplain impacts of multiple impoundments within the PA 5-15 area to inform decisions regarding repair, replacement, or decommissioning. The review integrates field observations, existing safety evaluations, and hydraulic modeling to characterize how each structure functions under both normal and high-flow conditions.

Across the system, many of the lakes are aging earthen dams with a range of deficiencies that affect both safety and performance. Common issues include deteriorated or leaking outlet pipes, inadequate dam crest widths, over-steepened slopes, high seepage rates, and encroachment of large woody vegetation into dam embankments. WDFW identifies Spring Lake as the only lake without a working bottom-drain outlet and notes that Deer Lake has a new bottom-drain culvert. Outlet condition and other structural deficiencies should therefore be described and evaluated separately for each lake.

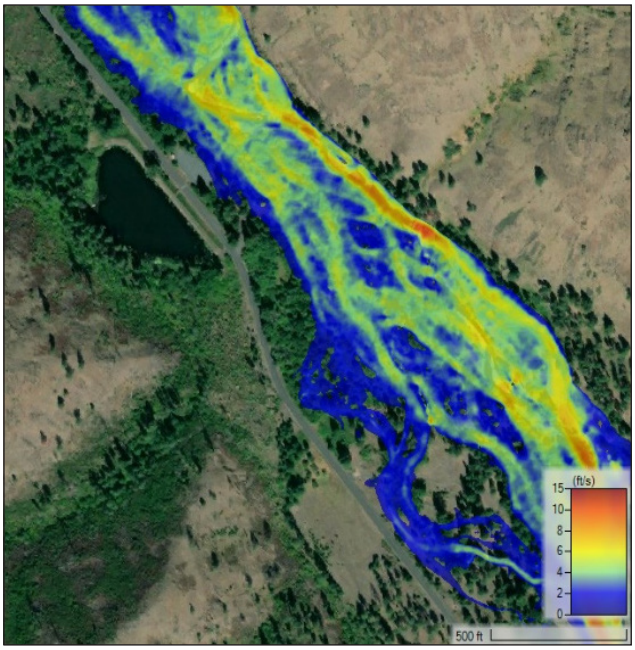
These structural deficiencies are compounded by the spatial footprint of the impoundments within the valley. Many lakes occupy a substantial portion of the floodplain cross-section—often exceeding 50%—which significantly constrains natural flow paths and limits the river's ability to distribute energy across the floodplain. This confinement increases hydraulic pressure on dam structures during high flows and reduces overall system resilience. Hydraulic modeling indicates that several impoundments become engaged during relatively common flood events, with elevated velocities at the toe of dams creating high erosion potential. Under these conditions, even moderate floods can initiate slope failure, piping, or overtopping, particularly where seepage or structural weaknesses are already present.

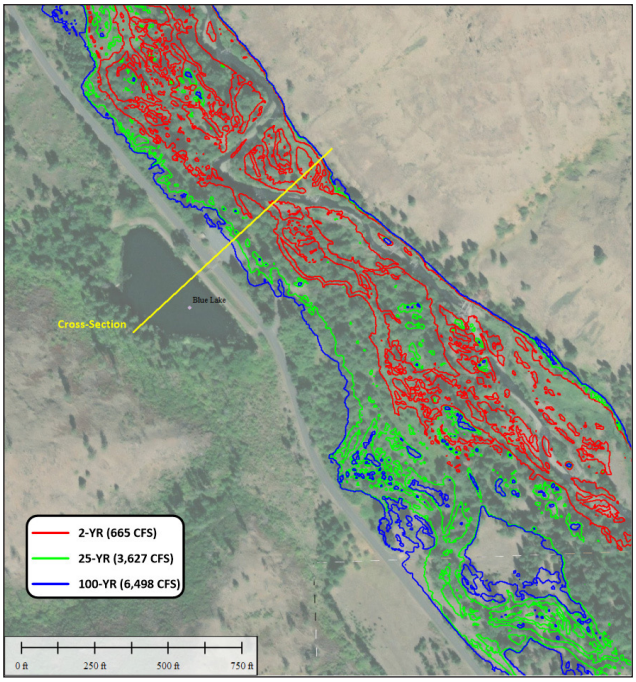
The analysis also highlights variability among lakes in terms of risk and functionality. Some impoundments remain relatively stable, with limited safety concerns and lower interaction with flood flows, while others exhibit significant operational challenges and high exposure to flood-related impacts. In higher-risk systems, past flood events have demonstrated vulnerabilities, including overtopping, erosion, and uncontrolled inflows. In these cases, continued operation without intervention increases the likelihood of future failure and associated downstream risks.

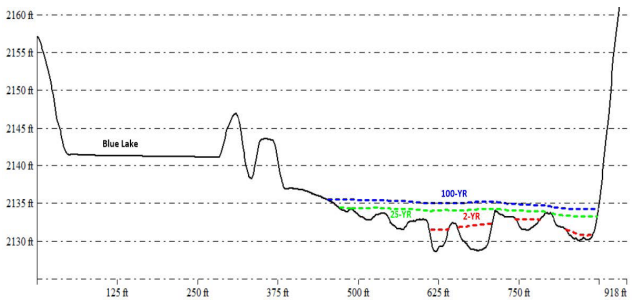
Repairing these structures is feasible but often complex and costly. Typical corrective actions include replacing aging pipe infrastructure, regrading dam slopes to meet safety standards, widening dam crests, removing vegetation from embankments, and addressing seepage through excavation and recompaction. However, these repairs carry inherent uncertainty, as modifying earthen dams often reveals additional deficiencies that increase cost and complexity.

Given these constraints, the assessment agrees with the Floodplain Management Plan that decommissioning or relocation should be strongly considered for impoundments with significant structural deficiencies and high floodplain occupancy. These actions would reduce safety risks, restore natural floodplain connectivity, and improve hydraulic performance during high-flow events.

Overall, the findings emphasize that many of the existing lakes represent a trade-off between recreational use and long-term system performance. Where structural risks and floodplain constraints are high, maintaining these impoundments in their current condition is increasingly difficult and costly. Transitioning toward a system that prioritizes safety, floodplain function, and resilience will require a combination of targeted repairs for lower-risk structures and strategic decommissioning.







Figures 22 - 24. Top to bottom: HEC-RAS flow simulation showing velocity at 4,200 cfs; Flood inundation extents from hydraulic modeling; Cross-section showing terrain and water surface elevations.

7. WETLANDS

Overview

Construction of road grades and other infrastructure, combined with channel incision and the loss of side channels, has reduced both surface and subsurface hydrologic connectivity between floodplain wetlands and the river.

Wetland functionality has declined, including reduced water quality benefits, diminished flood attenuation capacity, and decreased trophic support for salmonid prey species. Habitat availability for juvenile salmonids has also declined, resulting in fewer off-channel refuges and reduced winter-rearing environments. At the same time, the prevalence of non-native plant species has increased, while overall wetland acreage has decreased.

Loss of forested wetlands and riparian shading can reduce thermal buffering. The wetland delineation does not, by itself, establish a measured temperature trend in the mainstem or associated wetlands.

Restoring floodplain connectivity can be achieved through channel filling and removal of artificial structures to improve surface and subsurface hydrology. These actions aim to maintain higher water tables and support wetland function. Restoration may also include developing side channels and placing large wood to improve hydrologic connectivity, as well as removing invasive species and replanting native vegetation.

Technical Discussion

This memorandum documents wetland mapping and ordinary high water mark (OHWM) delineation for the Tucannon River PA 5–15 Assessment and Conceptual Design Project. The study covers an approximately ten-mile reach within the W.T. Wooten Wildlife Area and supports a multi-partner effort to evaluate floodplain conditions and develop integrated restoration strategies.

Table 1: Cowardin classified wetland types found in the project area.

Cowardin classification	Acres
Palustrine emergent	29.7
Palustrine emergent/Unconsolidated bottom	17.3
Palustrine forested	14.3
Palustrine scrub-shrub	3.3
Palustrine unconsolidated bottom	4.5



Figure 25. Beaver Lake is a PEM/PUB classified wetland.



Figure 26. A wetland complex adjacent to Curl Lake. Each pond has adjacent wetlands due to berm seepage.

Wetland identification combined desktop analysis—including LiDAR, aerial imagery, soils data, and National Wetland Inventory mapping—with field verification of vegetation, hydrology, and geomorphic indicators. This approach identified approximately 69 acres of wetlands across multiple types, including riverine, depressional, pond-associated, and hillslope seep systems.

The study area is heavily influenced by artificial lakes, levees, and flow diversions that have altered natural floodplain processes. These features contribute to channel confinement, sedimentation, and infrastructure challenges, reducing habitat quality.

Findings indicate that current conditions reflect a legacy of floodplain disconnection and simplified channel form, limiting ecological performance and system resilience. At the same time, the project area presents opportunities to restore connectivity, improve habitat complexity, and reduce long-term maintenance demands.

Wetland and OHWM delineations provide a foundation for evaluating impacts, supporting Clean Water Act permitting, and informing restoration design.

8. RECREATION

Overview

The W.T. Wooten Wildlife Area is both a landscape and a legacy—a long, narrow river valley shaped by water, forest, recreation, and generations of human use. The project area contains a remarkably concentrated mix of recreational and ecological resources: eight lakes, ten campgrounds, a fish hatchery, an Environmental Learning Center, extensive road access, and a valley floor nearly a thousand feet wide.

But the significance of the area extends far beyond recreation infrastructure. The Tucannon River forms the ancestral boundary between the Umatilla and Nez Perce Tribes, embedding the landscape within a much deeper cultural history. Over time, the valley evolved through successive eras of homesteading, logging, state land acquisition, dam mitigation projects, road expansion, and, more recently, ecological restoration. Each phase left its imprint on how people access and experience the area today.

Eight artificial lakes were constructed in the 1950s and later deepened and improved under the Lower Snake River Compensation Plan. These lakes have operated as popular “put and take” fisheries, stocked with trout from the Tucannon and Lyons Ferry Fish Hatcheries. The valley also serves as a major outdoor destination for campers, hunters, hikers, and bird watchers (among other uses). All users have experienced changes to the valley over time. Understanding these changes informs potential improvements for the community and user groups.

Efforts to assess recreational resources have included geospatial mapping to quantify lake size and fishable shoreline. Online user surveys have also been conducted to assess the user profile and experience. These efforts provide a foundation for evaluating potential impacts and improvements associated with land-management and infrastructure changes.

Considering recreational user experiences is an integral part of restoration and infrastructure upgrade strategies identified in this project.

Discussion

The 2024 recreation survey revealed a user community with unusually deep ties to the landscape. Most respondents have been visiting for decades, with the largest group reporting more than 31 years of use. These are not transient visitors; they are repeat users with long-term familiarity and emotional investment in the Wildlife Area. Recreational use is also relatively immersive. While day trips remain common, many visitors stay overnight, often for multiple days, reinforcing the role of the valley as a destination rather than simply a stop along the way.

Fishing clearly defines the recreational identity of the area. Lake fishing was the single most common primary activity identified by respondents, followed by camping and more generalized outdoor enjoyment.

Certain lakes—particularly Rainbow Lake and Big Four Lake—emerge as focal points of use, likely reflecting a combination of accessibility, fishing quality, and established visitor patterns.

Overall satisfaction with the recreational experience remains high. Visitors consistently value the area's ease of access, strong fishing opportunities, and the broader experience of being immersed in nature. Yet the survey also points toward growing pressures and unmet expectations. Overcrowding was the most frequently cited negative issue, suggesting that the area's popularity may now be straining the qualities visitors value most. Maintenance concerns and the perceived lack of dedicated fly-fishing opportunities also surfaced repeatedly, hinting at both infrastructure and user-conflict challenges. The shoreline accessibility data further illustrates how recreation is unevenly distributed across the lakes.

Some lakes offer extensive accessible shoreline for anglers, while others remain constrained by terrain, vegetation, or infrastructure limitations. This imbalance likely concentrates users into a smaller subset of highly accessible lakes, contributing to crowding and diminished visitor experience in peak periods.

Taken together, the story emerging from the survey is not one of decline, but of transition. The W.T. Wooten Wildlife Area remains highly valued and deeply loved by its users, yet increasing demand is beginning to test the balance between accessibility, solitude, recreation quality, and ecological stewardship. The central management question moving forward is no longer simply how to provide recreation, but how to guide and distribute use in ways that preserve the qualities that have drawn people back to the valley for generations.

Scour Study In Process

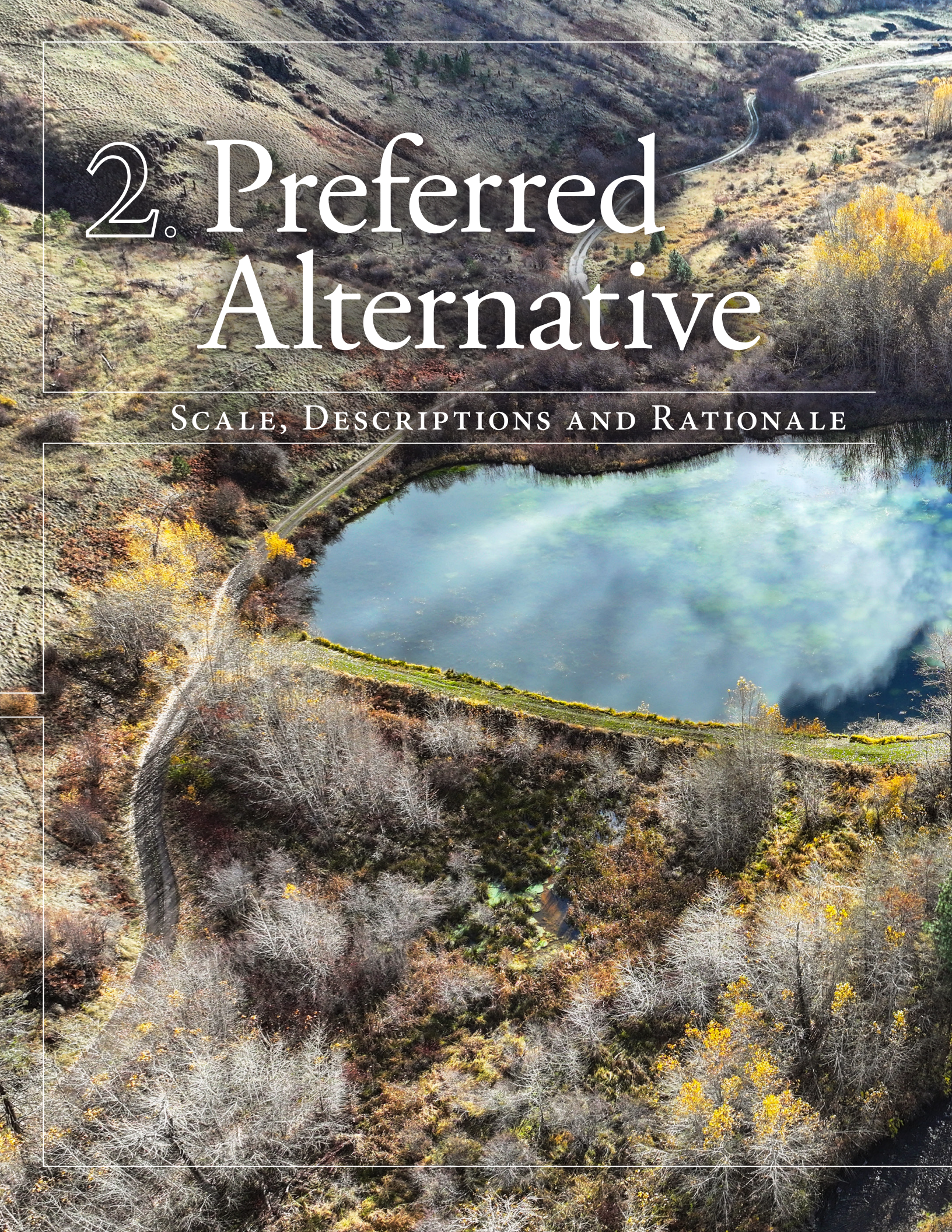
The project team is actively working on a study of the project reach to measure streambed scour depths and patterns and assess the ongoing risks from incision. The currently planned phase of the scour study will likely be completed late in 2027, which is after the completion of this conceptual design report. The scour study is intended as an analysis supporting feasibility evaluation and design needed to carry the plan toward implementation. As such, the scour study is unlikely to change the high-level plan outlined in this report, but it will likely influence design-level decision making and will support continued learning about the most critical restoration needs and approaches for the Tucannon River.



Figure 27 - Recreational Fishing at W.T. Wooten Wildlife Area lake.

2. Preferred Alternative

Scale, Descriptions and Rationale





The Vision for the Tucannon PA 5-15 Reach is to restore physical and ecological floodplain function to benefit key fish and aquatic species, while broadening and enhancing recreational opportunities, through coordinated planning and conceptual restoration designs for the floodplain and adjacent lands of WT Wooten Wildlife Area.

Development and evaluation of the Reach-Scale Preferred Alternative included identifying those actions that provide continued recreational use of the reach while allowing as much functional restoration of the floodplain and ecosystem as possible within existing land uses.

■ *Tucannon River and Deer Lake; PA 5-15*

The Preferred Alternative is a coordinated set of actions that, when implemented, would substantially improve river and floodplain processes and function throughout the PA 5-15 reach.

The planned actions will expand the total area of connected and functional floodplain within the project reach from 231 acres to 379 acres, restoring floodplain processes and connectivity across the full extent of those 379 acres. These actions will also restore the minimum target floodplain width along approximately 40 percent of the 10.2-mile reach. Key actions include removal of the Beaver and Watson Lakes from the active floodplain, reconnection and restoration of approximately 84 acres of floodplain through lake removal, road relocation, and channel restoration, and construction of a new fishing lake outside of the floodplain to maintain recreational opportunities while improving floodplain function.

Rationale

The proposed project is part of a long-term, multi-phase effort to restore floodplain function, improve salmon habitat, reduce flood risk, and sustain recreation within the W.T. Wooten Wildlife Area along the Tucannon River. The project emerged from recognition that past approaches focused too narrowly on individual infrastructure needs rather than the broader ecological and recreational function of the valley. Through a 10-mile assessment process involving technical analysis, public outreach, tribal guidance, and interagency coordination, the Co-Managers identified floodplain reconnection and infrastructure relocation as essential actions to restore natural river processes while maintaining the area's recreational and economic importance.

Decades of channelization, floodplain confinement, road construction, and lake infrastructure have narrowed and disconnected the Tucannon River floodplain, increasing stream power, accelerating erosion, degrading salmon habitat, and creating recurring flood damage to roads, campgrounds, and recreation facilities. The project directly addresses these issues by relocating vulnerable infrastructure out of the floodplain, reconnecting floodplain habitat, and restoring channel complexity and lateral connectivity. These actions are expected to reduce flood hazards, improve wood and gravel retention, support riparian forest recovery, and create improved spawning and rearing habitat for ESA-listed spring Chinook, steelhead, and bull trout. At the same time, the project seeks to maintain lake-fishing opportunities through replacement lakes and improved access. The proposed changes would alter the number and distribution of lakes, and their effects on camping access, crowding, and visitor experience will need to be evaluated during design.

The project also advances broader community and cultural objectives. A functioning floodplain will better store and slowly release water, helping sustain summer baseflows, reduce downstream flood impacts, and improve ecosystem resilience to wildfire and climate variability. Restoring productive salmon habitat is central to rebuilding fisheries that support tribal treaty rights and cultural continuity, while protecting recreation access that contributes significantly to the local economy. The project represents a coordinated investment in ecological recovery, public safety, recreational opportunity, and long-term watershed resilience.

Reach Scale Strategy

At the reach scale, the project envisions a comprehensive restoration of the Project area corridor by reconnecting floodplains, removing outdated infrastructure, and reimagining recreational access in ways that better align with long-term ecological function. Central to this effort is the removal of the remnants of Big Four Lake and its associated infrastructure, followed by restoration of the river channel and adjacent floodplain. Similar restoration actions would occur at Beaver-Watson Lakes, where the lakes and related infrastructure would be removed to allow the floodplain and channel to function more naturally once again. Deer Lake would also be relocated upstream, with its existing in-stream diversion removed and replaced by a groundwater well, enabling restoration of the river channel and surrounding floodplain in that reach.

Several infrastructure modifications are proposed to support these restoration goals while maintaining access and utility services. The overhead powerline would be rerouted into the Tucannon Road right-of-way, and Tucannon Road itself would be rerouted at three locations to reconnect and restore adjacent floodplain areas currently constrained by the roadway. Access to Camp Wooten and the USFS Tucannon Campground would be improved through construction of a new bridge across the Tucannon River and reconfiguration of the campground access road. As part of this work, the portion of the existing USFS campground located on the west side of the river would be decommissioned, allowing the channel and floodplain between Tucannon Road and the campground access road to be reconnected and restored.

To maintain and enhance recreational opportunities within the corridor, a new lake would be constructed outside the active floodplain downstream of Blue Lake, replacing the recreational functions currently associated with Beaver-Watson Lakes and the now non-functioning Big Four Lake. Beaver-Watson Lakes would not be decommissioned until New Lake is constructed and operational, with replacement recreational functions confirmed by WDFW. Existing Deer Lake would likewise remain until the relocated Deer Lake is constructed and operational, with replacement recreational functions confirmed by WDFW.

Additional fishing-access improvements may be considered through separate planning and review by WDFW. Specific improvements at Spring and Blue Lakes have not been established as implementation commitments under this plan.

- *Table 2: Preferred Alternative Recreation and Floodplain metrics*

Sub-reach/ACTION	EXISTING FISHABLE SHORELINE (ft)	PROPOSED FISHABLE SHORELINE (ft)	EXISTING LAKE AREA (ac)	PROPOSED LAKE AREA (ac)	FLOODPLAIN AREA RESTORED (ac)
1 - Tucannon Campground	NA	NA	NA	NA	30.7
2- Curl Lake	1112	0	2.0	0.0	32.0
3 - Big Four	0	0	0.0	0.0	118.7
4 - Beaver-Watson	1642	0	4.2	0.0	83.9
5 - Deer Lake	605	2080	2.3	4.3	58.2
6 - New Lake	0	1220	0.0	1.9	55.8
Total	**3359**	**3300**	**8.5**	**6.2**	**379.3**

Note: The existing-condition totals treat Big Four Lake as nonfunctioning and assign it no currently available fishable shoreline or lake area. These totals therefore compare the proposal with current conditions rather than the historical recreation opportunities available when Big Four Lake was operational.

The Washington Department of Fish and Wildlife is implementing improvements at Rainbow Lake independently of the broader restoration effort.

This project also includes proposed changes to fish-management infrastructure. A new downstream adult collection weir would be located, acquired through purchase or lease, designed, and constructed to support changes in fish collection and acclimation operations that would allow Curl Lake to be decommissioned. The existing structure near Rainbow Lake would remain necessary for hatchery and Rainbow Lake operations and may continue to serve other fish-management functions. Curl Lake would not be decommissioned until the downstream facility is operational and WDFW confirms that the necessary fish-management functions have been accommodated.

Conceptual Designs by Sub-reach

The PA 5–15 Reach is divided into six sub-reaches based on distinct physical characteristics and the suite of restoration and infrastructure actions identified within the Preferred Alternative (Figure 31). Organizing the reach into sub-reaches allows for a more detailed evaluation of existing conditions, restoration opportunities, and planned actions within each portion of the corridor.

Across all six sub-reaches, the primary focus is the reconnection and restoration of the river channel and floodplain to improve geomorphic function, floodplain engagement, and aquatic habitat conditions while maintaining needed infrastructure to support recreation. Restoration actions generally include channel filling and shaping to address the effects of historic incision and channelization, as well as floodplain grading to remove or recontour artificially elevated surfaces. These grading efforts are intended to improve floodplain connectivity by creating swales, low-lying areas, and side channels that increase inundation frequency and support more dynamic floodplain processes.

The restoration approach also includes extensive installation of large wood habitat structures and distributed floodplain wood throughout the corridor. Wood would be placed both within the active channel and across the floodplain to promote channel complexity, improve habitat diversity, encourage sediment retention, and support natural floodplain processes. Invasive species control and revegetation with native, multi-layer, multi-species riparian plant communities would further enhance ecological function, long-term channel stability, and habitat quality throughout the reach.

Section 3 presents the conceptual designs and considerations for each sub-reach, including concept-level cost estimates, proposed geomorphic grade line (GGL) targets, and conceptual cut-and-fill polygons illustrating anticipated grading extents and material balance. These concepts will be refined through subsequent feasibility analysis and design.

Sub-reach 1 - Tucannon Campground

Within this sub-reach, access to Camp Wooten and the USFS Tucannon Campground would be improved through the design and construction of a new bridge crossing the Tucannon River. Associated roadway improvements would include raising the elevation of the access road between the two camp areas to improve resilience during high-flow events, with consideration given to installing one or more relief culverts to maintain floodplain connectivity and conveyance across the roadway corridor.

As part of the broader floodplain restoration effort, the portion of the existing USFS Tucannon Campground located on the west side of the river would be decommissioned. This would allow approximately 31 acres of channel and floodplain between Tucannon Road and the campground access road to be reconnected and restored, improving floodplain function, habitat complexity, and river processes within the reach.

Additional infrastructure modifications include relocation of the existing overhead powerline into the Tucannon Road right-of-way near the downstream end of the sub-reach, reducing conflicts with restoration activities and floodplain

function. Implementation of these actions will require close coordination with both Washington State Parks, which manages Camp Wooten, and the U.S. Forest Service.

Sub-reach 2 - Curl Lake

The actions proposed within this sub-reach are dependent upon the construction and operation of a new adult collection weir in the lower Tucannon River, which would replace existing fish collection and acclimation functions currently associated with Curl Lake. Following implementation of the new downstream facility, Curl Lake and its associated infrastructure would be removed, allowing for restoration of more natural channel and floodplain processes within the reach.

Supporting infrastructure modifications would include relocation of the existing overhead powerline and rerouting of Tucannon Road near the USFS Tucannon Guard Station (VM 40) to reduce constraints on floodplain connectivity and accommodate restoration activities. These actions would enable the design, reconnection, and restoration of approximately 32 acres of channel and floodplain habitat, improving floodplain engagement, habitat complexity, and overall river function within the sub-reach.

Sub-reach 3 - Big Four

Within this sub-reach, restoration efforts would focus on removing the remnants of Big Four Lake and its associated infrastructure to eliminate existing constraints on channel and floodplain function. The existing overhead powerline would also be relocated into the Tucannon Road right-of-way, reducing infrastructure conflicts within the active floodplain corridor and supporting long-term restoration objectives.

These actions would facilitate the design, reconnection, and restoration of approximately 119 acres of channel and floodplain habitat. Restoration activities would aim to improve floodplain engagement, enhance channel complexity, and restore more natural geomorphic and ecological processes throughout the reach.

Sub-reach 4 - Beaver-Watson Lakes

Restoration actions within this sub-reach would include removal of Beaver and Watson Lakes and their associated infrastructure, including the existing in-channel diversion and water supply channel, only after New Lake is constructed and operational, with replacement recreational functions confirmed by WDFW. Eliminating these features would allow the river and floodplain to function more naturally and reduce ongoing constraints on channel processes and habitat connectivity.

Additional infrastructure modifications would include relocation of the existing overhead powerline into the Tucannon Road right-of-way and possible realignment of Tucannon Road upstream of WDFW Campground 4 (VM 37) to the edge of the floodplain. Managers are considering shifting the roadway away from the active floodplain corridor to create additional space for river movement and floodplain engagement while improving long-term roadway resilience.

Together, these actions would support the design, reconnection, and restoration of approximately 84 acres of channel and floodplain habitat, enhancing geomorphic function, aquatic habitat complexity, and overall ecological condition within the sub-reach.

Sub-reach 5 - Deer Lake

Actions proposed within this sub-reach begin with completion of a detailed feasibility analysis to evaluate opportunities for relocating Deer Lake upstream and assessing the viability of supplying the lake with groundwater from a new well source. Development of the new water supply system may require modification or transfer of the existing water right associated with the lake.

Based on the results of that analysis, a new Deer Lake would be designed and constructed upstream of its current location, supported by a groundwater well that would replace the existing in-stream diversion. Existing Deer Lake and its associated diversion and infrastructure would

not be decommissioned until the relocated Deer Lake and its water supply are constructed and operational, with replacement recreational functions confirmed by WDFW. Removal of the diversion would reduce direct impacts to river flows and improve channel continuity and floodplain function within the reach.

These actions would support the design, reconnection, and restoration of approximately 58 acres of channel and floodplain habitat, improving geomorphic processes, floodplain engagement, and aquatic habitat conditions. Recreational enhancements could also be incorporated into the project, including installation of a fishing platform to improve public access and increase recreational use of the new lake.

Sub-reach 6 - New Lake

Actions within this sub-reach would begin with completion of a feasibility analysis to evaluate potential locations and design considerations for construction of a new lake outside the existing active floodplain downstream of Blue Lake. The new lake is intended to provide long-term recreational opportunities while reducing conflicts with floodplain restoration objectives elsewhere in the corridor.

Following completion of the feasibility analysis, the New Lake would be designed and constructed outside of the active floodplain area. New Lake would be constructed and operational, with replacement recreational functions confirmed by WDFW, before Beaver-Watson Lakes are decommissioned. Water for the lake could be supplied using flow from Blue Lake, with the existing outflow ditch rerouted to serve as the primary water source. To improve water quality and enhance ecological function, a polishing wetland would also be constructed to treat and moderate outflow from the new lake before it reenters the broader system.

Supporting recreational infrastructure would include development of an expanded parking area adjacent to the New Lake to improve public access and accommodate anticipated recreational use.

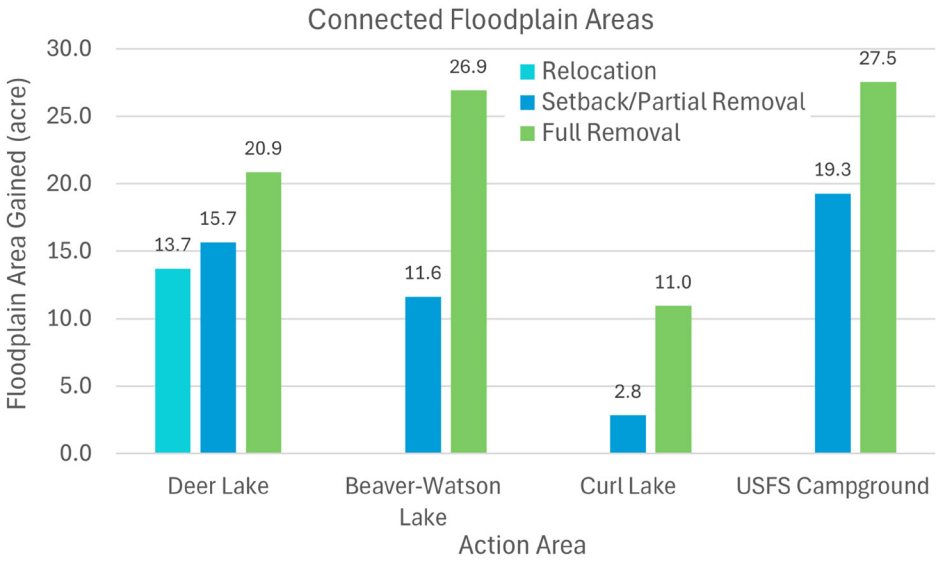
Project Benefits

The project provides interconnected community, habitat, agricultural, recreation, and flood-risk reduction benefits through large-scale floodplain reconnection and restoration actions in the Project area corridor. Across the full project reach, the Preferred Alternative would increase connected floodplain from approximately 231 acres to 379 acres, adding approximately 148 acres of connected floodplain and restoring function across the approximately 379-acre total. Approximately 84 acres of channel and floodplain restoration are associated with Sub-Reach 4, including Beaver-Watson Lakes. These actions will increase floodplain storage, reduce stream power during high flows, improve groundwater recharge, and reduce scour potential that threatens salmon redds and critical infrastructure. The project is intended to reduce flood exposure and maintenance demands associated with vulnerable lake, campground, and access infrastructure. The March 2026 flooding highlighted the need to evaluate infrastructure resilience, including damage at Deer Lake identified by WDFW. Construction of a replacement recreational lake outside the active floodplain is intended to maintain lake-fishing opportunities while reducing exposure to river flooding. Changes in lake locations, shoreline access, and the distribution of recreational use will need to be considered during design.

Ecologically, the project supports recovery of Tucannon River spring Chinook salmon, which are currently at critically low population levels, by improving floodplain connectivity, stabilizing spawning gravels, retaining large woody debris, and increasing overall ecosystem resilience. These habitat improvements also benefit Tribal communities by supporting salmon and other First Foods central to cultural values and Treaty Rights. At the same time, downstream agricultural producers benefit from increased flood attenuation, improved water storage, and reduced infrastructure vulnerability during high-flow events. Figures 28–30 compare the floodplain connectivity, functional width, and modeled redd resilience benefits of the evaluated restoration scenarios.

Preferred Alternative Map and Renderings

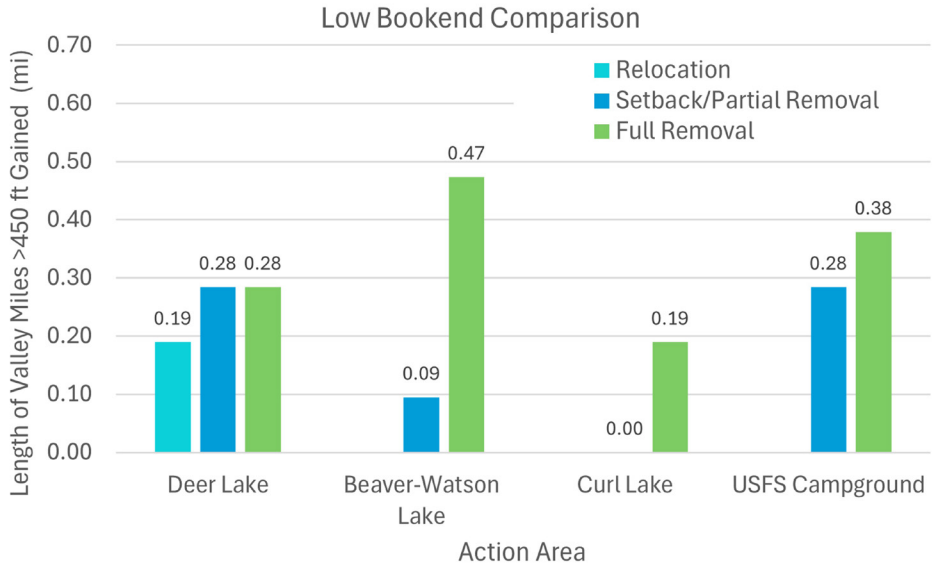
Figure 31 illustrates the Reach-Scale Preferred Alternative for PA 5–15. Figures 32–37 show existing conditions and preferred-alternative renderings for New Lake, Beaver-Watson Lakes, and Deer Lake. Sub-reach action overviews and concept designs are presented in Section 3 (Figures 38–49).



■ *Figure 28.*

Connected Floodplain Areas.

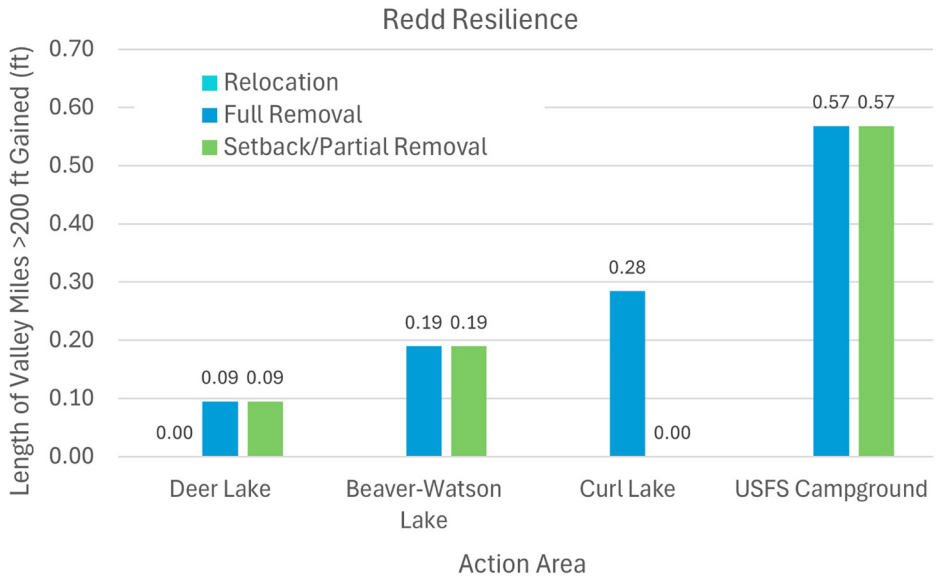
Connected floodplain area gains vary substantially by action type and location, with full infrastructure removal consistently providing the greatest increase in floodplain connectivity. Beaver-Watson Lake and the USFS Campground areas show the largest potential gains, exceeding 26 acres of reconnected floodplain under full removal scenarios.



■ *Figure 29.*

Low Bookend Comparison.

Full removal scenarios provide the greatest increase in valley segments meeting the 450-foot floodplain width target, particularly within the Beaver-Watson and USFS Campground reaches. These gains reflect substantially improved floodplain connectivity and capacity for lateral flow dissipation.

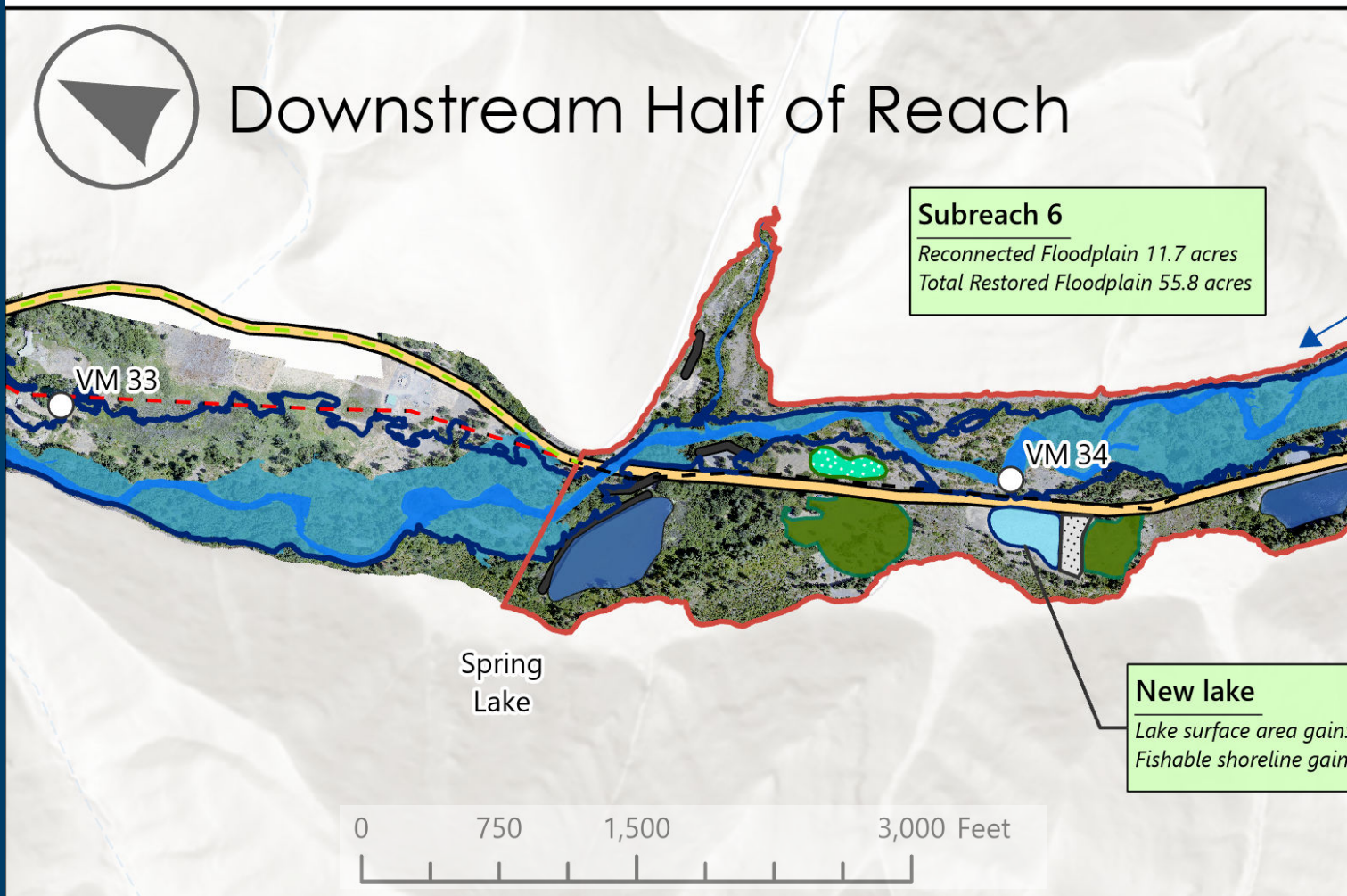


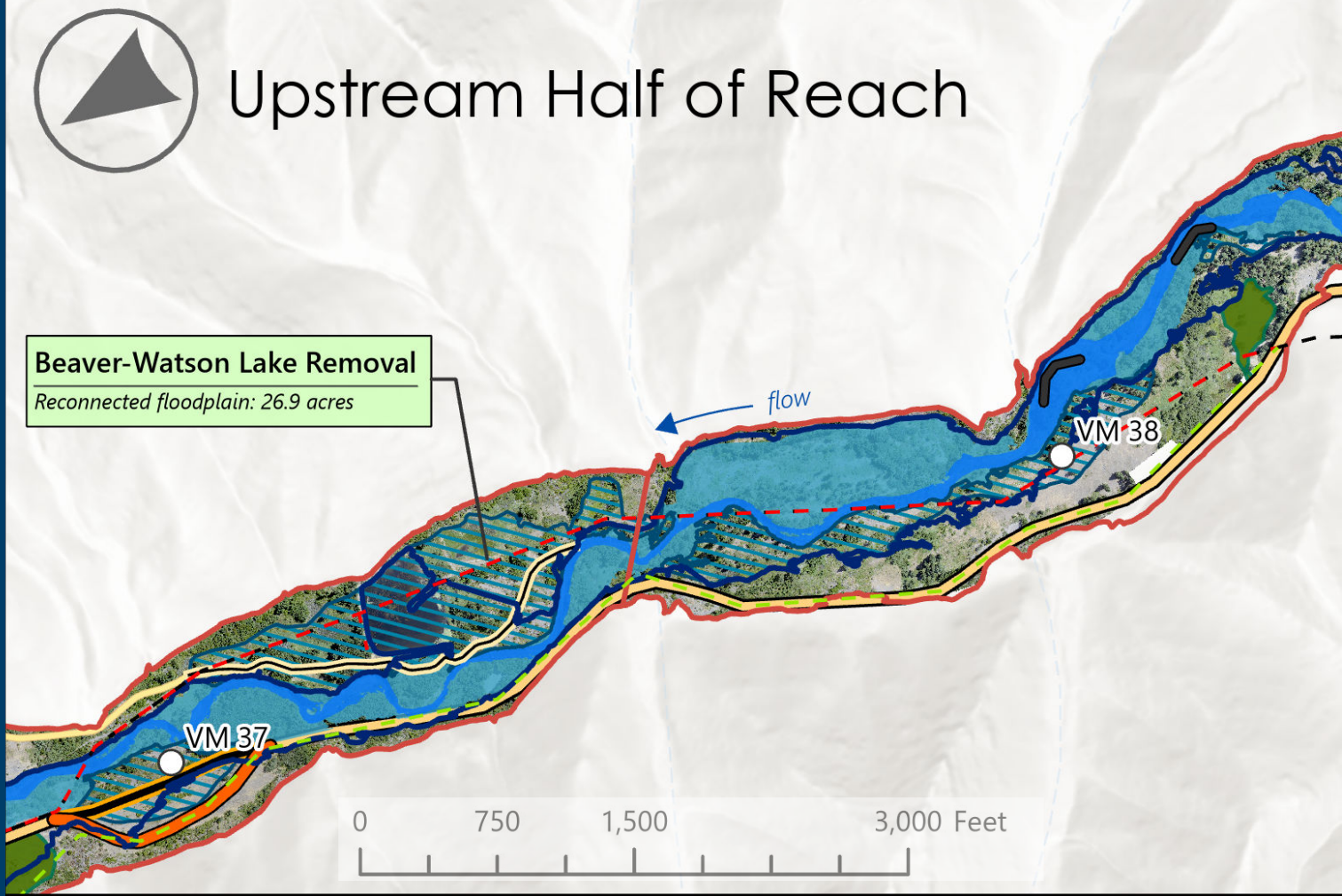
■ *Figure 30.*

Redd Resilience.

Improvements in redd resilience increase substantially under full removal and setback scenarios, particularly within the USFS Campground and Beaver-Watson reaches. These actions expand valley segments with reduced scour risk and improved spawning stability during high-flow events.

PA 5-15 - Reach Summary





Deer Lake Removal and Replacement
Reconnected floodplain: 19.2 acres

Rainbow Lake

VM 35

VM 36

flow

Blue Lake

Subreach 5
Reconnected Floodplain 19.2 acres
Total Restored Floodplain 58.2 acres

Subreach 4
Reconnected Floodplain 31.9 acres
Total Restored Floodplain 83.9 acres

VM 37

4.2 acres
: 1,793 ft

ACTION	EXISTING FISHABLE SHORELINE (ft)	PROPOSED FISHABLE SHORELINE (ft)	EXISTING LAKE AREA (ac)	PROPOSED LAKE AREA (ac)	FLOODPLAIN AREA GAINED (ac)	TOTAL FLOODPLAIN RESTORED (ac)	DESCRIPTION
Big Four Lake reach Restoration	NA	NA	NA	NA	NA	118.7	Remove lakes and associated infrastructure.
Beaver-Watson Lakes removal	1,642	0	4.2	0.0	26.9	83.9	Remove lakes and associated infrastructure.
Curl Lake removal	1,112	0	2.0	0.0	20.2	32.0	Remove lake and associated infrastructure. Lower Tucannon adult collection weir to be installed prior to lake removal.
Deer Lake removal and construct a replacement lake	605	2,080	2.3	4.3	19.2	58.2	Remove Deer Lake and associated infrastructure. Create a new 4.3-acre lake upstream and install groundwater well to supply lake.
New lake (near VM 34)	NA	1,220	NA	1.9	NA	55.8	Construct a 1.9-acre lake in the area between Blue and Spring Lakes.
Road and powerline setback	NA	NA	NA	NA	17.5	NA	Setback road and powerlines at three locations within the project area to increase floodplain connectivity by 17.5 acres.
Tucannon Campground	NA	NA	NA	NA	11.9	30.7	Reconfigure the campground, eliminate the existing access crossing, and install a new bridge near WT Wooten State Park.
Totals	3,359	3,300	9	6	96	379	Reconnect 96 acres of disconnected floodplain and restore a total of 379 acres of floodplain, substantially increasing floodplain connectivity and restoring floodplain and channel processes and functions throughout PA 5-15, while maintaining and enhancing recreational access and opportunities.

Big Four Lake Removal
Reconnected floodplain: 52.0 acres

Curl Lake Removal
Reconnected floodplain: 20.2 acres

VM 39

VM 40

USFS Tucannon Campground
Reconfigure the campground, remove the existing crossing, and install a new crossing at WT Wooten State Park, resulting in a net restoration of 11.9 acres of reconnected floodplain for a total of 30.7 acres of restored floodplain.

Subreach 3
Reconnected Floodplain 55.2 acres
Total Restore Floodplain 118.7 acres

Subreach 2
Reconnected Floodplain 20.2 acres
Total Restored Floodplain 32.0 acres

USFS Tucannon Guard Station

VM 41

Subreach 1
Reconnected Floodplain 11.9 acres
Total Restored Floodplain 30.7 acres

New Bridge

Existing Conditions
- Reach
- Approximate OHW
- Approximate 100 yr (4,160 cfs)
- WDFW campground
- USFS campground
- Levee
- Road
- Service road
- Valley mile (2017)

Actions
- Restore floodplain
- Reconnect floodplain
- New lake
- Polishing wetland
- Bridge
- Parking
- Camp access road
- Road removal
- Road setback
- Service road removal
- New alignment
- New levee
- Proposed OHP
- OHP removal
- Groundwater well
- New relief culvert

■ *Figure 31. Overview Map of PA 5-15 Preferred Alternative. Remove Big Four, Beaver-Watson, Curl, and Deer Lakes; construct two new lakes; relocate roads and powerlines at three locations; and reconfigure Tucannon Campground with a new bridge near Camp Wooten*



Figure 32- New Lake; existing conditions photo



Figure 33 - New Lake; preferred alternative rendering of future conditions



Figure 34- Beaver Watson complex; existing conditions photo



Figure 35 - Beaver Watson complex; preferred alternative rendering of future conditions



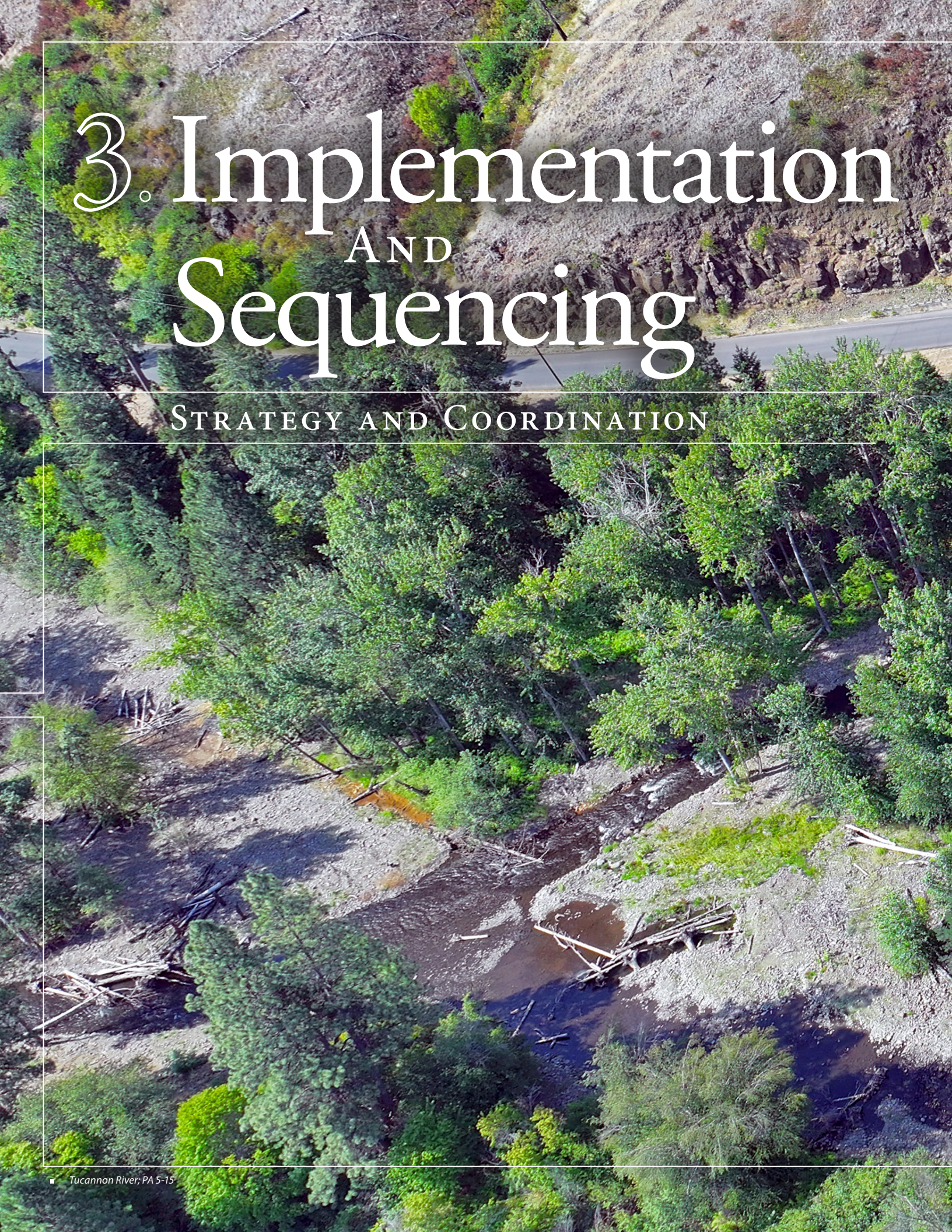
- *Figure 36- Deer Lake; existing conditions photo*



- *Figure 37 - Deer Lake; preferred alternative rendering of future conditions*

3. Implementation And Sequencing

Strategy and Coordination



Tucannon River, PA 5-15



Implementation of the Preferred Alternative will occur in phases, with actions sequenced to coordinate restoration, infrastructure relocation, fisheries improvements, and recreational access. Key early actions include Big Four Lake removal, construction of a replacement New Lake, powerline and road relocations, and development of a new downstream adult collection weir prior to Curl Lake removal. Other projects will advance as funding and opportunities allow.

Implementation of the Preferred Alternative will require coordination between several different actions. Some of the proposed actions are dependent upon a separate action being implemented first, and these actions will be accomplished in an order of sequence.

The vision for the Tucannon PA 5-15 Reach is to restore physical and ecological floodplain function to benefit key fish and aquatic species, while broadening and enhancing recreational opportunities, through coordinated planning and conceptual restoration designs for the floodplain and adjacent lands of WT Wooten Wildlife Area.

This section presents the Preferred Alternative and describes the general actions being considered for the 10.2-mile reach. This section includes Conceptual Designs and Considerations for each of six sub-reaches within the PA 5-15 project area, as well as an Implementation Sequencing Plan or Strategy.

Reach-Scale Preferred Alternative

The Preferred Alternative is a coordinated set of actions that, when implemented, would substantially improve river and floodplain processes and function throughout the PA 5-15 reach, and will support fish and aquatic species throughout the Tucannon watershed (Figure 31). The planned actions will increase the total area of connected floodplain in the reach from 231 acres to 379 acres and will restore functionality of all of those 379 acres. In completing these actions, the minimum target floodplain width identified and described in Section 1 will be restored on about 40 percent of the reach (Figure 31).

The assessment and concept development process covered the entire 10.2-mile reach. Some segments of the reach were determined to be functionally connected due to previous restoration actions, or to not be feasible for further treatment consideration at this time due to infrastructure constraints (the segment including Rainbow Lake and the Tucannon Fish Hatchery, and the segment downstream from Spring Lake).

Development and evaluation of the Reach-Scale Preferred Alternative included identifying actions that provide continued recreational use of the reach while allowing as much functional restoration of the floodplain and ecosystem as possible within existing land-uses. As described in Section 2 of this report, multiple different options were considered and evaluated for each sub-reach during the development of the Preferred Alternative.

Existing recreational benefits including the put-and-take fishery associated with the lakes and hatchery will be generally maintained, and there is potential for improved fishing opportunities for native fish within the restored river corridor.

The suite of actions outlined in this report are preliminary and further development of stakeholder and co-manager coordination, feasibility analyses, costs and benefits, and detailed designs and specifications will be needed for the Preferred Alternative to move forward.

The general actions shown at the full Project (PA 5-15) reach-scale include:

- Removing the remnants of **Big Four Lake** and infrastructure, and restoring the channel and floodplain.
- Rerouting the overhead **Powerline** to the Tucannon Road Right-of-Way.
- Rerouting **Tucannon Road** at three locations and reconnecting and restoring the floodplain adjacent to each.
- Constructing a **New Lake** outside of the existing floodplain (downstream from Blue Lake) to replace recreational opportunity associated with Beaver-Watson Lakes and the non-functioning Big Four Lake.
- Removing **Beaver-Watson Lakes** and infrastructure, and restoring the floodplain/channel.
- Moving **Deer Lake** upstream, removing and replacing the existing in-stream diversion and water source by drilling a well to supply the lake, and restoring the channel and floodplain.
- Locating, purchasing or leasing a site for a downstream adult collection weir, to support changes in adult collection operations, as well as to replace the need for acclimation functions at Curl Lake, designing and constructing the collection

weir, removing **Curl Lake** and infrastructure, and restoring the channel and floodplain. The existing collection weir near Rainbow Lake is used by WDFW to support Tucannon Hatchery operations and will remain in place for hatchery and Rainbow Lake operations and potential continued fish-management use.

- Installing a new bridge across the Tucannon River to access Camp Wooten and U.S. Forest Service Tucannon Campground, removing the existing bridge that accesses these camp areas, and reworking the existing access road between the camp areas. The portion of the existing **U.S. Forest Service Tucannon Campground** on the west side of the River will be decommissioned, and the channel and floodplain between Tucannon Road and the campground access road will be reconnected and restored.
- **Lake-based recreational opportunities** remain similar with slight reductions in fishable shoreline and lake area to account for additional parking and good access around the lakes.

Conceptual Designs by Sub-Reach

The PA 5-15 Reach is divided into six sub-reaches based on physical characteristics as well as potential actions identified in the Preferred Alternative (Figure 31). This allows a more in-depth description of each sub-reach as well as planned actions, and development of potential implementation costs for the suite of actions proposed for each of the sub-reach areas.

Each sub-reach includes a floodplain and channel reconnection and restoration component that incorporates some combination of the following actions:

- Channel fill and shaping to address the effects of incision and channelization.
- Floodplain reconnection areas that enhance lateral floodplain engagement and reduce stream power by removing artificially high areas through grading swales, low-lying areas, and side channels.
- Significant installation of wood habitat structures and floodplain wood throughout the reach, both in the channel and across the floodplain to enhance channel and floodplain processes and provide increased aquatic habitat.
- Invasive species control and planting of native, multi-layer, multi-species riparian vegetation.

The following items are included in the Conceptual Designs by Sub-Reach:

- Concept level restoration costs.
- Proposed geomorphic grade line (GGL) – A guide to potential actions within the sub-reaches over the next many years that helps answer the questions; “how much ‘higher’ does the riverbed need to be”, and “how much space or width does the floodplain need”. The GGL assumes reach scale restoration and will need to be tailored at future design iterations to account for sub-reach transitions and phasing.
- Concept level grading cut-fill polygons.

Conceptual Level Cost Estimates by Sub-Reach

The concept level estimates of probable cost per sub-reach shown in the tables below provide an approximation of quantities and total project costs. These tables do not include estimated project costs for design, permitting, monitoring, and/or ongoing maintenance. Note that the estimated costs are presented in 2026 dollars and the actual cost of construction may be impacted by inflation, implementation in future years, and the fluctuation of supply prices at the time the work is bid. Additionally, costs may change due to unforeseen events that would alter the concepts, such as major flooding or changes in co-manager preferences or agreements. Wolf Water Resources makes no warranty, expressed or implied, as to the accuracy of such opinions as compared to future bids or actual implementation costs.

The sub-reach estimated material quantities for excavation are shown in units of bank cubic yards (calculated in place prior to removal). Earthwork volumes were estimated from the difference between the 2020 LiDAR and the proposed geomorphic target grading elevation and are subject to change. Future work will include confirming LiDAR accuracy, refining the target elevation grading surface based on design phasing, and improving estimates for grading volumes.

Sub-Reach 1

Summary of Major Actions and Outcomes

- Relocate the Tucannon River bridge serving Camp Wooten and USFS Tucannon Campground.
- Conduct geotechnical analysis at the new bridge pier locations.
- Remove the access road connecting Tucannon Road to the existing bridge and campground.
- Decommission the USFS campground portion west of the river.
- Relocate the overhead powerline to the Tucannon Road right-of-way at the downstream end of the sub-reach.
- Reconnect and restore approximately 31 acres of channel and floodplain.
- Increase average available floodplain width from approximately 195 to 325 feet.
- Reduce wildland fire potential by replacing overhead power with underground power.

Concept Design Elements and Considerations

- Grade the floodplain to reconnect existing secondary channels and create self-sustaining side-channel and wetland habitats.
- Remove artificially elevated floodplain features, including the USFS campground bridge-access road and existing bridge; relocate or reconstruct the bridge upstream in an already confined valley section.
- Fill incised channels with selectively excavated material to maximize floodplain engagement and reverse past incision.
- Install medium-to-large instream and floodplain wood structures—including large and small channel-spanning, apex, and margin types—to mimic natural wood accumulation with minimal or no artificial anchoring.
- Revegetate disturbed areas with native riparian and wetland species.
- Coordinate access-road and bridge relocation with WDFW and USFS.
- Coordinate overhead power relocation with Columbia Power and USFS.

Estimate of Probable Cost

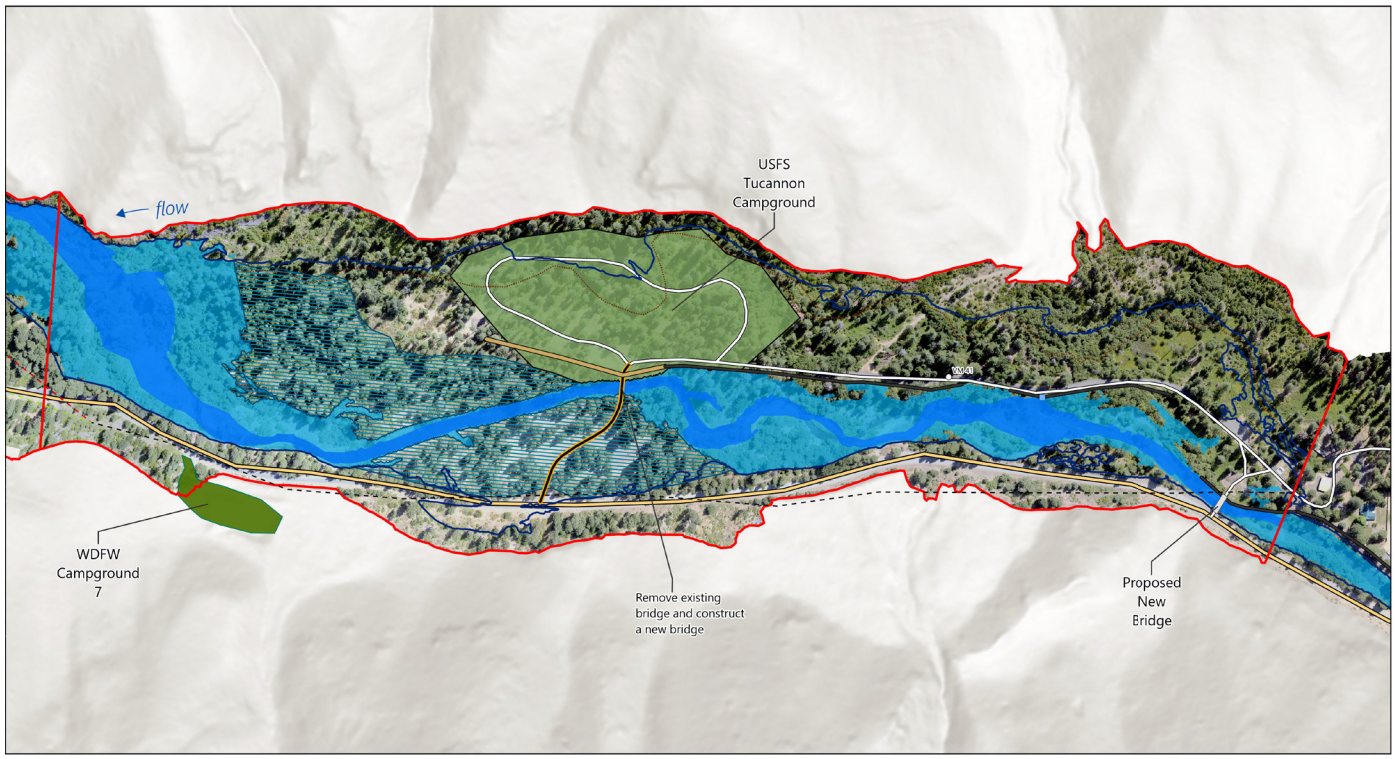
Table 3 includes the concept level estimate of probable cost for Sub-Reach 1 and provides an approximation of quantities and total project costs.

Primary assumptions of the cost estimate include:

- Unit costs: Include contractor markup, profit, and overhead.
- Mobilization/demobilization: Assumed at 10% of total.
- Temporary access and water management: Assumed at 12% of direct costs.
- Temporary sediment and erosion control: Assumed at approximately 2% of direct costs.
- Berm and embankment excavation: Assumes standard excavators, bulldozers, scrapers, and high-capacity dump trucks.
- Wood loading: Per-acre quantities and costs are based on similar regional projects and 2025/2026 bids.
- Onsite disposal: Native alluvium and streambed gravel excavated from floodplain and embankment areas will be reused as channel fill.
- Offsite disposal: Infrastructure associated with the USFS campground access road and bridge will be removed and hauled offsite.
- Overhead powerline relocation costs are excluded.
- Total bid estimate includes a 60% design contingency for future design changes and unforeseen conditions.

■ *Table 3: Sub-Reach 1 Concept Level Cost Estimate*

Item	Unit	Unit Cost	Qty	Sub-Reach 1
Site Preparation				**$576,000**
Mobilization / Demob.	LS	10%	1	$225,000
Temporary Access and Water Management	LS	12%	1	$241,000
Clearing/Grubbing	AC	$6,000	12	$72,000
Temporary Erosion Control	LS	2%	1	$38,000
Civil & Structural				**$1,036,000**
Removal / Salvage of Existing Infrastructure	LS	$50,000	1	$50,000
Road Removal	LF	$20	600	$12,000
Access Bridge	EA	$800,000	1	$800,000
Access Road	TON	$120	300	$36,000
New Levee	CY	$40	2,200	$88,000
Drainage Culvert	LS	$50,000	1	$50,000
Earthwork & Habitat Features				**$692,000**
Earthwork (Floodplain Excavation)	CY	$12	16,000	$192,000
Floodplain Wood	AC	$12,000	20	$240,000
Wood Habitat Structures	AC	$13,000	20	$260,000
Site Restoration and Planting				**$168,000**
Seeding and Planting	AC	$14,000	12	$168,000
Direct Subtotal				**$2,472,000**
Design Contingency		60%		$ 1,483,200
CONSTRUCTION TOTAL				**$3,956,000**

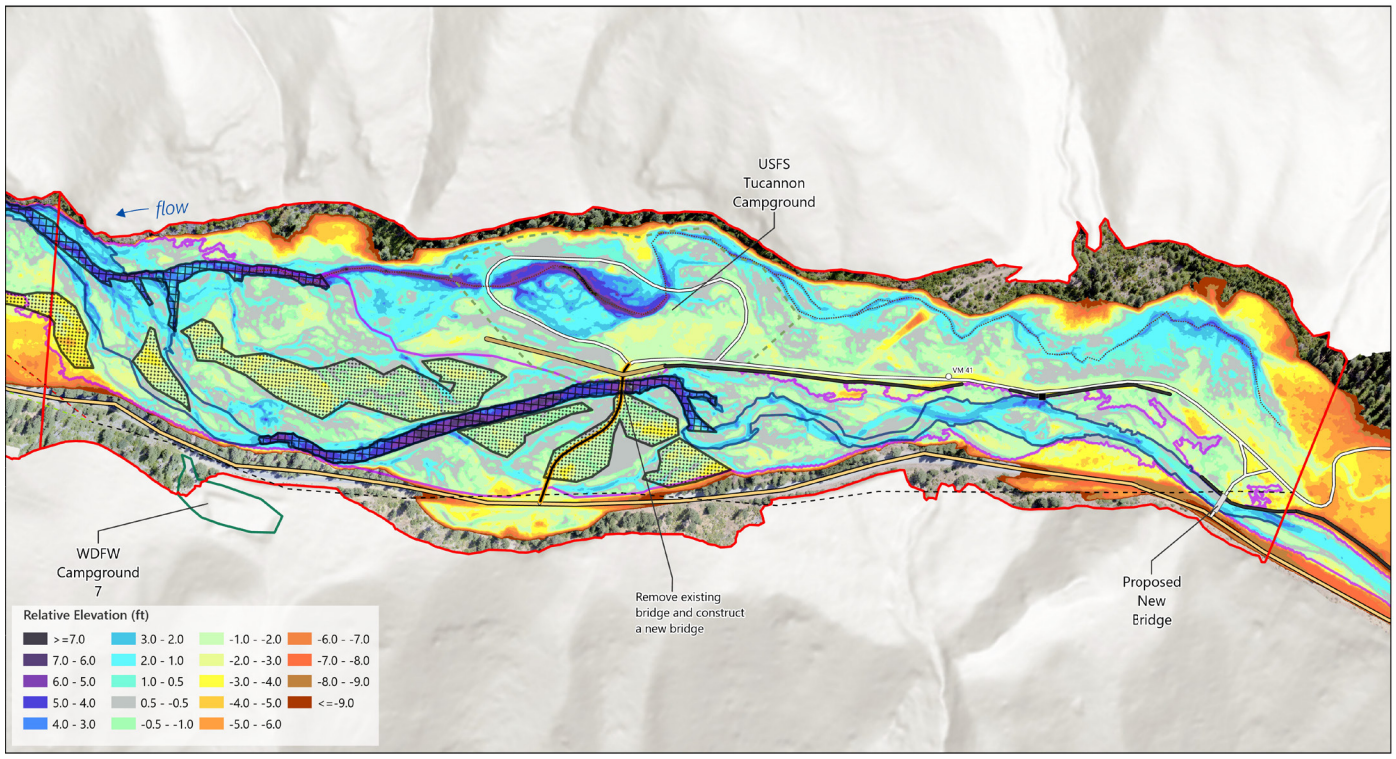


0 125 250 500 Feet

Reach
Approximate OHW
Approximate 100 yr (4,160 cfs)
WDFW campground
USFS campground
Floodplain channel
Berm
Road
Valley mile (2017)
Restored floodplain
Reconnected floodplain
Bridge
Camp access road
Road removal
New levee
Proposed OHP
OHP removal
New relief culvert

Tucannon PA 5-15
Sub-reach 1: VM 40.4 - VM 41.2

■ *Figure 38- Sub-Reach 1 Overview of Actions*



0 125 250 500 Feet

*Relative Elevation GGL: Derived from 2020 LiDAR, relative elevation represents existing ground elevation relative to the Geomorphic Grade Line (GGL). Positive values are above the GGL (potential cut), and negative values are below the GGL (potential fill).

Reach
Approx Ex OHW
USFS campground
WDFW campground
Berm
Road
Valley mile (2017)
Fill
Cut
Restored floodplain
Bridge
Camp access road
Road removal
New levee
Proposed OHP
OHP removal
New relief culvert

Tucannon PA 5-15
Concept Design
Sub-reach 1: VM 40.4 - VM 41.2

■ *Figure 39 - Sub-Reach 1 Concept Design*

Sub-Reach 2

Summary of Major Actions and Outcomes

Actions described here are dependent upon construction of new adult collection weir in lower part of the Tucannon River and include:

- Remove Curl Lake and associated infrastructure.
- Relocate the overhead powerline to the Tucannon Road right-of-way.
- Reroute Tucannon Road near the USFS Tucannon Guard Station (VM 40).
- Reconnect and restore approximately 32 acres of channel and floodplain.
- Increase average available floodplain width from approximately 120 to 370 feet.
- Reduce wildland fire potential by replacing overhead power with underground power.

Concept Design Elements and Considerations

- Grade the floodplain to reconnect existing secondary channels and create self-sustaining side-channel and wetland habitats.
- Remove artificially elevated floodplain features, including Curl Lake embankments, and set back the USFS Tucannon Road.
- Fill incised channels with selectively excavated material to maximize floodplain engagement and reverse past incision.
- Install medium-to-large instream and floodplain wood structures—including large and small channel-spanning, apex, and margin types—to mimic natural wood accumulation with minimal or no artificial anchoring.
- Revegetate disturbed areas with native riparian and wetland species.
- Coordinate Curl Lake and infrastructure removal with USFWS and WDFW; require the new lower Tucannon adult collection facility to be operational, with necessary fish-management functions confirmed by WDFW, before removal.
- Coordinate Tucannon Road relocation with USFS.
- Coordinate overhead power relocation with Columbia Power and USFS.

Estimate of Probable Cost

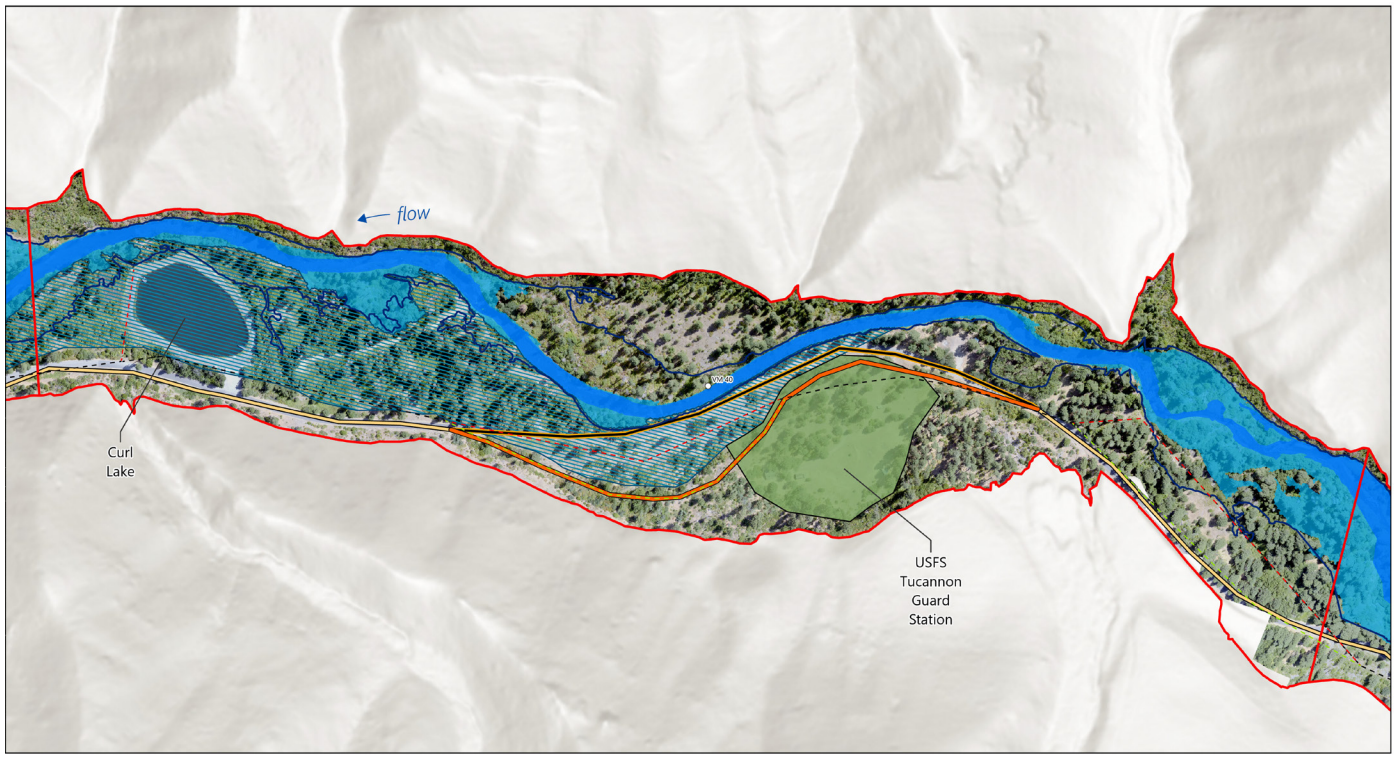
Table 4 includes the concept level estimate of probable cost for Sub-Reach 2 and provides an approximation of quantities and total project costs.

Primary assumptions of the cost estimate include:

- Unit costs: Include contractor markup, profit, and overhead.
- Mobilization/demobilization: Assumed at 10% of total costs.
- Temporary access and water management: Assumed at 12% of direct costs.
- Temporary sediment and erosion control: Assumed at approximately 2% of direct costs.
- Berm and embankment excavation: Assumes standard excavators, bulldozers, scrapers, and high-capacity dump trucks.
- Wood loading: Per-acre quantities and costs are based on similar regional projects and 2025/2026 bids.
- Onsite disposal: Assumes native alluvium and streambed gravel excavated from floodplain and embankment areas will be reused as channel fill.
- Offsite disposal: Assumes infrastructure associated with the USFS road will be removed and hauled offsite.
- Powerline relocation: Overhead powerline relocation costs are excluded.
- Contingency: Total bid estimate includes a 60% design contingency for future design changes and unforeseen conditions.

Table 4: Sub-Reach 2 Concept Level Cost Estimate

Item	Unit	Unit Cost	Qty	Sub-Reach 2
Site Preparation				**$821,000**
Mobilization / Demob.	LS	10%	1	$313,000
Temporary Access and Water Management	LS	12%	1	$336,000
Clearing/Grubbing	AC	$6,000	20	$120,000
Temporary Erosion Control	LS	2%	1	$52,000
Civil & Structural				**$790,000**
Removal / Salvage of Existing Infrastructure	LS	$50,000	1	$50,000
Road Removal	LF	$ 20	2,200	$44,000
Road Setback	TON	$ 120	5,800	$696,000
Earthwork & Habitat Features				**$1,554,000**
Earthwork (Floodplain Excavation)	CY	$12	67,000	$804,000
Floodplain Wood	AC	$12,000	30	$360,000
Wood Habitat Structures	AC	$13,000	30	$390,000
Site Restoration and Planting				**$280,000**
Seeding and Planting	AC	$14,000	20	$280,000
Direct Subtotal				**$3,445,000**
Design Contingency		60%		$ 2,067,000
CONSTRUCTION TOTAL				**$ 5,512,000**

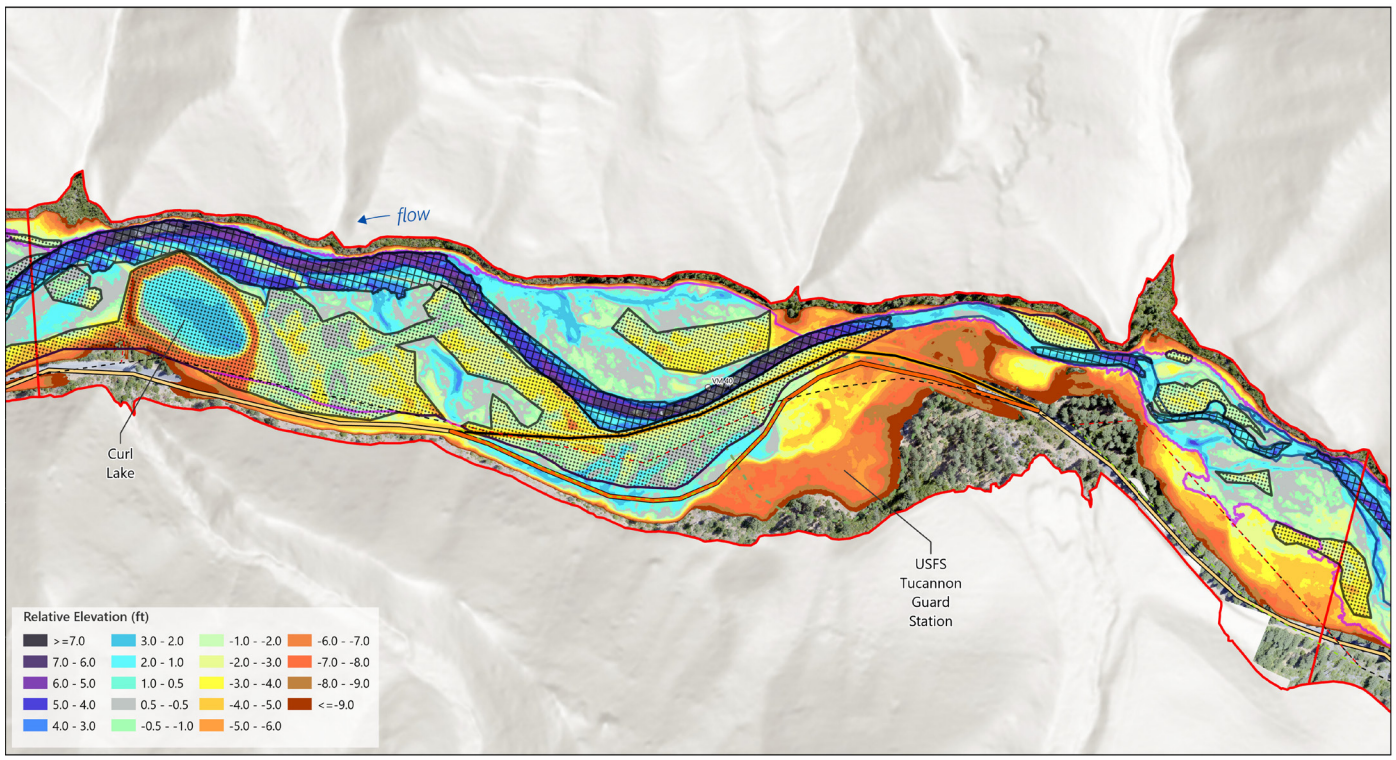


0 125 250 500 Feet

Reach
Approximate OHW
Approximate 100 yr (4,160 cfs)
USFS campground
Road
Valley mile (2017)
Restored floodplain
Reconnected floodplain
Road removal
Road setback
Proposed OHP
OHP removal

Tucannon PA 5-15
Sub-reach 2: VM 39.6 - VM 40.4

■ *Figure 40- Sub-Reach 2 Overview of Actions*



0 125 250 500 Feet

*Relative Elevation GGL: Derived from 2020 LiDAR, relative elevation represents existing ground elevation relative to the Geomorphic Grade Line (GGL). Positive values are above the GGL (potential cut), and negative values are below the GGL (potential fill).

Reach
Approx Ex OHW
USFS campground
Road
Valley mile (2017)
Fill
Cut
Restored floodplain
Road removal
Road setback
Proposed OHP
OHP removal

Tucannon PA 5-15
Concept Design
Sub-reach 2: VM 39.6 - VM 40.4

■ *Figure 41 - Sub-Reach 2 Concept Design*

Sub-Reach 3

Summary of Major Actions and Outcomes

- Remove the remnants of Big Four Lake and infrastructure.
- Relocate overhead powerline to Tucannon Road right-of-way.
- Reconnect and restore approximately 119 acres of channel and floodplain.
- Increase average available floodplain width from approximately 260 ft to 540 ft.
- Reduce wildland fire potential with underground power versus existing overhead power.

Concept Design Elements and Considerations

- Grade the floodplain to improve connectivity to existing secondary channels and to create new self-sustaining side channel and wetland habitats.
- Remove artificially high features on the floodplain including the Big Four Lake embankments and infrastructure.
- Fill incised channel areas with selectively excavated material to maximize floodplain engagement and reverse effects of past incision.
- Install habitat forming instream and floodplain wood placements, including medium-to-large wood structures (large and small channel spanning, apex, and margin types) to mimic the natural accumulation of wood with no or minimal artificial anchoring.
- Revegetate disturbed areas with native riparian and wetland vegetation species.
- Relocation of overhead power will require coordination with Columbia Power and U.S. Forest Service.

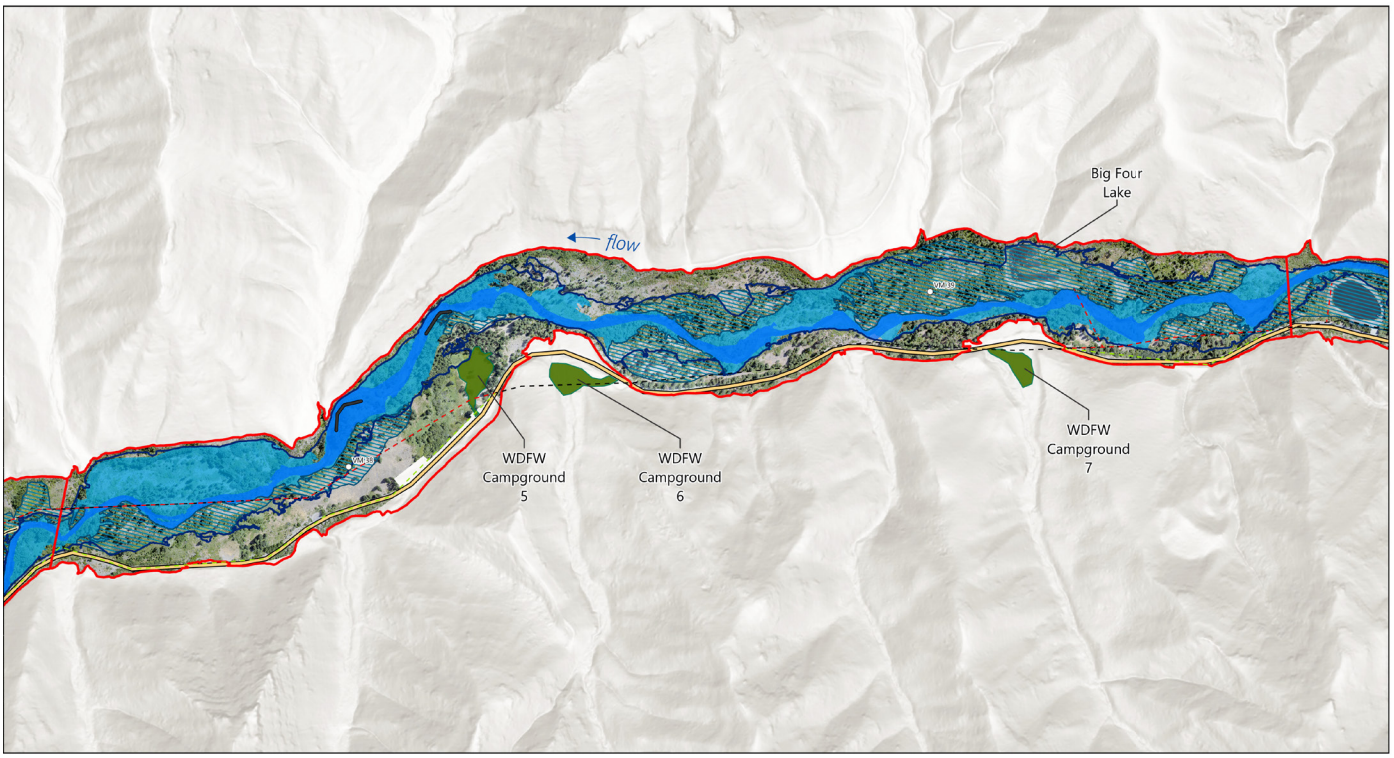
Estimate of Probable Cost

Table 5 includes the concept level estimate of probable cost for Sub-Reach 3 and provides an approximation of quantities and total project costs. Primary assumptions of the cost estimate include:

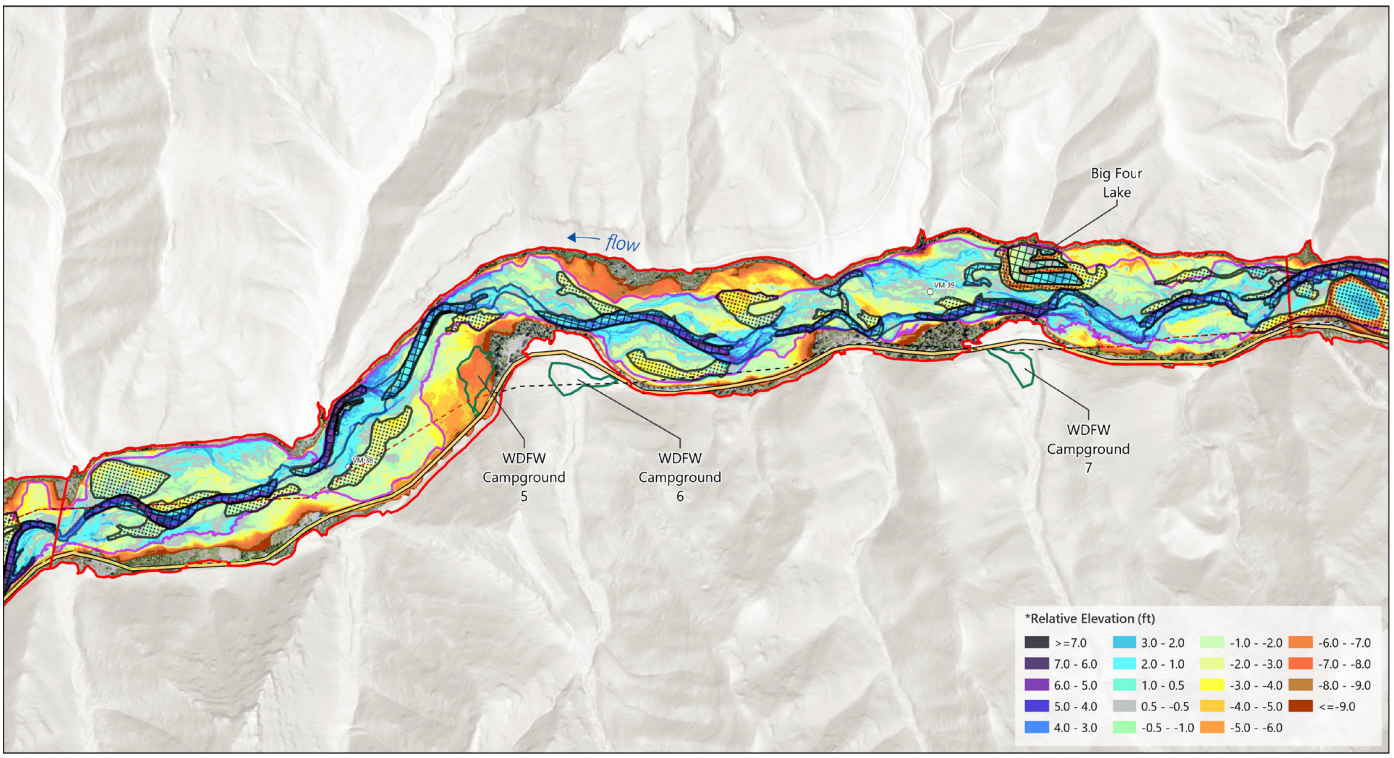
- Unit costs – include contractor markup, profit, and overhead;
- Mobilization/demobilization – Assumed to be 10% of total costs;
- Temporary access and water management – Assumed to be 12% of direct costs;
- Temporary sediment and erosion control – Assumed to be approximately 2% of direct costs;
- Berm and embankment excavation – excavation costs assume common excavator, bulldozer, scraper and high-capacity dump truck equipment;
- Wood loading per acre quantities and cost were estimated based on similar projects in the region and 2025/2026 bid results;
- Onsite Disposal – the cost estimate assumes that natural native alluvium and streambed gravel material excavated from the floodplain and embankment will be used as channel fill;
- Offsite Disposal – the cost estimate assumes that infrastructure associated with the Big Four Lake infrastructure will be removed and hauled offsite;
- Overhead powerline relocation costs are not included;
- Contingencies – 20% design contingency is included in the total bid estimate to closely resemble the 2026 80% Design estimate and proposed construction beginning in 2027.

Table 5: Sub-Reach 3 Concept Level Cost Estimate

Item	Unit	Unit Cost	Qty	Sub-Reach 3
Site Preparation				**$1,055,000**
Mobilization / Demob.	LS	10%	1	$417,000
Temporary Access and Water Management	LS	12%	1	$447,000
Clearing/Grubbing	AC	$6,000	20	$120,000
Temporary Erosion Control	LS	2%	1	$71,000
Civil & Structural				**$25,000**
Removal / Salvage of Existing Infrastructure	LS	$25,000	1	$25,000
Earthwork & Habitat Features				**$3,087,200**
Earthwork (Floodplain Excavation)	CY	$12	90,600	$1,087,200
Floodplain Wood	AC	$12,000	80	$960,000
Wood Habitat Structures	AC	$13,000	80	$1,040,000
Site Restoration and Planting				**$420,000**
Seeding and Planting	AC	$14,000	30	$420,000
Direct Subtotal				**$4,587,200**
Design Contingency		20%		$917,400
CONSTRUCTION TOTAL				**$5,505,000**



■ *Figure 42- Sub-Reach 3 Overview of Actions*



■ *Figure 43 - Sub-Reach 3 Concept Design*

Sub-Reach 4

Summary of Major Actions and Outcomes

- Remove Beaver and Watson Lakes and infrastructure, including in-channel diversion and water supply channel.
- Relocate overhead powerline to Tucannon Road right-of-way.
- Realign Tucannon Road to edge of floodplain upstream from WDFW Campground 4 (VM 37).
- Reconnect and restore about 84 acres of channel and floodplain.
- Increase average available floodplain width from approximately 340 ft to 550 ft.
- Reduce wildland fire potential with underground power versus existing overhead power.

Concept Design Elements and Considerations

- Grade the floodplain to reconnect existing secondary channels and create self-sustaining side-channel and wetland habitats.
- Remove artificially elevated floodplain features, including Beaver-Watson embankments and infrastructure.
- Fill incised channels with selectively excavated material to maximize floodplain engagement and reverse past incision.
- Install medium-to-large instream and floodplain wood structures—including large and small channel-spanning, apex, and margin types—to mimic natural wood accumulation with minimal or no artificial anchoring.
- Revegetate disturbed areas with native riparian and wetland species.
- Coordinate Beaver-Watson Lakes and infrastructure removal with WDFW; remove only after New Lake is constructed and operational, with replacement recreational functions confirmed by WDFW.
- Coordinate Tucannon Road relocation with USFS.
- Coordinate overhead power relocation with Columbia Power and USFS.

Estimate of Probable Cost

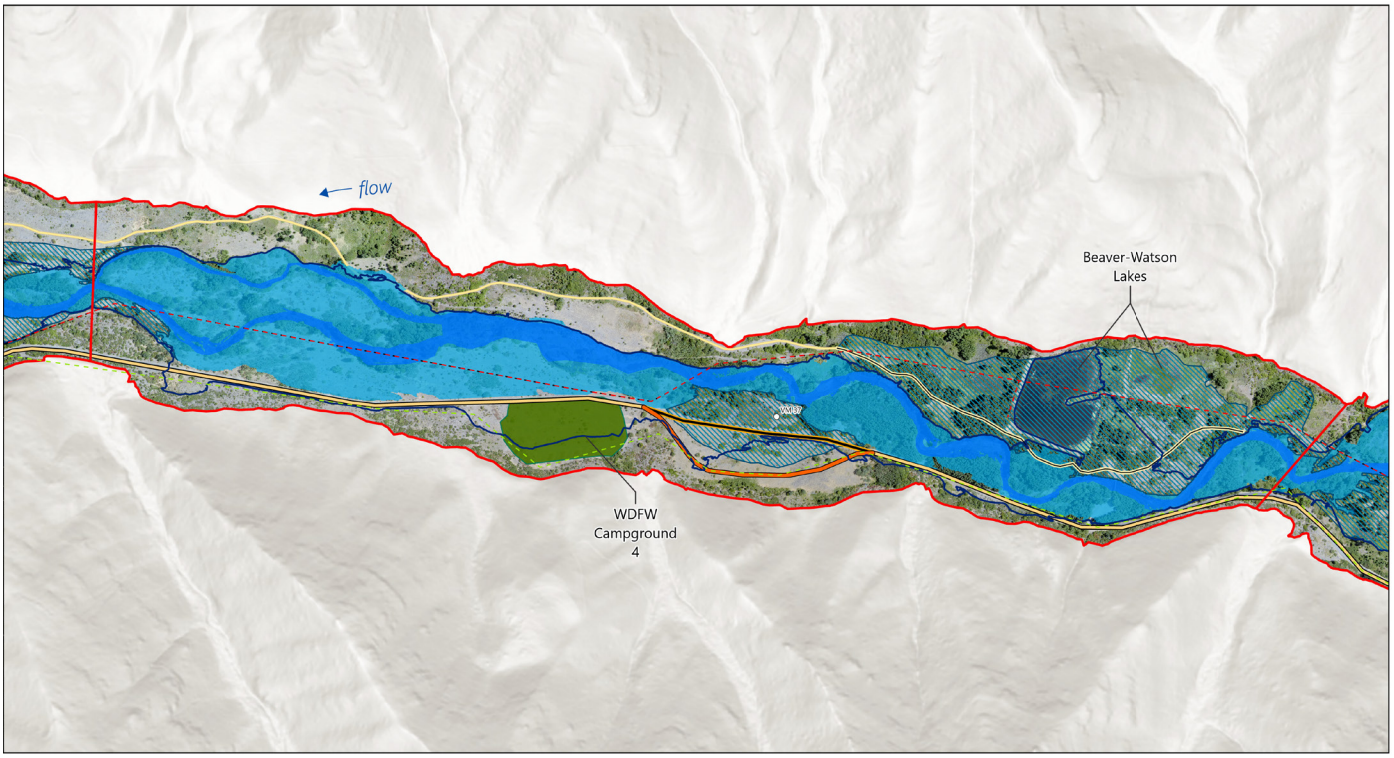
Table 6 includes the concept level estimate of probable cost for Sub-Reach 4 and provides an approximation of quantities and total project costs.

Primary assumptions of the cost estimate include:

- Unit costs: Include contractor markup, profit, and overhead.
- Mobilization/demobilization: Assumed at 10% of total costs.
- Temporary access and water management: Assumed at 12% of direct costs.
- Temporary sediment and erosion control: Assumed at approximately 2% of direct costs.
- Berm and embankment excavation: Assumes standard excavators, bulldozers, scrapers, and high-capacity dump trucks.
- Wood loading: Per-acre quantities and costs are based on similar regional projects and 2025/2026 bids.
- Onsite disposal: Assumes native alluvium and streambed gravel excavated from floodplain and embankment areas will be reused as channel fill.
- Offsite disposal: Assumes Beaver-Watson lake infrastructure will be removed and hauled offsite.
- Powerline relocation: Overhead powerline relocation costs are excluded.
- Contingency: Total bid estimate includes a 60% design contingency for future design changes and unforeseen conditions.

■ *Table 6: Sub-Reach 4 Concept Level Cost Estimate*

Item	Unit	Unit Cost	Qty	Sub-Reach 4
Site Preparation				**$1,452,000**
Mobilization / Demob.	LS	10%	1	$542,000
Temporary Access and Water Management	LS	12%	1	$580,000
Clearing/Grubbing	AC	$6,000	40	$240,000
Temporary Erosion Control	LS	2%	1	$90,000
Civil & Structural				**$533,000**
Removal / Salvage of Existing Infrastructure	LS	$25,000	1	$25,000
Road Removal	LF	$ 20	3,800	$76,000
Road Setback	TON	$ 120	3,600	$432,000
Earthwork & Habitat Features				**$3,412,000**
Earthwork (Floodplain Excavation)	CY	$12	76,000	$912,000
Floodplain Wood	AC	$12,000	100	$1,200,000
Wood Habitat Structures	AC	$13,000	100	$1,300,000
Site Restoration and Planting				**$560,000**
Seeding and Mulching	AC	$14,000	40	$560,000
Direct Subtotal				**$5,957,000**
Design Contingency		60%		$3,574,200
CONSTRUCTION TOTAL				**$9,532,000**



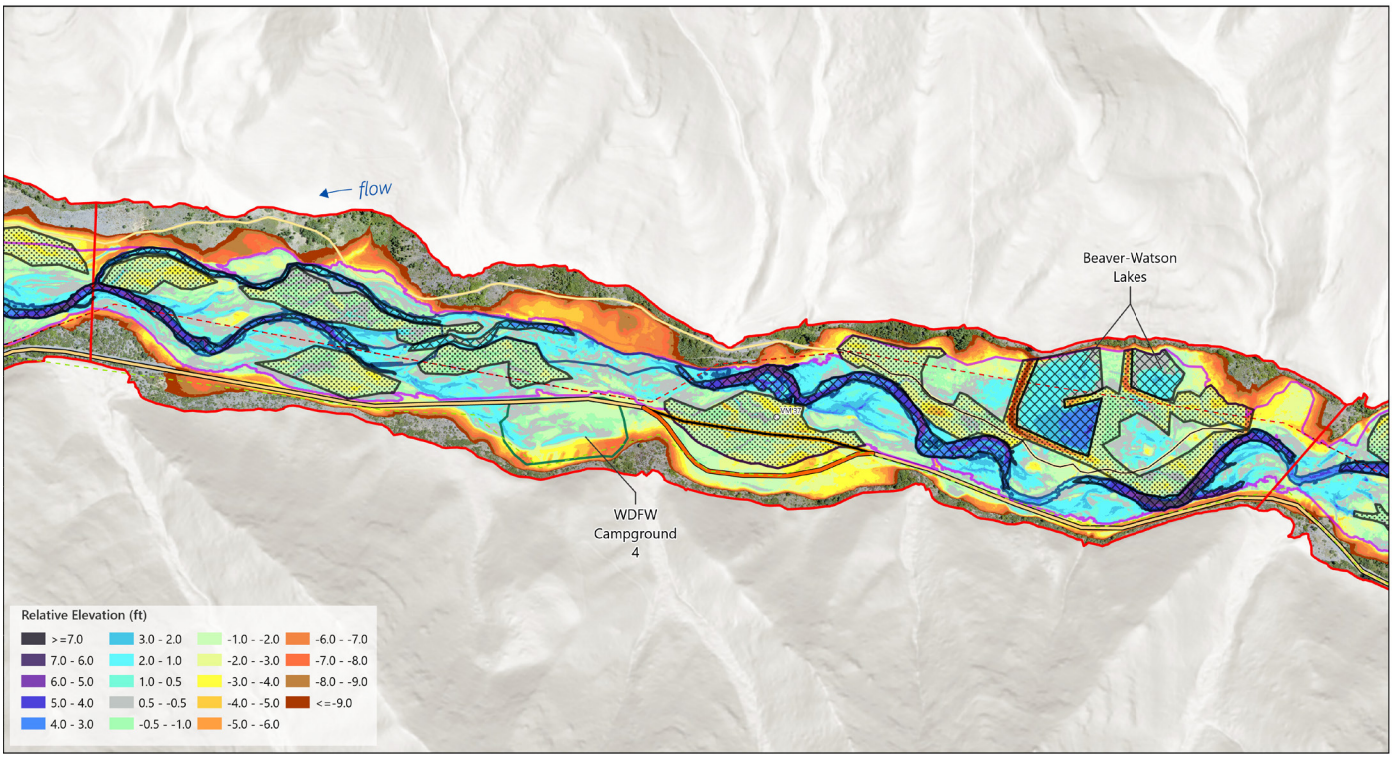
0 250 500 1,000 Feet

N

Reach
Approximate OHW
Approximate 100 yr (4,160 cfs)
WDFW campground
Road
Service road
Valley mile (2017)
Restored floodplain
Reconnected floodplain
Road removal
Road setback
Service road removal
Proposed OHP
OHP removal

Tucannon PA 5-15
Sub-reach 4: VM 36.6 - VM 37.6

■ *Figure 44- Sub-Reach 4 Overview of Actions*



0 250 500 1,000 Feet

N

*Relative Elevation GGL: Derived from 2020 LiDAR, relative elevation represents existing ground elevation relative to the Geomorphic Grade Line (GGL). Positive values are above the GGL (potential cut), and negative values are below the GGL (potential fill).

Reach
Approx Ex OHW
WDFW campground
Road
Service road
Valley mile (2017)
Fill
Cut
Restored floodplain
Road removal
Road setback
Service road removal
Proposed OHP
OHP removal

Tucannon PA 5-15
Concept Design
Sub-reach 4: VM 36.6 - VM 37.6

■ *Figure 45 - Sub-Reach 4 Concept Design*

Sub-Reach 5

Summary of Major Actions and Outcomes

- Complete Feasibility Analysis of relocation of Deer Lake.
  - Geotechnical site assessment (excavation, constructability)
  - Materials
  - Water source (water well)
- Drill well to supply water to Deer Lake (may require updating/changing the water right for the Lake).
- Relocate/construct new Deer Lake upstream.
- Remove in-stream diversion.
- Reconnect and restore approximately 58 acres of channel and floodplain.
- Increase average available floodplain width from approximately 405 ft to 690 ft.

Concept Design Elements and Considerations

- Grade the floodplain to reconnect existing secondary channels and create self-sustaining side-channel and wetland habitats.
- Remove artificially elevated floodplain features, including Deer Lake embankments and infrastructure.
- Fill incised channels with selectively excavated material to maximize floodplain engagement and reverse past incision.
- Install medium-to-large instream and floodplain wood structures—including large and small channel-spanning, apex, and margin types—to mimic natural wood accumulation with minimal or no artificial anchoring.
- Revegetate disturbed areas with native riparian and wetland species.
- Coordinate removal of existing Deer Lake, its diversion, and associated infrastructure with WDFW; remove only after relocated Deer Lake and its water supply are constructed and operational, with replacement recreational functions confirmed by WDFW.
- Coordinate overhead power relocation with Columbia Power and USFS.

Estimate of Probable Cost

Table 7 includes the concept level estimate of probable cost for Sub-Reach 5 and provides an approximation of quantities and total project costs. Primary assumptions of the cost estimate include:

- Unit costs: Include contractor markup, profit, and overhead.
- Mobilization/demobilization: Assumed at 10% of total costs.
- Temporary access and water management: Assumed at 12% of direct costs.
- Temporary sediment and erosion control: Assumed at approximately 2% of direct costs.
- Berm and embankment excavation: Assumes standard excavators, bulldozers, scrapers, and high-capacity dump trucks.
- Wood loading: Per-acre quantities and costs are based on similar regional projects and 2025/2026 bids.
- Onsite disposal: Assumes native alluvium and streambed gravel excavated from floodplain and embankment areas will be reused as channel fill.
- Offsite disposal: Assumes Deer Lake infrastructure will be removed and hauled offsite.
- Powerline relocation: Overhead powerline relocation costs are excluded.
- Contingency: Total bid estimate includes a 60% design contingency for future design changes and unforeseen conditions.

■ *Table 7: Sub-Reach 5 Concept Level Cost Estimate*

Item	Unit	Unit Cost	Qty	Sub-Reach 5
Site Characterization				**$75,000**
Geotech. Characterization & Groundwater Testing	LS	$75,000	1	$75,000
Site Preparation				**$1,652,000**
Mobilization / Demob.	LS	10%	1	$683,000
Temporary Access and Water Management	LS	12%	1	$732,000
Clearing/Grubbing	AC	$6,000	20	$120,000
Temporary Erosion Control	LS	2%	1	$117,000
Civil & Structural				**$200,000**
Removal / Salvage of Existing Infrastructure	LS	$25,000	1	$25,000
Water Supply Well	LS	$175,000	1	$175,000
Earthwork & Habitat Features				**$5,384,000**
Earthwork (Floodplain Excavation)	CY	$12	57,000	$684,000
Deer Lake	LS	$3,700,000	1	$3,700,000
Floodplain Wood	AC	$12,000	40	$480,000
Wood Habitat Structures	AC	$13,000	40	$ 520,000
Site Restoration and Planting				**$280,000**
Seeding and Mulching	AC	$14,000	20	$280,000
Direct Subtotal				**$7,591,000**
Design Contingency		60%		$4,554,600
CONSTRUCTION TOTAL				**$ 12,146,000**

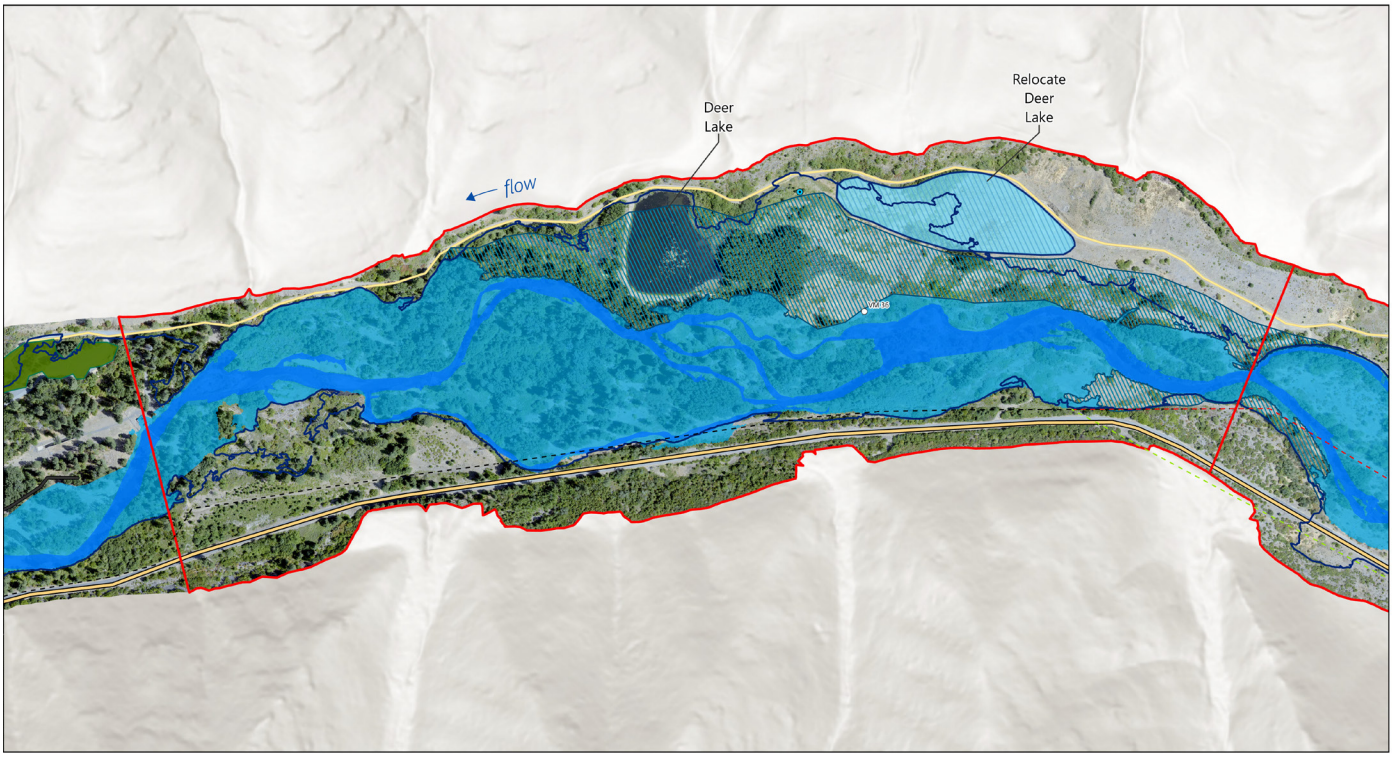


Figure 46- Sub-Reach 5 Overview of Actions

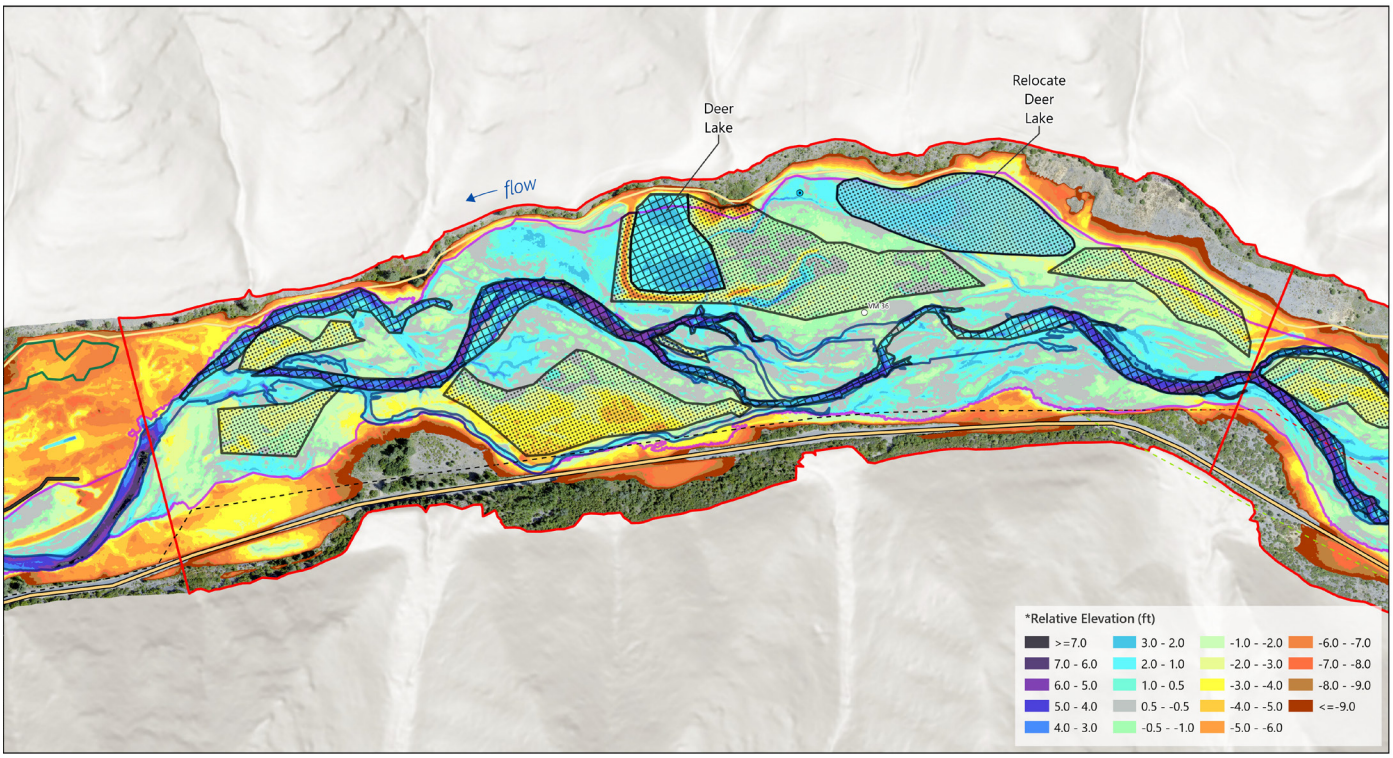


Figure 47 - Sub-Reach 5 Concept Design

Sub-Reach 6

Summary of Major Actions and Outcomes

- Complete Feasibility Analysis of New Lake location
  - Geotechnical site assessment (excavation, constructability) / Materials / Water source (use Blue Lake outflow if sufficient volume).
- Construct New Lake outside the existing floodplain, downstream of Blue Lake.
- Construct a polishing wetland for lake outflow.
- Add parking adjacent to New Lake.
- Relocate Tucannon Road in the upstream reach (VM 34.3).
- Relocate the powerline to the Tucannon Road right-of-way.
- Reconnect and restore approximately 56 acres of channel and floodplain.
- Increase average available floodplain width from approximately 270 to 345 feet.
- Reduce wildland fire potential by replacing overhead power with underground power.

Concept Design Elements and Considerations

- Grade the floodplain to reconnect existing secondary channels and create self-sustaining side-channel and wetland habitats.
- Remove artificially elevated floodplain features.
- Fill incised channels with selectively excavated material to maximize floodplain engagement and reverse past incision.
- Install medium-to-large instream and floodplain wood structures—including large and small channel-spanning, apex, and margin types—to mimic natural wood accumulation with minimal or no artificial anchoring.
- Revegetate disturbed areas with native riparian and wetland species.
- Coordinate New Lake and infrastructure with WDFW; New Lake must be constructed and operational, with replacement recreational functions confirmed by WDFW, before Beaver-Watson Lakes are decommissioned.
- Coordinate Road relocation with USFS.
- Coordinate overhead power relocation with Columbia Power and USFS.

Estimate of Probable Cost

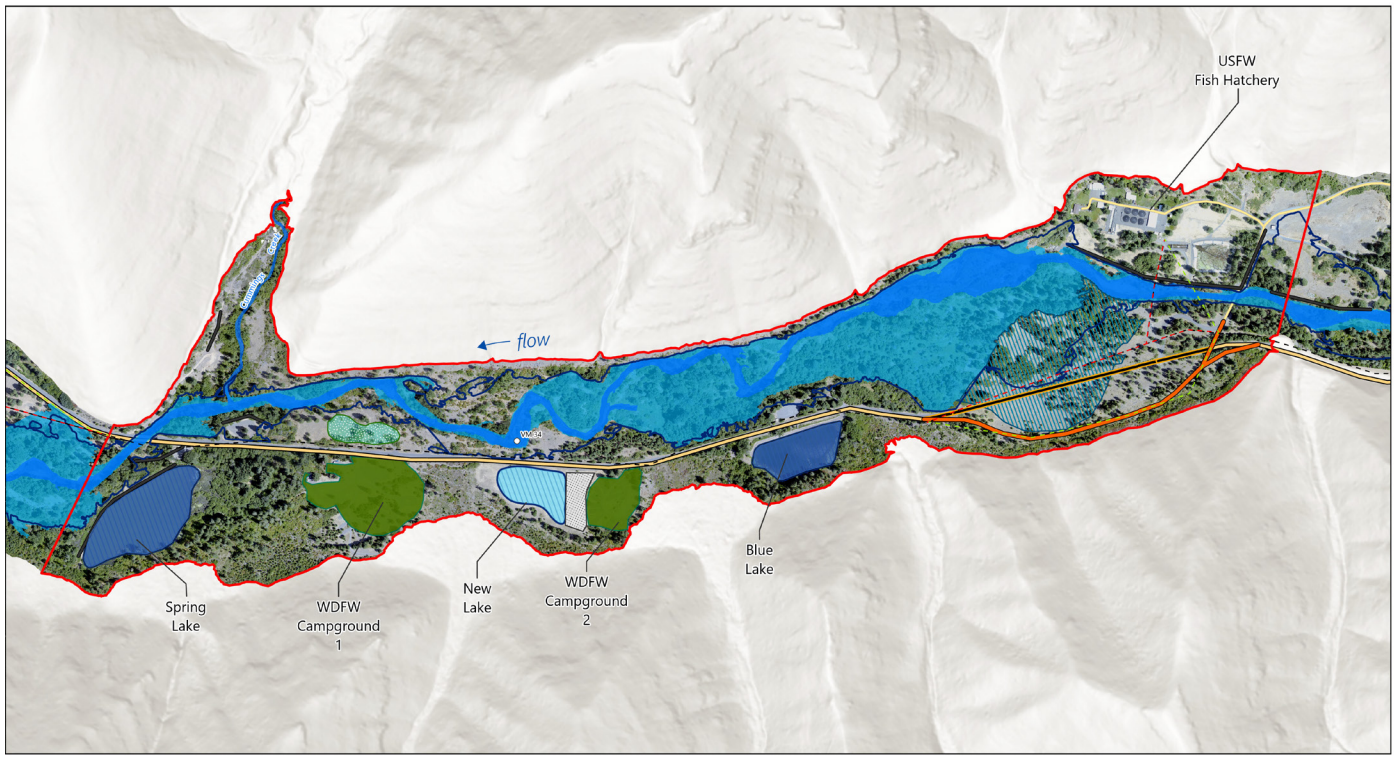
Table 8 presents the conceptual estimate of probable cost for Sub-Reach 6, including approximate quantities and total project costs.

Key assumptions include:

- Unit costs: contractor markup, profit, and overhead.
- Mobilization/demobilization: Assumed at 10% of total cost.
- Temporary access and water management: Assumed at 12% of direct costs.
- Temporary sediment and erosion control: Assumed at approximately 2% of direct costs.
- Berm and embankment excavation: Assumes standard excavators, bulldozers, scrapers, and high-capacity dump trucks.
- Wood loading: Per-acre quantities and costs are based on similar regional projects and 2025/2026 bids.
- Onsite disposal: Assumes native alluvium and streambed gravel excavated from floodplain and embankment areas will be reused as channel fill.
- Offsite disposal: Assumes infrastructure associated with the USFS road will be removed and hauled offsite.
- Powerline relocation: Overhead powerline relocation costs are excluded.
- Contingency: Total bid estimate includes a 60% design contingency for future design changes and unforeseen conditions.

Table 8: Sub-Reach 6 Concept Level Cost Estimate

Item	Unit	Unit Cost	Qty	Sub-Reach 6
Site Characterization				**$75,000**
Geotech. Characterization & Groundwater Testing	LS	$75,000	1	$75,000
Site Preparation				**$2,049,000**
Mobilization / Demob.	LS	10%	1	$794,000
Temporary Access and Water Management	LS	12%	1	$851,000
Clearing/Grubbing	AC	$6,000	45	$270,000
Temporary Erosion Control	LS	2%	1	$134,000
Civil & Structural				**$937,000**
Removal / Salvage of Existing Infrastructure	LS	$25,000	1	$25,000
Road Removal	LF	$ 20	1,800	$36,000
Road Setback	TON	$ 120	6,100	$732,000
Parking Lot	TON	$ 120	1,200	$144,000
Earthwork & Habitat Features				**$5,122,000**
Earthwork (Floodplain Excavation)	CY	$12	31,000	$372,000
New Lake and Infrastructure	LS	$3,500,000	1	$3,500,000
Floodplain Wood	AC	$12,000	50	$600,000
Wood Habitat Structures	AC	$13,000	50	$650,000
Site Restoration and Planting				**$630,000**
Seeding and Planting	AC	$14,000	45	$630,000
Direct Subtotal				**$8,813,000**
Design Contingency		60%		$5,287,800
CONSTRUCTION TOTAL				**$14,101,000**

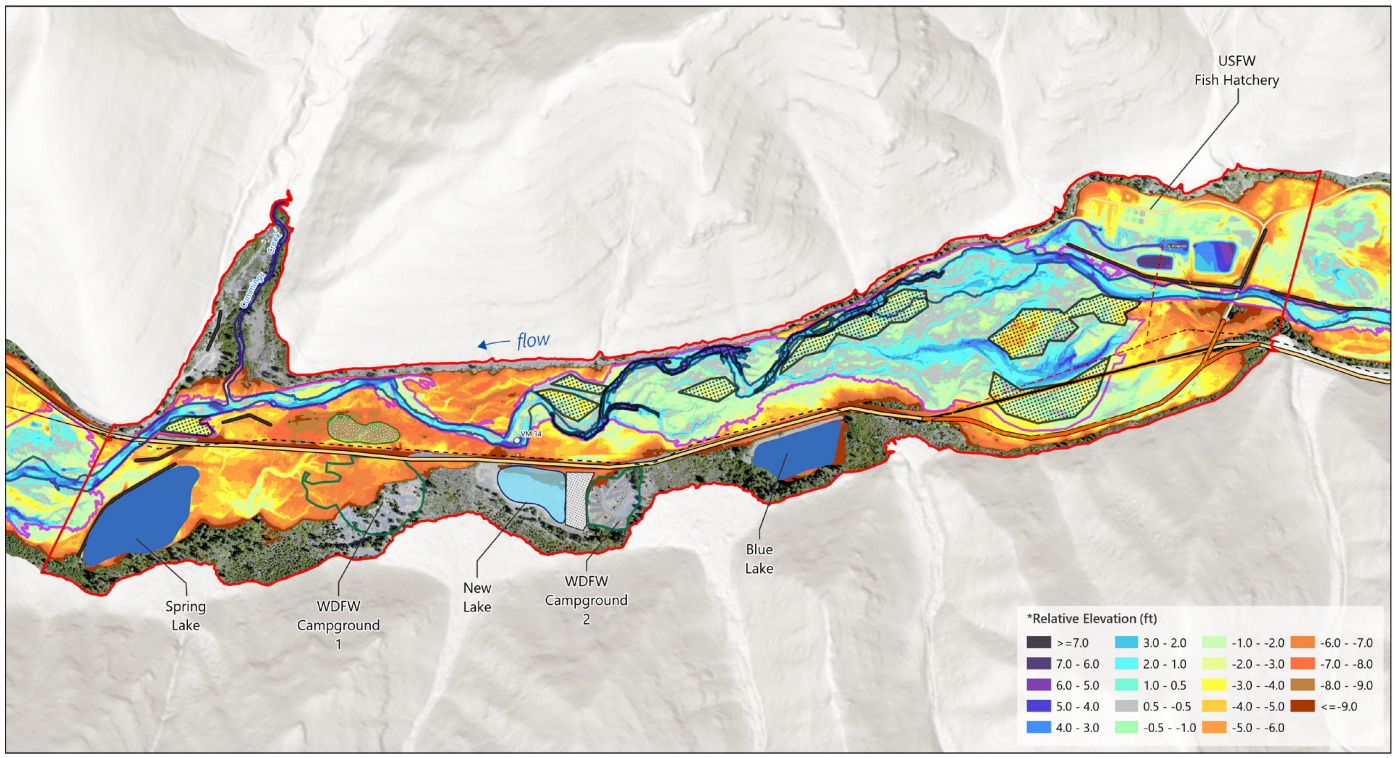


0 250 500 1,000 Feet

Reach
Approximate OHW
Approximate 100 yr (4,160 cfs)
WDFW campground
Berm
Road
Service road
Valley mile (2017)
Restored floodplain
Reconnected floodplain
New lake
Polishing wetland
Parking
Road removal
Road setback
Proposed OHP
OHP removal

Tucannon PA 5-15
Sub-reach 6: VM 33.5 - VM 34.7

■ *Figure 48- Sub-Reach 6 Overview of Actions*



0 250 500 1,000 Feet

*Relative Elevation GGL: Derived from 2020 LiDAR, relative elevation represents existing ground elevation relative to the Geomorphic Grade Line (GGL). Positive values are above the GGL (potential cut), and negative values are below the GGL (potential fill).

Reach
Approx Ex OHW
WDFW campground
Berm
Road
Service road
Valley mile (2017)
Fill
Cut
Restored floodplain
New lake
Polishing wetland
Parking
Road removal
Road setback
Proposed OHP
OHP removal

Tucannon PA 5-15
Concept Design
Sub-reach 6: VM 33.5 - VM 34.7

■ *Figure 49 - Sub-Reach 6 Concept Design*

Action Sequencing and Implementation Plan

Implementation of the Preferred Alternative will require coordination between several different actions. Some of the proposed actions are "clustered" or dependent upon another action being implemented first, and these actions will be accomplished in an order of sequence to meet the project partner's needs.

Implementation within each sub-reach area will likely be phased based on many factors including in-water work window, complexity, and time needed for construction.

In addition to the required sequencing, actions will be considered based on priority evaluated by the following factors:

- Opportunity (funding availability and access).
- Relative benefit to identified goals and objectives (recreation, endangered species/ habitat, and Tribal Treaty Rights).

Dependent (Clustered) Actions

Some of the identified projects or project components must be completed prior to commencing other projects or project components. These are "clustered actions" that are dependent on each other and will require coordination between components within different sub-reaches, with specifics by sub-reach listed in the table below (Table 9).

Priority 1

Implementation of actions within sub-reach 6 (New Lake) and sub-reach 4 (Beaver-Watson Lakes) are interdependent. New Lake will be constructed and operational, with replacement recreational functions confirmed by WDFW, prior to decommissioning and removal of Beaver-Watson Lakes. Feasibility analysis to determine potential size, placement, water source, and constructability for New Lake in sub-reach 6 will be completed prior to final design and implementation.

Channel and floodplain restoration within sub-reach 6 may be implemented after New Lake and the polishing wetland for its outlet are constructed, or may be planned and implemented concurrently. Channel and floodplain restoration within sub-reach 4 may be implemented concurrently with decommissioning and removal of Beaver and Watson Lakes and the infrastructure associated with them.

Due to the scope and size of actions within both of these sub-reaches, it is probable that both sub-reach 4 and 6 will be implemented in phases over at least two years each.

Priority 2

Implementation of actions within most sub-reaches is somewhat dependent on, or concurrent with, the planned realignment and burial of the powerline through the reach, as well as realignment of segments of Tucannon Road as described in the Conceptual Designs by Sub-Reach section of this report. Feasibility analysis to determine potential benefit and constructability for the road relocation segments will be completed prior to final design and implementation.

Channel and floodplain restoration associated with the road relocation segments may be implemented concurrently with those channel and floodplain actions planned for each respective sub-reach.

Priority 3

Implementation of actions within sub-reach 2 (Curl Lake) are dependent on replacement of adult collection and juvenile rearing functions currently associated with the collection weir near Rainbow Lake and the Tucannon fish Hatchery, and existing Curl Lake. Completion of a new adult salmonid collection weir in the lower 10-mile section of the Tucannon River must occur prior to decommissioning Curl Lake.

Channel and floodplain restoration within sub-reach 2 may be implemented concurrently with decommissioning and removal of Curl Lake and the infrastructure associated with it.

Due to the scope and size of actions within sub-reach 2, implementation is likely to occur in phases over at least two years.

■ ***Table 9. Dependent Actions*** *- Proposed prioritized sequencing for implementation for dependent actions*

Priority	Step	Action	Sub-reach	PA
1	A	**New Lake (VM 33.5-34.7)** a. Landowner agreements b. Scope and Fee c. Feasibility analysis d. Design e. Construct New Lake and make it operational, with replacement recreational functions confirmed by WDFW, before Beaver-Watson Lakes are decommissioned.	6	14.1-14.3
	B	**Beaver-Watson Lakes (VM 36.6-37.6)** a. Landowner agreements b. Scope and Fee c. Decommission both lakes after New Lake is operational and WDFW confirms its replacement recreational functions. d. Floodplain restoration design and implementation, including water supply diversion and inlet/outlet channels e. Channel restoration to address incision f. Includes floodplain restoration at VM 37/WDFW Campground 4 (after road relocation)	4	10.3-11.2
2	A	**Power Line – Reroute out of floodplain area to Tucannon Road Right-of-Way** a. Sub-reach 3 (Big Four Project) (VM 37.6-39.6) b. Road Relocation segments (VM 40, 37, & 34.3) c. Remaining PA 5-15 reach where applicable	2, 4, 6	
	B	**Reroute Tucannon Road at these locations:** a. Near USFS Guard Station (VM 40) b. Upstream from Blue Lake (VM34.3) c. at/near VM 37/Campground 4 (PA 11.1/11.2) d. Design and construct added floodplain restoration of area between rerouted road sections and Tucannon River if not already within other Project Areas	All	
3	A	**Adult Collection Weir** Lower River (Mile 0 to 10) adult collection weir prior to Curl Lake removal a. Locate, procure weir site b. Design, construct weir	NA	
	B	**Curl Lake & USFS Guard Station (VM 39.6-40.4)** a. Decommission Curl Lake b. Floodplain restoration design and implementation, including area near USFS Guard Station/road relocation	2	6-8

■ ***Table 10. Independent Actions*** *- The following proposed actions are not dependent on any other actions within the PA 5-15 Reach and will be implemented based on opportunity and funding*

Action	Sub-reach	PA
Big Four Lake and Infrastructure decommissioning, and channel and floodplain restoration **(VM37.6-39.6). Implementation within this sub-reach is not dependent on actions in other sub-reaches**	3	8-10.3
Deer Lake – move upstream and decommission existing Lake (VM 35.5-36.6) a. Feasibility/Geotech for rebuild/relocate b. Water Supply well i. Water right ii. location iii. feasibility c. New Deer Lake i. Design ii. Construction (includes new well) iii. Decommission existing Deer Lake and its associated infrastructure only after the relocated lake and water supply are operational and WDFW confirms its replacement recreational functions. iv. Channel and floodplain restoration entire reach (diversion included)	5	11.2-12
USFS Tucannon Campground (VM 40.4-41.2) a. Geotechnical evaluation of new bridge abutments/piers b. Design changes/new road and bridge(s) c. Construct new road, bridge(s), campground alterations d. Channel and floodplain restoration	1	5-6

Independent Actions

The following proposed actions are not dependent on any other actions within the PA 5-15 Reach and will be implemented based on opportunity and funding. As with other full sub-reach scale actions, implementation of these actions is likely to be phased over two or more years (Table 10).

- Implementation of actions within sub-reach 3 (Big Four Lake) is not dependent on actions within other reaches, and implementation is designed and planned in three phases beginning in 2027 with completion in 2029.
- Relocation of Deer Lake upstream is not dependent on other actions and can move forward with feasibility.
- The modifications to the U.S. Forest Service campground access road and bridge are not dependent on other actions within the PA 5-15 project area, but require coordination with the U.S. Forest Service.

Implementation Timeline (General)

The timeline for implementation of the entire reach-scale Preferred Alternative is unknown, and will be dependent on many factors, primarily including funding, and co-manager and landowner capacity and agreement (Table 11).

Feasibility, design, and construction of the majority of each of the sub-reach projects are likely to be multi-year efforts. While it is possible that more than one sub-reach would be constructed during the same timeframe, the probability of this occurring is not high due to availability of funding, landowner and co-manager capacity, availability of materials, and the commitment to maintain public recreation opportunity within the reach. The following timeline forecast is based on potential construction of each sub-reach project individually, and consecutively rather than planning multiple projects during the same time periods.

Based on implementation for sub-reach 3 from 2027 through 2029, and forecasting a minimum of three years for feasibility, design and permitting, and construction of each subsequent sub-reach, the most aggressive or optimistic potential timeline for implementation of the full PA 5-15 reach is 2027 through 2039 (Table 11).

■ ***Table 11: Potential Implementation Timeline***

	Sub-Reach 3 Big Four	Sub-Reach 6 New Lake	Sub-Reach 4 Beaver-Watson	Sub-Reach 5 *Deer	Sub-Reach 2 **Curl	Sub-Reach 1 ***Tucannon Campground
Feasibility	NA	2027	NA	2032	NA	NA
Design	2025-27	2027-28	2030	2033	2035	2037
Construction	2027-29	2029-30	2031-33	2034-35	2036-37	2038-2039

*Sub-Reach 5 (Deer Lake) timeline can begin at any time, total 4 to 5 years.

**Sub-Reach 2 (Curl Lake) - Locate, purchase/lease site, design, and construct new adult salmonid collection weir 2028-2034.

***Sub-Reach 1 (U.S. Forest Service Tucannon Campground).

A significant amount of time will likely be required to complete necessary coordination, approvals and permitting for this reach, and design start date reflects this probability.



Tucannon River; PA 5-15

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Glossary

Term	Definition
Action	Proposed activities to improve selected physical and ecological processes that may be limiting the productivity, abundance, spatial structure or diversity of the focal species. Examples include removing or modifying passage barriers to reconnect isolated habitat, planting appropriate vegetation to reestablish or improve the riparian corridor along a stream that reconnects channel-floodplain processes, placement of large wood to improve habitat complexity, cover and increase biomass.
Active channel	The portion of an alluvial stream considered a short-term geomorphic feature subject to change by prevailing discharges; its upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with lower limit of perennial vegetation so that the two features, individually or in combination, define the active-channel reference level.
Aggradation	The raising or elevating of a bottomland surface through the process of alluvial deposition; conceptually it is the vertical component of accretion and is most frequently applied to sediment deposition on a channel bed, bar or other near-channel surfaces, flood plain, or, less often, low-lying alluvial terrace.
Alluvial deposit	alluvium
Alluvium	A general term for detrital deposits made by streams on river beds, floodplains, and alluvial fans; esp. a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time.
Anthropogenic	Caused by human activities.
Armoring	The winnowing of fine particles from the uppermost bed sediment of a stream channel, resulting in a bed-surface layer of generally gravel to boulder sizes that are resistant to scour; because armoring occurs at specific flow rates, the armor layer may be susceptible to removal by higher flow and sedimentation during lower flow.
Avulsion	A rapid change in the course or position of a stream channel, especially by incision (erosion) of lowland alluvium, to bypass a meander and thereby shorten channel length and increase channel gradient; avulsion commonly occurs during floods but also can occur by normal processes of lateral migration of a stream channel during non-flood discharges.
Bank	A sloping margin of a natural, stream-formed, alluvial channel that confines discharge during non-flood flow; within the earth sciences, designation of a right or left bank is done when looking in the downstream direction.
Bankfull discharge	The flow rate (m3 s-1) when the stage (height) of a stream is coincident with the uppermost level of the banks -- the water level at channel capacity, or bankfull stage. Thus, the concept of bankfull discharge, which often approximates the mean annual flood for perennial streams, includes the flood plain as a unique, identifiable geomorphic surface, all higher surfaces of alluvial bottomlands being terraces, and acknowledgement that bankfull discharge occurs only when stream stage is at flood-plain level.
Bank material	The sediment of which the mostly sloping sides, or banks, of a stream channel are formed; like bed material, it is generally reflective of the size range of the total sediment load of the stream, may be partly residual, but for regime channels is mostly indicative of the suspended-load transported by streams during non-flood periods.
Bar	In-channel sediment of relatively coarse bed material, typically coarse sand through cobbles in size, that is generally deposited during the recession of a high flow and is mostly exposed during periods of low flow.

Term	Definition
Bed	The bottom surface of a water course, generally of a stream channel, upon which water and sediment move during periods of discharge.
Bed load	The sediment that is moved by saltation, rolling, or sliding on or near the stream bed, essentially in continuous contact with it. Also considered as the sediment discharged as bed load.
Bed material	The sediment of which the mostly horizontal bed of a stream channel is formed; it is generally reflective of the size range of the total sediment load of the stream, in many cases may be partly residual, but is mostly indicative of the bed-load sizes transported by the stream.
Bedrock	The solid rock that underlies gravel, soil or other superficial material and is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
Benthos diversity	A measure of the diversity and production of the benthic macroinvertebrate community; also used to describe the diversity of the physical structure along a streambed (i.e., benthos habitat diversity).
Cfs	Cubic feet per second; a measure of water flows
Channel forming flow	Sometimes referred to as the effective flow or ordinary high water flow and often as the bankfull flow or discharge. For most streams, the channel forming flow is the flow that has a recurrence interval of approximately 1.5 years in the annual flood series. Most channel forming discharges range between 1.0 and 1.8 years. In some areas it could be lower or higher than this range. It is the flow that transports the most sediment for the least amount of energy, mobilizes and redistributes the annually transient bedload, and maintains long-term channel form.
Channel morphology	The physical dimension, shape, form, pattern, profile and structure of a stream channel.
Channel planform	The two-dimensional longitudinal pattern of a river channel as viewed on the ground surface, aerial photograph or map.
Channel units	Morphologically distinct areas within a channel segment that are on the order of at least one to many channel widths in length and are defined by distinct hydraulic and geomorphic conditions within the channel (i.e. pools, riffles, and runs). Channel unit locations and overall geometry are somewhat stage dependent as well as transient over time, and observers may yield inconsistent classifications. To minimize the inconsistencies, channel units are interpreted in the field based on the fluvial processes that created them during channel forming flows, then mapped in a geographic information system (GIS) to provide geospatial reference.
Control	A natural or human feature that restrains a streams ability to move laterally and/or vertically.
Critical shear stress	The lowest required value of shear stress applied by flowing water to initiate motion of individual particles of specified size (diameter) along the bed of a stream.
Degradation	The lowering of a bottomland surface through the process of erosion; conceptually it is the opposite of the vertical component of aggradation and is most frequently applied to sediment removed from a channel bed or other low-lying parts of a stream channel.
Discharge	The movement downstream per unit length of channel of a volume of water; water discharge is given in volume per unit time, typically cubic meters per second (m3 s-1). As a sedimentology term, discharge is the movement of a mass of sediment per unit length of channel in a specified time interval; technically it is expressed in watts per meter (W m-1), but informally it is viewed as mass per unit time. Owing to theoretical considerations, the term sediment-transport rate is preferred to that of sediment discharge.
Diversity	Genetic and phenotypic (life history traits, behavior, and morphology) variation within a population. Also refers to the relative abundance and connectivity of different types of physical conditions or habitat.
Ecosystem	An ecologic system, composed of organisms and their environment. It is the result of interaction between biological, geochemical and geophysical systems.
Extirpation	The loss of a local or regional population, with the species continuing to survive elsewhere.
Fine sediment	Sand, silt and organic material that have a grain size of 2.0 mm or less.
Flood	Any climatically controlled, relatively high streamflow that overtops the natural or artificial banks in any reach of a stream, thereby being of geomorphic significance; where a flood plain exists, a flood is any flow that spreads over or inundates the floodplain.

Term	Definition
Floodplain	The portion of relatively smooth land bordering a stream, built of sediment carried by the stream and deposited in slackwater beyond the influence of the swift current of the channel; the level of the floodplain is generally about the stage of the mean annual flood, and therefore one and only one floodplain level can occur in a limited reach of valley bottom land.
Fluvial	Pertains to the action of a river or stream; included are stream processes (fluvial processes), fluvial landforms, such as fluvial islands and bars, and biota living in and near stream channels. Common usage is often extended by geomorphologists to hydrologic processes on hillslopes.
Fluvial process	A process related to the movement of flowing water that shape the surface of the earth through the erosion, transport, and deposition of sediment, soil particles, and organic debris.
Geomorphic reach	An area containing the active channel and its floodplain bounded by vertical and/or lateral geologic controls, such as alluvial fans or bedrock outcrops, and frequently separated from other reaches by abrupt changes in channel slope and valley confinement. Within a geomorphic reach, similar fluvial processes govern channel planform and geometry resulting from streamflow and sediment transport.
Geomorphology	A composite science in the study of landforms, including investigations into the processes that cause and alter the landforms.
GIS	Geographical information system. An organized collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.
Gradient	The rate of elevation change between two specified sites of horizontal distance measured along the thalweg of the channel; it is generally expressed as a non-dimensional number (m m-1)
Hydrology	The cycle of water movement from the atmosphere to land, surface-water, and ground-water bodies, including movement among land and water bodies, before returning to the atmosphere.
Indicator	A variable used to forecast the value or change in the value of another variable; for example, using temperature, turbidity, and chemical contaminants or nutrients to measure water quality.
Instability	As a descriptor of geomorphic processes and landforms, refers to a condition of imbalance between inflows and outflows of matter through or over a landscape feature. As a geomorphic concept, instability is often expressed as some state of dynamic- or quasi-equilibrium, signifying that geomorphic processes and landforms are almost always in a condition of dis-equilibrium and are almost always adjusting to regain relative stability; an objective if applying the term is to determine the degree to which a process or landform deviates from stability or equilibrium.
Large woody material (LWM)	Large downed trees or parts of trees that are transported and deposited by the river during high flows and are often deposited on gravel bars or at the heads of side channels as flow velocity decreases. The trees can be downed through river erosion, wind, fire, landslides, debris flows, or human-induced activities. Synonymous with large woody debris (LWD).
Limiting factor	Any factor in the environment that limits a population from achieving complete viability with respect to any Viable Salmonid Population (VSP) parameter.
Meander	One of a series of regular, sharp, freely developing, and sinuous curves, bends, loops, turns, or windings in the course of a stream; the process of stream meandering is a means of channel-gradient adjustment through sorting of stored sediment by erosion at the outside of a bend and deposition, as a point bar, at the inside of the bend.
Pool	A relatively deep, low velocity reach of quiescent flow between upstream and downstream riffles, or rapids, at which the flows are ordinarily more rapid and turbulent.
Pool-riffle sequence	A succession of one or more combinations of pools and riffles along the channel in the downstream direction; during flood the normally low water velocities in pools and higher water velocities at riffles are reversed, causing scour and removal of accumulated sediment from pooled reaches and deposition of bed sediment on riffles.
Reach	An uninterrupted part of a stream channel between two points; generally the two points are where readily recognizable tributary inflows occur, but can also include features such as meander bends, gorges, or a significant change in geology.
Restoration	The attempt to recreate the adjusted physical and biological conditions that were present prior to alteration by human activity; a goal of restoration, therefore, is to minimize and eliminate the effects of human-induced alterations, thus promoting stable landforms, bioproductivity, and species diversity.
Riffle	A short, relatively shallow and coarse-bedded length over which the stream flows at ordinarily higher velocity and greater turbulence than it does through upstream and downstream pooled reaches where cross-sectional areas of the channel are greater, bed material is smaller, and velocities and turbulence are less.

Term	Definition
Riparian area	An ecological term referring to that part of the fluvial landscape inundated or saturated by flood flows; it consists of all surfaces of active fluvial landforms up through the flood plain including channel, bars, shelves, and related riverine features such as oxbow lakes, oxbow depressions, and natural levees. Particularly in arid and semiarid (water-deficient) environments, the riparian zone may support plants and other biota not present on adjacent, drier uplands.
Riverine	That characteristic by which a feature or process pertains to or is formed by a river.
River mile (RM)	Miles measured in the upstream direction beginning from the mouth of a river or its confluence with the next downstream river.
Salmonid	Fish belonging to the family Salmonidae, including steelhead trout and salmon.
Saltation	The process by which sediment, generally of sand size and coarser, bounces along the stream bed by the impact of the flow of water or of other moving particles.
Sediment	Detached fragmental material that originates from either chemical or physical weathering of rocks and minerals and is transported by, suspended in, or deposited by water or air or is accumulated in beds by other natural agencies.
Sediment yield	Sediment-transport rate per unit area, generally from watersheds or drainage basins larger than the field scale; erosion studies, however, may consider sediment yield from smaller areas of the hillslope or plot scale.
Shear	A strain, or change in shape or volume of a body resulting from stress; as applied to fluvial processes and sediment transport, it typically refers to the stress that is exerted on sediment particles by a moving fluid – air, water, and ice.
Shear stress	That portion of stress acting tangentially as a tearing action (as opposed to that portion that acts as a normal stress) to a plane or surface; thus, a sediment particle resting on a channel bed is affected by the shear stress created by water moving on the bed.
Side channel	A distinct channel with its own defined banks that is not part of the main channel, but appears to convey water perennially or seasonally/ephemerally. May also be referred to as a secondary channel.
Sinuosity	A non-dimensional ratio, generally expressed in meters per meter or kilometers per kilometer, of the length of the channel thalweg to the length of the stream valley, measured between the same points.
Slope	Any inclined surface of the earth. As a geomorphic measurement, slope is the inclination, generally measured in degrees departure from horizontal or expressed as a non-dimensional number (meters per meter), of any surface of the earth's landscape (including sub-aqueous surfaces); for application to models of hillslope soil loss, steepness is often used synonymously with slope.
Stability	A condition of approximate balance between inflows and outflows of matter through or over a landscape feature. As a geomorphic concept, stability generally is regarded as being an integration of processes affecting a system and thus has time-independence; the term often is used synonymously with (dynamic or quasi) equilibrium.
Subwatershed	A subwatershed (or sub-watershed) represents the drainage area within a larger defined watershed; synonymous with sub-basin.
Terrace	A relatively stable, planar surface formed when the river abandons its floodplain. It often parallels the river channel, but is high enough above the channel that it rarely, if ever, is covered by over-bank river water and sediment. The deposits underlying the terrace surface are primarily alluvial, either channel or overbank deposits, or both. Because a terrace represents a former floodplain, it may be used to interpret the history of the river.
Thalweg	The line within a stream channel connecting the lowest points at all locations along the channel.
Tributary	A stream feeding, joining, or flowing into a larger stream or lake.
Valley segment	An area of river within a watershed sometimes referred to as a subwatershed that is comprised of smaller geomorphic reaches. Within a valley segment, multiple floodplain types exist and may range between wide, highly complex floodplains with frequently accessed side channels to narrow and minimally complex floodplains with no side channels. Typical scales of a valley segment are on the order of a few to tens of miles in longitudinal length.
Viable salmonid population	An independent population of Pacific salmon or steelhead trout that has a negligible risk of extinction over a 100-year time frame. Viability at the independent population scale is evaluated based on the parameters of abundance, productivity, spatial structure, and diversity.
Watershed	A drainage divide or a "water parting", but common usage of the term has been altered to signify a drainage-basin area contributing water to a network of stream channels, a lake, or other topographic lows where water can collect.

Appendices

Tucannon River PA 5-15

Technical Reports

WOLF WATER RESOURCES

1001 SE Water Ave.
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Technical Memorandum

Date:	APRIL 25TH, 2024
To:	Kris Fischer
From:	Luke Russell, Jeremiah Green, Nick Legg, and Terril Stevenson
Project:	Tucannon River Planning PA 5-15, Subtask 5A
Subject:	Geomorphology, Riparian Vegetation, and Connectivity Summary Memo

Introduction

This memo details the existing geomorphic and ecologic conditions of the Tucannon River floodplain within Project Areas (PA) 5 through 15, river mile 36 to 46, to support the planning and design of floodplain restoration efforts. For a visual summary of the results in this memo see the associated maps in Appendix A. This assessment builds upon an existing body of literature of geomorphic and ecologic analyses pertaining to the Tucannon River, primarily from the 2011 and 2021 Anchor QEA reports.

This project provides collaborative analysis that supports refinement and re-evaluation of previous conceptual project ideas for the Tucannon River headwaters. The Project Vision is to *Restore physical and ecological floodplain function to benefit key fish and aquatic species, while broadening and enhancing recreational opportunities, through coordinated planning and conceptual restoration designs for the floodplain and adjacent lands of Wooten Wildlife Area.* The project is co-managed by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Nez Perce Tribe (NPT), and Washington Department of Fish and Wildlife (WDFW) and is encompassed within the Washington State Department of Fish and Wildlife (WDFW) W.T. Wooten Wildlife Area.

Project products include conceptual designs and a prioritization scheme that will lead to implementable project designs to uplift ecosystems, elevate First Foods, and add quality recreational opportunities in this key area. These projects will improve natural floodplain connectivity by addressing stream power inequity and enhancing habitat and floodplain complexity and will support restoration efforts targeting bull trout, lamprey, mussels, and threatened Snake River steelhead and spring Chinook salmon in the Tucannon River Basin.

In this memo we use floodplain width to quantify the existing impacts from confining infrastructure and the potential benefits from floodplain reconnection. Increasing floodplain connectivity and

addressing excessive stream power are both functions of floodplain width; a wider floodplain with more room to spread out water and sediment will be less erosive, more dynamic, and ultimately more beneficial for the fish and aquatic species that inhabit the floodplain.

The geomorphic assessment focuses on floodplain-channel connectivity and the factors that limit floodplain width. The two primary types of floodplain disconnection include confining infrastructure (roads, levees, and artificial lakes) and channel incision. By determining the reduced width due to a given disconnecting factor we can quantify and isolate its impacts on floodplain erosivity and benefits gained by addressing that factor.

In addition to the geomorphic assessment, we performed a basic characterization of ecological communities within the floodplain to understand what ecological benefits are gained from a better-connected floodplain. For this step, we completed a planning-level assessment to identify ordinary high water (OHW) and wetlands within the project reach through means of field survey and desktop analysis. Methodology and results of the wetland and OHW assessment can be found in the Wetland Memo (W2r 2024).

Reach Description

The Tucannon River is a tributary of the Snake River entering below Little Goose Dam. The project area is located near Dayton, Washington, and spans 10 miles of the upper Tucannon River (Figure 1), from approximately river mile (RM) 36 to RM 46 (Valley Mile 32 to 41). Both river miles and valley miles are based on the 2017 river and valley centerlines provided by CTUIR. The project reach is identified as Project Areas (PA) 5-15 (Anchor QEA 2011).

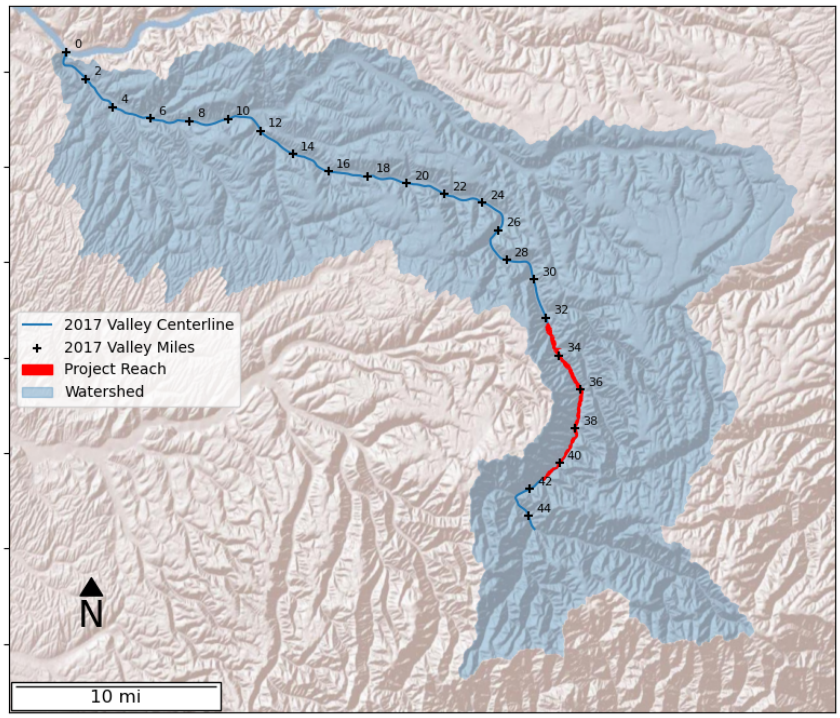


Figure 1: Overview map of the Tucannon watershed and project reach.

Historical Context

Past and Present Impacts

A historical summary of the Tucannon River watershed is provided in the Tucannon River Geomorphic Assessment and Habitat Restoration Study (Anchor QEA, 2011) and the Geomorphic Assessment and Restoration Prioritization (Anchor QEA, 2021). Specific to the project area, some channel clearing and gravel removal, push-up levees or side-cast berms, and road and bridge building have directly impacted the channel and floodplain processes. These impacts include decreased floodplain connectivity, increased stream power, and channel incision. Channel wood-clearing and removal of large trees from the floodplain and adjacent areas have decreased the volume of large wood material available for recruitment as well as decreased shading leading to increased water temperatures. Anthropogenic floodplain lakes constrict the floodplain, reduce channel migration, and contribute to hydrologic modification of the river by diverting water. Restoration activities in this reach over the recent past have focused on restoring large wood, promoting pool formation, and increasing floodplain connectivity.

Historical channel straightening has been identified as having a significant impact on the Tucannon River. Based on comparison of a series of aerial photographs (1937, 1954, 1964, and 1978), Hecht (1982) estimated that the Tucannon River channel through the project area shortened by about 12.3 percent of channel length between 1937 and 1978. The study noted that the Tucannon River appeared to be trending toward a braided channel form rather than a "stable meandering pattern" over this same time period. Another observation in the study was that the most visible significant change in the photos was the reduction in floodplain vegetation and canopy cover as well as total length of "wooded banks". The portion of the comparison study relevant to the Tucannon PA 5-15 project focused on a 4.31-mile segment of the river at and just beyond the downstream end of the project reach. The largest amount of change was noted to have occurred following the 1964-65 "flood of record" and the subsequent response to this flood on the Tucannon. The author acknowledged that the Tucannon is a relatively steep alluvial channel with a geomorphic propensity to develop braided channels rather than a single-thread meandering channel and that the noted channel straightening in this upper segment of the river was largely a result of channel response to major floods.

General Geology and Geomorphic Conditions

The geology and general geomorphic conditions of the Tucannon River watershed are also summarized in the Tucannon River Geomorphic Assessment and Habitat Restoration Study (Anchor QEA, 2011) and the Geomorphic Assessment and Restoration Prioritization (Anchor QEA, 2021). Geologic influences within the project reach include bedrock consisting of Miocene-aged Columbia River Basalt flows of the Grande Ronde, Wanapum, and Frenchman Springs members which exert some control on valley margins as well as sporadically on channel bed and banks. The valley fill is recent Quaternary river alluvium along the valley floor (Anchor QEA 2011a, Anchor QEA 2021).

Significant alluvial fan and hillslope deposits are present in many locations and locally constrict the valley and floodplain width. Sheet and rill erosion on non-forested slopes, shallow landslides from steep valley walls, and debris flows in the mountain reaches deliver upland sediment to the reach (USDA 2002).

The project reach has a floodplain gradient averaging 1.2% within the project reach and a predominantly unconfined valley with widths 4 to 8 times the bankfull channel. The average bankfull width is 45 feet and the average connected floodplain width is 210 feet. The channel form ranges from single-threaded in confined and/or incised settings to anastomosing (multi-threaded) in unconfined and well-connected settings. Tree and large wood removal from the channel and floodplain as well as flow modification resulting from lake construction and management have had significant impacts resulting in simplified channel planform and bed geometry and a general reduction or lack of large pools (Figure 2).



Figure 2: Aerial image comparison revealing channel and floodplain changes over 70 years since channel straightening and simplification. The specific changes noted include floodplain widening, formation of multiple channel threads, and expansion of the riparian zone. Images show the upper section of Project Area 11.2. Source: landscapeexplorer.org.

Channel incision appears to have been occurring since the influx of European settlement in the past two centuries. By the beginning of the 20th century the channel was already severely impacted and degraded from settler activity, such as channel diversion, draining wetlands, and deforesting the valley floodplain (Johnson 1995). The construction of a series of lakes within the floodplain along the project reach in the 1950s arrested the channel in its incised state and in many cases exacerbated channel incision. The encroachment of infrastructure has further prevented the channel from widening or developing a multi-thread channel and limited the recovery potential. It is the combination of these impacts that initiated the process of channel incision and their legacy continues to influence the channel today. Despite these impacts, over the last 70 years the formation of an inset floodplain has generally widened and become more complex (where the space was available), likely a result of both natural process and restoration activities in the watershed (Figure 2).

Methodology

Floodplain Connectivity

Floodplain connectivity was determined using a cross-section based geospatial analysis; using cross-sections allows us to easily relate floodplain characteristics to width. We identified and mapped four main causes of floodplain disconnection:

- Incision: Vertical disconnection based on a qualitative assessment using aerial imagery, relative elevation models, and field observations. The extent of vertically disconnected area closely matches the 10-year inundation extent modeled in the Anchor 2021 report.
- Roads: Lateral disconnection defined by the portion of floodplain separated from the main channel.
- Levees: Lateral disconnection defined by the portion of floodplain separated from the main channel.
- Lakes: Lateral disconnection defined by all floodplain area between the main channel and valley toe and within the lake's zone of influence, stretching longitudinally from lake intake to lake outflow.

First, we generated a height above water surface (HAWS) relative elevation model (REM) using available LiDAR data (Quantum 2020). We then delineated the valley bottom using a threshold of 16 feet above the low water surface because this roughly encompasses the valley bottom while omitting features such as alluvial fans, Pleistocene age terraces, and other elevated features (built or natural) that do not directly influence floodplain dynamics. We then generated a series of cross-sections clipped to the valley bottom at approximately 20-foot intervals along the 2017 valley centerline. An example of the HAWS and clipped valley bottom cross-sections are shown in Figure 3.

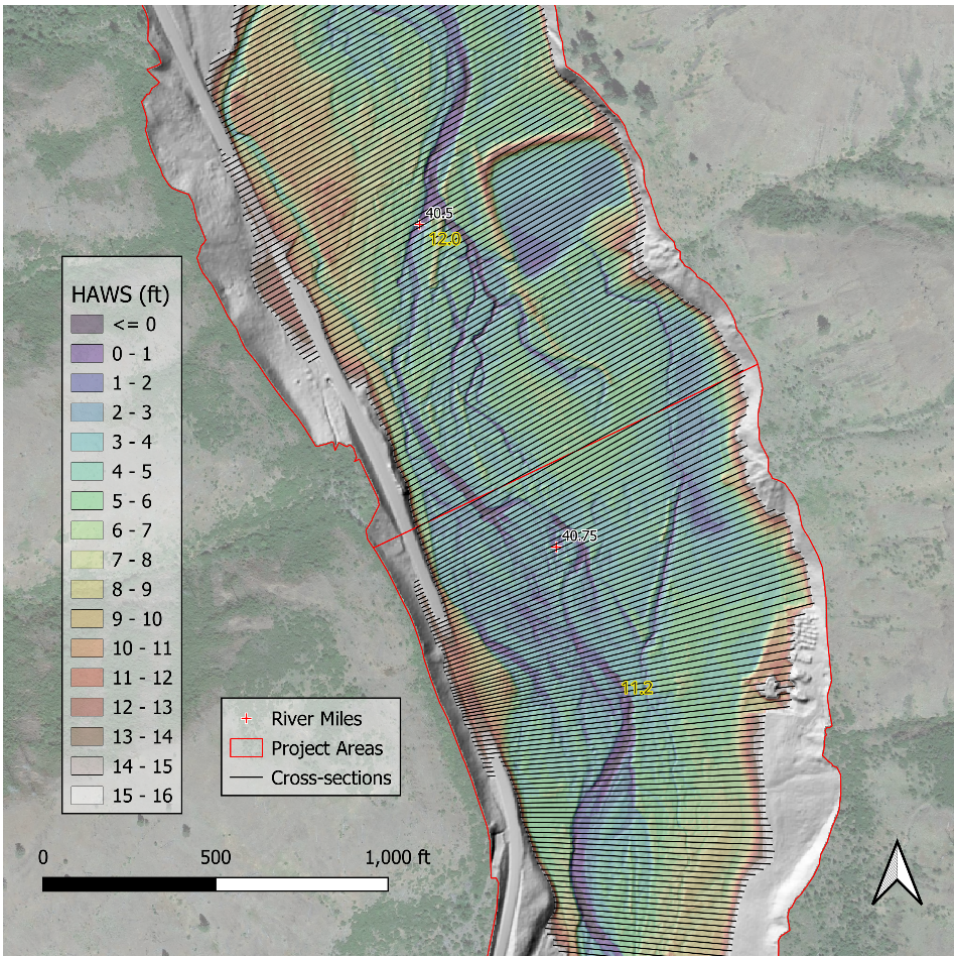


Figure 3: Excerpt of HAWS map and generated cross-sections used for the connectivity and stream power analyses.

To address floodplain disconnection via incision we created another REM. Unlike the HAWS REM, the zero elevation of this REM represents the threshold elevation between connected and disconnected floodplain. The extent of this elevation threshold closely matches the extent of the modeled 10-year flood (Anchor QEA 2021); we did not initially try to match the 10-year extent, but this corroborates our floodplain delineation in that it is the regular and semi-frequent (<10-year) flood events that dictate the active floodplain.

We used a combination of aerial imagery, HAWS mapping, and field observations to determine the elevation threshold for each project area. The presence of riparian vegetation and low-lying floodplain elevations were the primary factors used to discern connected from disconnected floodplain; field observations, such as high water marks and relict channels, were used to verify the mapped threshold elevations of floodplain disconnection. The approximate range of elevations representing vertically disconnected floodplain and the longitudinal profile used to generate the REM are shown in Figure 4.

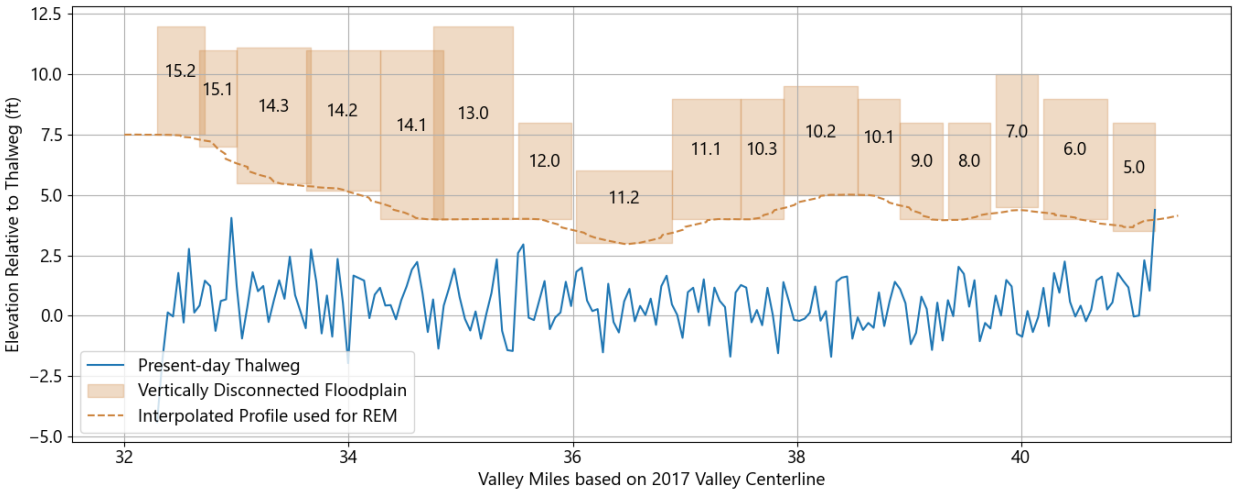


Figure 4: Longitudinal profile of disconnected floodplain elevations relative to the thalweg elevation by project area. The lower bound of these ranges was interpolated to generate the REM.

In many cases there were overlapping features causing disconnection. In these instances, we used a ranking system to determine the primary source of floodplain disconnection. A lake's zone of influence was considered the dominant factor of floodplain disconnection, followed by roads, then levees and berms, and lastly, incision was considered dominant only when confining infrastructure was not present.

The cross-sections generated from this exercise are used to estimate connected and disconnected floodplain widths and ultimately to inform impacts of restoration actions. Figure 5 shows an example of mapped floodplain disconnection, from both channel incision and laterally confining infrastructure. The maps in Appendix A include the entire PA 5-15 project area.

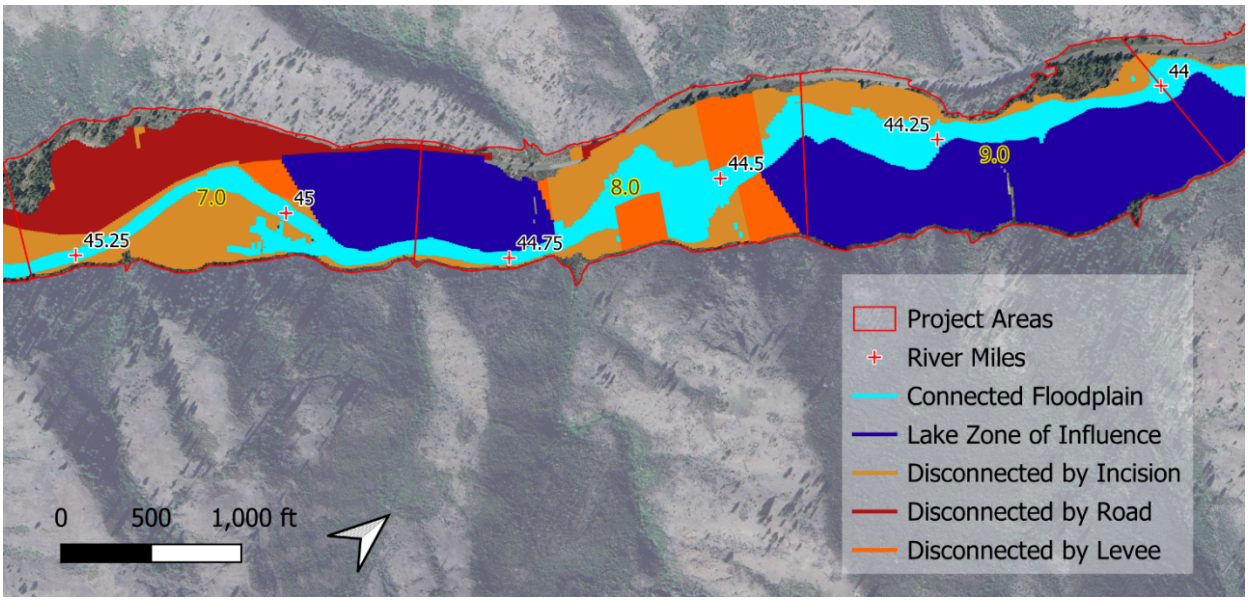


Figure 5: Example of cross-section-based connectivity analysis showing the reach between Curl Lake and Big Four Lake.

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Stream Power

We used stream power to relate mapped floodplain widths to stream erosivity and sediment transport in order to address the question: how much space does the river need? This assessment builds upon the stream power analysis completed by Anchor QEA in 2021, and further contextualizes the stream power results as they relate to stream erosivity and the mobility of spawning gravels for ESA listed species. We translate abstract values of stream power into an understandable measure of critical grain size (i.e. the grain size experiencing incipient motion) and relate these hydraulic conditions to observed grain size distributions and desired gravel sizes for spawning. The mobility of spawning gravels is of particular importance given that redd scour has been identified as a limiting factor in the Tucannon (Hecht, 1982).

Stream power is a measure of energy, but understanding the context behind these values is an important first step towards working with and interpreting the data. There are two ways to describe stream power mathematically: (1) as the product of discharge (Q), slope (S), and specific gravity (ρg) divided by width (b) and (2) as the product of shear stress (τ) and velocity (U). Both equations produce a measure of energy acting on the bed: stream power per unit area (Bagnold 1966).

$$\omega = \frac{\rho g Q S}{b} \quad (1)$$

$$\omega = \tau * U \quad (2)$$

On the following page, Table 1 summarizes a literature review of studies which developed stream-power based thresholds for erosion. While the erosion-deposition thresholds vary from study to study there is a general trend of the thresholds ranging between 25 and 60 W/m^2 (1.7 to 4.1 lb-ft/s). The two studies referenced at the bottom of Table 1 individually determined that severe erosion and major geomorphological change occurs at 300 W/m^2 (21 lb-ft/s).

Table 2 shows stability thresholds of streambed materials compiled from a series of empirical studies, both in-situ and flume (Fischenich 2001). Using Equation 1 above we were able to combine these shear stress and velocity thresholds into a single stream power threshold. With this relationship we can tie stream power to critical grain size (i.e. the grain size which is experiencing incipient motion). When comparing Table 1 and Table 2 we can see that the range of erosion-deposition thresholds (1.7 to 4.1 lb-ft/s) is centered on the stream power threshold related to incipient motion of coarse gravels (~2.7 lb-ft/s) which conveniently correlates to the measured D_{50} within the project reach at approximately 50 mm (2.2 inches) (Anchor QEA 2011).

Table 1: Summary of a literature review of relevant empirical studies that aimed to determine the specific stream power associated with erosion-deposition thresholds.

Publication	Specific Stream Power Deposition-Erosion Threshold		Description of Threshold
	(W/m^2)	(lb-ft/s)	
Nanson and Croke (1992)	10	0.7	Compilation of literature comparing floodplain type/morphology to calculated stream power. Values shown here best represent gravel-bedded meandering rivers – "usually middle to lower valley reaches".
	60	4.1	
Brookes (1987)	25	1.7	Incising streams eventually enter a non-erosion phase when they have enlarged to a point with ω <35 W/m^2; a related deposition-to-erosion threshold in altered streams equates to ω =25 W/m^2.
Orr et al. (2008)	30–35	2.1–2.4	Found the deposition-erosion threshold occurs between ω =30 and 35 W/m^2.
Watson and Bledsoe (2001)	50	3.4	Categorized rural and urban reaches by specific stream power, with "low rural stream power conditions" having ω <50 W/m^2, "high rural stream power conditions" having ω >50 W/m^2, and urban areas having ω >100 W/m^2.
Miller (1990)	300	21	Found that a major flood caused severe erosion when ω >300 W/m^2, but did not find a strong link between specific stream power and geomorphic change due to the size and rarity of the flood event.
Magilligan (1992)	300	21	Evaluated variation in stream power associated with the 2-year to 500-year flood events, for which it was found the threshold for causing major morphological adjustments in low gradient, alluvial channels in humid to sub-humid environments corresponds to ω >300 W/m^2.

Table 2: Excerpt of stability thresholds of different grain sizes from Fischenich 2001. Stream power values were computed from these shear stress and velocity thresholds. The highlighted row indicates the general restoration target based on spawning gravel sizes.

Grain Size - Class	Stability Thresholds (Fischenich 2001)		Specific Stream Power	
	Shear Stress (lb/ft^2)	Velocity (ft/s)	(lb-ft/s)	(W/m^2)
Silt	0.045	2	0.09	1.3
1-in. – Medium Gravel	0.33	2.5	0.83	12
2-in. – Coarse Gravel	0.67	4.0	2.7	39
6-in. - Cobble	2.0	4.8	9.5	139
12-in. - Boulders	4.0	5.5	22	321

Using Equation 1, we distilled stream power to a function of width, to explore the influence of encroaching infrastructure, incision, and potential restoration actions. Observations from partners at SRSRB and CTUIR indicate that the Tucannon River and floodplain begin to achieve desirable habitat and function at roughly 300 feet in active floodplain width. The 2-year specific stream power when assuming a 300-foot width is roughly the upper limit of preferred Chinook gravel spawning size, around 50 mm (Kondolf and Wolman 1993). This width serves only as a minimum target, because benefits to fish, riparian health, and aquatic species continue to be gained with increases in width up to full valley-wide reconnection.

Floodplain Ecology

We overlayed geospatial ecological data onto valley wide cross-sections to summarize vegetation conditions within the project reach in terms of floodplain width. We categorized and mapped the floodplain into five primary ecological communities:

1. Ordinary High Water (representing the active channel and riparian zone)
2. Wetlands
3. Grasses/Forbs
4. Shrub/Scrub
5. Forested/Canopy

A planning–level assessment of wetland areas was performed in September 2023. This evaluation included a desktop assessment which was refined through field verification of the presence or absence of wetlands. National Agriculture Imagery Program (NAIP) imagery and a relative elevation model were used to identify the OHWM boundary and where wetland hydrology was likely present.

During the field investigation, vegetation communities and geomorphic position were observed and documented.

Within the study area, there are eight artificial lakes managed by WDFW for recreation. These lakes are primarily maintained using surface water diversions from the Tucannon River. The lakes are shallow and permanently flooded and are considered depressional wetlands. Each artificial lake has an adjacent wetland complex with hydrology originating from water seeping through the lake berm and margins. These wetlands occur on both the upstream and downstream margins of the lakes. During high-flow events, these wetlands are hydrologically connected to the water table of the adjacent river. Additionally, we observed numerous instances of groundwater contributing to hillslope seeps at the slope toe and floodplain edge. In total, approximately 69 acres of likely wetland was mapped within the study area. Five wetland types were identified based on Cowardin classification.

A wetland assessment memorandum draft was submitted to CTUIR January 24, 2024. Description of observed wetlands and determination methodology are described in further detail in this memo. This assessment of wetland areas is not comprehensive. Varying sources of wetland hydrology limit predictability of wetland hydrogeomorphic classification. Additional project specific fieldwork will be required once projects are better defined. We used the resulting shapefiles of delineated ordinary high water (OHW) and wetland features in this assessment.

Incision in a floodplain may create a gradient of ecological niches, influencing the spatial distribution and structure of vegetation. Vegetation heights can often reflect the duration and frequency of inundation. To determine canopy height (CH) relative to the ground surface, the first return surface from the Quantum 2020 LiDAR was subtracted from the bare earth surface. Canopy height was separated into forested, scrub-shrub, and herbaceous categories. Canopy thresholds generally align with wetland Cowardin class typing (FGDC 2013). The Cowardin classification for maximum scrub-shrub wetland vegetation height is 20 ft. For this analysis, we chose a conservative height limit of 15 ft for the scrub-shrub category. Vegetation with heights above 15 ft is considered forested canopy. Canopy cover for areas with heights less than 3 ft includes grasses and forbs, bare ground, and road surfaces.

Results

To see the connectivity and ecological mapping exercise that informs the results and discussion of this memo refer to the maps in Appendix A.

Roughly 74% of the floodplain is disconnected from the river to some degree. Incision disconnects 36% of the valley bottom and is the highest percentage contributing factor, followed by the lakes

which disconnect nearly 20% of the valley bottom (Figure 6). The discussion section of this report includes a more detailed breakdown of the results of this connectivity analysis.

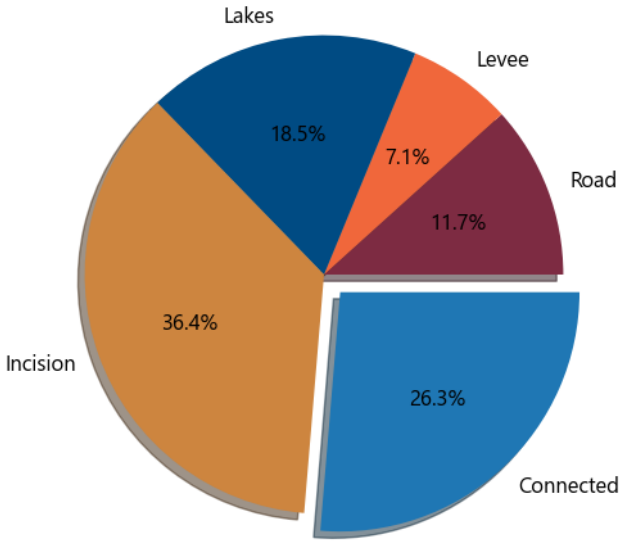


Figure 6: Area-based summary of floodplain connectivity and disconnectivity by causal mechanism.

Table 3 shows the calculated specific stream power at different flow events under reach-averaged existing conditions and assuming a constant 300-foot floodplain width. Using the stream power-grain size relationship established in Table 2 we also represented these calculated stream power values as critical grain size diameter.

Table 3: Average specific stream power and related critical grain size diameter within Project Areas 5-15 for existing floodplain width and using an assumed 300-foot width. These are reach-average values across Project Areas 5-15, and actual values vary laterally and longitudinally within the project reach.

	Avg Existing Conditions		Assumed Constant 300-ft Width	
Flow Event	**ω (lb-ft/s)**	**D_c (mm)**	**ω (lb-ft/s)**	**D_c (mm)**
1-year	1.3	29	0.9	22
2-year	3.3	63	2.3	47
5-year	5.4	94	3.8	71
10-year	7.7	126	5.3	95
25-year	11.4	175	7.9	131
50-year	15.1	221	10.5	166
100-year	19.8	276	13.8	207

To summarize the impacts of different restoration scenarios (removal of confining infrastructure and/or addressing incision) we calculated the critical grain size derived from specific stream power values determined by restored floodplain width. Plotting these critical grain sizes by flow event reveals the sediment transport regime of the floodplain (Figure 7). The transport regime line shows

at grain sizes are stable (right side of the transport regime line) on the bed or mobilized (left side of the transport regime line) for various scenarios. A reduction in floodplain width would shift the transport regime line further right on the figure, while increases in width will shift the line to the left. For example, the increased width from removing the lakes would push the transport regime line to the left from the existing width to just left of 300-feet.

Under current conditions our stream power assessment indicates that spawning-size gravels, equivalent to the reach D_{50} and smaller (roughly 20 to 50 mm), are generally mobilized with flows at and above the 1-year event (320 cfs). As a result, redds within the project reach may be susceptible to erosion during moderate winter floods. Figure 7 also indicates that only the upper limit of Chinook and Steelhead spawning gravels become stable with 300 feet in floodplain width, so this should only be considered a minimum target width for restoration efforts. However, it is also at this width that the reach-average D_{50} becomes stable, which means that roughly half of the bed load will remain stable/depositional during the 2-year event. It is only under valley-wide reconnection that we see the full range of spawning gravels stable during the 2-year flow event (Figure 7).

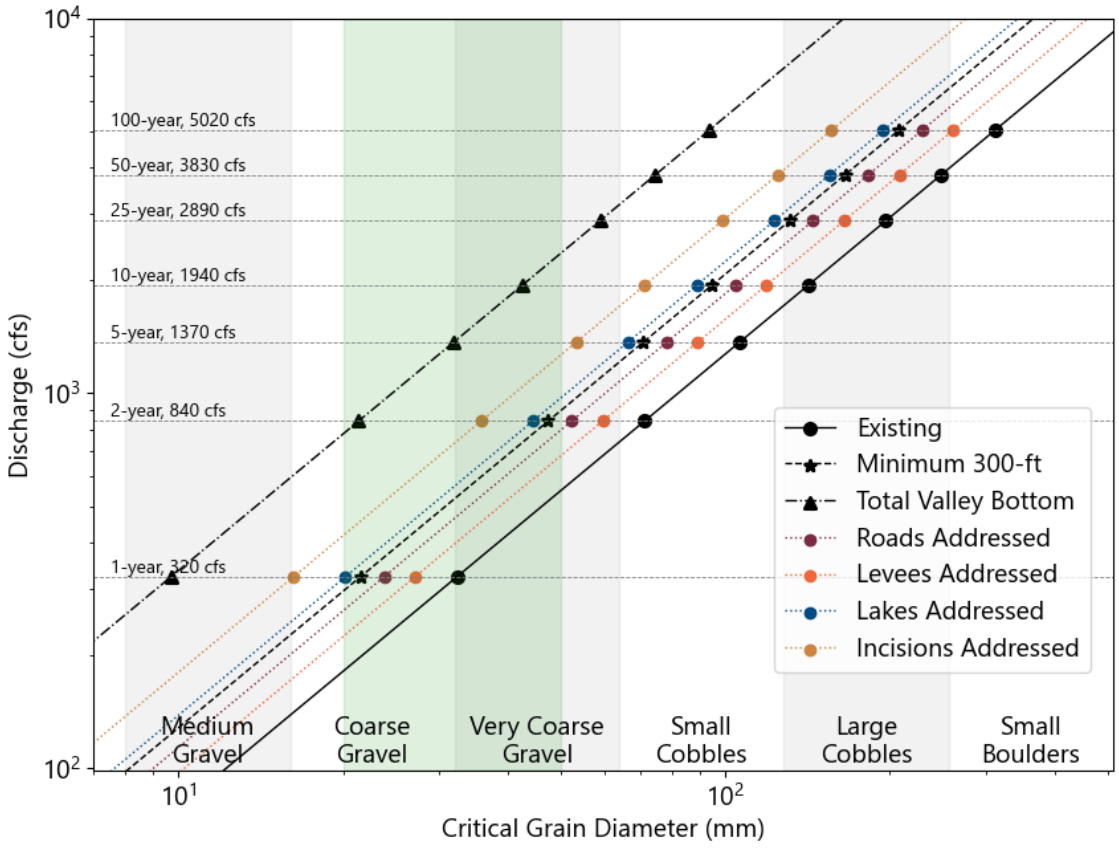


Figure 7: Bed material stability thresholds of different restoration scenarios (see legend) under the current hydrologic regime. Grain sizes to the left of each line are considered mobile, while grain sizes to the right are considered stable. Existing and target thresholds are from Table 3. Spawning gravels are represented as the interquartile range (25-75%) of sampled Chinook and Steelhead spawning gravel sizes (Kondolf and Wolman 1993). This figure represents project reach averages; actual values of stream power and stability will vary both longitudinally and laterally across the floodplain.

Table 4 shows the same stream power results as Figure 7 broken down by Project Area and only for the 2-year flow event. Refer to the maps in Appendix A to see which areas would be reconnected for each restoration scenario.

A key takeaway from Table 4 is that a restoration target of stable spawning gravels at the 2-year flood and below cannot be met in all Project Areas without addressing both incision and confining infrastructure. By addressing only incision, such as filling the channel without removing infrastructure, we can exceed the minimum width target in most project areas. However, actions that only address incision do not consider impacts of those actions to infrastructure that would likely need to be accommodated and/or mitigated. The results in Table 4 assume that when addressing or removing infrastructure any associated incision is also addressed, and conversely that when incision is addressed proper consideration is taken to protect the affected infrastructure from increased flooding. Ultimately, addressing impacts from both infrastructure and incision simultaneously will achieve target floodplain widths most effectively.

Table 4: Results from the stream power assessment. Specific stream power (ω) and critical diameter (D_c) were calculated for the 2-year flow. Widths are median values from each project area. Removal of infrastructure assumes that related incision would be addressed simultaneously. The color scale represents high relative erosivity as red and low relative erosivity as green. The check marks and X's represent whether or not a reach meets the 2-year stream power target (2.3 lb-ft/s) identified in Table 3.

Project Area	Connected Floodplain			Levee Removal			Lake Removal			Road Removal			Incision Addressed			Total Floodplain		
	Width	ω	D_c	Width	ω	D_c	Width	ω	D_c	Width	ω	D_c	Width	ω	D_c	Width	ω	D_c
5	171	✗4.3	79	204	✗3.6	68	171	✗4.3	79	530	✓1.4	31	269	✗2.7	54	660	✓1.1	26
6	205	✗3.6	68	275	✗2.7	54	205	✗3.6	68	241	✗3.1	60	498	✓1.5	33	605	✓1.2	28
7	83	✗7.9	131	105	✗6.2	107	228	✗2.9	56	305	✓2.1	44	260	✗2.5	51	652	✓1.0	24
8	152	✗3.9	73	276	✓2.1	44	340	✓1.7	37	162	✗3.6	69	307	✓1.9	41	628	✓0.9	22
9	125	✗6.2	107	125	✗6.2	107	620	✓1.3	28	156	✗5.0	89	210	✗3.7	70	707	✓1.1	26
10.1	143	✗5.6	99	143	✗5.6	99	565	✓1.4	32	151	✗5.3	94	328	✗2.5	50	758	✓1.1	25
10.2	298	✓2.1	44	416	✓1.5	33	320	✓2.0	41	312	✓2.0	42	540	✓1.2	27	695	✓0.9	22
10.3	245	✗3.2	61	245	✗3.2	61	245	✗3.2	61	251	✗3.1	60	776	✓1.0	24	784	✓1.0	23
11.1	181	✗3.6	69	182	✗3.6	69	529	✓1.2	28	312	✓2.1	44	337	✓2.0	41	817	✓0.8	20
11.2	180	✗3.6	69	197	✗3.3	64	346	✓1.9	40	274	✗2.4	49	531	✓1.2	28	809	✓0.8	20
12	207	✗3.3	63	215	✗3.2	61	419	✓1.6	35	240	✗2.8	56	652	✓1.0	24	906	✓0.7	19
13	95	✗6.7	115	300	✓2.1	44	514	✓1.3	29	166	✗3.9	73	237	✗2.7	54	876	✓0.7	18
14.1	371	✓1.8	39	499	✓1.4	31	398	✓1.7	37	605	✓1.1	26	665	✓1.0	24	1027	✓0.7	17
14.2	185	✗3.5	67	198	✗3.3	63	210	✗3.1	60	391	✓1.7	36	464	✓1.4	31	683	✓0.9	23
14.3	318	✓2.1	43	322	✓2.0	43	356	✓1.9	39	366	✓1.8	38	826	✓0.8	20	905	✓0.7	18
15.1	328	✓2.2	46	444	✓1.7	36	331	✓2.2	46	377	✓2.0	41	916	✓0.8	20	1083	✓0.7	17
15.2	330	✓1.8	38	424	✓1.4	31	330	✓1.8	38	333	✓1.8	38	849	✓0.7	18	946	✓0.6	16

Lastly, it is important to remember that the values presented in Figure 7 and Table 4 represent average bed material mobility/stability in the floodplain both spatially over a large area and temporally over long periods of time (decades to centuries). In the short-term, stream power conditions will vary laterally and longitudinally across the floodplain. These average values are effective for generalized, large-scale decision making, but may not serve as accurate goals for specific project design and objectives.

Figure 8 shows a summary of the ecological communities as a function of floodplain width. Again, the data corroborates the notion that 300 feet is the minimum desired width considering that the presence of wetlands within the floodplain are not present at widths less than 300 feet.

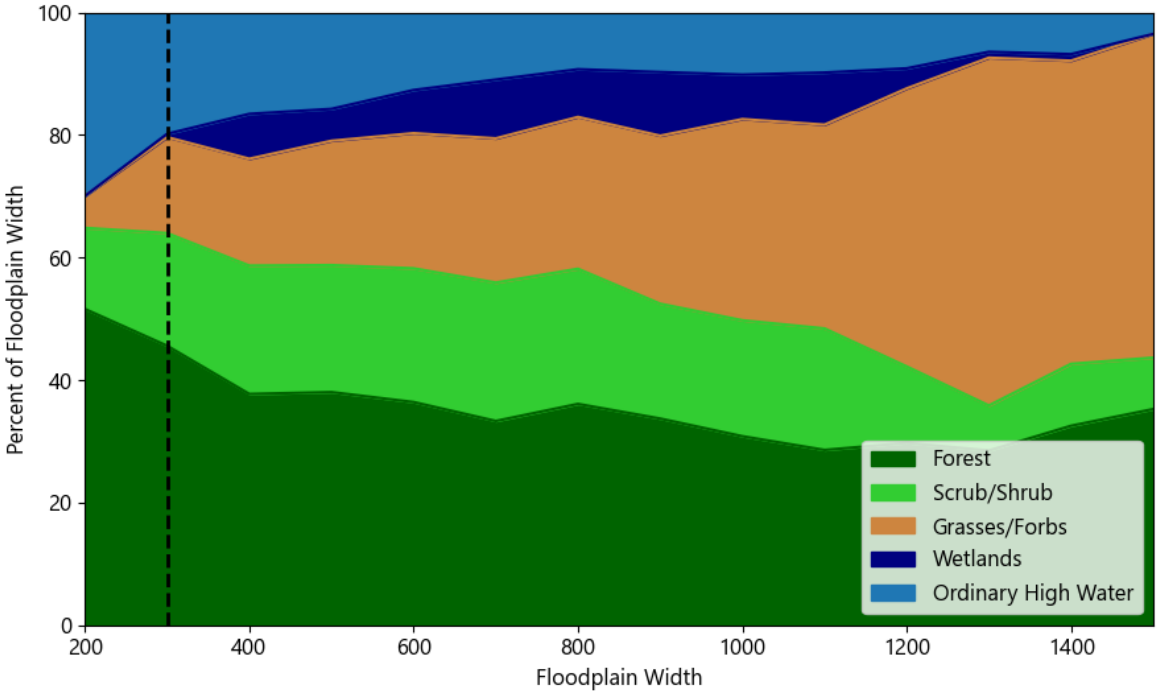


Figure 8: Summary of distribution of ecological communities by floodplain width. Results show the mean value per 100-foot floodplain width bin. Dashed black line denotes the minimum desired width of 300 feet.

Discussion

The results of this assessment largely support and corroborate the findings in the 2021 Restoration Prioritization memo that the river has experienced widespread incision, and that confining infrastructure diminishes the natural recovery potential of the river. Given the dynamism of the Tucannon River and observed propensity to widen and develop a multi-thread channel when space is available, we conclude that the river is impacted by elevated sediment transport capacity due to incision and confinement relative to historic conditions.

Based on the elevated sediment transport capacity within the reach, treatment alternatives beyond the 2021 Gravel Augmentation Plan, which calls for annual placement of small quantities (<1000 CY) along channel margins, should be evaluated to overcome the legacy of incision and confinement. Additionally, the construction of pilot channels and side channels down to the existing low flow water surface (300 cfs per the Anchor QEA 2021 report) does not address incision directly (by raising the bed) and only marginally increases the wetted/floodplain width. To achieve the greatest amount of functional uplift of the channel-floodplain interaction, and therefore, habitat, it will be necessary to

address the effects of the incision and reduced floodplain connectivity more aggressively and holistically. We agree with the general restoration recommendations laid forth in the Anchor QEA 2021 report (address encroaching features, reconnect/develop side channels, develop instream structure – wood, riparian zone enhancement, modify or remove obstructions, road relocation), however, our analysis identifies the need for large-scale floodplain restoration and reconnection.

Some specific recommendations to more directly address incision include reconfiguration or relocation of confining infrastructure where possible, floodplain grading to remove artificially high areas such as berms and roads and reconnect existing low-lying terrain, selective filling of the channel (while avoiding sensitive wetlands) to further engage flow across the floodplain, and increasing roughness through wood habitat structures and/or roughened channels. These actions effectively restore floodplain and channel elevations to maximize floodplain engagement, minimize stream power per unit width, re-initiate sediment deposition, and raise groundwater tables to promote vegetation success.

Conclusion

In conclusion, we summarize the findings of the analyses and results in this memo with three key takeaways:

- A 300-foot width floodplain should only serve as a minimum target for floodplain reconnection; benefits to fish and aquatic species continue to be gained with increasing width up to full valley-wide reconnection. The relationship between space and floodplain function is being evaluated from multiple perspectives in a separate memo.
- Incision and infrastructure should be addressed in concert; addressing only one or the other is often impractical and insufficient in achieving the minimum floodplain width target.
- Incision can be addressed through means of floodplain grading, channel fill, and increased roughness to overcome the elevated stream power and yield desired floodplain width restoration targets.

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Benefits and Needs for Floodplain Space in the Tucannon River

Project: Tucannon River Project Area 5-15 Assessment and Conceptual Design

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Date: March 2, 2026

ABSTRACT

The valley bottom of the Tucannon River within the W.T. Wooten Wildlife Area has multiple demands on limited space. To support multi-use planning of restoration, infrastructure, and recreation, we conducted an assessment to understand the (1) current state of the floodplain, (2) benefits from providing the river space, and (3) minimum space needed to support long-term floodplain resilience. Our geomorphically-based floodplain mapping approach revealed that the active floodplain is approximately 30% the area of the pre-disturbance floodplain. Incision is the major factor causing that historical disconnection, with artificial lakes, roads, and levees representing additional and significant factors (W2r, 2024). To understand benefits of space, we developed reach-specific regressions that relate floodplain width to various hydraulic, geomorphic, and habitat measures. These "benefit curves" and related analyses revealed that wider floodplains, and therefore restoration, provide more flood inundation, reduced erosion potential, improved infrastructure resilience, reduced redd scour, increased edge habitat, and more wood retention. The benefit curves provide planning tools for alternatives evaluation and future design phases. The analysis of space need revealed that a floodplain width of at least 450 feet (~10 times bankfull width) provides resilience against future incision. This low bookend target was based on multiple analyses of floodplain width relative to bed stability, gravel deposition potential, and wood retention. It provides a general guide for planning that should be augmented with site-specific analyses.

1 Introduction

The Tucannon Project Area (PA) 5-15 Assessment and Design Project (Project) will create a plan to restore the floodplain of the W.T. Wooten Wildlife Area (managed by Washington Department of

Fish and Wildlife [WDFW]) for multiple objectives and uses. The project area, which includes the river and the surrounding valley bottom, provides key services for the ecosystem and local community. The project area is a core spawning and rearing area for Tucannon River spring Chinook, a First Food for members of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Nez Perce Tribes (NPT) that is critically imperiled. Restoration actions geared toward recovery, in part, emphasize floodplain restoration. The valley bottom also experiences significant recreational use, housing seven constructed fishing lakes, nine public campgrounds, a fish hatchery, miles of roads, and other infrastructure. In short, both the ecosystem needs and recreational uses require space. Therefore, balancing space needs will be central to decision making for the overall project.

Here, we report on an assessment of floodplain space to support the complex considerations involved in balancing multiple uses within this valley bottom area. We have addressed three key questions to help inform an integrated and well-rationalized plan that makes the best use of the space available in the project area. These questions and our approach include:

- **What is the state of the floodplain?** We mapped the current floodplain to understand existing connectivity and factors causing disconnection. We also mapped the historical floodplain to understand pre-disturbance conditions and to contextualize loss in connectivity over time. The work to understand the state of the floodplain is integrated with previous mapping by Wolf Water Resources (W2r).
- **What are the benefits of space?** Through site-specific technical analysis, we quantified the benefits of floodplain space to understand relative trade-offs in restoration and multi-use planning. Our general approach was to develop a series of curves ("benefit curves") relating floodplain width to various hydraulic, geomorphic, and habitat related parameters. We specifically addressed floodplain inundation patterns, stream power, erosion risk, salmon redd resilience, habitat complexity, and large wood retention. These curves provide tools to support alternatives analyses and other planning-level assessments.
- **How much space does the river need?** This analysis resulted in a recommended minimum floodplain width to support long-term ecosystem function. The corresponding "low bookend space target" is intended to support planning of restoration and infrastructure actions. The minimum width may support balanced decision making around questions like "how much does infrastructure need to be setback?" and "how much floodplain needs to be restored?"

This work relied on hydraulic modeling by W2r, and input and data from CTUIR, WDFW, NPT, and Snake River Salmon Recovery Board (SRSRB). We appreciate those contributions.

This report is also accompanied by an attached map of the reach and floodplain.

2 | Background – Importance of Floodplains and Space

Process space is fundamental to healthy riverine function and resilience (Hauer et al. 2016). Connected floodplains support diverse aquatic and terrestrial habitats through processes like attenuation of peak floods, sediment deposition and sorting, nutrient and wood retention and

cycling, and increased habitat diversity (e.g., Hauer et al., 2016). When rivers have adequate lateral space, they can adjust to disturbance events (e.g., large floods), evolve and build habitat naturally through processes like channel migration and bar formation, and support well-connected floodplain and riparian habitats for the benefit of aquatic and terrestrial species (e.g., Biron et al., 2014)

Low-lying and gently sloped floodplain areas have historically represented opportunities for land and infrastructure development (e.g., Hauer et al., 2016). In addition to encroaching and developing within historical floodplains, land development typically involved significant efforts to tame dynamic river processes. Most often, historical land development confined streams and narrowed their floodplains, which concentrated water and energy within a smaller space. In turn, streams became more erosive and degraded through processes of incision and channel erosion, which further reduced natural stream condition, habitat diversity, and floodplain connectivity (Cluer and Thorne, 2014). At the same time, concentrated erosion and flood potential often exacerbated risks and management challenges for communities and infrastructure owners within or adjacent to the floodplain. These negative feedback loops highlight the complex challenges and needs for balanced management approaches in floodplains.

In recognition of these challenges, communities have developed tools to map channel migration zones and process space (e.g., Rapp and Abbe, 2003; Olson et al. 2014; and Biron et al., 2014). These methodologies often map broad areas with similar extents to the historical floodplains. A parallel and recently emerging focus relates to the space *needs* for rivers (e.g., Nelson et al. 2024). The question of need comes into play especially where managers desire to maintain sustainable river function in a corridor while maintaining some amount of development on the floodplain margin or fringe.

This study addresses both the benefits and needs for space with an analysis specific to the Tucannon River. The objective is to support decision-making and targets for floodplain restoration and infrastructure resilience.

3 | Study Area & Baseline Conditions

3.1 Study Area

The Tucannon River PA 5-15 project area encompasses the valley bottom area of a 10-mile reach (river miles 36.25 – 46.5) within the W.T. Wooten Wildlife Area managed by WDFW. The US Forest Service (USFS) also owns a small portion of the project area. The project area supports ESA-listed Snake River spring Chinook, summer steelhead, and bull trout and has been a focus of restoration by multiple sponsors throughout the previous decades. The approximately 800-1000-foot-wide valley bottom includes eight artificial fishing ponds, nine official campgrounds (eight managed by WDFW, one managed by US Forest Service), the Tucannon River Fish Hatchery and other features. The Tucannon River road and several spur roads run the length of the reach and cross the river three times.

3.2 Historical Summary of Stream Impacts

The project reach has a well-documented history of impacts to the river from homesteading, beaver trapping, logging, wood removal, channel straightening, road construction, fishing lake construction, and levee construction (e.g., Anchor, 2021; Figure 1). In effect, these historical activities encroached on the floodplain and increased conveyance efficiency of the channel. Together these factors increased stream power and caused widespread incision (W2r, 2024).



Figure 1 | Historical photograph, taken 1906, of a log mill in the Tucannon River floodplain. Source: USFS

4 | Data and Methods

The methodological descriptions in this section address core elements of the study. Additional calculations and rationale are described later in the report to maintain continuity with reporting of results.

4.1 Baseline Datasets and Modeling

We used topographic and geomorphic datasets throughout the study. We used topo-bathymetric Light Detection and Ranging (LiDAR) data collected 2020 (NV5). We used physical stream data, including sediment gradations and bankfull channel measurements, measured by the Columbia Habitat Monitoring Program (CHaMP). We used additional sediment gradation data measured by Del Groat and Dowdy (2008).

We used hydraulic modeling results produced by W2r for a significant portion of our analysis. They modeled hydraulics using HEC-RAS 2D program, utilizing relevant flow inputs shown in **Table** 1. Their modeling utilized terrain from the same LiDAR (2020). Our analysis made use of model outputs including raster representations of simulated flow depth, velocity, shear stress, and water surface elevation. The hydrology estimates and hydraulic modeling methods are described in greater detail in related project documentation.

Table 1 | Peak flood statistics utilized for hydraulic model runs relevant to this study

Annual Exceedance Probability (AEP)	Recurrence Interval (Year)	Discharge
0.5	2	670
0.1	10	2300
0.01	100	6500

4.2 Floodplain Mapping

Mapping of the Currently Connected (Active) Floodplain

Our study approach required a consistently defined and contiguous polygon representing the actively connected floodplain along the project area. Because river flows naturally vary though time and with watershed position, the definition of a connected floodplain is often subjective and cannot easily be set with a single flow rate or inundation extent. For the purposes of this study, the definition also needed to capture variations in vertical and lateral connectivity along the river corridor.

The definition of flood prone width, originally established by Rosgen (1994), meets the objectives above. Flood prone width is a geomorphic definition measured at a specified height above the thalweg equivalent to two times bankfull stage (Figure 2). In a traditional field application, flood prone width is measured at the crest of riffles, because of their role as local hydraulic controls for floodplain inundation. The definition is independent of scale, captures variations in floodplain width based on both lateral and vertical changes in connectivity, and can be applied spatially to map a connected flood prone area (polygon) as well as width.

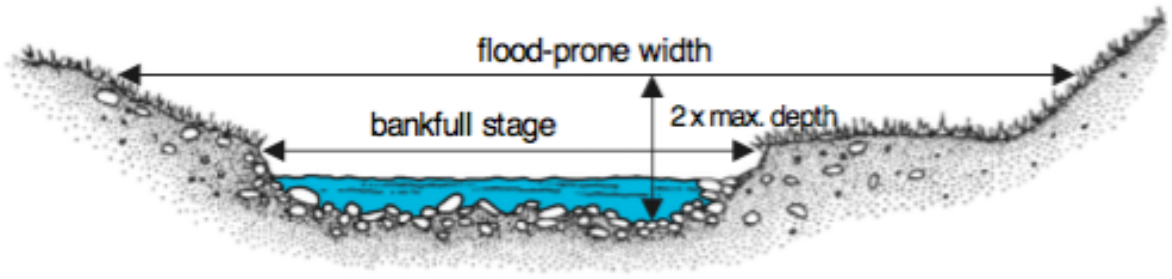


Figure 2 | Flood prone width (Rosgen, 1994), visually defined along a channel cross-section. Figure source: North Caroline State University

We mapped flood prone area and width using available LiDAR data and bankfull measurements (CHaMP) distributed along the project reach. The mapping process involved the following steps:

1. Calculated reach-average bankfull depth at 1.7 feet (n = 26 measurements). We determined it was appropriate to apply a single average, because the reach has no major tributary confluences and had no detectable along-stream trends in the bankfull measurements. For general reference, we also calculated the reach-average bankfull width at 44 feet.
2. Developed a Relative Elevation Model (REM) using the Inverse Distance Weighted (IDW) methodology outlined by Olson et al. (2014). We developed the REM using a baseline profile represented as points along the channel centerline. The profile points used for the REM were identified as probable riffle crests based on having a local maximum elevation value within a moving window along the stream profile. This step was necessary because the LiDAR captures bathymetry including deep pools that otherwise would lower the smoothed baseline profile used for the REM.

3. Applied a relative elevation threshold of 2x bankfull depth to define an area (polygon) meeting the relative elevation criteria of flood prone width.
4. Excluded areas from the floodplain polygon that were isolated from the connected floodplain by high topography or infrastructure. This process involved a manual mapping process to remove these areas from the raw polygon produced in step 3 above.

The process resulted in a contiguous and consistently defined polygon representing an actively connected floodplain along the stream. Throughout this report, we refer to both flood prone width and area. From the mapping of flood prone area, we calculated average flood prone width using the following equation:

$$Flood\ Prone\ Width\ (ft) = \frac{Flood\ Prone\ Area\ (ft)}{Length\ Along\ Valley\ (ft)}$$

For the purposes of this work, length was measured along a centerline following the general trend of the mapped flood prone area. This centerline is generally more sinuous than the valley centerline and less sinuous than the channel centerline.

Historical Floodplain Mapping

We also hand-mapped the historical floodplain throughout the project reach based on geomorphic interpretation of the valley bottom. We assumed that the Tucannon River actively interacted with the full extent of the alluvial valley bottom prior to vertical incision caused by anthropogenic disturbances (i.e., Stage 0, Cluer and Thorne, 2014). We identified the historical valley bottom extent by mapping the transition from alluvial valley bottom to hillslope and confining landforms such as alluvial and colluvial fans and Holocene terrace deposits. We identified these confining features through analysis of LiDAR-based elevation and slope rasters.

4.3 Benefit Curve Development from Hydraulic Modeling Results

We proceeded with a general hypothesis that river parameters (e.g. hydraulics, habitat metrics, or stream power) would vary with flood prone width in a regular and quantifiable way. In turn, we expected that these variations would yield "benefit curves" that would inform the potential benefits and trade-offs from restoration or management actions that change the width of the floodplain. The curves follow a similar concept to the riparian benefit curves developed by the Forest Ecosystem Management Assessment Team (1993, Figure 3).

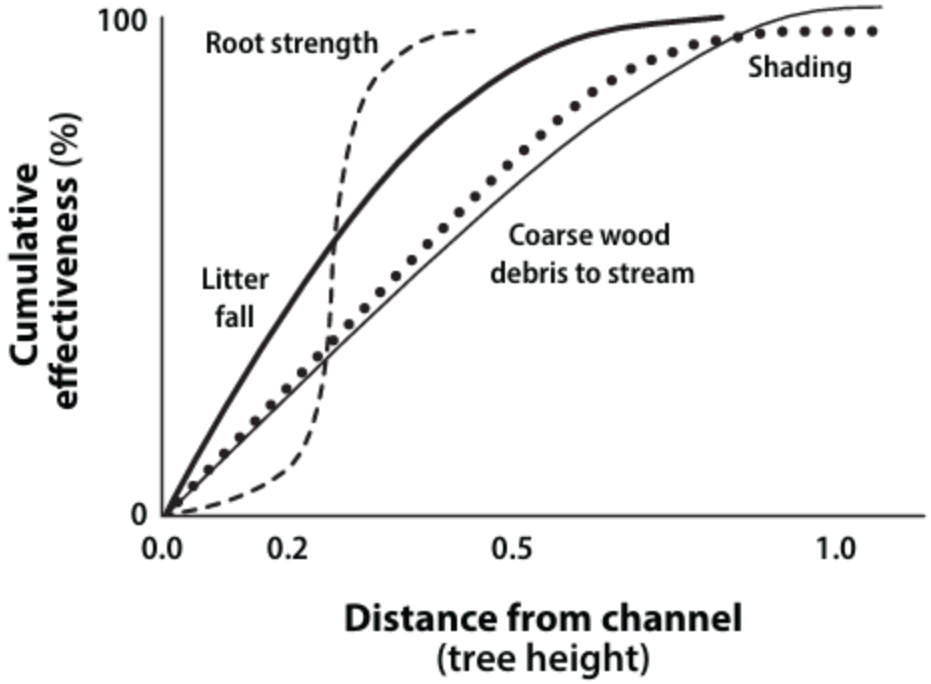


Figure 3 | "FEMAT curves" demonstrating the concept of relative benefits along the lateral dimension of streams and floodplains. Source: Rentz et al. [2020]

We further hypothesized that the benefit curves might have a non-linear shape, implying that marginal benefits from floodplain expansion would also vary depending on the starting width.

To develop benefit curves, we first segment the flood prone area polygon based on equally spaced cross-valley transects. We then measured or modeled river parameters within the segments and developed regression equations using flood prone width as the independent variable.

5 | State of Floodplain Mapping

5.1 Previous State of Floodplain Mapping (W2r)

In a precursor and accompanying memo for the Project, W2r (2024) mapped the state of floodplain connectivity within the project reach (Figure 4). Their mapping distinguished areas of connected and disconnected floodplains within the historical valley bottom. In the disconnected floodplain areas, they mapped areas that were vertically disconnected by historical stream incision and laterally disconnected by infrastructure features. The mapping distinguished laterally disconnected areas by their responsible features, including roads, levees, and fishing lakes.

The mapping by W2r found that approximately 30% of the historical floodplain area remains as connected floodplain (Figure 4). The remainder (~70%) of the historical valley bottom was found to be disconnected. Of the disconnected area, incision is the majority contributor (representing 37% of the historical floodplain). Lateral disconnection accounts for 34% of the historical floodplain, with fishing lakes representing the most impactful laterally confining feature type.

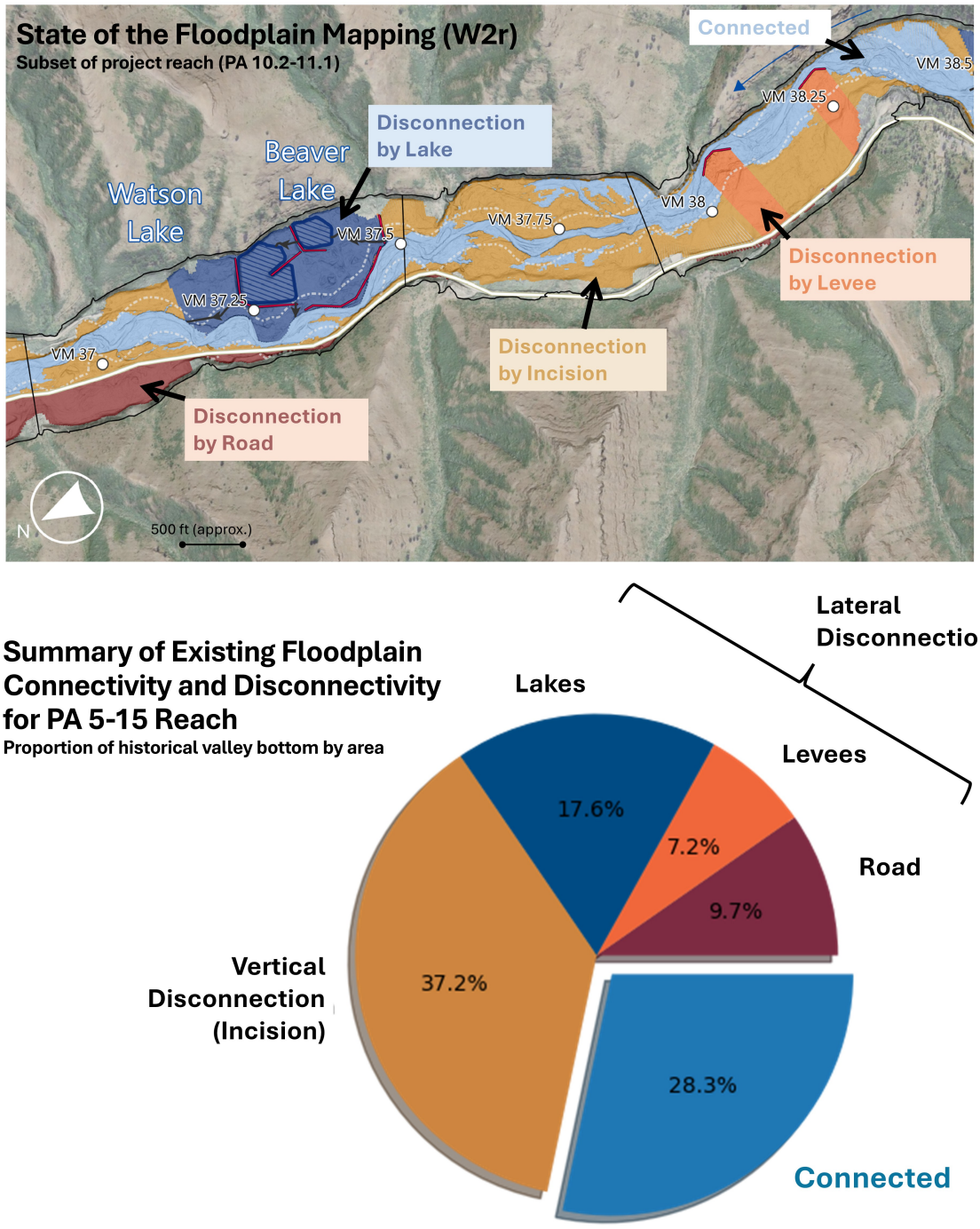


Figure 4 | State of floodplain mapping results by W2r (2024). The mapping assessed (by area) connected and disconnected areas of the historical floodplain within the PA 5-15 project reach.

5.2 Floodplain Mapping for This Study

The mapping of flood prone and historical floodplains (Figure 5, Appendix A) provided a consistent picture of floodplain connectivity in the project area. The mapping in **Figure** 5 also shows the 500-ft segments used for the subsequent analyses.

The mapping revealed an average flood prone width of 220 feet and an average historical floodplain width of 760 feet (**Figure** 6 and 7). Contemporary flood prone widths are 50-650 feet wide, whereas historical widths were 200-1300 feet wide. On average, the flood prone width is about 29% of its historical floodplain extent. These figures generally agree with the original mapping by W2r (2024). Locally, contemporary floodplains are as little as 10% of their historical width.

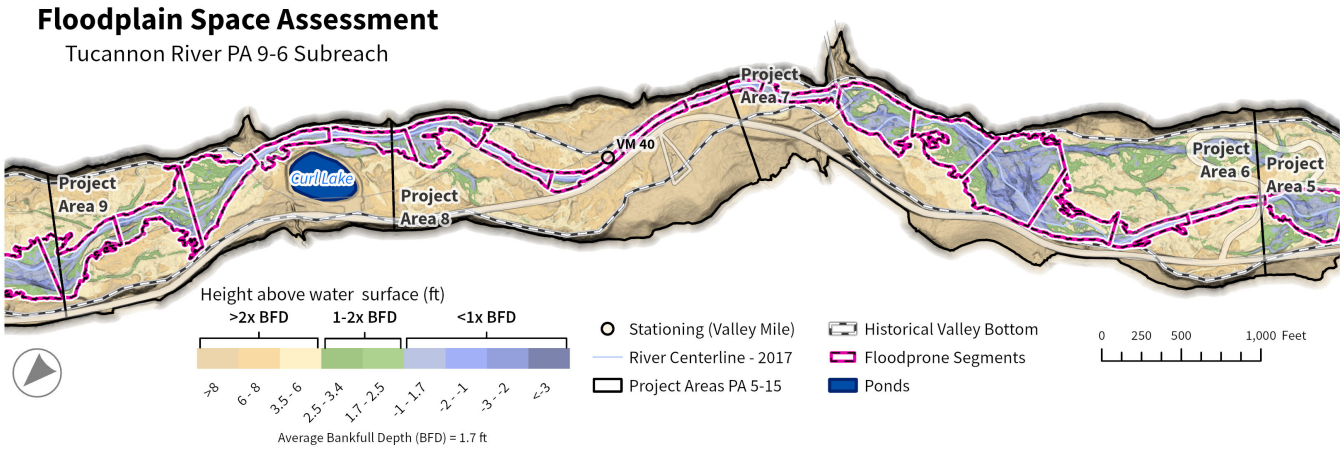


Figure 5 | Mapping of contemporary and historical floodplain extents on a relative elevation model basemap. Attachment A displays this mapping for the whole project reach. The flow direction is right to left.

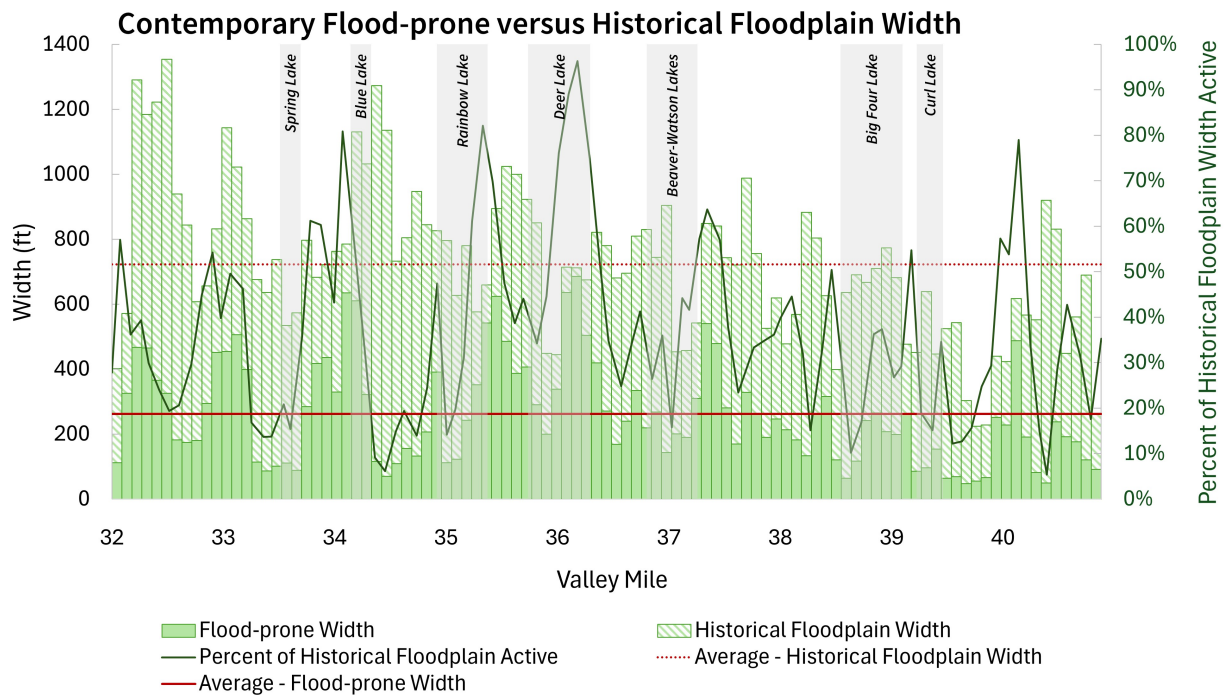


Figure 6 | Historical versus contemporary (flood prone) floodplain width along the PA 5-15 Reach.

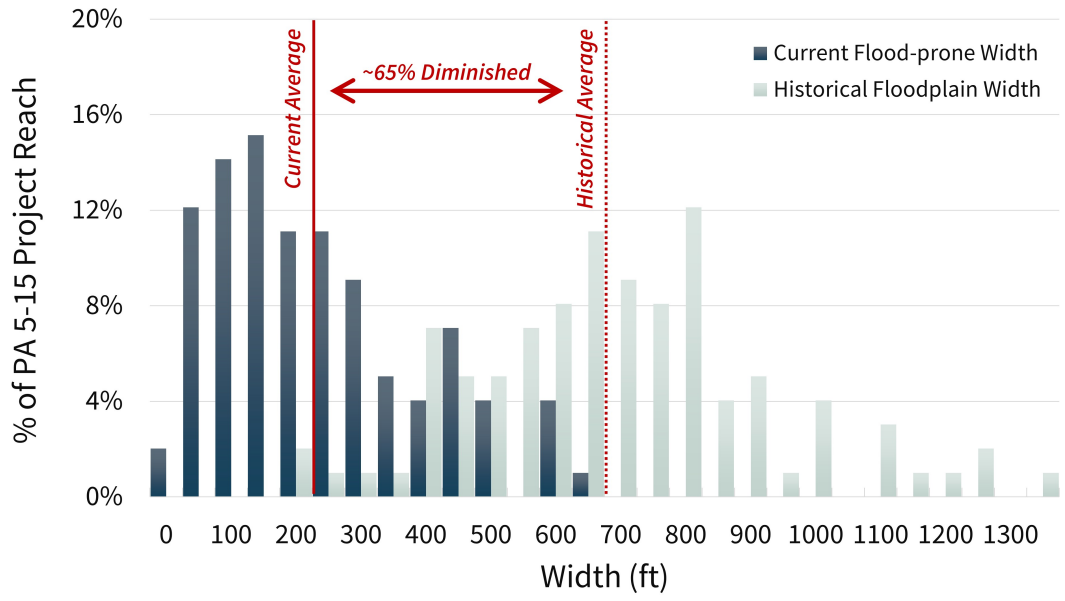


Figure 7 | Histograms of existing floodplain (flood prone) widths and historical valley bottom widths.

6 | What are the Benefits of Space?

As generally described in Section 4.3, we analyzed the benefits of space by developing relationships of flood prone width to a series of hydraulic, geomorphic, and habitat parameters. The specific benefit curves include relationships for river hydraulics (inundation depth, area and velocity), stream power, shear stress (relative to flood erosivity and risk), scour depth (relative to scour depth and redd resilience), and edge habitat. We also assessed the relationship of wood mobility to space using a case study and field observations by SRSRB. The discussions below are organized into the following groupings (1) hydraulics and inundation, (2) erosion and stream power, (3) habitat conditions, and (4) large wood mobility.

6.1 Hydraulics and Inundation

Flood inundation is a core process and measure of floodplain connectivity which varies based on the physical configuration of the floodplain and the stream discharge (e.g. flood event). In this case, we measured the patterns of inundated area (width), volume, and velocity in relation to the flood prone area and width. We assessed these patterns modeled 2-, 10-, and 100-year floods.

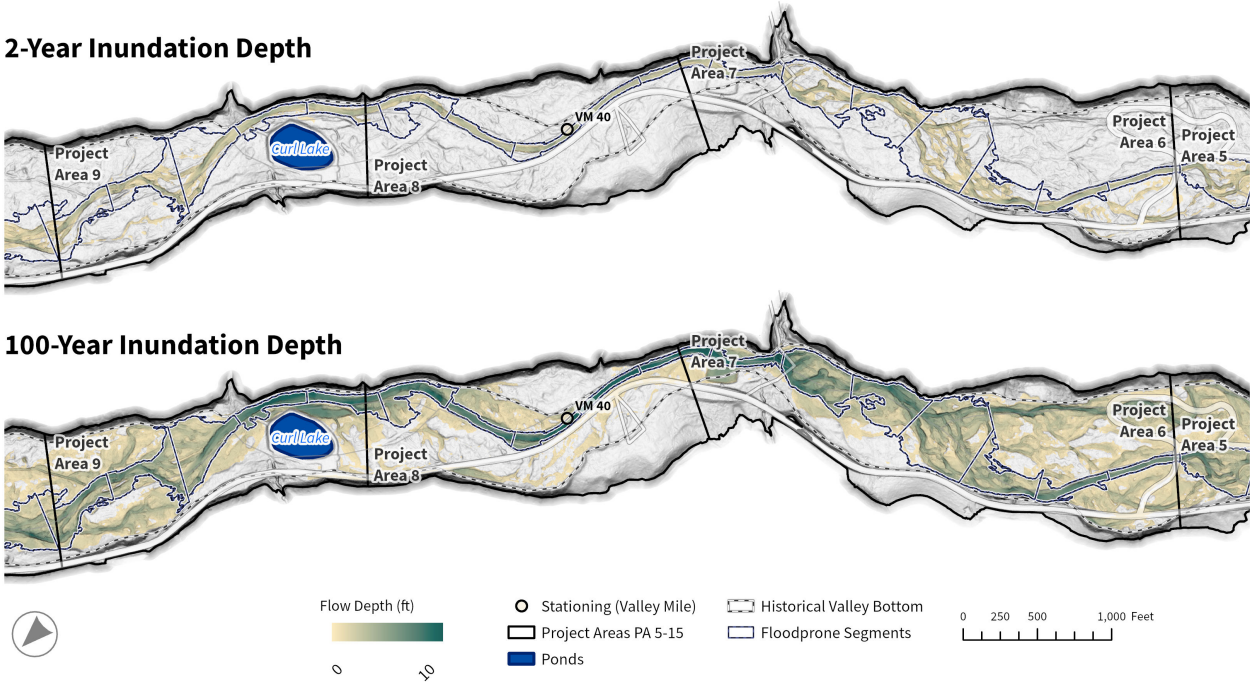


Figure 8 | Example maps of modeled inundation relative to the flood prone area. The flow direction is right to left.

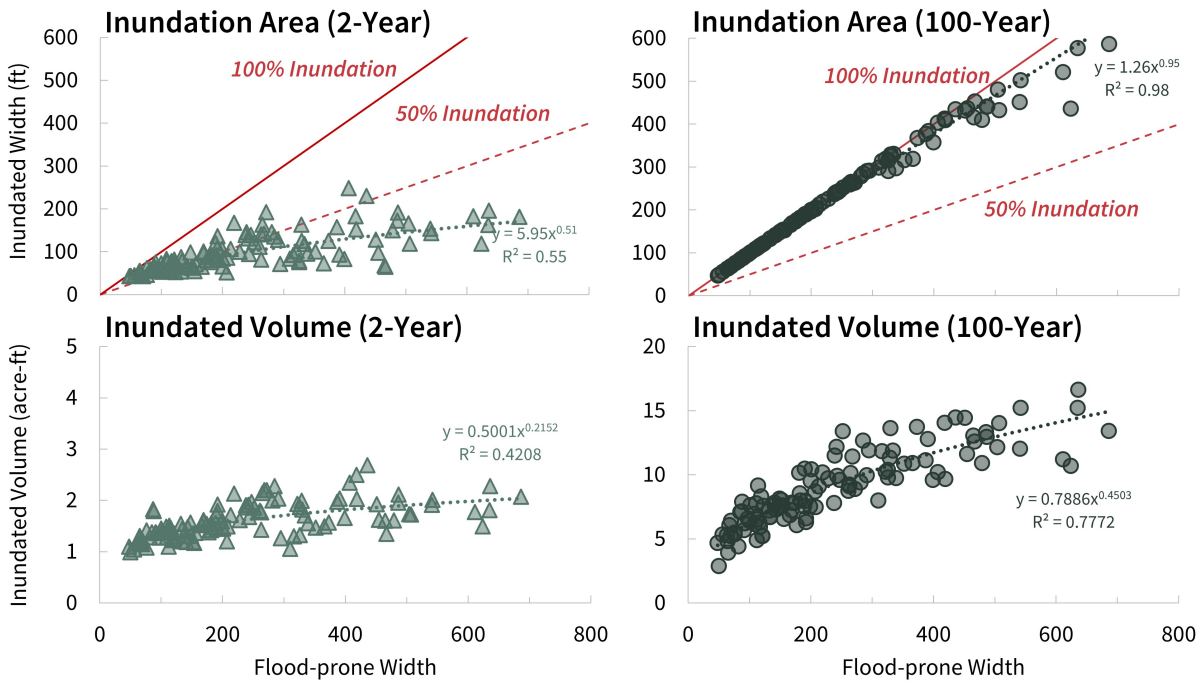


Figure 9 | Inundation width versus floodplain width. Each data point represents a modeled inundation value within a 500-foot segment. Proportional inundation curves (50% and 100% in red) show the inundated area as a portion of the flood prone area. The reported inundation values shown do not include the amounts that may spill outside of the flood prone area for each segment.

6.1.1 Inundated Area and Volume

Figure 9 shows a positive relationship between floodplain width and inundation (area and volume) for both the 2- and 100-year flood events. While not shown, positive relationships also hold for the 10-year flood.

During the 2-year flood, the trends are non-linear such that inundated area as a proportion of flood prone area decreases with increasing width. This pattern is represented by the trend in area diverging from the 1:1 line (100% inundation). It indicates that the 2-year flood is generally insufficient in volume to fill the capacity of the floodplain, except in the narrowest of floodplain segments (i.e., in segments less than 100 feet wide). These patterns are generally visible in Figure 8 where narrow segments (e.g., near Curl Lake) have near full inundation, and wider segments have only part of their area inundated.

The inundation versus width relationship produced for the 100-year event follows a more linear trend along the 1:1 line (**Figure 9** – upper right), indicating that the inundation is more likely to fill the flood prone area to capacity. This is particularly the case in segments narrower than 300 feet where inundation consistently covers 100% of the flood prone area, and significant flooding occurs outside the flood prone area (Figure 8). In floodplains wider than 300 feet, the flood inundates 90-100% of the flood prone area.

Because wider flood prone areas are less likely to fill to capacity, they are also more likely to contain a greater proportion of the total flood inundation (**Figure 10**). In effect, this trend means that areas adjacent to constricted segments are more likely to flood because the flood prone area overflows.

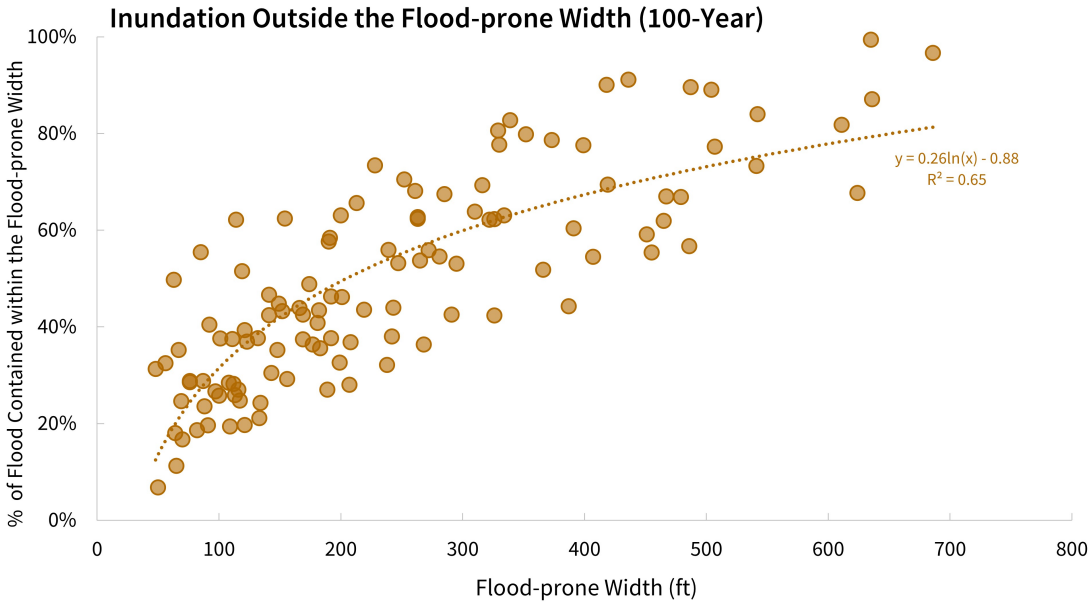


Figure 10 | Flood containment in the flood prone area, as a percentage of total area.

6.1.2 Flow Velocity

The analysis also demonstrates that stream velocities decrease as flood prone width increases (**Figure 11**). These negative relationships exist for both the 2-year and 100-year floods, when averaged by area and volume. The velocity relationships are generally stronger in the 100-year flood, reflecting its tendency to fill the flood prone area to capacity. Average velocities in the narrowest segments are often double or triple the velocities modeled in reaches with flood prone widths >400 ft.

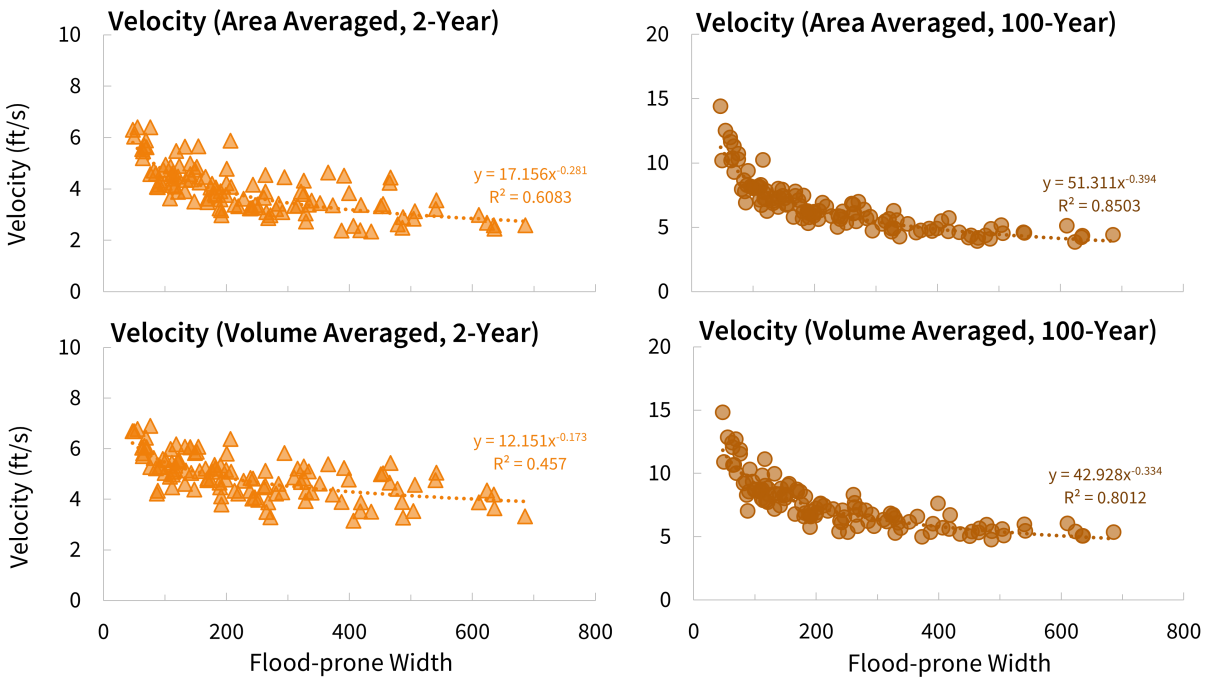


Figure 11 | Modeled flow velocity versus flood prone width.

6.1.3 Implications for Restoration and Management

The analyses of flood inundation and hydraulics have multiple potential implications for restoration and management activities in the project reach.

Restoration Approach

The inundation versus flood prone width relationships imply two general approaches to improving floodplain connectivity, particularly at smaller floods that are more relevant for habitat (in this case, represented by the 2-year flood). First, floodplain reconnection efforts can expand the overall space available (i.e., increase the flood prone width) – this widening approach is represented by moving along the x-axis in **Figure 9**. The alternative reconnection strategy expands the area of inundation *within physical space* defined by the flood prone area. This approach is represented by moving vertically within the data scatter in **Figure 9**. It may be achieved by roughening actions (e.g., wood placement) or grading actions within the active flood prone area. The shapes of the inundation curves versus the degree of scatter imply that widening actions have relatively more connectivity benefit in narrow (artificially constricted) floodplains, whereas the second approach provides more benefit in floodplains that are already quite wide.

Inundation Benchmarks for Design and Planning

The inundation benefit curves provide a generalized reference for future design and planning efforts. For example, a project sponsor might evaluate a given design alternative relative to these benefit curves to assess whether the inundation is appropriate for a given space available. A modeled design alternative with inundation area well above the curve (e.g., high in the data scatter)

would suggest that the opportunity is being maximized for the given space available. Conversely, a design alternative with modeled inundation well below the curve may suggest potential for design improvements.

Potential Flood Impacts and Risks

The inferred patterns of floodplain capacity and overflowing (Figure 10) imply trade-offs with flood risk. In essence, artificially constricted floodplains are more likely to overflow during large floods, and flood overflow typically spills into adjacent areas with roads, campgrounds, and lakes. In other words, the same artificial constrictions that create space for recreational infrastructure also increase the likelihood of that infrastructure being flooded during large events.

Flood Attenuation Potential

The analysis quantitatively demonstrates that floodplain reconnection actions will increase transient storage volumes (Figure 9) and reduce velocities (Figure 11) of floods. Both factors are recognized as important for attenuating peak floods for downstream areas (Paiva and Lima, 2024). Therefore, reconnecting floodplain space in the project area may reduce the magnitude of flood peaks in the lower Tucannon River. While we have not explicitly modeled flood attenuation, these results suggest that there may be benefits from the project that extend to downstream communities.

6.2 Erosion and Stream Power

6.2.1 Specific Stream Power

Stream power is a measure of the energy that water is exerting on the bed and banks of a river (e.g., Yang, 1972). It can be closely linked to a flood's capacity to do geomorphic work (e.g., bank erosion, sediment transport) and is a generalized measure of erosion potential. Natural streams vary in their power through time and spatially along their networks in response to variations in slope, discharge, and valley geometry. Therefore, stream power is not inherently negative and in many cases is positive because it drives natural dynamism that in turn builds diverse and connected habitats (e.g., Beechie et al. 2006). However, stream power is often damaging when it is elevated as a result of land use impacts to the watershed or floodplain. In the case of the Tucannon River, stream power is elevated because of floodplain confinement and incision (W2r, 2024).

We calculated specific stream power (stream power per unit width) by multiplying modeled depth, modeled velocity, reach average slope (0.013), and the specific gravity of water (62.4 lb/ft^3). We applied the calculation to modeled outputs for the 2-, 10-, and 100-year flood events. **Figure 12** shows an example of the corresponding mapping results.

To contextualize the outputs, we compared specific stream power values to thresholds established in Yochum et al. (2017) as follows:

- **Moderate (>16 lb/ft-s):** Potential for substantial channel widening
- **High (>33 lb/ft-s):** Potential for avulsions, braiding and loss of adjacent road embankments
- **Extreme (>48 lb/ft-s):** Major geomorphic change likely

For each segment, we extracted the modeled mean plus two standard deviation value of specific stream power. Based on inspection, this value was determined as a general surrogate for the specific stream power values found in the channel where the highest values are typically concentrated (Figure 12).

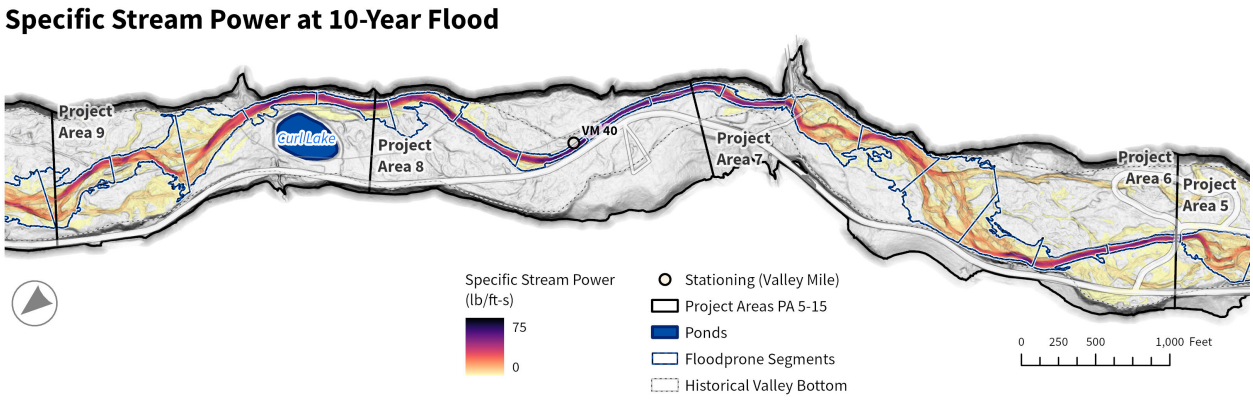


Figure 12 | Map of modeled specific stream power at the 10-year flood relative to the mapped flood prone area. The flow direction is right to left.

On a visual basis, the mapping results (**Figure 12**) suggest a negative association between the flood prone width and the specific stream powers modeled instream (for example, compare high instream values near Curl Lake to the low instream values in the central part of Project Area 6). **Figure 13** demonstrates that the relationship between flood prone width and specific stream power holds for the 2- and 100-year modeled floods.

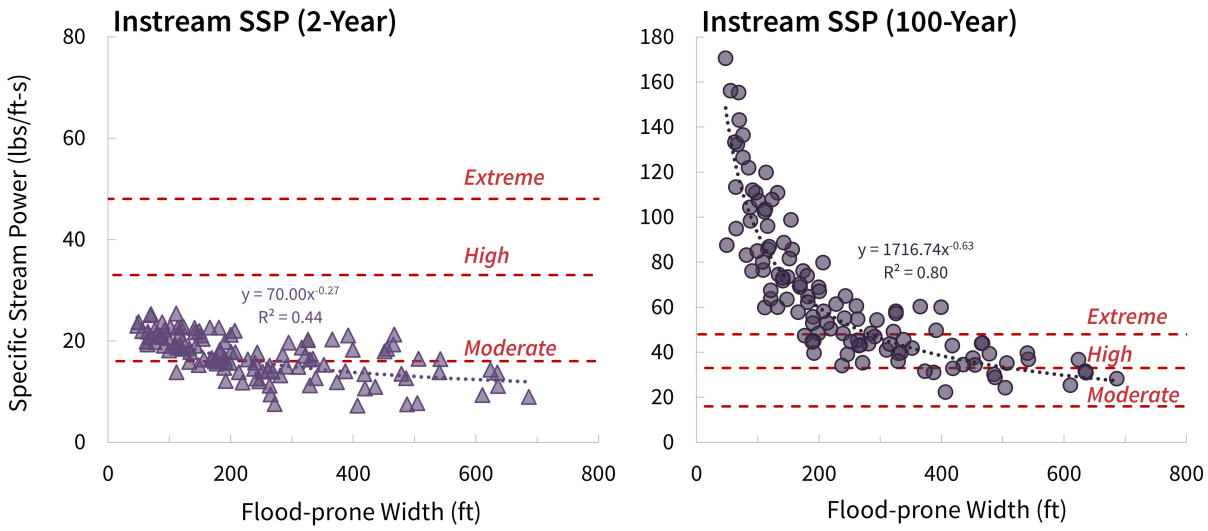


Figure 13 | Instream specific stream power (SSP) for the 2-year (left) and 100-year (right) floods. SSP erosive potential thresholds established by Yochum et al. (2017) are shown in red. The instream SSP value was extracted as the value corresponding to the mean plus two standard deviations within a segment.

At the 2-year flood, specific stream power consistently exceeds the moderate risk threshold in flood prone segments less than 200 ft wide. As flood prone width increases, stream power generally falls below the moderate erosion threshold.

At the 100-year flood, specific stream power values are consistently above the moderate threshold (Yochum et al., 2017) for all segments and flood prone widths. The values are consistently "extreme" at widths narrower than 250 feet, and "high" at widths ranging from 250 feet to 500 ft. As compared to the 2-year flood, specific stream power has an even stronger relationship to flood prone width. This pattern likely results from the 100-year flood filling and engaging with a larger proportion of the flood prone area as described in the previous discussion of flood inundation.

6.2.2 Erosion Potential at Floodplain Margins (Infrastructure Risk)

Stream erosion can directly impact infrastructure such that it fails entirely or requires on-going maintenance. Several points of on-going erosion have been considered in this Project, including at roads, water intakes, and bridge abutments. These infrastructure elements in the project reach are located on the margins of the flood prone area. Based on these spatial relationships, we evaluated the relationship between flood prone width and erosion potential at the margins of the current flood prone area.

Rather than stream power, we selected an analysis approach based on shear stress because it directly informs the physics of erosion and engineering measures (e.g., rock sizing) needed to stabilize against erosion. We first extracted modeled shear stresses (for the modeled 2, 10, and 100-year floods) within 50-foot inward-facing buffers along the floodplain margin of each segment. We then applied the Sheilds (1936) equation to calculate the mobile grain size thresholds:

$$\tau_C = \tau^*(\rho_s - \rho)gD$$

where τ_c is the mean critical shear stress defining the threshold for motion for a given grain diameter (D), assuming τ^* as the dimensionless Shields parameter (assumed 0.03 based on Wilcox et al., 2009), ρ_s and ρ are the densities of sediment and water respectively, and g is gravitational acceleration. This calculation yields maps of critical grain size (**Figure 14**), where larger grain sizes imply greater erosive force and more effort and/or need to stabilize infrastructure elements if present.

Figure 15 shows the critical grain sizes modeled at floodplain margins for the 2-, 10- and 100-year modeled flood events. All three events show a negatively sloped power relationship between width and critical grain size, indicating that erosive force at the floodplain margins decreases as floodplain space increases.

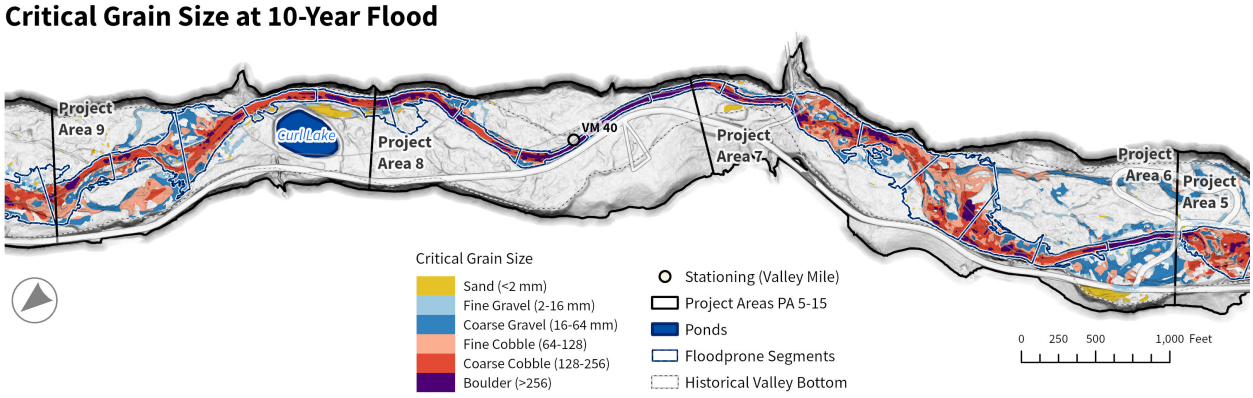


Figure 14 | Map of critical diameter (mm) produced from modeled shear stresses at the 10-year flood. The flow direction is right to left.

At the 2-year flood, narrow flood prone segments (<200 ft) experience sufficient shear stress to mobilize cobbles, while the wider segments (>450 ft) show threshold grain sizes in the gravel range. The erosive potential increases in the 10-year flood where large cobbles are mobilized in narrow segments. The 100-year flood reveals elevated erosion risk at all floodplain widths. In the narrowest flood prone segments, predicted mobile grain sizes reach boulder dimensions, indicating that most natural bank materials would be susceptible to entrainment. In a relative sense, the curves imply that the artificial pinch points created by lakes and infrastructure have converted the erosion potential of a 2-year flood to what would be expected for a 100-year flood in a 700-foot-wide floodplain.

Based on observations of the mapping (**Figure 14**), the relationships appear to result from two general situations. First, shear stresses appear to increase overall as the flood prone area narrows. This pattern likely results from increased flow depths within a constrained space. Secondly, segments with narrower flood prone areas have increased likelihood that the channel will follow the outer margin. In the most extreme cases, the flood prone area is the width of the channel (see VM 40 point in **Figure 14**). These situations pose infrastructure challenges when they follow a roadway or other infrastructure, such as is the case at the bridge crossing to the USFS campground near the upstream end of **Figure 14**.

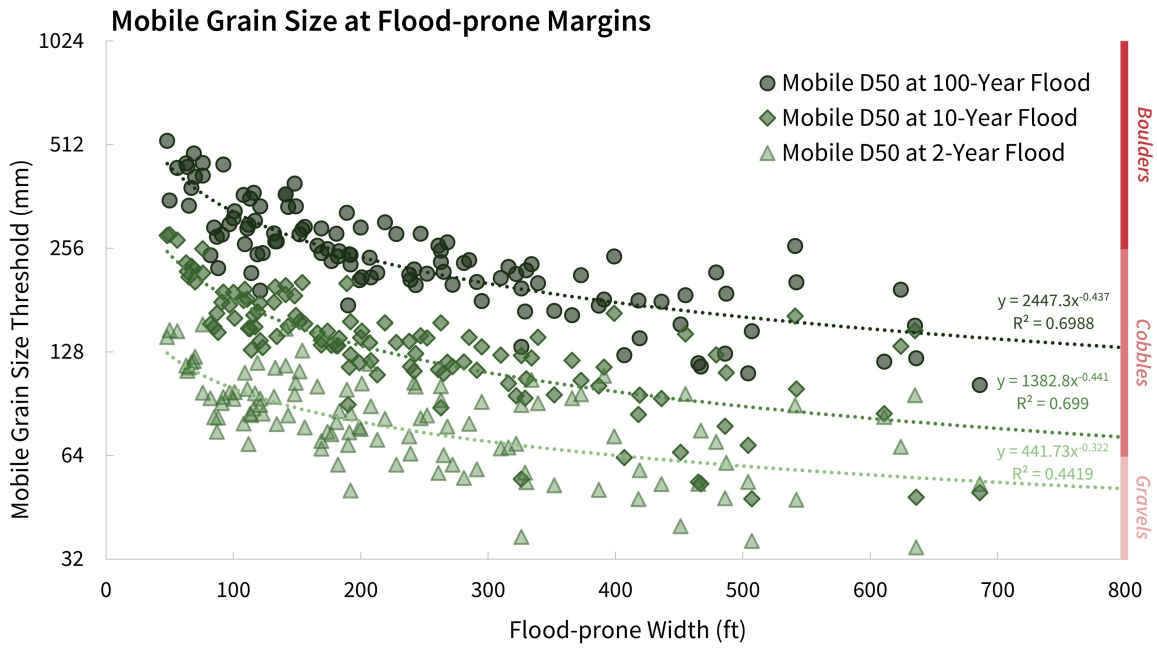


Figure 15 | Mobile grain size at the margins of the flood prone region at the 2-year (triangle), 10-year (diamond), and 100-year (circle) floods.

6.2.3 Implications for Restoration and Management

The analyses reveal expected patterns of increased specific stream power with floodplain narrowing. The increased stream power has several implications including increased incision potential and reduced habitat resilience, which are addressed more explicitly later in this report. The analysis of erosivity at floodplain margins highlights the increased combination of risk, engineered stability, and potential maintenance needed for infrastructure located at along constricted floodplains. Therefore, infrastructure investments that reduce or avoid constrictions of the floodplain may improve longevity and lower life cycle costs.

6.3 Salmon Habitat Conditions

Our analyses of salmon habitat relative to floodplain width addressed key adult and juvenile life histories. We first analyzed scour potential relative to Chinook redds and then evaluated edge habitat length as a surrogate for rearing habitat potential.

6.3.1 Redd Resilience

Background and Motivation

A previous study of the Tucannon River (Hecht et al., 1982[1]) suggested, based on limited data, that excessive scour of the bed and buried salmon eggs was a potentially significant issue and life history

[1] Hecht et al. (1982) investigated bed mobility and redd scour along the Tucannon River from Camp Wooten to Powers Road, near the confluence with the Snake River. They used a combination of scour chains (WY 1980) and artificial redds (WY 1981).

bottleneck. Specifically, mobilization and scouring of bed sediments to depths below buried eggs, during the timing of egg incubation, can result in loss of viability (e.g., May et al., 2009).

In this effort, we evaluated a hypothesis that wider and more well-connected floodplains would reduce scour potential. We focused on impacts to spring Chinook, which are highly imperiled and spawn in the project reach.

Timing of Fish Use and Potentially Scouring Flows

The Tucannon River historically exhibits a snowmelt-influenced hydrograph characterized by elevated mean flows in the spring (especially March through June; **Figure 16**). However, flood events and annual maximum flows, which better reflect the timing of potentially scour inducing flows, have historically been distributed throughout the winter and spring (December-June; **Figure 17**). Furthermore, the seasonal distribution of annual maximum flows suggests a tendency for larger flows to concentrate earlier in the winter from January to February.

Mean Annual Hydrograph and Typical Timing of Life History Stages for Spring Chinook Salmon in the Tucannon Basin

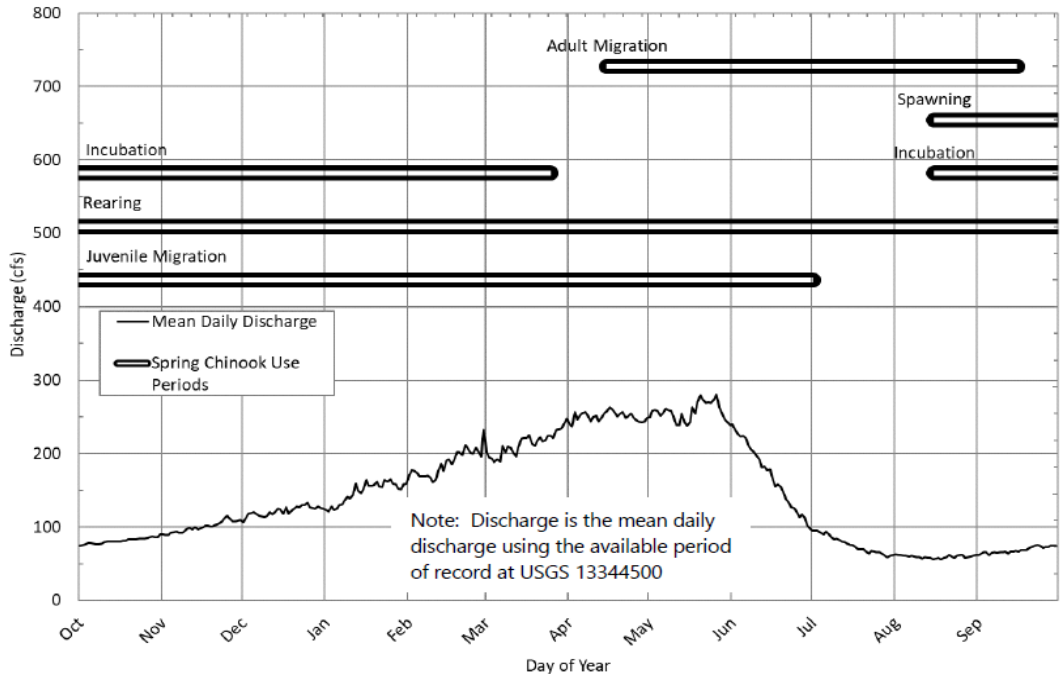


Figure 16 | Mean annual hydrograph relative to use periodicity for spring Chinook (source: Anchor 2021)

Scour chains placed in WY 1980 could not be relocated following high January flows indicating probable scour threatening or destroying redds. Of the five artificial redds placed in WY 1981, only the site near Powers Road, which has a finer bed substrate than upstream sites, experienced sufficient bed scour to disturb redds. The artificial redd study only investigated net scour. It is very likely that maximum scour before infilling on the falling limb of the hydrograph exceeded the maximum scour depth. The combination of results from WY 1980 and WY 1981 that high flow events present redd scour risk along the Tucannon River but additional research was recommended to fully understand redd scour risk.

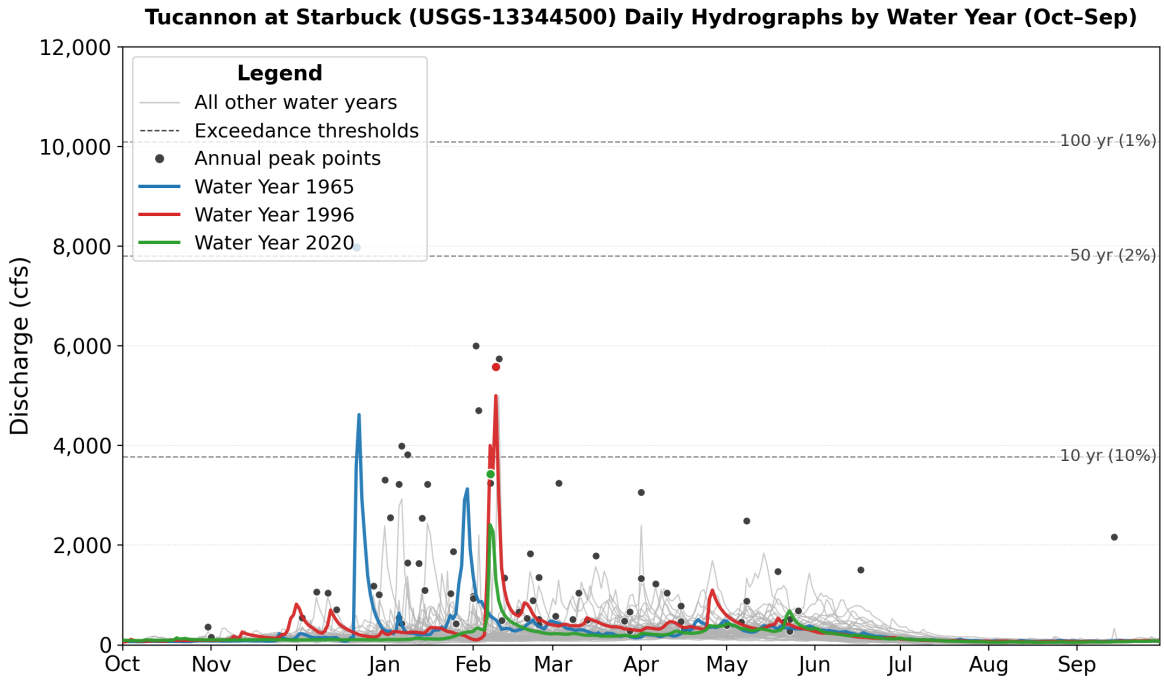


Figure 17 | Plot of individual year hydrographs with annual maxima and the hydrographs of three notable flood years (1965, 1996, and 2020) shown.

Egg incubation timing for critical salmonid species is also distributed throughout the winter and spring. Spring Chinook incubate from October through April (**Figure 16**), fall Chinook incubate from late October to early March, and steelhead eggs incubate from mid-March through late-June (Anchor QEA, 2021).

The fish use and hydrographic data indicate a strong overlap in timing of incubation periods and potentially scouring flows. Furthermore, climate change effects are projected to increase peak flows while shifting them toward autumn and winter (Clifton et al., 2018). These changes potentially exacerbate the potential for redd scour. Collectively, these data and projections reinforce the potential for redd scour based on relative timing of potential scour and incubation periods.

Scour Depth Methodology

As with previous benefit curve analyses, we sought to predict scour depth relative to flood prone width to understand patterns of existing scour risk as well potential effectiveness of restoration as a mitigation measure. We used an empirical relationship developed by May et al. (2009) as a base for scour predictions. The relationship is favorable because it ingests site-specific bed gradation data and shear stress, both of which were available for our study of the Tucannon River. Their relationship predicts relative scour depth (scour depth/90^{th} percentile grain diameter) based on the average dimensionless shear stress (τ*) on the streambed:

$$Relative\ Scour\ Depth = 9301 \times \tau^{*3.29}$$

We first extracted shear stress values (2- and 10-year floods) modeled along the summer low-flow channel mapped within each floodplain segment. The emphasis on the low flow channel reflects the fact that spring Chinook spawn in the late summer season and must build their redds within the wetted channel at that time. Therefore, it is the shear stresses imposed by floods within that low flow footprint that matters for redd resilience. We then converted shear stress (τ) values into dimensionless shear stress (τ^*) using the rearranged Shields (1936) equation:

$$\tau^* = \frac{\tau}{(\rho_s - \rho)gD}$$

where D represents the median grain diameter (D_{50}) as determined using CHaMP data. We estimated D_{50} at the segment level based on an observed downstream fining correlation found in CHaMP. Calculated values of τ^* were then input into the May et al. (2009) equation to yield predictions of relative scour depth within each floodplain segment.

We also needed estimates of D_{90} for each segment to convert predicted values of relative scour depth to absolute scour depth. Because the CHaMP data did not include measured D_{90} values, we used measured ratios of D_{50}/D_{84} from a series of pebble counts by Del Groat and Dowdy (2008) to D_{50} values to D_{90} values for each segment. These calculations yielded a predicted scour depth in centimeters for each floodplain segment, which could then be related to flood prone width in the same fashion as previous benefit curves. We then compared scour depths to egg burial depths reported for Chinook, which ranges from 15-50 centimeters (DeVries, 1997).

Importantly, this approach produces unvalidated scour depth predictions. While our predictions use data and inputs specific to the project reach, we have made no actual measurements of scour depth in the reach. Therefore, the results are preliminary in nature.

Scour Depth Results

Figure 18 displays predicted scour depths as a function of flood prone width for the 2-year and 10-year flood events. Under 2-year flood conditions, the scour depths were generally predicted to be shallower than the top of the egg pocket (15 cm, per the range reported by DeVries [1997]). However, some of the segments narrower than 300 ft width were predicted to scour deeper than 15 centimeters with the deepest prediction of about 28 centimeters. In short, the highest redd scour risk does occur in the narrowest floodplains, but the risk is not definitive at the 2-year flood.

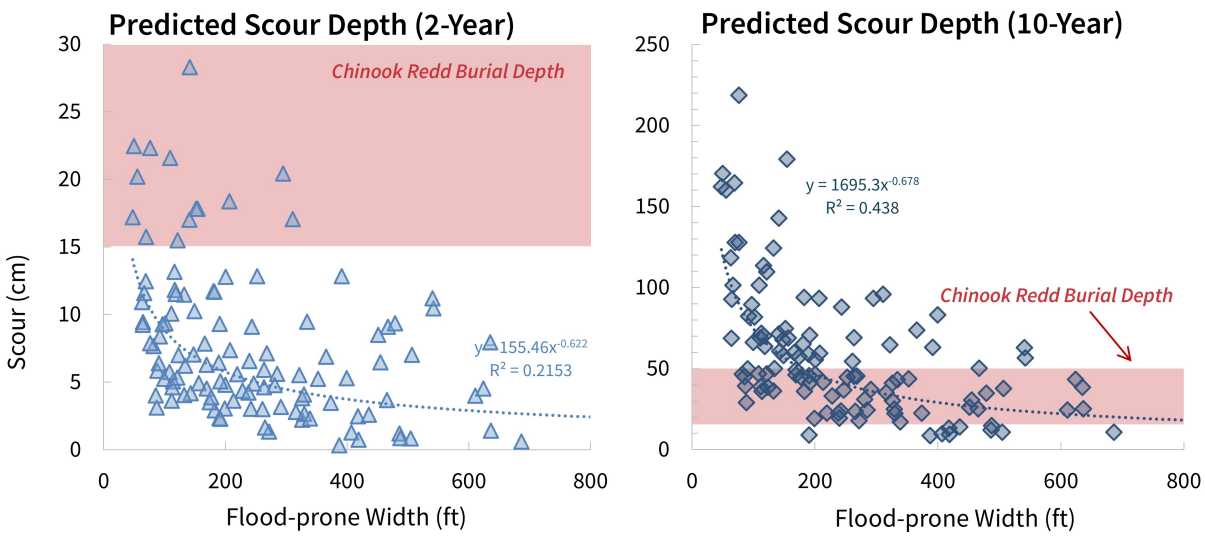


Figure 18 | Predicted scour depth versus flood prone width. Target chinook burial depths from DeVries (1996) highlighted in redd.

At the 10-year flood, predicted scour depths range from 10-220 cm and exhibit a pronounced negative relationship with flood prone width (**Figure 18**). Predicted scour depths consistently exceed 50 cm in the narrowest (<200 ft) segments, suggesting a high scour risk and full disturbance of the egg pockets. In widths from 200-400 feet wide, scour depths consistently exceed 15 cm, and sporadically exceed 50 cm. Risk of egg disturbance remains relatively high in these moderate widths. In segments wider than 400 feet, scour depths are generally below the 50 cm threshold, but still exceed 15 cm. This suggests that egg pocket disturbance is possible at all floodplain widths during the 10-year flood, although wider floodplains offer greater resilience for spawning gravels.

The findings above highlight that redd scour as a probabilistic process that occurs based on variability in hydrology, hydraulics, sediment gradations, egg burial depths, floodplain widths, and other factors. **Figure 19** captures part of this reality by translating scour depth predictions (**Figure 18**) into probabilities of exceedance for the critical burial depth thresholds. We developed these probabilistic curves by analyzing the variability in our predictions (i.e., residuals in **Figure 18**) to calculate exceedance probabilities for 15 cm and 50 cm scour thresholds at any given floodplain width.

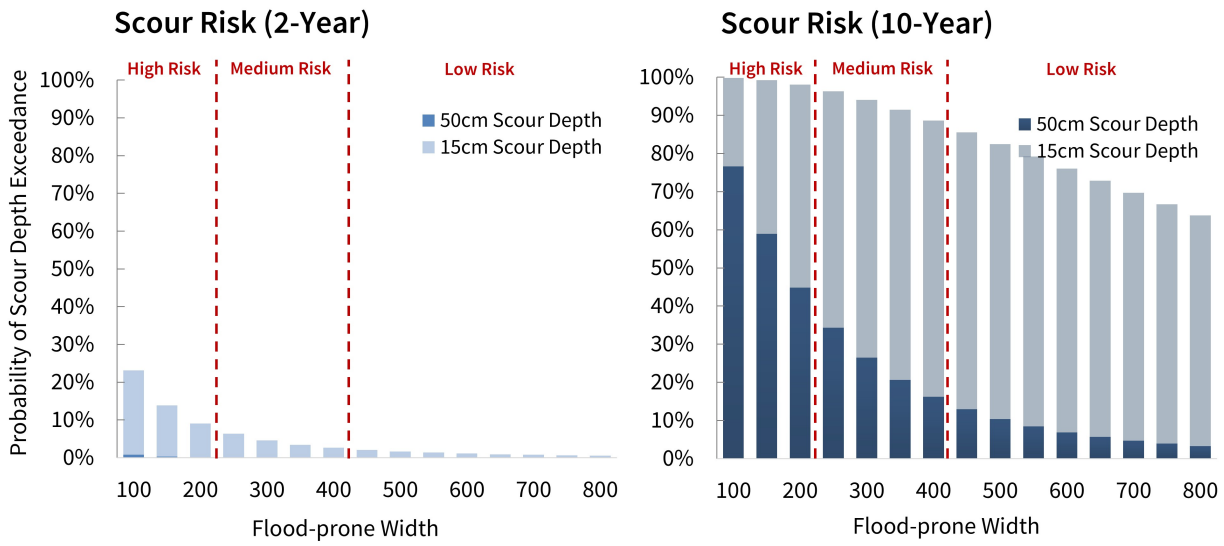


Figure 19 | Probability of exceeding scour depths of 15 cm and 50 cm at the 2-year and 10-year floods. High-risk (<200 ft), medium-risk (200-400 ft), and low-risk (>400 ft) regions delineated by red bars.

Regardless of the flood event, these figures show the increase in scour risk as floodplains become more confined. For planning and communication purposes, we categorized segments into three risk classes based on flood prone width: high risk (less than 200 ft), medium risk (200 – 400 ft), and low risk (greater than 400 ft).

During the 2-year flood, the probability of scouring at least 15 cm exceeds 10% in high-risk segments but drops below 5% in medium-risk areas and becomes negligible in low-risk segments. The 10-year flood presents substantially higher scour risk across all floodplain widths. In segments less than 200 ft, the risk of scouring to 50 cm exceeds 40% with probabilities of exceeding 15 cm approaching 100%. In low-risk segments, the risk of scouring to 15 cm remains above 60%, but the risk of scouring the entire egg pocket drops to below 15%.

6.3.2 Edge Habitat/Complexity

Edge habitat is well-established for its role in providing critical refuge, feeding, and rearing areas for salmonids, particularly during high flow events when main channel velocities are high (Beechie et al. 2005). We took a simplified approach to assess the relationship of edge habitat quantity to flood prone width. For the modeled 2-year flood, we measured perimeter of inundated area within each floodplain segment. We then divided that total perimeter the segment length. With this relative metric, the minimum edge habitat value of two occurs in segments where a single channel has the same length as the floodplain segment (the value of two represents the two channel banks). In this analysis, we take this relative edge habitat metric as a proxy for habitat complexity, where ratios above two may represent increased sinuosity or complex channel-floodplain features like side channels or backwater alcoves.

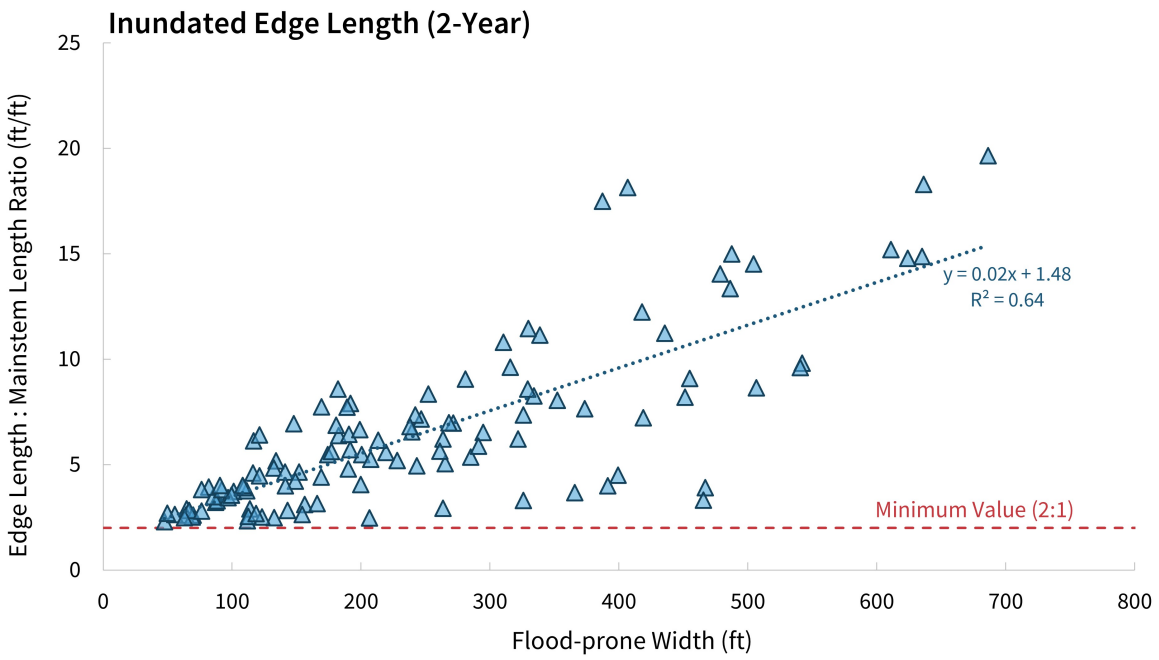


Figure 20 | Edge Length to Mainstem Length ratio compared to flood prone width. The minimum value of 2:1 noted with red dashed line.

Figure 20 shows that edge length increases with flood prone width. The narrowest floodplain segments consistently exhibit edge length ratios near the minimum value, reflecting single-threads with no opportunity for sinuosity or off-channel feature development. As flood prone width increases, edge habitat ratios increase to values up to 15-20 in the widest flood prone segments. These patterns confirm that wider floodplains and more space create potential for more habitat complexity. The wide scatter of these data around the general trend also indicates potential to improve edge habitat complexity within the floodplain space available, especially when the available space is already significant.

6.3.3 Implications for Management and Restoration

The assessed habitat benefit curves quantitatively show increased resilience for salmon life histories with more process space and connected floodplain.

Redd resilience – Our desktop analysis shows that wider floodplains reduce instream shear stresses and, in turn, scour depth. Wider floodplains benefit redd resilience at the full range of floods assed (2- to 10-year floods), but the benefits appear to be more pronounced at the larger floods. We developed probabilistic curves to inform potential scour impact to incubating Chinook eggs. These curves provide preliminary guides for floodplain reconnection strategies that address a potentially key life history bottleneck in the Tucannon River. Climate-related shifts in flood timing and magnitude suggest potentially increasing scour risks through time.

The analysis provides quantifiable information that supports floodplain reconnection as an approach to add life history resilience. Because our analysis was desktop only, future work should include validation and calibration of our relationships using field measurements of scour. Further mapping of spawning gravel availability relative to floodplain width would also provide a broader understanding of spawning suitability and resilience relative to floodplain space.

Rearing habitat complexity – The results show an increased potential for edge habitat and overall flow complexity with increased space. These findings more specifically address juvenile life histories that rely on floodplain habitats for refuge. The assessed relationships suggest that restoration actions can either widen floodplains or restore connectivity within the floodplain space available. The latter approach is most applicable where the floodplain space is already sufficient.

6.4 Case Study: Resilience of Large Wood Treatments

Wood mobility and retention are processes that were also hypothesized to be influenced by the floodplain space available. Wood retention is generally considered desirable from a habitat and ecosystem benefit standpoint because wood supports multiple processes including fish habitat development, hydraulic diversity, sediment sorting, reduced erosion potential, riparian development, and floodplain engagement (e.g., Abbe and Montgomery, 1996; Beechie and Sibley, 1997; Collins et al., 2012). Additionally, installation of large wood as a restoration measure represents a major investment in the Tucannon River and in streams regionwide (Roni et al., 2015). Understanding the role of space in supporting durable wood placements has potential to improve the long-term pay-off from restoration actions.

Wood transport is a dynamic process in river corridors that depends on multiple hydraulic forces and processes including wood buoyancy, sliding, and rotation (Braudrick and Grant, 2000). Wood mobility also depends strongly on the interactions between wood pieces and other obstructions along stream channels, like riparian vegetation (Kramer and Wohl, 2017). These interactions support wood racking and jam formation that are not easily predictable with simple hydraulic calculations and modeling. For these reasons, we elected to assess the relationship between wood mobility and space using an observational case study (led by SRSRB staff) in the project reach.

The case study involved a comparison of two project sites located within the broader PA 5-15 project area, where large wood jams were installed prior to the large flood of 2020 (estimated at 25-year recurrence interval). The two subject projects at PA 6 and PA 9-10.1 involved similar wood loading treatments in 2017, but the two project areas have significantly different amounts of floodplain space available. According to the mapping of flood prone widths for this study, PA 6 has an average of 320 feet of space as compared to 170 feet in PA 9-10.1. In both project areas, SRSRB staff counted wood and documented habitat features at five junctures from 2017-2024. This monitoring captured densities in pre-restoration, post restoration, and post-flood conditions (**Figure 21** shows PA 6 mapping). The relative changes in wood density inform potential wood resilience benefits in a period with a large flood.

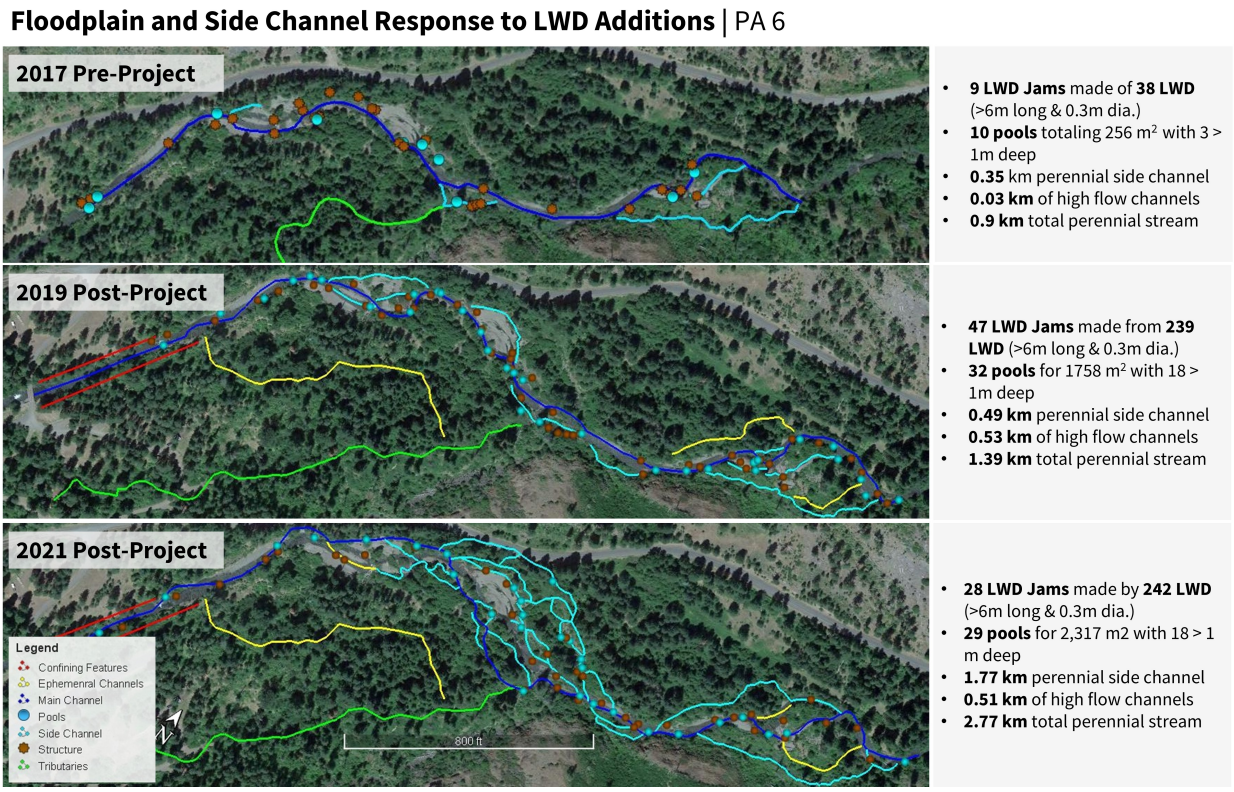


Figure 21 | Aerial imagery comparing pre- and post- restoration LWD and stream length.

Figure 22 shows the large wood counts PAs 6 and 9-10.1 in the period of measurements capturing pre-restoration, post-restoration (e.g., as-built), and post-flood conditions. Counts at both sites capture a significant increase in wood quantities with the additions for restoration purposes. Following installation, the most significant difference in relative site trajectories of wood counts occurs over the period of 2020 flood. The more spacious PA 6 shows negligible differences in pre- and post-flood wood counts, whereas the more confined PA 9-10.1 experienced a 45% reduction. While the loss of wood did not fully negate the original additions, it does represent a significant loss of those investments within a relatively short 5-year period. Supplemental to these data, observational accounts confirm that several constructed wood jams flushed out of the PA 9-10.1 project area during the flood (personal communication, K. Buelow).

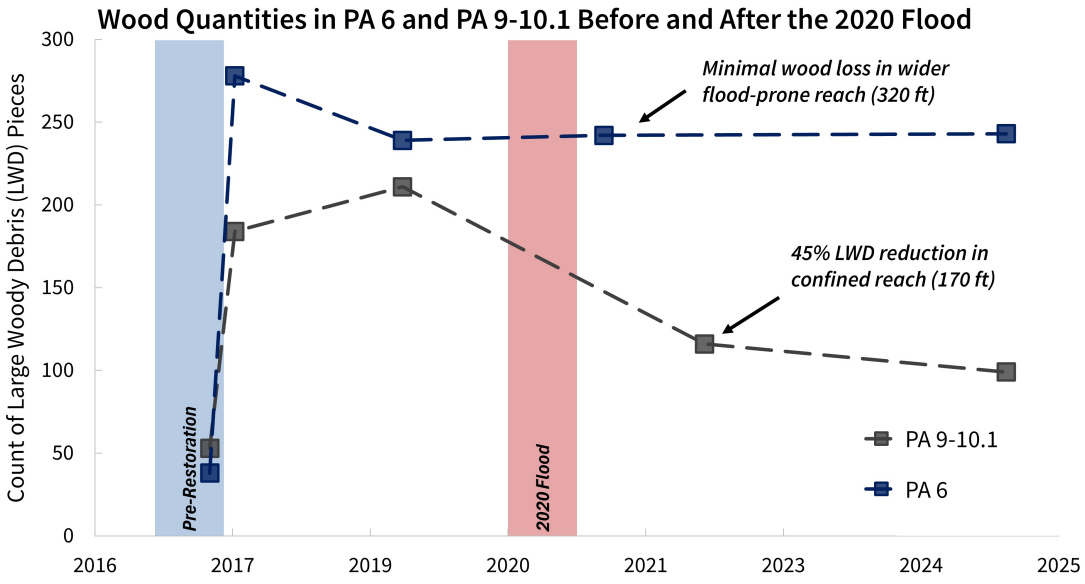


Figure 22 | Large woody debris counts before and after restoration and the 2020 flood in two reaches with contrasting flood prone widths. PA 9-10.1 (grey) has an average flood prone width of 170 ft. PA 6 (blue) has an average flood prone width of 320 ft.

In addition to wood density changes, **Figure 21** illustrates the habitat development that occurred in association with wood retention and space in PA 6. Following the 2017 addition of large wood, both the pool counts and length of perennial stream increased from 2017 (pre-project) and 2019 (post-project). The 2020 flood resulted in temporary reduction in pools. The same period saw a reduction in quantity of wood jams while the count of individual pieces increased slightly, reflecting local redistribution and consolidation of wood into a fewer number of larger jams. Perennial stream length nearly doubled as side channels and multiple flow-paths developed. While not shown here, the more confined PA 9 -10.1 reach had limited change in side channel length in addition to the observed wood losses.

Together, the contrasting flood responses observed in this comparative case study suggest that floodplain space provides benefits for wood retention and habitat formation, especially during flood events. We interpret that extra space in PA 6 reduced the likelihood of wood export by lessening flow depths and velocities, which in turn decreased the likelihood for buoyancy and sliding of wood pieces (Braudrick and Grant, 2000). Engagement and interaction of floodwaters with the floodplain also probably led to increased wood-vegetation and wood-wood interactions so that wood in transport was more likely to rack up and form jams rather than flushing out of the reach. In turn, jam formation and space respectively created the driving processes (e.g., flow splitting, flow concentration, and localized erosion) and opportunities for side channel development. These process interactions together suggest that space was a pre-condition that allowed wood to promote a positive habitat response from the flood in PA 6, rather than the degradation-inducing response observed in PA-9-10.1. Therefore, space – in the form of floodplain width – may represent a

prerequisite condition for successful wood-based restoration measures that set positive trajectories with lasting benefits.

6.5 Summary of Space Benefits

We used several analyses to quantify the benefits of floodplain space for multiple river processes and perspectives. In general, we found that wider floodplains result in more inundation, lower erosion potential, increased habitat potential, and more wood retention. In all cases, when we refer to the width of floodplains or space available, we are referring to the connected floodplain area meeting the definition for flood prone width. Notable findings are summarized below.

Floodplain Hydraulics: Wider floodplains yield greater inundated area and volume, and lower velocities, across all modeled flood events. At smaller, habitat-relevant floods (2-year), inundated area is more variable relative to floodplain width — highlighting opportunities to expand connectivity within existing floodplain space through roughening or grading actions. At larger floods (100-year), floodwaters are more likely to fill the floodplain to capacity. Therefore, wider floodplains show a substantially stronger ability to contain floodwaters within the flood prone area — reducing flood risk to adjacent roads, campgrounds, and recreational infrastructure. Separately, the overall increases in transient storage volume and reductions in velocity across all flood events suggest that floodplain reconnection in the project area has potential to attenuate peak flows for downstream communities.

Stream Power and Erosion: Specific stream power decreases markedly with increasing flood prone width. In the narrowest segments (<200 ft), stream power consistently exceeds moderate-to-extreme erosion thresholds even at the 2-year flood. Erosive force at floodplain margins similarly declines with widening, reducing potential risk and long-term maintenance needs at roads, lakes, and water intakes.

Salmon Habitat Benefits (Redd Scour Resilience and Edge Habitat Potential): Potential scour-inducing flood events overlap strongly with incubation periods for spring Chinook, and this overlap is expected to intensify with climate change. Our probabilistic analysis revealed that predicted scour depth decreases significantly with increasing floodplain width. During the 2-year flood, predicted probability of egg disturbance is relatively low overall despite being elevated in the most constrained floodplains. At the 10-year flood, potential redd disturbance is high in narrow in floodplains, and reduces in wider floodplains. In general, high redd scour risk is concentrated in floodplain segments narrower than 200 ft, moderate risk in the 200–400 ft range, and lower risk above 400 ft. The findings of this scour analysis provide a potentially significant linkage between floodplain connectivity and a key life history bottleneck. The predictions should be validated with field data and additional study.

Separately, edge habitat length during the 2-year flood increases with flood prone width, with the narrowest segments offering minimal opportunity for sinuosity or off-channel features. Wider floodplains support greater habitat complexity, with edge length ratios up to 15–20x in the widest segments. These findings provide support for floodplain reconnection as a strategy for improving juvenile rearing habitats.

Large Wood Retention: Observational evidence from two large wood loading projects installed before the 2020 flood shows that space strongly influenced wood retention and associated habitat development. The more spacious PA 6 (average 320 ft) retained nearly all placed wood, while the confined PA 9-10.1 (average. 170 ft) lost ~45% of its wood load during the flood. PA 6 also showed significant post-flood habitat development, including jam formation and side channel expansion. Together, these findings suggest that adequate floodplain space is a prerequisite for durable wood-based restoration that generates positive habitat responses.

Benefit Curves as Planning Tools: The benefit curves provide useful relationships to inform restoration planning and design in the PA 5-15 reach. They serve two general purposes. First, the curves can project expected benefits from actions that expand floodplain space, informing alternatives analyses by translating proposed width changes into anticipated improvements in hydraulics, erosion potential, habitat, and wood retention. Second, the curves provide benchmarks for evaluating restoration designs within a given footprint — a design achieving inundation or habitat complexity well above the curve suggests the space available is being well utilized, while results falling below the curve may indicate room for design improvement.

7 | How Much Space Does the Tucannon River Need?

The PA 5-15 project planning process requires balancing of multiple objectives with sometimes opposing demands on space within the Tucannon River valley bottom. To inform discussions and decisions about floodplain restoration strategies and infrastructure setbacks, we developed estimates of the minimum space needed for the Tucannon River. This minimum "low bookend" space target provides a guideline for multi-use decision making.

7.1 Conceptual Framework

We established conceptual definition for minimum space based on the specific challenges and needs of the project area. In general, the question of how much space a river needs is not one that can be answered universally to meet all settings, perspectives, and objectives. River floodplains naturally vary in width, in both space and time. The ecological functions and needs also vary based on climate and bioregion. Human uses and needs also vary by setting, land use type, and community. Therefore, space needs are dependent on context and must be established based on the specific setting and application.

The definition for minimum space established for this project and the subsequent analysis was:

> *The "low bookend space" is the width of connected floodplain (i.e., flood prone width) that supports long-lasting connectivity and function of the Tucannon River floodplain. The primary threat to long-lasting function in the project reach is stream incision, in part because incision within one stream segment often threatens several reaches upstream. Therefore, the low bookend width is one which minimizes the potential for stream incision to support whole system resilience over the reach and watershed scale.*

The process of incision occurs when streambed erosion systemically outpaces deposition and replacement by incoming sediment (Booth, 1990). While some previous studies have defined thresholds to map incision potential (e.g., Bizzi and Lerner, 2015), the applicability of these thresholds beyond their original study areas is not clear. Incision is inherently a function of reach-

scale characteristics such as hydrology, sediment size, and sediment supply. Furthermore, stream power naturally varies along river corridors so that one stream power threshold may be natural in one reach and highly erosive in another.

We based on our low bookend determination on reach-specific analyses to establish a minimum space that supports non-incising conditions. Recognizing that incision potential is a function of multiple conditions, we identified three beneficial processes and conditions that individually should contribute to low incision potential:

- **Bed stability:** Incision potential is low if the bed is relatively stable in regular floods.
- **Deposition potential:** Incision potential is low if the actively supplied bed material is likely to deposit instream during regular floods.
- **Large wood retention:** Incision potential is low if large wood is likely to be retained within the channel and floodplain. When retained in the channel, the roughness provided by large wood partitions shear stress and reduces erosion potential (Manga and Kirchner, 2000).

Using multiple-lines-of-evidence approach, we evaluated the space requirements to meet each of the conditions above and then selected a low bookend target for flood prone width as the one meeting all criteria above.

7.2 Technical Analyses to Determine Low Bookend Space Target

7.2.1 Bed Stability

Our bed stability analysis utilized a Shields (1936) incipient motion approach. The Shields equation relates bed shear stress to a grain size experiencing incipient motion. We used the Shields analysis to define the threshold for bed mobility/stability, comparing that threshold to a benefit curve relating flood prone width to shear stress. As with previous Shields analyses in this study, we assumed a Shields parameter of 0.03 (Wilcock et al., 2009).

We developed the relationship between shear stress and flood prone width using the hydraulic model results for the 10-year flood.[2] The 10-year flood represents a relatively large and frequently occurring flood event. It is commonly within the upper range of geomorphically effective flows, which are typically responsible for a disproportionately large amount of sediment transport over time based on their combined frequency and magnitude of sediment transport (Wolman and Miller 1960). In essence, a 10-year flood is sufficiently large to cause significant erosion, while occurring often enough to be responsible for significant changes over the period of several years and decades.

To calculate a bed stability threshold, we used bed gradation data from Del Groat and Dowdy (2008), which included five pebble counts within the wetted channel of the project reach. We selected the average value of the 84th percentiles (D84) measured from those five pebble counts to define the bed stability threshold **Table** 2, based on the recommendations for bed stability assessments by Olsen et al. (1997). The underlying rationale follows that D84 grains structure the bed framework and “hold”

[2] We selected the modeled shear stresses for the 10-year flood from the wetted low flow channel (as mapped with the LiDAR dataset) to select for shear stresses acting on the exposed bed of the main channel.

the bed together. Based on this structural role, bed mobility is relatively minor until the D84 grain mobilizes, at which point wholesale bed mobility becomes more likely.

Table 2 | Grain sizes selected from Del Groat and Dowdy (2008) for low bookend.

	Average of the Five Pebble Counts	**Finest of the Five Pebble Counts**
D50	70 mm	52 mm
D84	160 mm	125 mm

Figure 23 shows the shear stress benefit curve relative to the calculated stability threshold (80 pascal). The benefit curve follows a power law function where shear stress decreases (and bed stability increase) with wider floodplains. The regression curve crosses the stability threshold at a floodplain width of about 450 feet, implying that beds are relatively stable in floodplains wider than this value.

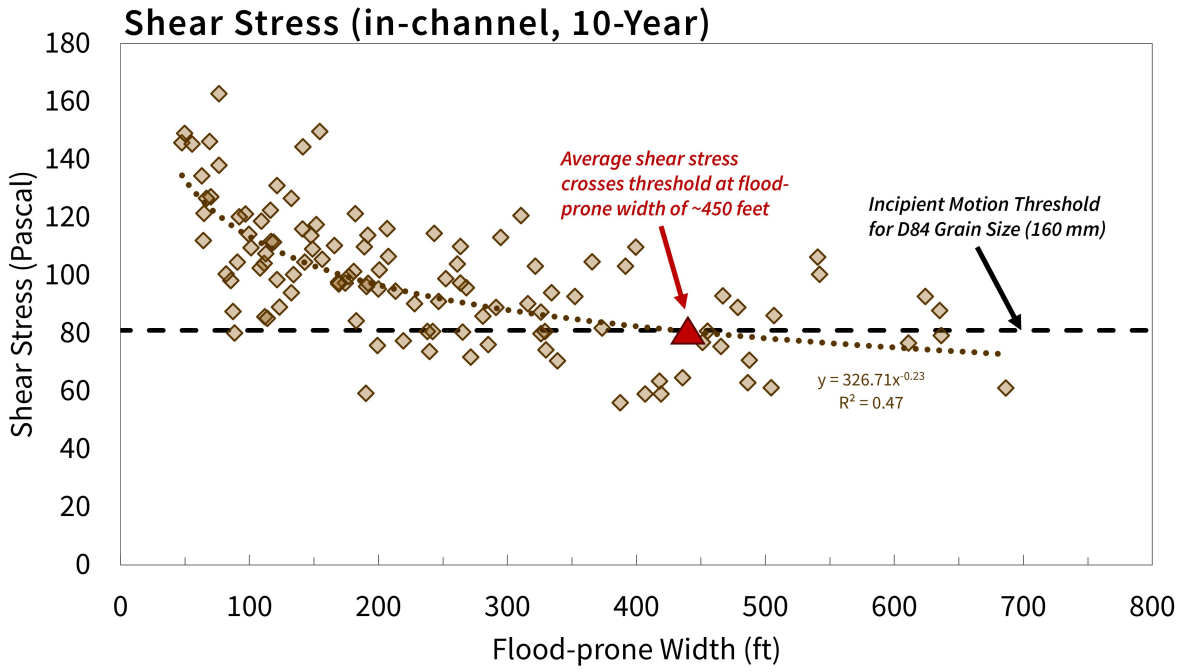


Figure 23 | Relationship between shear stress and flood prone width at the 10-year flood. The selected bed stability threshold is plotted.

7.2.2 Deposition Potential

To assess potential for sediment deposition, we considered the dynamic interplay of sediment transport capacity *and* supply. In a relative sense, deposition potential is high when the ratio of sediment transport capacity to supply is low (Stroth et al. 2017). In essence, as the supply of sediment outpaces the stream's ability to transport it, deposition becomes more likely. In turn, incision becomes less likely.

We followed the same benefit curve framework to capture and assess deposition potential in relation to flood prone width. We also recognized that the benefit curve approach could capture well the sediment transport capacity element in deposition potential but was less well suited to capture sediment supply, at least directly. Therefore, we applied a conceptual framework that allowed us to infer deposition potential while avoiding the need to fully quantify both transport capacity and supply. The conceptual framework was founded on the following sequence of logic:

1. **Externally sourced sediment should be relatively constant along the reach.** The project reach has no major tributaries except for Cummings Creek entering at its lower end. The lack of tributaries indicates that there are no significant and persistent point sources of sediment. Therefore, most of the bed material load must either be sourced from the reaches upstream (i.e., above PA 5) or by recruitment from local sources through bank or bed erosion. Given that the reach has relatively consistent valley geomorphology, there is no evidence to suggest that local sources create persistent variations in supply along its length.
2. **Variations in sediment supply are more likely to occur in response to longitudinal variations in transport capacity of the river.** Specifically, response reaches with wide and well-connected floodplains have lower transport capacities that promote deposition. They accordingly act as local sinks for bed material sediment, which in turn creates relative reductions in supply for reaches immediately downstream. Conversely, confined segments are likely to pass sediment more quickly, supporting relatively higher sediment supply in reaches immediately downstream.
3. **The worst-case incision potential (i.e., lowest deposition potential)** should occur where the stream transitions from an unconfined reach to a confined reach. In this situation, the transport capacity should be relatively high in response to the constriction, and the sediment supply should be relatively low due to preferential storage in the unconfined reach immediately upstream.
4. **To maintain deposition potential (and minimize incision potential) within the identified worst-case, the goal should be to minimize the *difference* in sediment transport capacity from the unconfined reach upstream to the confined reach below.**

We then applied benefit curve approach to evaluate relative transport capacity in the "worst case" scenario described above. To implement this framework, we applied the Wong and Parker (2006) relationship to calculate bedload transport capacity relative to flood prone width. Their equation predicts dimensionless bedload transport capacity (q^*), or volumetric transport rate per unit width of the channel, using the following relationship:

$$q^* = 3.97(\tau^* - 0.0495)^{1.5}$$

where, τ^* is the dimensionless shear stress described by the following equation:

$$\tau^* = \frac{\tau}{(\rho_s - \rho_w) * g * D50}$$

In the above, τ is shear stress acting on the bed, ρ_s is the density of the sediment grain, ρ_w is the density of water, g is gravitational acceleration, and D50 is the 50th percentile grain size.

For similar reasons as described with the bed stability analysis, we used the in-channel shear stresses (**Figure** 23) modeled at the 10-year flood to perform these calculations using a relatively large, geomorphically effective flood. We selected the finest D50 grain size measured from the five pebble counts reported by Del Groat and Dowdy (2008) to represent the gravel likely to be in regular and active transport within the reach. All other input values are constants.

The calculations were then applied for the population of floodplain segments (of varying width) to yield relationship of transport capacity (q^*) to flood prone width (**Figure** 24). The relationship shows that bedload transport rate generally decreases as the Tucannon River floodplain widens. This trend confirms the conceptual model that wide and well-connected floodplain segments slow bedload transport relative to those that are laterally pinched or constricted by natural or anthropogenic features.

To assess "worst case" incision potential at hypothetical pinch points, we assessed relative transport capacities using two assumed width transitions. Both scenarios assumed that the well-connected segment upstream of the pinch point had a 700-foot flood prone width (labeled "A" in **Figure** 24). This value represents approximate average of the historical floodplain width in the project reach (**Figure** 6). It also approximates the widest and most well-connected segments of floodplain currently in the project reach. It also represents a reasonable target for full floodplain restoration. The two scenarios were defined by pinch point widths of 450 feet and 50 feet. The 50-foot pinch point (labeled "C" in **Figure** 24) approximates the most anthropogenically confined stream segments currently in the project reach (e.g., see pinch points created by Curl Lake and the hatchery). The 450-foot pinch point (labeled "B" in **Figure** 24) represents a floodplain meeting the bed stability threshold described in the section above.

Due to the non-linearity in the benefit curve (**Figure** 24), the two scenarios are quite divergent in the relative bedload transport capacity changes. The downstream transition from 700 ft to 50 ft results in calculated ratio of bedload transport capacity of 5.4 (440% increase). The transition from 700 ft to 450 ft has a calculated ratio of 1.3 (30% increase).

Based on this analysis, current pinch points of 50 feet clearly and demonstrably reduce deposition potential and increase erosion potential, thereby encouraging incision and threatening the sustainability of reaches immediately upstream. In contrast, the increase in transport capacity experienced at the 450 feet pinch point is small relative to the scatter of data points around the benefit curve (**Figure** 24). This finding suggests that the 450 wide pinch point has a reasonable expectation for bedload deposition, even in the worst-case scenario where the reach transitions from 700 to 450 feet.

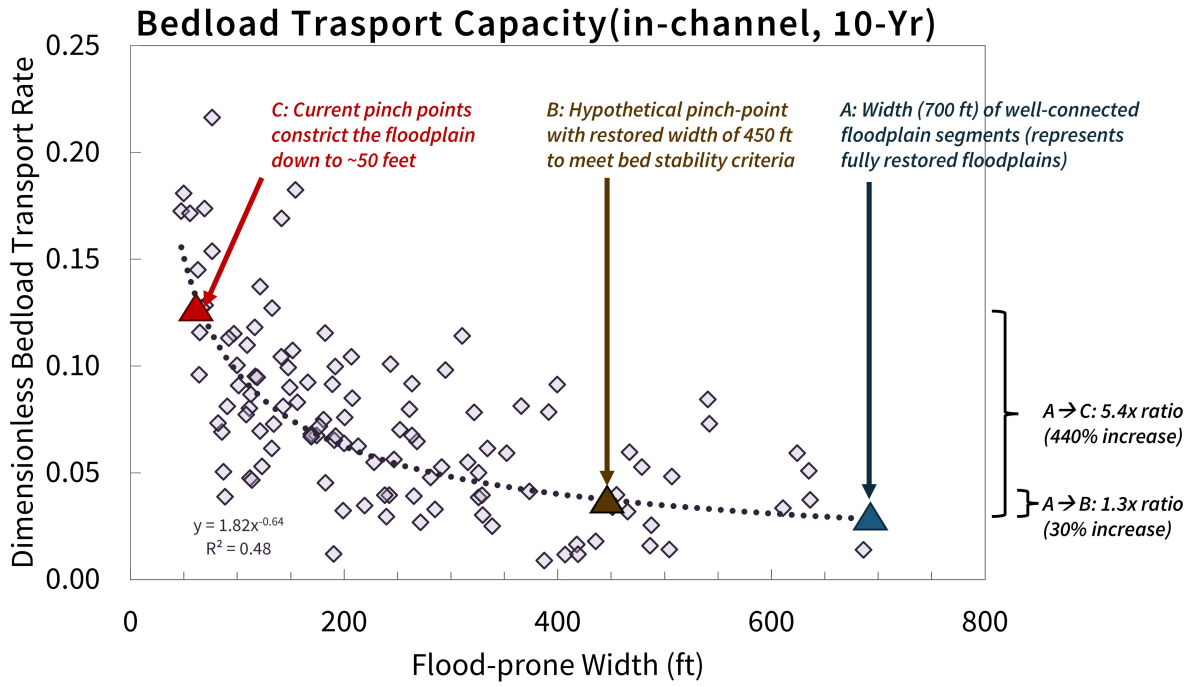


Figure 24 | Relationship of dimensionless bedload transport rate to flood prone width with analysis scenarios shown.

7.2.3 Large Wood Retention

Based on the complexities of modeling wood transport, we elected to rely on the empirical observations presented in Figure 21 andFigure **22** to assess wood retention relative to flood prone width. The results showed that reach (PA 6) with flood prone width of 320 feet retained a vast majority of placed wood during the large flood of 2020. These findings suggest that a 450 feet target width would further promote natural retention of large wood.

7.2.4 Low Bookend Space Target

Our multi-analysis approach revealed that a flood prone width of at least 450 feet promotes bed stability, sediment deposition potential, and wood retention. These three conditions and processes collectively should reduce incision potential and promote sustainable floodplain connectivity throughout the project reach. The 450-foot width is therefore the selected low-bookend target. This target defines an approximate minimum need for space specific to this project reach. It provides a guide for planning infrastructure and restoration actions. The low bookend target is intended for reach-scale planning purposes only and should always be validated with site specific analyses at design phases.

The 450-foot target is approximately 10 times the average bankfull channel width (44 feet) in the project reach. While we have not confirmed its applicability outside the project reach, this ratio may provide a preliminary estimation of space needs for other alluvial rivers with similar settings and

characteristics. We recommend caution in applying this value until it is validated and calibrated elsewhere.

8 | Conclusions

Our space assessment addressed three key questions to support multi-use planning in the valley bottom of the W.T. Wooten Wildlife Area.

What is the state of the floodplain?

Our mapping revealed a contemporary floodplain width of 220 feet and an average historical floodplain width of 760 feet. Therefore, anthropogenic disturbances have reduced the active floodplain area to approximately 30% of its pre-disturbance extent, on average. On a segment scale, the contemporary floodplain is as little as 10% of its historical extent. Based on mapping by W2r, incision is the major cause of floodplain disconnection, representing over half of the reduced area. Lateral disconnection by lakes, roads, and levees are also responsible for significant reductions in connected floodplain area.

What are the benefits of floodplain space in the Tucannon River?

We assessed the benefits of space by developing reach-specific relationships of floodplain width to a series of hydraulic, geomorphic, and habitat parameters. These "benefit curves" provide quantitative relationships and tools for restoration planning in this project and future design phases. In general, they reveal that wider floodplains, which may be created by restoration, support in more inundation, lower erosion potential, increased habitat potential, and more wood retention. Our specific findings of benefit include:

- Wider floodplains yield greater inundation area and volume, especially at larger floods.
- Wider floodplains are more likely to contain large floods, thereby reducing flood risk to adjacent recreational areas.
- Wider floodplains increase transient storage and reduce flow velocities, suggesting that restoration has potential to attenuate floods for downstream communities.
- Wider floodplains reduce stream power, which lowers incision potential, increases habitat resilience, and reduces risk and maintenance at adjacent infrastructure (e.g., roads, lakes, and water intakes).
- Wider floodplains reduce potential for scour and loss of Chinook redds, potentially addressing a key life history bottleneck. Additional resilience for incubation and spawning life stages is particularly critical given anticipated climate driven shifts in timing and magnitude of scour inducing floods.
- Wider floodplains have more edge habitat potential, addressing juvenile life history needs.
- Wider floodplains lead to more wood retention and durable wood placements that induce positive habitat trajectories. These findings, which were based on a comparative case study from SRSRB observations, suggest that adequate space may be a pre-requisite for successful wood placement projects.

How much space does the Tucannon River need?

Based on modeling and sediment transport analyses, we developed a low bookend space target according to the estimated minimum floodplain width needed to sufficiently reduce incision potential. We analyzed space needs to support a stable streambed, promote gravel deposition, and retain large wood. Floodplains of at least 450 feet wide addressed all three criteria. The 450-foot target is approximately 10 times the average bankfull channel width (44 feet) in the project reach. This low bookend target is intended for planning to support long-term resilience of the Tucannon River floodplain.

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Tucannon River Project Area 1.1-15.2

Summer Stream Temperature Assessment

Technical Report

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Background

In the Pacific Northwest, summer months are anticipated to become increasingly stressful for cold-water species due to rising stream temperatures, likely reducing and shifting the distributions of suitable habitat for many species (Jones et al., 2014; Isaak et al., 2015). Here, we evaluate recent historic and future projected summer stream temperature scenarios for the Tucannon River watershed and compare them to life stage-specific temperature thresholds for focal species. The goal of this assessment was to determine whether summer stream temperature was a potential factor limiting fish population productivity and to identify and prioritize restoration actions that could reduce stream temperatures to mitigate future impacts of a warming climate.

Methods

Recent historic (2002-2011) and projected (2040 & 2080) August mean stream temperature predictions (Isaak et al., 2017) were used in combination with species- and life stage- specific temperature thresholds to evaluate potential habitat limitations within the Tucannon River watershed with a focus on Project Areas 1.1-15.2 (hereafter "PA 1.1–15.2"; Figure 1). August mean stream temperatures were used to quantify the amount of stream habitat exceeding optimum, maximum, and acute temperature thresholds for focal species present in the Tucannon River watershed. Additionally, a scenario where hypothetical restoration actions reduced mean August stream temperatures by 1^{o}C relative to the recent historic temperature scenario was evaluated to illustrate the potential benefits to thermal habitat suitability.

Focal Species

The focal species evaluated in the summer stream temperature assessment included:

- Spring-run Chinook salmon (*Oncorhynchus tshawytscha*)
- Middle Columbia River summer steelhead (*Oncorhynchus mykiss*)
- Columbia River bull trout (*Salvelinus confluentus)*
- Pacific lamprey (*Entosphenus tridentatus*)

These species were selected for ecological and cultural importance, regulatory status, and/or presence within the Tucannon River watershed during the summer period.

Study Area

The spatial extent of the summer stream temperature assessment encompassed the entire Tucannon River watershed, with an emphasis on PA 1.1–15.2. Additional consideration was given to upstream reaches and major tributaries influencing thermal conditions within PA 1.1–15.2, including Cummings Creek, Little Tucannon River, Panjab Creek, Meadow Creek, Turkey Creek, Sheep Creek, Cold Creek, and Bear Creek (Figure 1).

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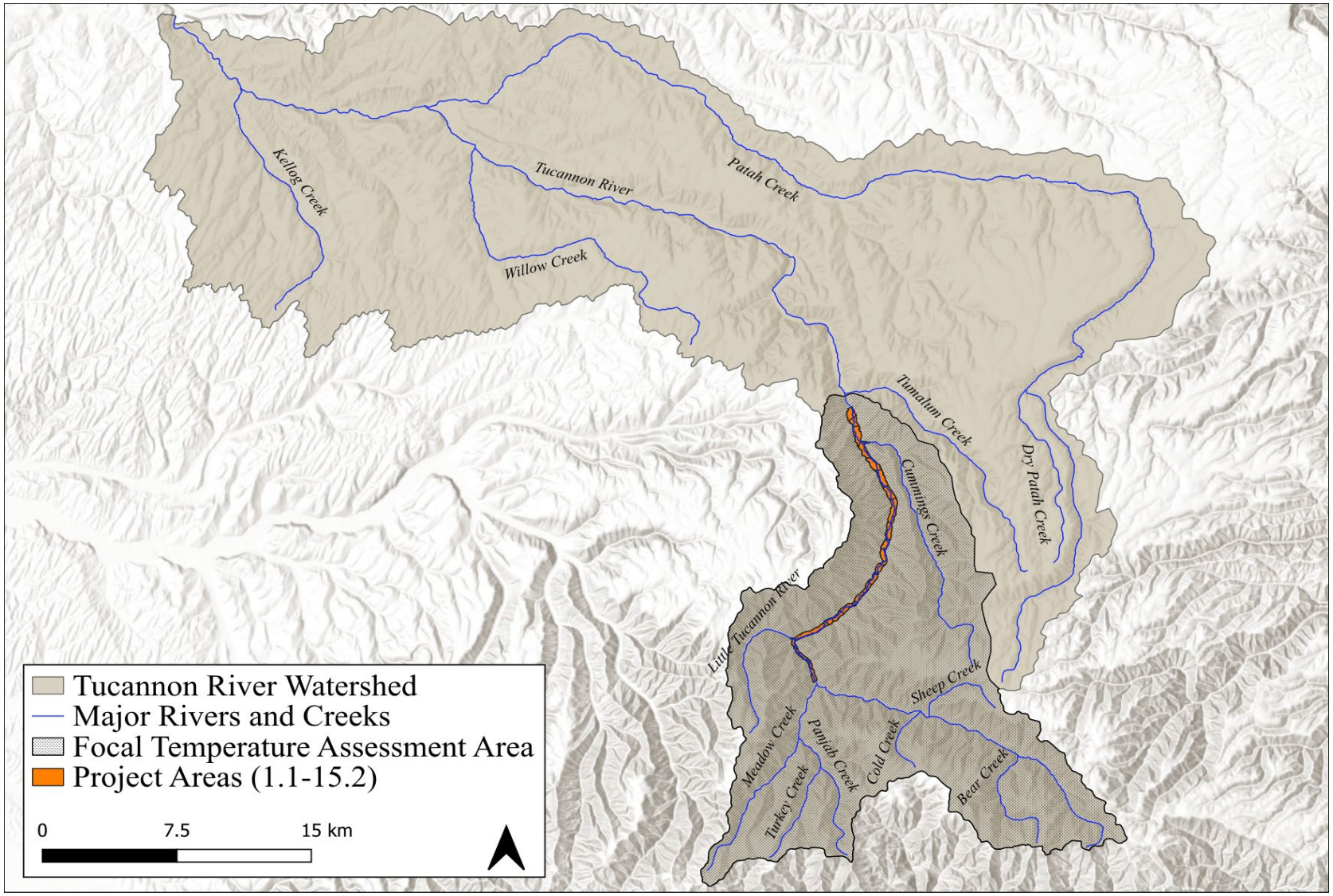


Figure 1. Map of the Tucannon River watershed.

Climate Scenarios

Three NorWeST summer stream temperature scenarios were considered. The Recent Historic scenario was intended to represent a contemporary scenario, whereas the 2040 Projected and 2080 Projected scenarios represent mid-century and late-century climate warming scenarios, respectively. Definitions of each scenario are as follows:

- Recent Historic: A historical composite scenario representing the 10-year average August mean stream temperatures for 2002-2011 (Isaak et al., 2017).

- 2040 Projected: A future August mean stream temperature scenario based on average projected changes in August air temperature and stream discharge for the 2040s (2030-2059). Projected changes in streams accounted for differential sensitivity among streams so that cold streams warm less than warm streams (Isaak et al., 2017).

- 2080 Projected: A future August mean stream temperature scenario based on average projected changes in August air temperature and stream discharge for the 2080s (2070-2099). Projected changes in streams accounted for differential sensitivity among streams so that cold streams warm less than warm streams (Isaak et al., 2017).

- A hypothetical scenario (Recent Minus 1^{o}C) was also considered, in which summer stream temperatures were reduced by 1^{o}C relative to the Recent Historic scenario. This scenario represents a situation where various restoration actions (e.g., riparian planting, increased floodplain connectivity) increase stream shading, reduce solar loading, and/or increase hyporheic exchange within the watershed resulting in cooler August stream temperatures. Each of the scenarios are summarized in Figures 2 and 3.

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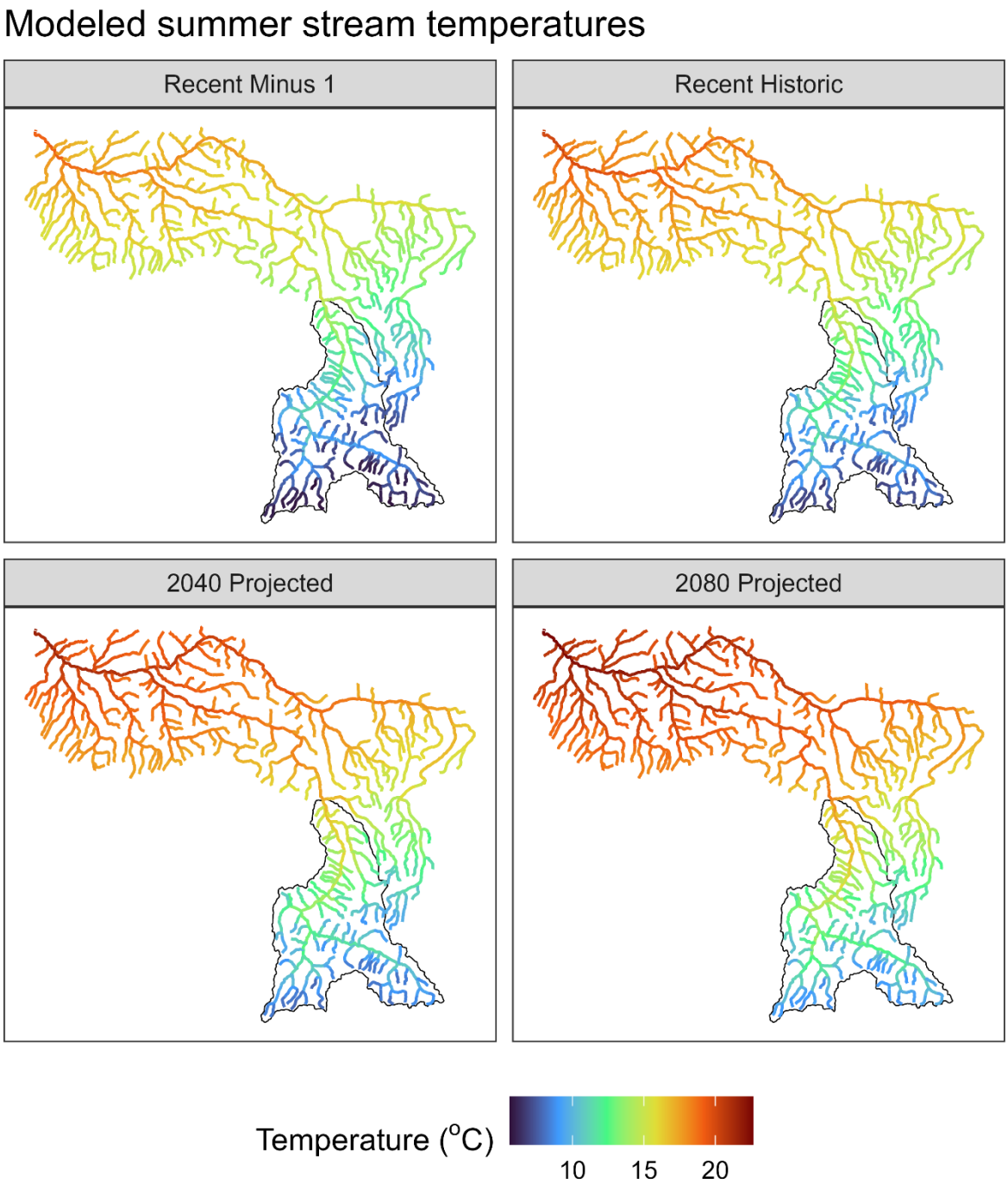


Figure 2. Modeled average August stream temperatures (°C) within the Tucannon River watershed for the Recent Historic, 2040 Projected, 2080 Projected, and Recent Minus 1 (°C) temperature scenarios. The portion of the Tucannon River watershed that is the focal area for the assessment, and includes Project Areas 1.1-15.2, is outlined in black.

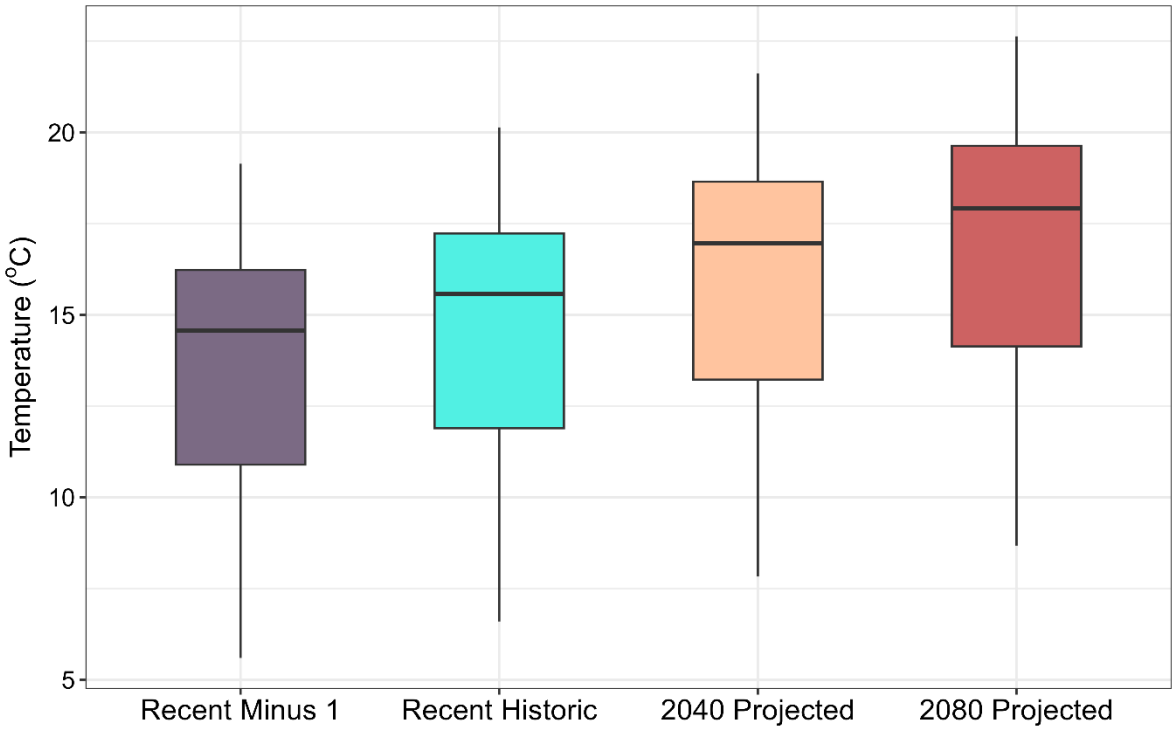


Figure 3. Distribution of average August stream temperatures (°C) within the Tucannon River watershed for the Recent Minus 1 (°C), Recent Historic, 2040 Projected, and 2080 Projected scenarios.

Stream Temperature Thresholds

Temperature thresholds were evaluated for Chinook salmon and steelhead life stages that occupy the Tucannon River watershed in August. This included Chinook salmon spawning and summer parr life stages and the steelhead summer parr life stage. Temperature thresholds (expressed as the maximum weekly maximum temperature [MWMT]) identified in a literature review conducted by Carter (2005) were used for Chinook salmon and steelhead. Chinook spawning was observed over a wide range of temperatures (5.6 - 17.7°C); however, most observations cite maximum temperatures at 14.5°C. The optimal temperature range for juvenile Chinook salmon growth and rearing was 10 - 16°C. Temperatures above 19°C generally did not support Chinook salmon parr growth and Chinook salmon parr were rarely present in reaches with temperatures greater than 22°C. Juvenile steelhead summer parr have a slightly higher temperature tolerances for growth and rearing compared to Chinook salmon ranging from 10-18°C.

Bull trout tended to have more specific habitat requirements compared to other salmonids, requiring colder stream temperatures. Although bull trout have been reported in stream temperatures above 20°C, they are seldom found in waters where temperatures exceed 15 - 16°C. Temperatures above 16°C are detrimental for bull trout feeding and growth and are

unlikely to be suitable for their long-term survival (Selong et al., 2001 and references therein). At temperatures greater than 18°C, bull trout exhibit reduced consumption, growth, and survival (Selong et al., 2001).

Pacific lamprey can tolerate a temperature range of 5 - 25°C (Clemens et al., 2017). Pacific lamprey spawning typically occurs between 10 - 18°C with early juvenile development between 14 - 19°C, and preferred temperatures by adults ranging from 16 - 17°C (Clemens et al., 2016; Clemens et al., 2017). Temperatures greater than 19°C are typically associated with stress, tissue damage, and potential mortality in Pacific lamprey (Clemens et al., 2016). Temperature thresholds along with descriptions of the thresholds are shown in Table 2 and Table 3.

Table 1. Life stage timing and minimum, optimum, maximum, and acute temperature (°C) thresholds for summer life stages of Chinook salmon, steelhead, bull trout, and Pacific lamprey. Chinook salmon and steelhead temperatures are expressed as the Maximum Weekly Maximum Temperature.

Species	Life stage	Source	Timing	Minimum (°C)	Optimum (°C)	Maximum (°C)	Acute (°C)
Chinook salmon	Spawning	Carter 2005	8/10 - 9/30	3.3	7.2 - 14.5	17.7	20
Chinook salmon	Summer parr	Carter 2005	6/10 - 10/15	4.5	10 - 16	19	22
Steelhead	Summer parr	Carter 2005	6/10 - 10/15	4.5	10 - 18	19	22
Bull trout	All	Selong et al. 2001	7/1 - 8/31	0	10.2 - 16	18	20
Pacific lamprey	All	Clemens et al. 2016, 2017	7/1 - 8/31	5	10 - 17	20	25

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Table 2. Descriptions of maximum weekly maximum temperature and temperature thresholds used in the assessment.

Term	Description
MWMT	The maximum weekly maximum temperature (also known as the seven-day average of daily maximum temperatures [7-DADM]) is the maximum of the daily maximum temperatures over a running seven-day consecutive period. The MWMT is useful because it describes the maximum temperatures in a stream but is not overly influenced by the maximum temperature of a single day.
Minimum	A temperature below which physiological stress occurs including reduced growth and activity. Prolonged exposure below this temperature can lead to eventual mortality.
Optimum	The optimum or preferred stream temperature that fish most frequently inhabit when allowed to freely select temperatures in a thermal gradient (USEPA 1999). Also described as those temperatures at which growth rates are maximal (Armour 1991).
Maximum	A temperature above which physiological stress occurs including reduced growth and activity. Prolonged exposure above this temperature can lead to eventual mortality.
Acute	An instantaneous maximum temperature above which can be lethal in a short time.

Analytical Approach

Four separate assessments were conducted using the climate scenarios and temperature thresholds described above to evaluate the potential impacts of summer stream temperatures on the species and life stages of interest:

1. Optimal Temperature Evaluation

   We examined the proportion of summer stream temperature predictions that fell within optimum temperature ranges (Table 2) for each species and life stage under the Recent Historic, Projected 2040, and Projected 2080 scenarios. We estimated the percentage, by length, of the stream network that fell within optimum temperature thresholds. For this evaluation, we considered the entire NorWeST modeled extent, disregarding current species distribution constraints to account for potential upstream expansion as partial or full migration barriers are removed.

2. Exceedance of Thermal Thresholds

   Following, we examined the frequency that stream reaches exceed optimum, maximum, and acute temperature thresholds under the Recent Historic, Projected 2040, and Projected 2080 temperature scenarios.

3. Theoretical Cooling Scenario

   Next, we quantified the benefit of reducing summer stream temperatures with the Recent Minus 1°C scenario. We estimated the length of stream within the Tucannon River watershed that would be "gained" (i.e., fall below optimum, maximum, and acute temperature thresholds) relative to the Recent Historic scenario.

4. Project Area Summary

   Finally, stream temperatures under the Recent Historic scenario were summarized by project area to evaluate temperature limitations to species distribution and productivity. We estimated the proportion of each project area that exceeded optimum, maximum, and acute thresholds.

Results

Optimum Temperature Evaluation

Under the Recent Historic scenario, lower mainstem reaches in the Tucannon River watershed were projected to fall outside the optimal stream temperature ranges for all evaluated species and life stages (Table 3; Figure 4). In contrast, headwater reaches were generally projected to remain below optimal temperature thresholds under the scenario. Among the life stages evaluated, Chinook salmon spawning exhibited the narrowest thermal tolerance range and the highest frequency of stream segments exceeding optimal stream temperature conditions across all scenarios. Even for steelhead parr, which had the highest upper thermal threshold (18°C), 110.66 km in the lowest portions of the watershed exceeded the threshold under Recent Historic conditions.

The 2040 and 2080 Projected scenarios resulted in a substantial increase in stream reaches above threshold temperatures relative to the Recent Historic scenario. Thermally optimal habitat shifted upstream and decreased by up to 37% across all species and life stages for the 2080 Projected scenario, compared to the Recent Historic scenario.

Table 3. Stream length (km) within optimum temperature ranges in the Tucannon River watershed, summarized by species, life stage, and temperature scenario across the NorWeST modeled extent.

Life stage	Recent Historic (km)	2040 Projected (km)	2080 Projected (km)
Chinook salmon spawning	388.7	341.0	295.5
Chinook salmon parr	408.2	323.5	306.6
Steelhead parr	769.1	585.5	485.5
Bull trout	399.6	309.8	296.3
Pacific lamprey	587.8	434.7	382.0

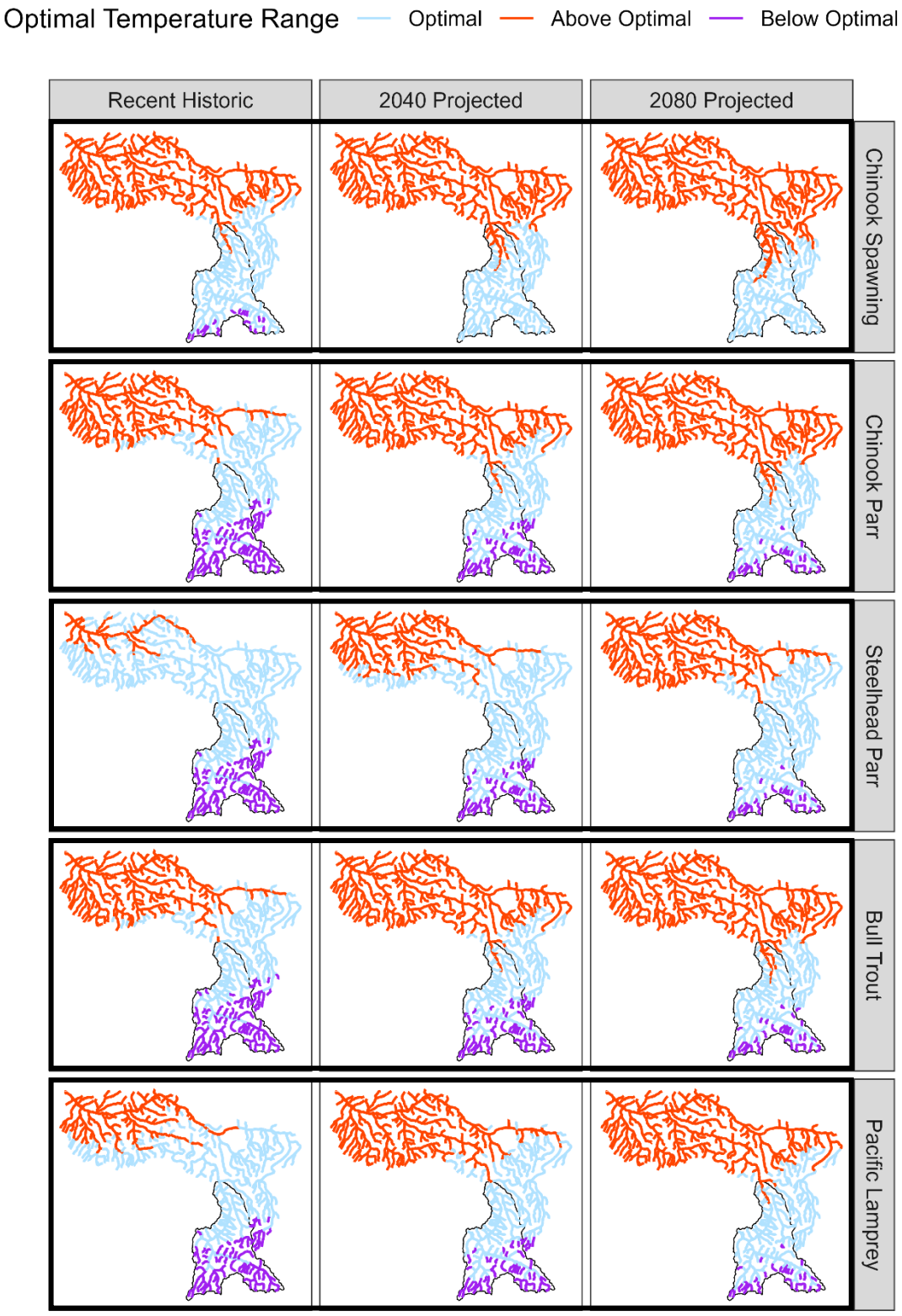


Figure 4. August mean stream temperatures for Recent Historic, 2040 Projected, and 2080 Projected modeled scenarios. Reaches were categorized as within, above, or below optimal temperature ranges for summer life stages of focal species in the Tucannon River watershed.

Threshold Exceedances

Chinook Salmon Spawning

Under the Recent Historic scenario, approximately 7.5 km within PA 1.1-15.2 were projected to exceed the optimum temperature threshold for Chinook salmon spawning during August (Table 4; Figure 5). The stream extent that exceeded optimum ranges was projected to increase by an additional 5.1 km under the 2040 Projected scenario and by 7.9 km under the 2080 Projected scenario. By the 2080 Projected scenario, an estimated 0.9 km within PA 1.1-15.2 were projected to exceed the maximum temperature threshold for Chinook salmon spawning. No stream segments within the project area were projected to exceed acute thermal thresholds under any of the evaluated climate scenarios (Table 4; Figure 5).

Table 4. Stream lengths (km) within Tucannon River Project Areas 1.1–15.2 exceeding temperature thresholds for Chinook salmon spawning under modeled temperature scenarios.

Life stage	Scenario	Above optimum (km)	Above maximum (km)	Above acute (km)	Total PA 1.1-15.2 (km)
Chinook salmon spawning	Recent Historic	7.5	0.0	0.0	20.9
Chinook salmon spawning	2040 Projected	12.6	0.0	0.0	20.9
Chinook salmon spawning	2080 Projected	16.9	0.9	0.0	20.9

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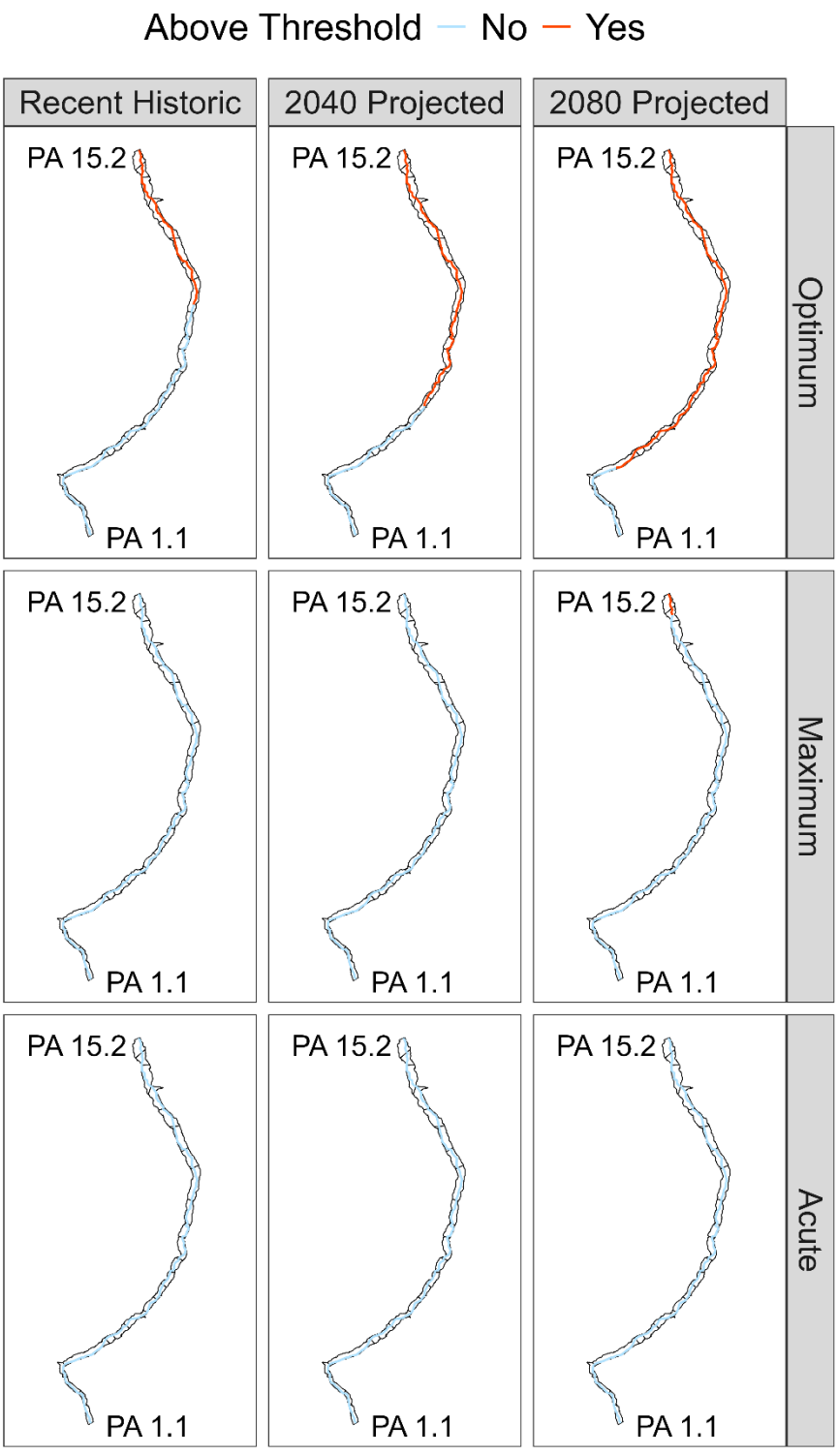


Figure 5. Tucannon River Project Areas 1.1-15.2 that are above optimum, maximum, and acute temperature thresholds for Chinook salmon spawning under Recent Historic, 2040 Projected, and 2080 Projected modeled scenarios.

Chinook Salmon Parr

Under the Recent Historic scenario, no stream segments within PA 1.1–15.2 exceeded the optimum temperature threshold for Chinook salmon parr (Table 5; Figure 6). However, the total length of stream exceeding the optimum threshold was projected to increase to 7.5 km under the 2040 Projected scenario and to 10.7 km under the 2080 Projected scenario. No stream segments within PA 1.1–15.2 were projected to exceed the maximum or acute temperature thresholds for Chinook salmon parr under any of the evaluated temperature scenarios.

Table 5. Stream lengths (km) within Tucannon River Project Areas 1.1–15.2 exceeding temperature thresholds for Chinook salmon parr under modeled temperature scenarios.

Life stage	Scenario	Above optimum (km)	Above maximum (km)	Above acute (km)	Total PA 1.1-15.2 (km)
Chinook Parr	Recent Historic	0.0	0.0	0.0	20.9
Chinook Parr	2040 Projected	7.5	0.0	0.0	20.9
Chinook Parr	2080 Projected	10.7	0.0	0.0	20.9

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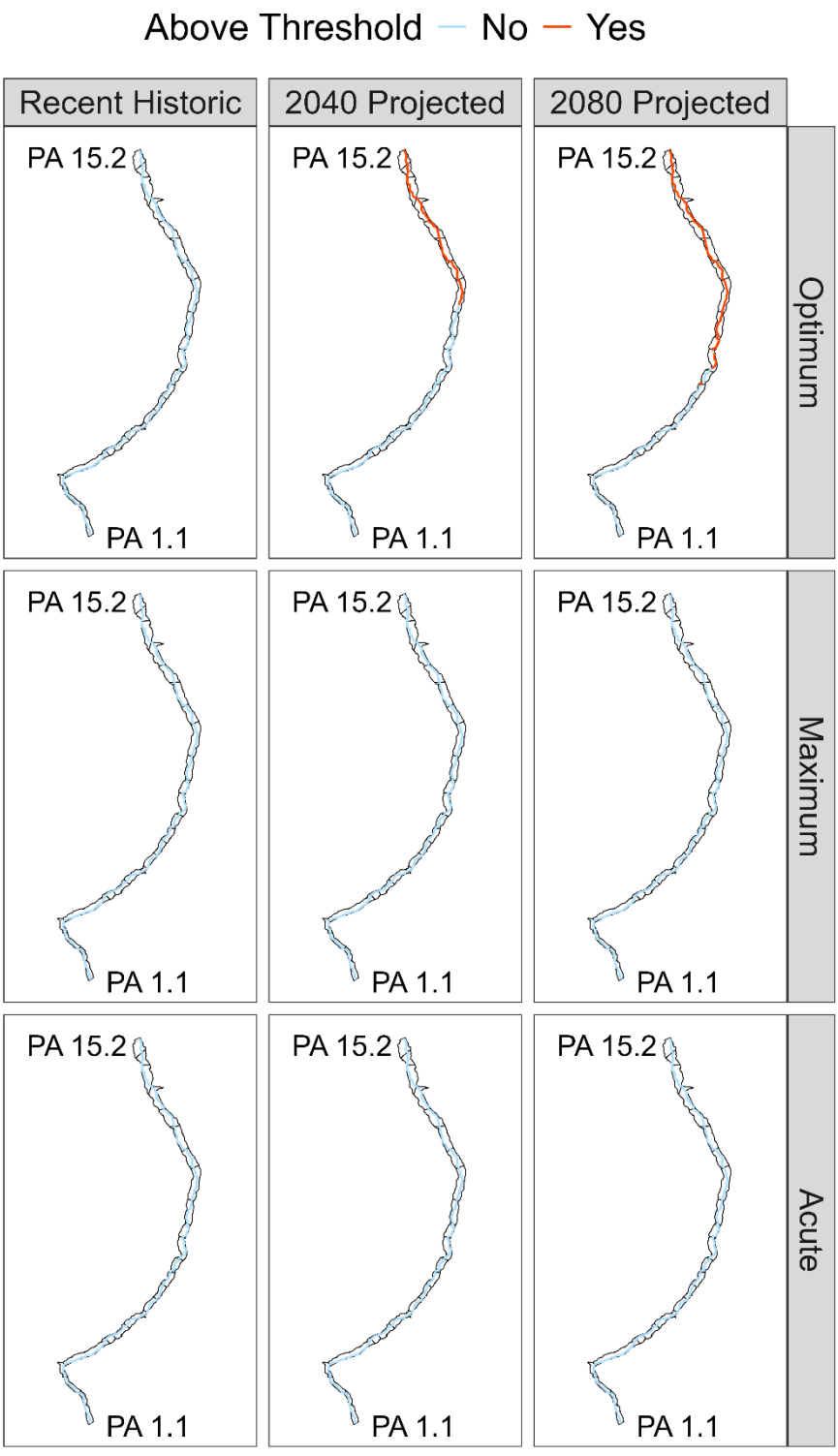


Figure 6. Tucannon River Project Areas 1.1-15.2 that are above optimum, maximum, and acute temperature thresholds for juvenile Chinook salmon parr under Recent Historic, 2040 Projected, and 2080 Projected modeled scenarios.

Steelhead Parr

Temperature thresholds for steelhead parr were higher than all other focal species life stages, so no temperature thresholds were exceeded under the modeled scenarios within PA 1.1-15.2 (Table 6, Figure 7).

Table 6. Stream lengths (km) within Tucannon River Project Areas 1.1–15.2 exceeding temperature thresholds for steelhead parr under modeled temperature scenarios.

Life stage	Scenario	Above optimum (km)	Above maximum (km)	Above acute (km)	Total PA 1.1-15.2 (km)
Steelhead Parr	Recent Historic	0.0	0.0	0.0	20.9
Steelhead Parr	2040 Projected	0.0	0.0	0.0	20.9
Steelhead Parr	2080 Projected	0.0	0.0	0.0	20.9

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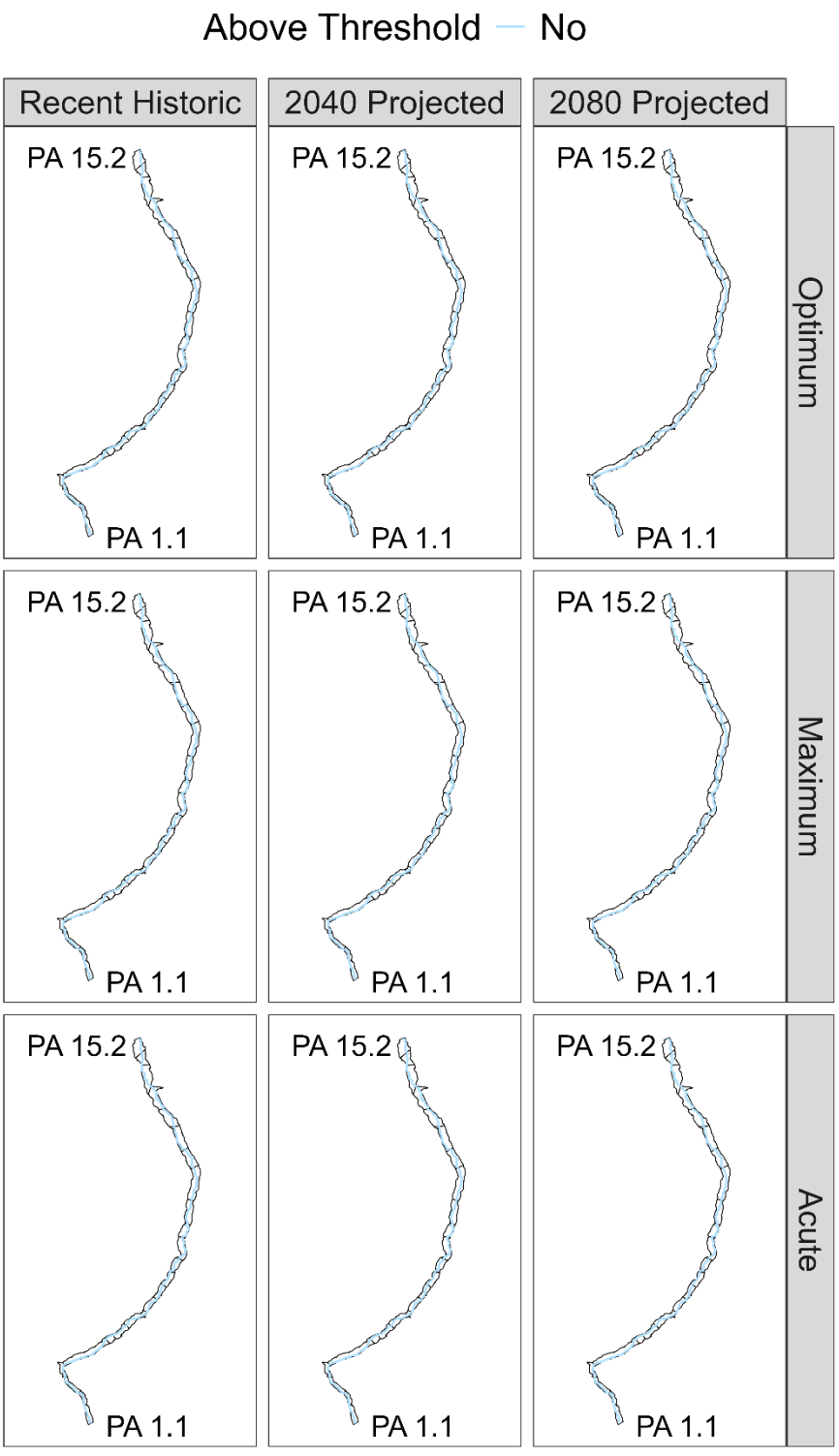


Figure 7. Tucannon River Project Areas 1.1-15.2 that are above optimum, maximum, and acute temperature thresholds for juvenile steelhead under Recent Historic, 2040 Projected, and 2080 Projected modeled scenarios.

Bull Trout

None of the stream segments within PA 1.1-15.2 were projected to exceed the optimum temperature threshold for bull trout during the Recent Historic scenario (Table 7; Figure 8). Consistent with projections for Chinook salmon parr, approximately 7.5 km were projected to exceed the bull trout optimum threshold under the 2040 Projected scenario, with an additional 3.2 km exceeding the threshold under the 2080 Projected scenario. No stream segments within PA 1.1-15.2 were projected to exceed the maximum or acute temperature thresholds for bull trout under any of the evaluated climate scenarios.

Table 7. Stream lengths (km) within Tucannon River Project Areas 1.1–15.2 exceeding temperature thresholds for bull trout under modeled temperature scenarios.

Life stage	Scenario	Above optimum (km)	Above maximum (km)	Above acute (km)	Total PA 1.1-15.2 (km)
Bull Trout	Recent Historic	0.0	0.0	0.0	20.9
Bull Trout	2040 Projected	7.5	0.0	0.0	20.9
Bull Trout	2080 Projected	10.7	0.0	0.0	20.9

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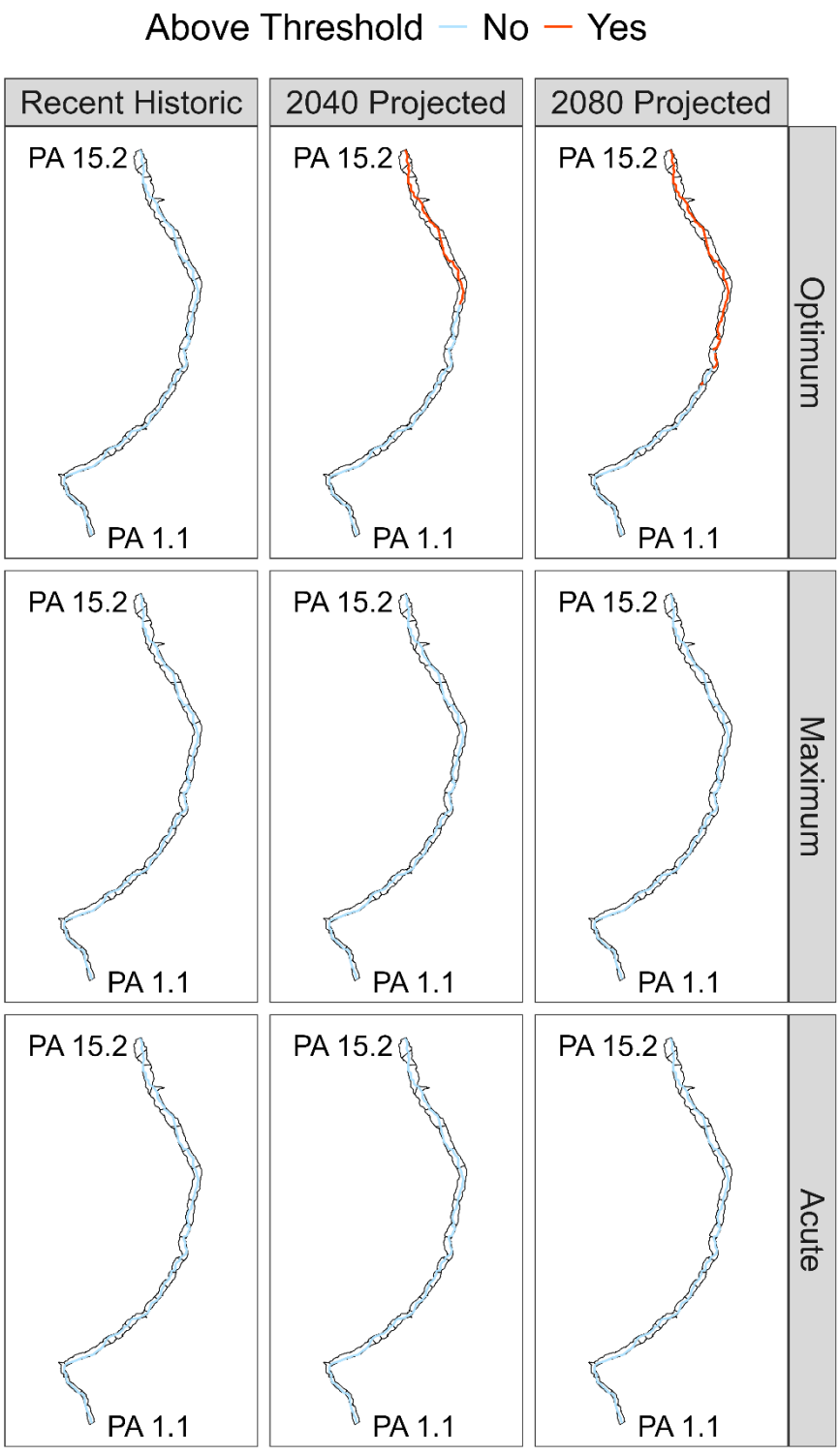


Figure 8. Tucannon River Project Areas 1.1-15.2 that are above optimum, maximum, and acute temperature thresholds for bull trout under Recent Historic, 2040 Projected, and 2080 Projected modeled scenarios.

Pacific Lamprey

No stream segments within PA 1.1-15.2 were projected to exceed the optimum, maximum, or acute stream temperature thresholds for Pacific lamprey under the Recent Historic or 2040 Projected scenarios. However, under the 2080 Projected scenario, approximately 5.4 km were projected to exceed the optimum temperature threshold. No exceedances of the maximum or acute thresholds were projected under any scenario.

Table 8. Stream lengths (km) within Tucannon River Project Areas 1.1–15.2 exceeding temperature thresholds for Pacific lamprey under modeled temperature scenarios.

Life stage	Scenario	Above optimum (km)	Above maximum (km)	Above acute (km)	Total PA 1.1-15.2 (km)
Pacific Lamprey	Recent Historic	0.0	0.0	0.0	20.9
Pacific Lamprey	2040 Projected	0.0	0.0	0.0	20.9
Pacific Lamprey	2080 Projected	5.4	0.0	0.0	20.9

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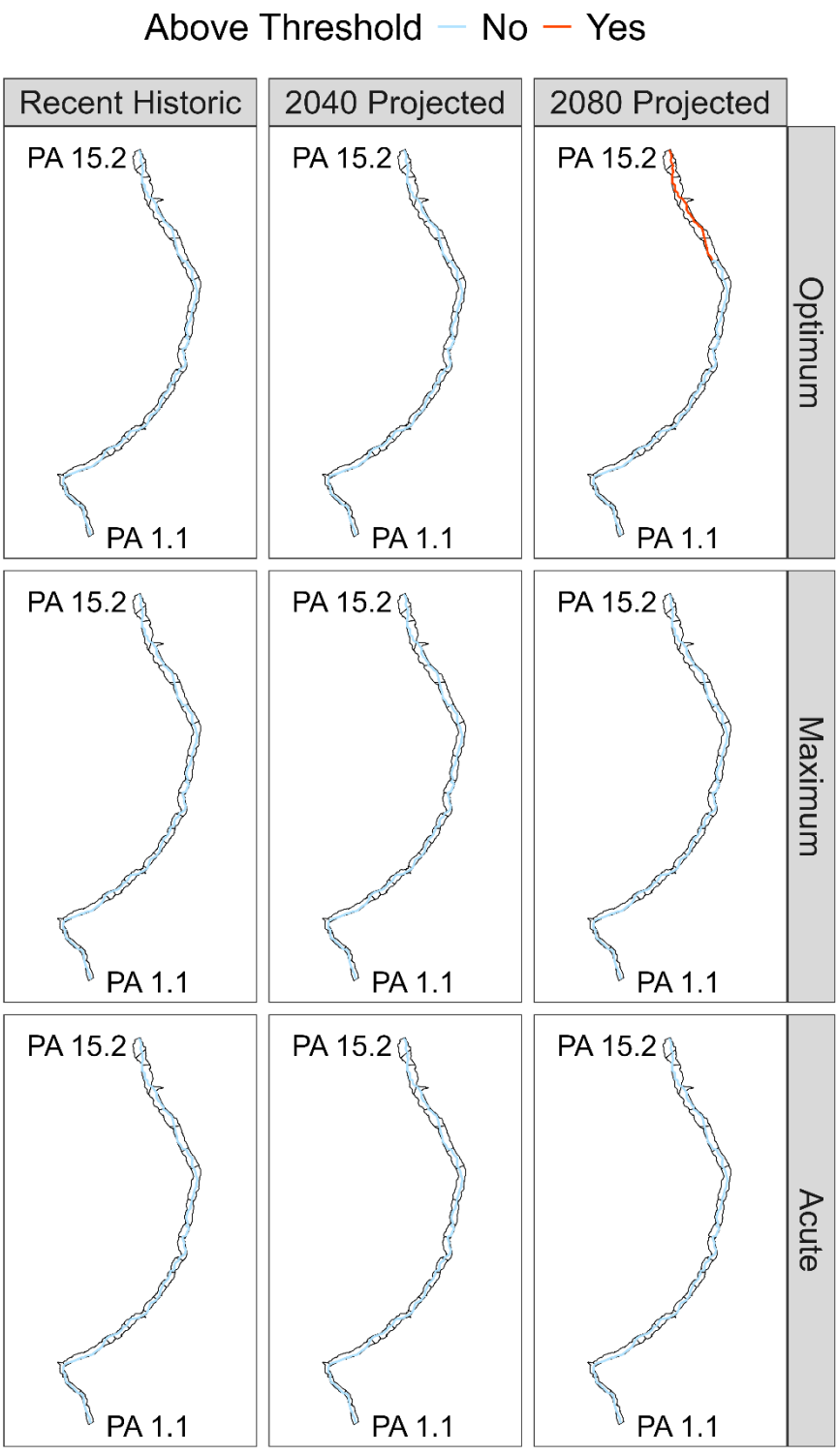


Figure 9. Tucannon River Project Areas 1.1-15.2 that are above optimum, maximum, and acute temperature thresholds for Pacific lamprey under Recent Historic, 2040 Projected, and 2080 Projected modeled scenarios.

Recent Minus 1 (°C) Scenario

Reducing stream temperatures to 1°C cooler than the Recent Historic scenario had minimal impact on the amount of focal species habitat under temperature thresholds. Spawning Chinook salmon were the only species and life stage affected, increasing the stream length of PA 1.1-15.2 within optimum temperatures by 7.4 km. For all other focal species and life stages, the entirety of PA 1.1–15.2 was already within or below the optimum temperature thresholds.

Project Area Summary

In the Projected 2040 scenario, seven of twenty-three project areas within PA 1.1–15.2 were estimated to have more than 50% of their stream length exceed optimum temperature thresholds, averaged across all species and life stages (Table 9; Figure 10). By the Projected 2080 scenario, this number increased to ten project areas (Table 10; Figure 11).

Nine remaining project areas in the Projected 2080 scenario had at least one species and life stage exceed optimum thresholds. Only nine project areas-PA 1.1 through PA 7—were projected to remain below optimum thresholds for all species and life stages in the Projected 2040 scenario. However, under the Projected 2080 scenario, five additional project areas were projected to exceed optimum temperatures for Chinook salmon spawning under the Projected 2080 scenario.

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Table 9. Minimum, maximum, and mean average August stream temperatures (°C), total stream length (km), and the percentage of each Project Area exceeding optimum temperature thresholds for each species and life stage under the Projected 2040 temperature scenario.

Project area	Min (°C)	Mean (°C)	Max (°C)	Length (km)	Chinook salmon spawning (%)	Chinook salmon parr (%)	Steelhead parr (%)	Bull trout (%)	Pacific lamprey (%)	Species mean (%)
1.1	12.5	12.7	12.9	0.8	0	0	0	0	0	0
1.2	12.9	12.9	12.9	0.6	0	0	0	0	0	0
2	12.9	13.1	13.3	1.0	0	0	0	0	0	0
3.1	12.8	13.2	13.5	0.6	0	0	0	0	0	0
3.2	13.5	13.7	13.8	2.1	0	0	0	0	0	0
4	13.8	13.8	13.8	0.4	0	0	0	0	0	0
5	13.8	13.9	13.9	0.7	0	0	0	0	0	0
6	13.8	13.9	14	1.1	0	0	0	0	0	0
7	14	14	14	0.7	0	0	0	0	0	0
8	14	14.4	14.9	0.7	50	0	0	0	0	10
9	14.8	14.9	15.2	0.6	100	0	0	0	0	20
10.1	14.9	15.1	15.2	0.8	100	0	0	0	0	20
10.2	14.9	15.1	15.4	1.1	100	0	0	0	0	20
10.3	15.3	15.5	15.8	0.8	100	0	0	0	0	20
11.1	15.8	15.8	15.8	1.1	100	0	0	0	0	20
11.2	15.8	15.9	16	1.4	100	66.7	0	66.7	0	46.7
12	16	16	16	0.9	100	100	0	100	0	60
13	16	16.1	16.1	1.2	100	100	0	100	0	60
14.1	16.1	16.1	16.1	0.9	100	100	0	100	0	60
14.2	16.1	16.3	16.6	1.2	100	100	0	100	0	60
14.3	16.6	16.6	16.6	1.1	100	100	0	100	0	60
15.1	16.6	16.7	16.8	0.6	100	100	0	100	0	60
15.2	16.8	16.8	16.9	0.7	100	100	0	100	0	60

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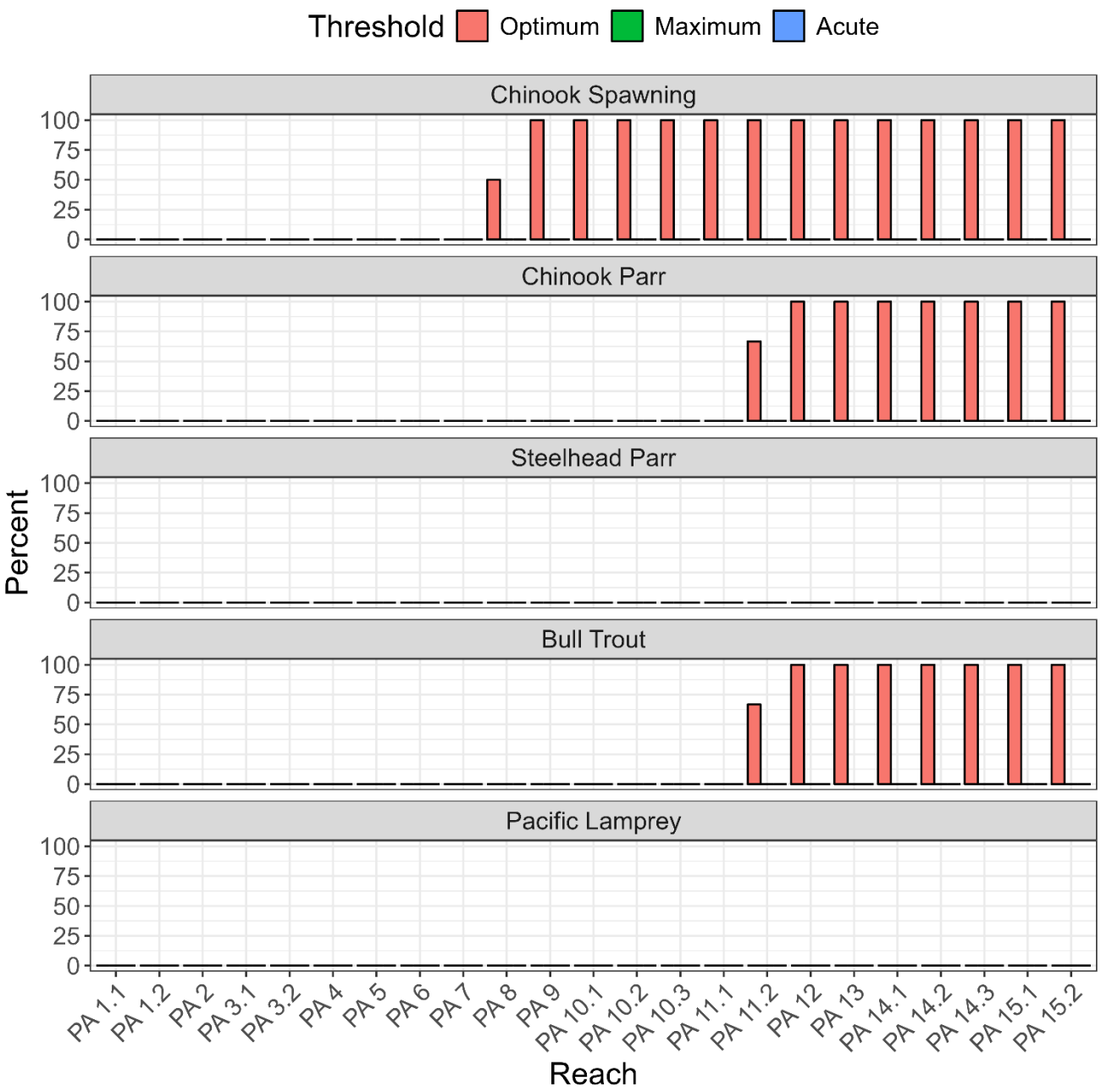


Figure 10. Percentage of stream length within each project area exceeding optimum, maximum, and acute temperature thresholds for each species and life stage under the Projected 2040 scenario.

Table 10. Minimum, maximum, and mean average August stream temperatures (°C), total stream length (km), and the percentage of each Project Area exceeding optimum temperature thresholds for each species and life stage under the Projected 2080 temperature scenario.

Project area	Min (°C)	Mean (°C)	Max (°C)	Length (km)	Chinook salmon spawning (%)	Chinook salmon parr (%)	Steelhead parr (%)	Bull trout (%)	Pacific lamprey (%)	Species mean (%)
1.1	13.4	13.6	13.8	0.8	0	0	0	0	0	0
1.2	13.8	13.8	13.8	0.6	0	0	0	0	0	0
2	13.8	14	14.2	1.0	0	0	0	0	0	0
3.1	13.8	14.1	14.4	0.6	0	0	0	0	0	0
3.2	14.4	14.6	14.8	2.1	50	0	0	0	0	10
4	14.8	14.8	14.8	0.4	100	0	0	0	0	20
5	14.8	14.8	14.9	0.7	100	0	0	0	0	20
6	14.8	14.9	14.9	1.1	100	0	0	0	0	20
7	14.9	14.9	14.9	0.7	100	0	0	0	0	20
8	14.9	15.4	15.8	0.7	100	0	0	0	0	20
9	15.8	15.9	16.1	0.6	100	33.3	0	33.3	0	33.3
10.1	15.9	16	16.1	0.8	100	50	0	50	0	40
10.2	15.9	16	16.4	1.1	100	50	0	50	0	40
10.3	16.3	16.4	16.7	0.8	100	100	0	100	0	60
11.1	16.7	16.7	16.7	1.1	100	100	0	100	0	60
11.2	16.7	16.9	17	1.4	100	100	0	100	0	60
12	17	17	17	0.9	100	100	0	100	0	60
13	17	17	17.1	1.2	100	100	0	100	66.7	73.3
14.1	17.1	17.1	17.1	0.9	100	100	0	100	100	80
14.2	17.1	17.3	17.5	1.2	100	100	0	100	100	80
14.3	17.5	17.5	17.5	1.1	100	100	0	100	100	80
15.1	17.5	17.6	17.7	0.6	100	100	0	100	100	80
15.2	17.7	17.8	17.9	0.7	100	100	0	100	100	80

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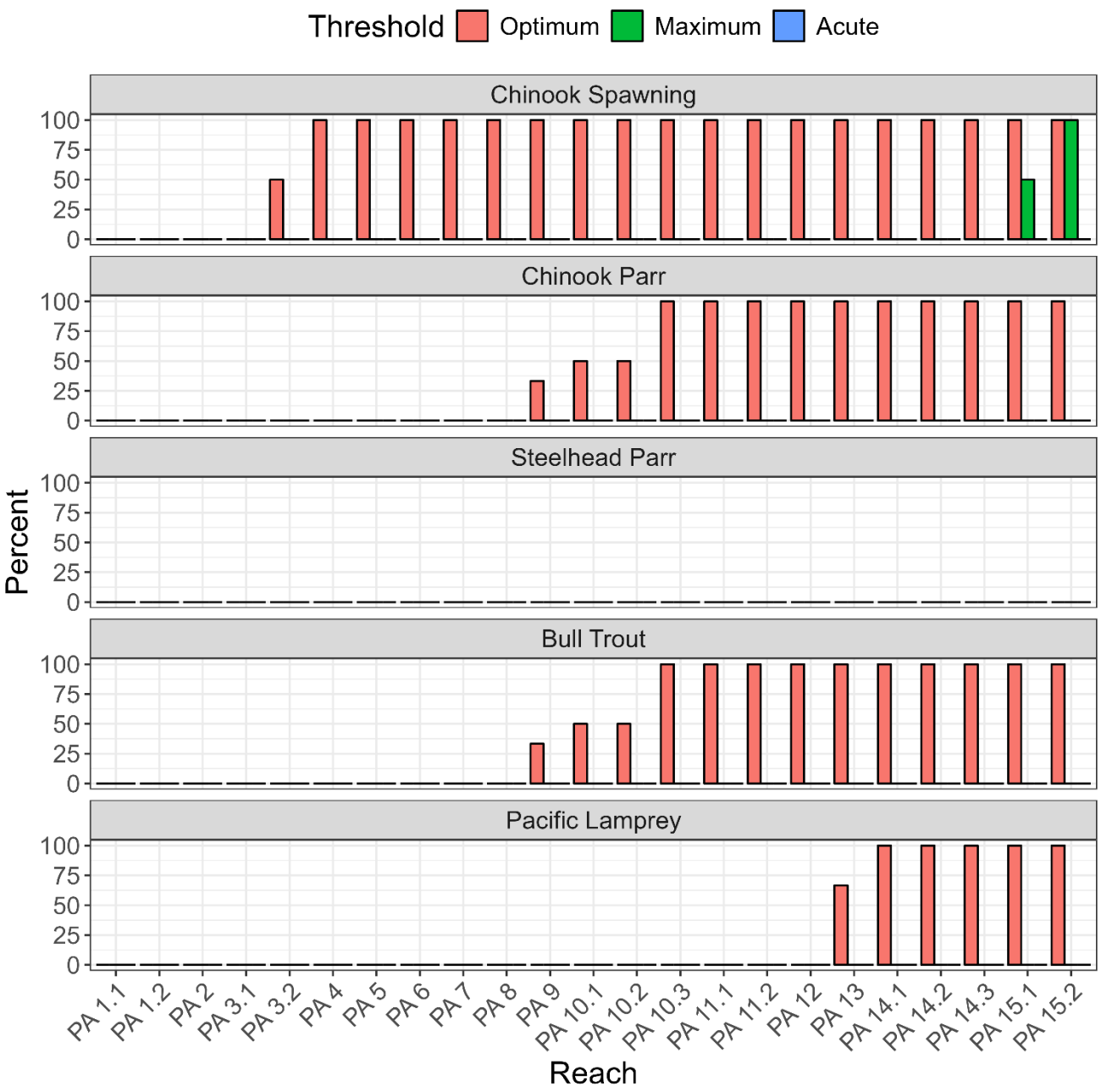


Figure 11. Percentage of stream length within each project area exceeding optimum, maximum, and acute temperature thresholds for each species and life stage under the Projected 2080 scenario.

Discussion

In both the Projected 2040 and 2080 climate scenarios, a greater portion of the Tucannon River watershed was projected to fall outside of optimum temperature thresholds for each species and life stage, relative to the Recent Historic scenario. By the Projected 2080 scenario, only approximately 300 km of the stream network remained within optimum thermal ranges for

Chinook salmon spawning, Chinook salmon parr, and bull trout. While steelhead parr (485 km) and Pacific lamprey (382 km) retained the greatest extent of habitat within optimal temperature ranges in the Projected 2080 scenario, these two species and life stages also experienced the largest absolute declines in thermally optimal habitat (37% and 35%, respectively) relative to the Recent Historic scenario.

It is important to note that the broader watershed assessment evaluated thermal conditions across the entire modeled stream network, regardless of current species presence or connectivity into the habitats. While some headwater reaches may warm into optimal temperature ranges under projected scenarios, it is unlikely that stream flows and habitat conditions in many of these areas could support long-term use by focal species and life stages. As a result, projected "gains" in thermally suitable habitat in headwater areas may overestimate habitat availability, particularly when compared to losses of suitable habitat in lower watershed reaches that are more likely to support multiple species and life stages.

Within PA 1.1-15.2, results indicate that this portion of the watershed may function as a transitional zone for thermal suitability under future climate conditions. The extent of stream length exceeding optimum temperature thresholds increased across both future scenarios. In the Projected 2040 scenario, seven of the twenty-three project areas within PA 1.1-15.2 exceeded optimum thresholds in more than 50% of their stream length; this number increased to ten project areas under the Projected 2080 scenario. These areas should be considered priority locations for potential restoration or management actions aimed at mitigating thermal stress and improving habitat conditions. Additionally, actions implemented in upstream or adjacent areas may provide downstream thermal benefits and should also be considered.

Although the Recent Minus 1 (°C) scenario represents a hypothetical condition, it illustrates how cooler stream temperatures would increase the amount of thermally suitability habitat within PA 1.1-15.2 for Chinook salmon spawning, as well as increased thermal suitability in project areas downstream from PA 15.2 for all species. Justice et al. (2017) similarly evaluated a 2080s climate change scenario and demonstrated that despite substantial increases in summer stream temperatures, basin-wide restoration of riparian vegetation and channel width could help offset climate impacts in the Upper Grande Ronde and Catherine Creek watersheds in eastern Oregon.

Future restoration and rehabilitation efforts in the Tucannon River watershed should account for projected stream temperatures and prioritize design strategies that can reduce thermal stress, particularly in reaches expected to exceed optimum, maximum, or acute thresholds. Potential strategies include reducing solar loading (e.g., increasing riparian vegetation, narrowing channel width, removing lakes, and improving shading), enhancing hyporheic exchange through floodplain reconnection, and increasing summer streamflow (e.g., by reducing withdrawals or augmenting flows). Implementation of such actions throughout PA 1.1-15.2, and more broadly across the watershed, will likely help mitigate the impacts of climate warming on summer stream temperatures and help support the long-term persistence of cold-water fish populations.

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Tucannon River Project Area 1.1-15.2
Hydraulic Habitat Suitability Assessment

Technical Report

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MOUNT HOOD ENVIRONMENTAL

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Background

Decades of anthropogenic impacts have altered aquatic and riparian habitats, geomorphic processes, and stream hydraulics for watersheds throughout the Pacific Northwest. For many watersheds, this has resulted in significant changes in the species composition and abundance of aquatic communities. Stream hydraulics are a foundational component of habitat conditions that directly and indirectly affect aquatic species. Habitat suitability indices, and more specifically, hydraulic habitat suitability (HHS) indices have been developed for several Endangered Species Act listed salmonids to provide relative scores of hydraulic conditions (depth and velocity) specific to a species and particular life stage. While HHS assessments do not account for many critical components of habitat conditions that impact the overall suitability of habitat (e.g. temperature, substrate composition, cover), they do provide insight into the relative suitability of hydraulic conditions within a stream network and can be valuable for restoration prioritization when considered in context of other biological, geomorphic, and social assessments.

This technical report summarizes HHS within Project Areas 1.1–15.2 (hereafter PA 1.1–15.2) of the Tucannon River for three Endangered Species Act listed salmonids, Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*) across a range of depth and velocity conditions and evaluates the relationship between floodplain connectivity and hydraulic suitability for each species during winter juvenile rearing, as well as summer rearing and spawning for Chinook salmon.

Study Area

The Tucannon River, located in southeast Washington, is one of the last major tributaries entering the Snake River upstream of its confluence with the Columbia River. PA 1.1-15.2 extends from approximately 1.5 km upstream of the confluence with the Little Tucannon River at river kilometer (rkm) 80.74 (PA 1.1) downstream to below the confluence with Cummings Creek at rkm 58.50 (PA 15.2) (Figure 1; Table 1).

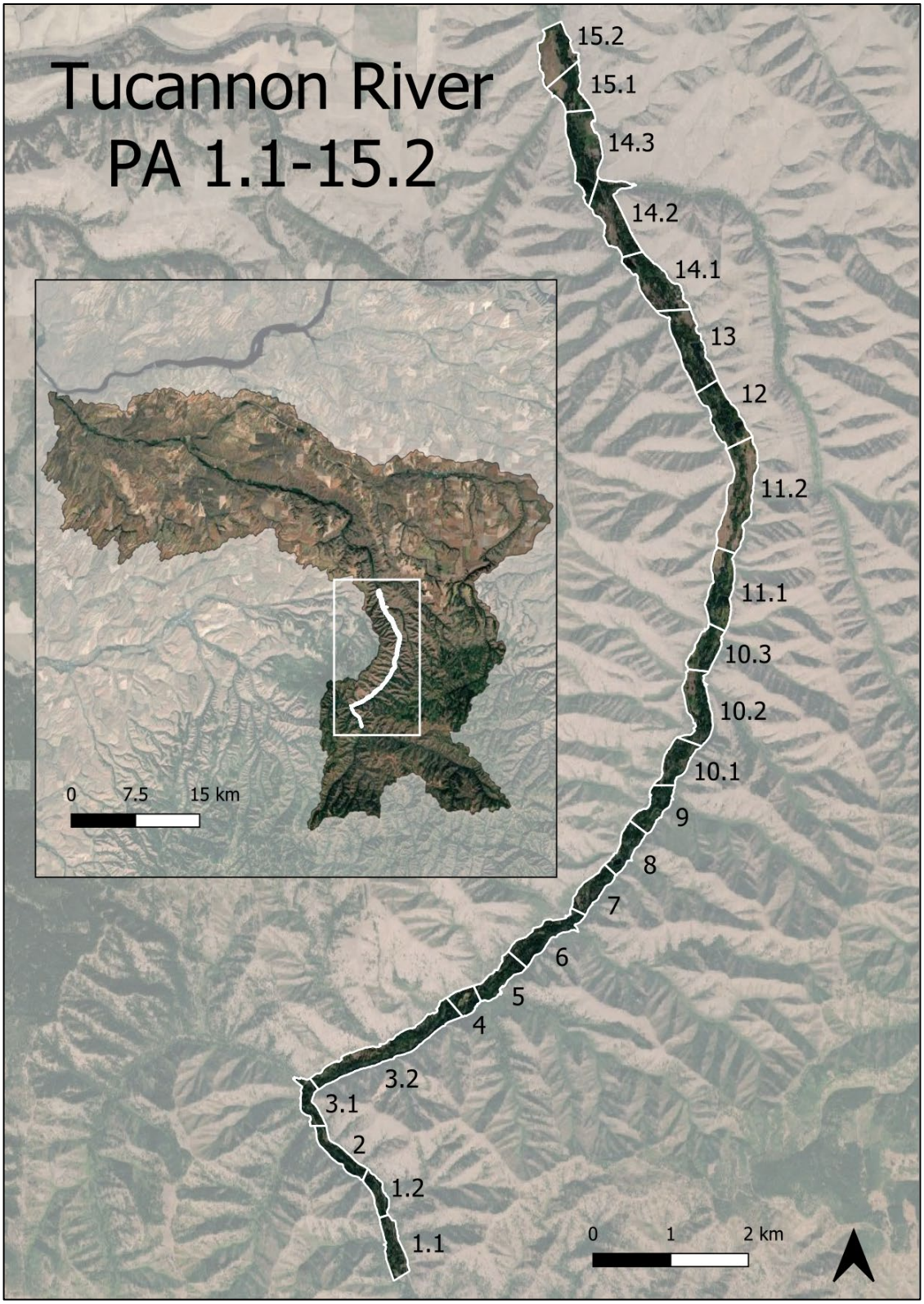


Figure 1. Map of Project Areas 1.1-15.2 in the Tucannon River watershed. Within this study reach, flow direction is generally from south to north.

Table 1. Upstream and downstream river kilometer (rkm) extents and total length of each project area in the Tucannon River. River kilometers decrease in the downstream direction, beginning with Project Area 1.1.

Project Area	Min rkm	Max rkm	Length (m)
1.1	79.86	80.74	884
1.2	79.23	79.86	630
2	78.19	79.23	1,034
3.1	77.59	78.19	598
3.2	75.28	77.59	2,316
4	74.89	75.27	382
5	74.16	74.89	729
6	72.97	74.16	1,195
7	72.24	72.97	724
8	71.52	72.24	723
9	70.87	71.52	644
10.1	70.12	70.87	751
10.2	68.96	70.12	1,158
10.3	68.29	68.96	667
11.1	67.09	68.29	1,206
11.2	65.54	67.09	1,546
12	64.49	65.54	1,047
13	63.26	64.49	1,230
14.1	62.28	63.26	981
14.2	60.96	62.28	1,322
14.3	59.80	60.95	1,157
15.1	59.18	59.80	612
15.2	58.50	59.18	680

Methods

Hydraulic Habitat Suitability

Juvenile winter rearing HHS depth and velocity scores used in this assessment were calculated by Anchor QEA (2023) and provided to Mount Hood Environmental. Initially, Anchor QEA conducted HHS analyses for Chinook salmon, steelhead, and bull trout juvenile winter rearing under three winter flow scenarios. Juvenile summer rearing depth and velocity suitability curves developed by the Washington Department of Fish and Wildlife (WDFW 2022) were modified based on expert input to reflect winter rearing preferences and were used to generate winter HHS scores (Anchor QEA 2023; Figure 2). Although composite suitability was originally calculated as the product of depth and velocity suitability scores, the geometric mean of these values was used in this assessment. The geometric mean prevented single variables with low suitability from disproportionately reducing composite scores when conditions were otherwise suitable. The mean winter flow scenario (300 cfs at the Tucannon River gage #13344500; Tucannon River near Starbuck, WA) was selected to represent typical winter flow conditions experienced by juvenile salmonids in the Tucannon River.

A second HHS analysis was conducted to evaluate Chinook salmon spawning and juvenile Chinook salmon summer rearing hydraulic suitability. Wolf Water Resources developed a two-dimensional hydraulic model and predicted depths and depth-averaged velocities for a discharge of 67.7 cfs at the Tucannon River near Marengo gage (Station ID 35B150, Washington State Department of Ecology). This discharge corresponded to the average two-week flow during peak Chinook salmon spawning and was also generally representative of summer rearing conditions (Wolf Water Resources, personal communication). Habitat suitability scores were calculated using species- and life stage-specific curves identified in WDFW (2022; Figure 2) for each 1.00 m × 1.00 m pixel within the model raster. As in the winter rearing assessment, composite suitability was calculated as the geometric mean of depth and velocity suitability scores for each pixel.

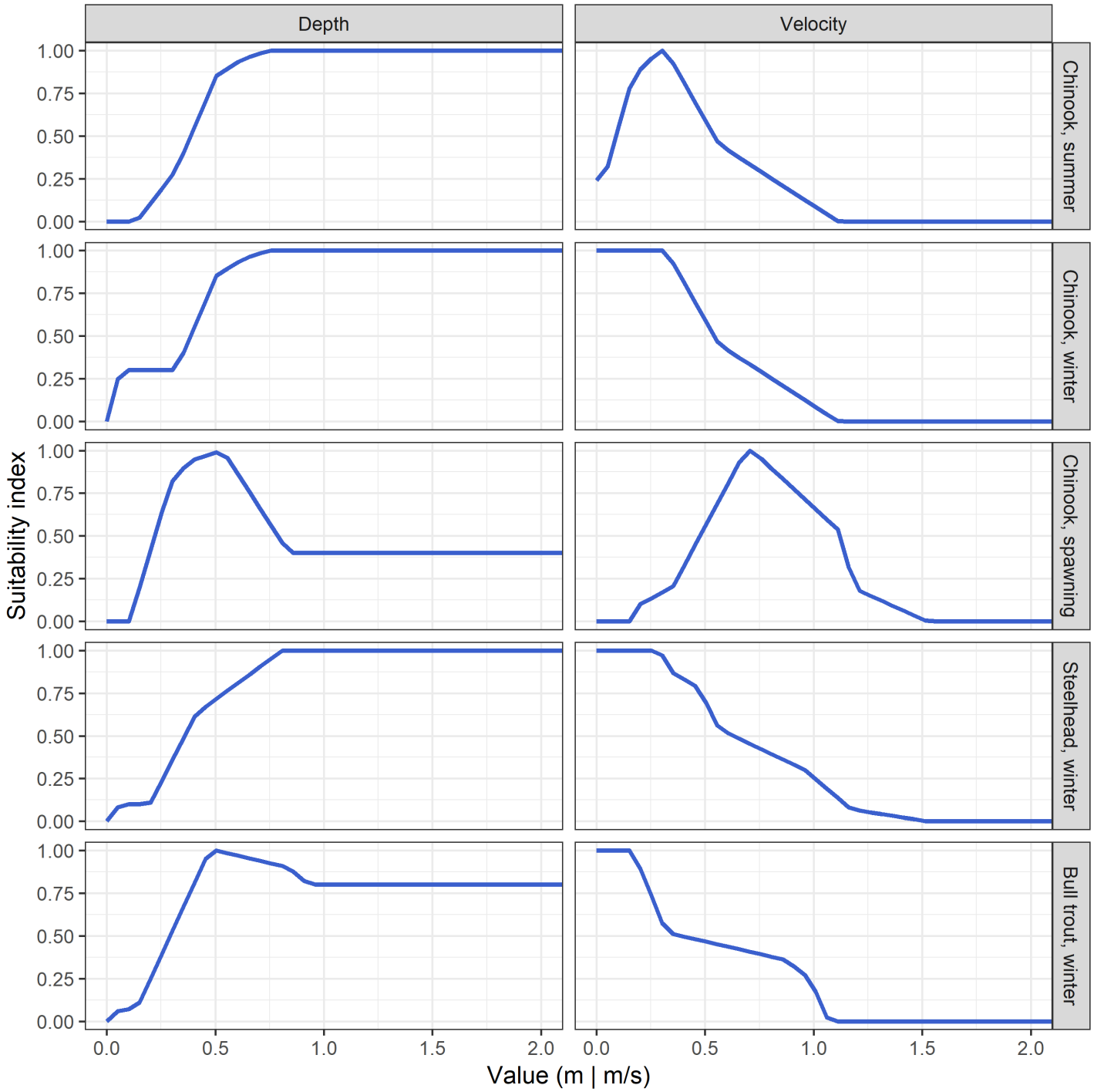


Figure 2. Depth and velocity hydraulic suitability curves for juvenile Chinook salmon summer rearing, juvenile Chinook salmon winter rearing, Chinook salmon spawning, juvenile steelhead winter rearing, and juvenile bull trout winter rearing.

Floodplain Connectivity and HHS Modeling

A set of models were developed to evaluate the effect of floodplain connectivity on hydraulic suitability within PA 1.1-15.2. This involved fitting beta regression models using the area of floodplain connected within each project area (Table 2) and a species effect to predict mean depth, velocity, and composite suitability scores for juvenile winter rearing. A second model was developed for the summer Chinook salmon life stages (spawning and juvenile summer rearing) using the same floodplain covariate and incorporating a life stage effect. All models were fit in the statistical software R (R Core Team, 2025) using the betareg() function from the *betareg* package (Cribari-Neto and Zeileis, 2010). Model performance was evaluated using pseudo-R^2 values and diagnostic evaluation of residual and normal Q–Q plots.

Table 2. Floodplain connectivity summarized by project area within the Tucannon River.

Project area	Disconnected area (acres)				Connected area (acres)	Total area (acres)	Proportion connected
	Road	Levee	Lake	Incision			
PA 1.1	0.3	0.7	0.0	8.5	17.2	26.7	0.65
PA 1.2	0.0	1.5	0.0	5.5	6.9	13.9	0.49
PA 2	1.5	0.4	0.0	6.0	20.0	27.9	0.72
PA 3.1	0.0	0.3	0.0	5.3	8.7	14.3	0.61
PA 3.2	0.5	2.2	1.4	38.6	27.9	70.5	0.40
PA 4	0.1	4.7	0.0	0.7	1.2	6.7	0.19
PA 5	18.6	1.7	0.0	5.1	8.9	34.3	0.26
PA 6	2.8	5.4	0.0	22.8	15.9	46.9	0.34
PA 7	11.2	1.2	7.4	9.0	4.2	32.9	0.13
PA 8	0.5	6.2	9.4	7.8	7.6	31.5	0.24
PA 9	1.5	0.0	23.9	4.1	6.0	34.1	0.18
PA 10.1	0.4	0.0	20.7	9.1	7.0	37.1	0.19
PA 10.2	1.1	9.3	1.8	19.0	23.3	54.5	0.43
PA 10.3	0.3	0.0	0.0	24.2	11.2	35.7	0.31
PA 11.1	9.8	0.1	26.0	11.6	13.5	61.0	0.22
PA 11.2	10.2	1.9	18.0	38.1	19.5	87.7	0.22
PA 12	2.1	0.5	13.2	27.8	12.9	56.6	0.23
PA 13	5.8	16.8	34.2	11.6	7.8	71.6	0.11
PA 14.1	15.3	8.3	1.7	19.2	24.3	67.3	0.36
PA 14.2	16.7	1.0	2.0	22.6	15.0	55.3	0.27
PA 14.3	3.5	0.3	2.7	37.1	23.3	66.1	0.35
PA 15.1	1.9	4.6	0.1	23.2	13.0	42.8	0.30
PA 15.2	0.1	4.6	0.0	25.2	16.0	46.0	0.35

Results

Hydraulic Habitat Suitability

Juvenile Chinook salmon summer rearing

Juvenile Chinook salmon summer rearing composite suitability scores were low across all project areas due to shallow and relatively high-velocity conditions, with mean values ranging from 0.05 to 0.20 (Figure 3, Table S1). Low depth suitability scores were observed throughout the reach under the summer flow scenario, reflecting generally shallow conditions across project areas. Velocity suitability was more variable, with the highest mean values occurring in Project Area 11.2 and the lowest in Project Area 7.

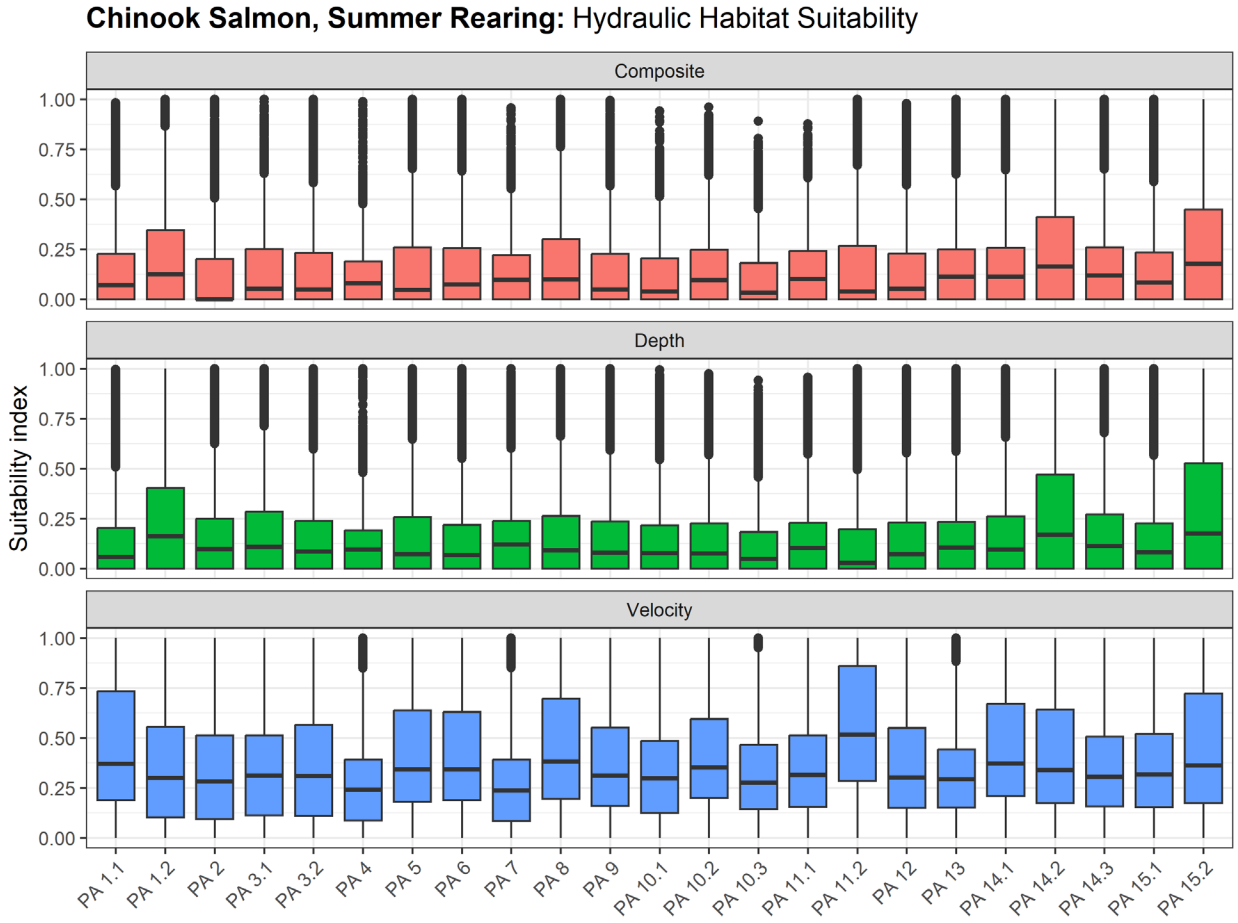


Figure 3. Box plots of composite, depth, and velocity suitability values for juvenile Chinook salmon summer rearing, summarized by project area, in PA 1.1-15.2 of the Tucannon River.

Juvenile Chinook salmon winter rearing

Juvenile Chinook salmon winter rearing composite suitability scores averaged approximately 0.25, with notably lower scores in PA 4, PA 7, and PA 14.3 (Figure 4, Table S2). In these project areas, velocity suitability was the primary limiting factor, as depth suitability scores were comparable to those in other project areas. Overall, winter depth suitability for juvenile Chinook salmon remained relatively consistent across the study area, averaging roughly 0.3.

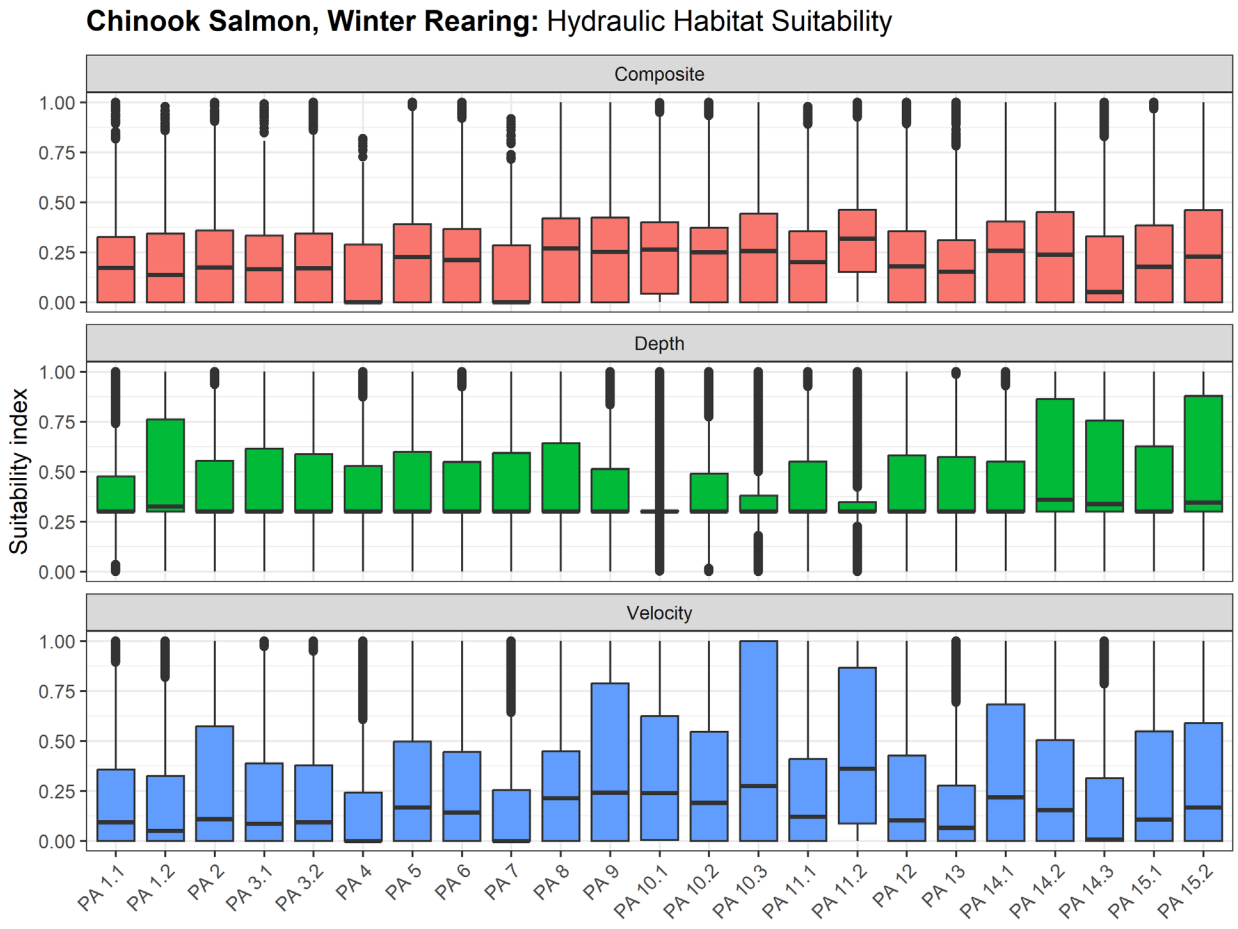


Figure 4. Box plots of composite, depth, and velocity suitability values for juvenile Chinook salmon winter rearing, summarized by project area, in PA 5-15.2 of the Tucannon River.

Chinook salmon spawning

Composite hydraulic suitability scores for Chinook salmon spawning were generally higher across all project areas compared to other Chinook salmon life stages, juvenile steelhead winter rearing, and juvenile bull trout winter rearing (Figure 5, Table S3). Higher velocities under the summer flow scenario contributed to higher velocity suitability scores. Although depths remained

relatively low during the summer flow scenario, they were more consistent with preferred spawning depths than summer rearing depths.

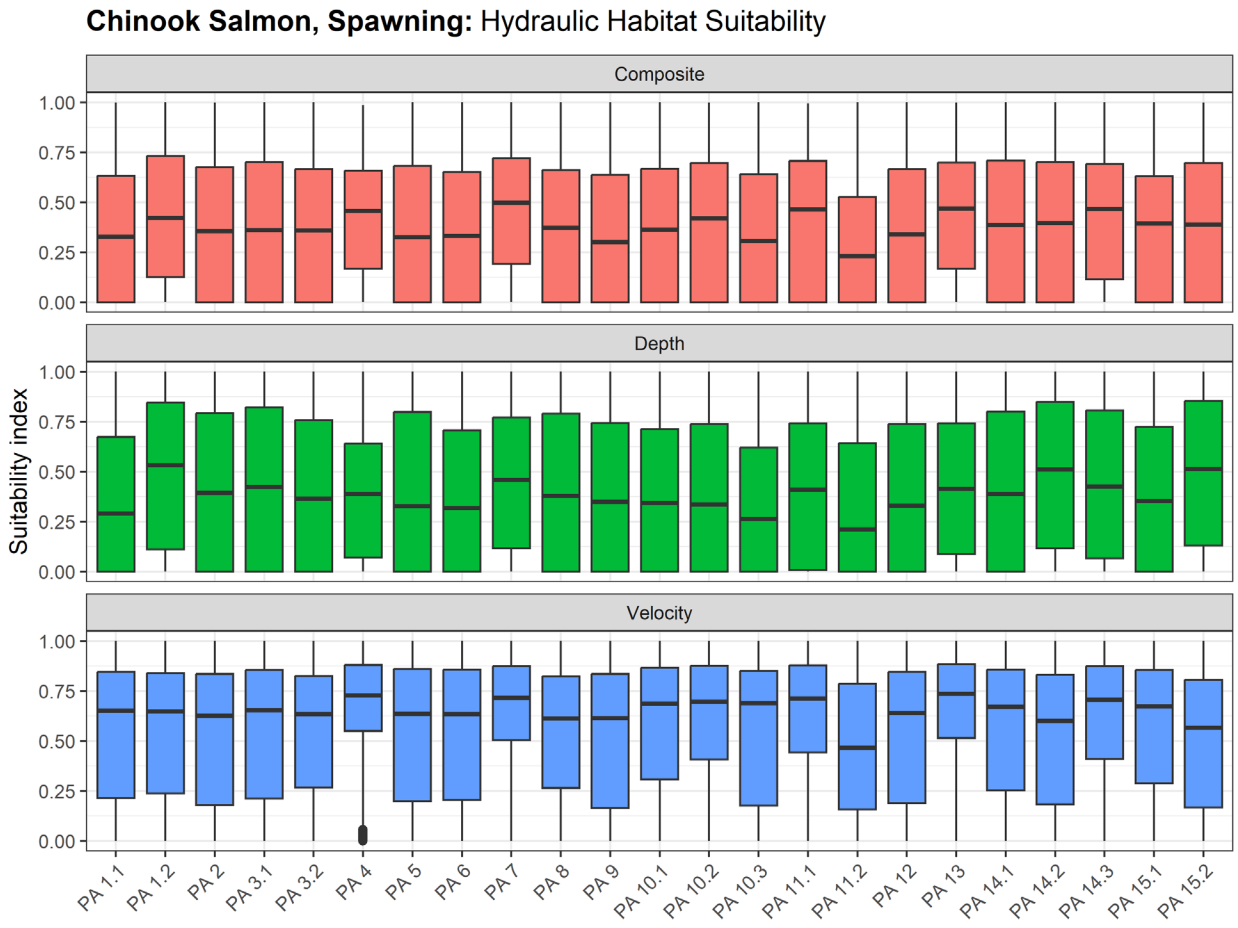


Figure 5. Box plots of composite, depth, and velocity suitability values for Chinook salmon spawning, summarized by project area, in PA 1.1-15.2 of the Tucannon River.

Juvenile steelhead winter rearing

Juvenile steelhead winter rearing suitability followed a similar pattern to Chinook salmon winter rearing with average composite suitability scores of approximately 0.25 (Figure 6, Table S4). However, variability in composite suitability scores was lower for juvenile steelhead than for juvenile Chinook salmon. Depth suitability was generally consistent across project areas, although suitability was lower in PA 10.1, PA 10.3, and PA 11.2. A common pattern across project areas was that lower suitability in one hydraulic metric was often offset by higher suitability in the other, resulting in more uniform composite scores overall. For example, PA 9 exhibited high velocity suitability but lower depth suitability, whereas PA 13 showed the opposite pattern, producing moderately low composite scores in both reaches.

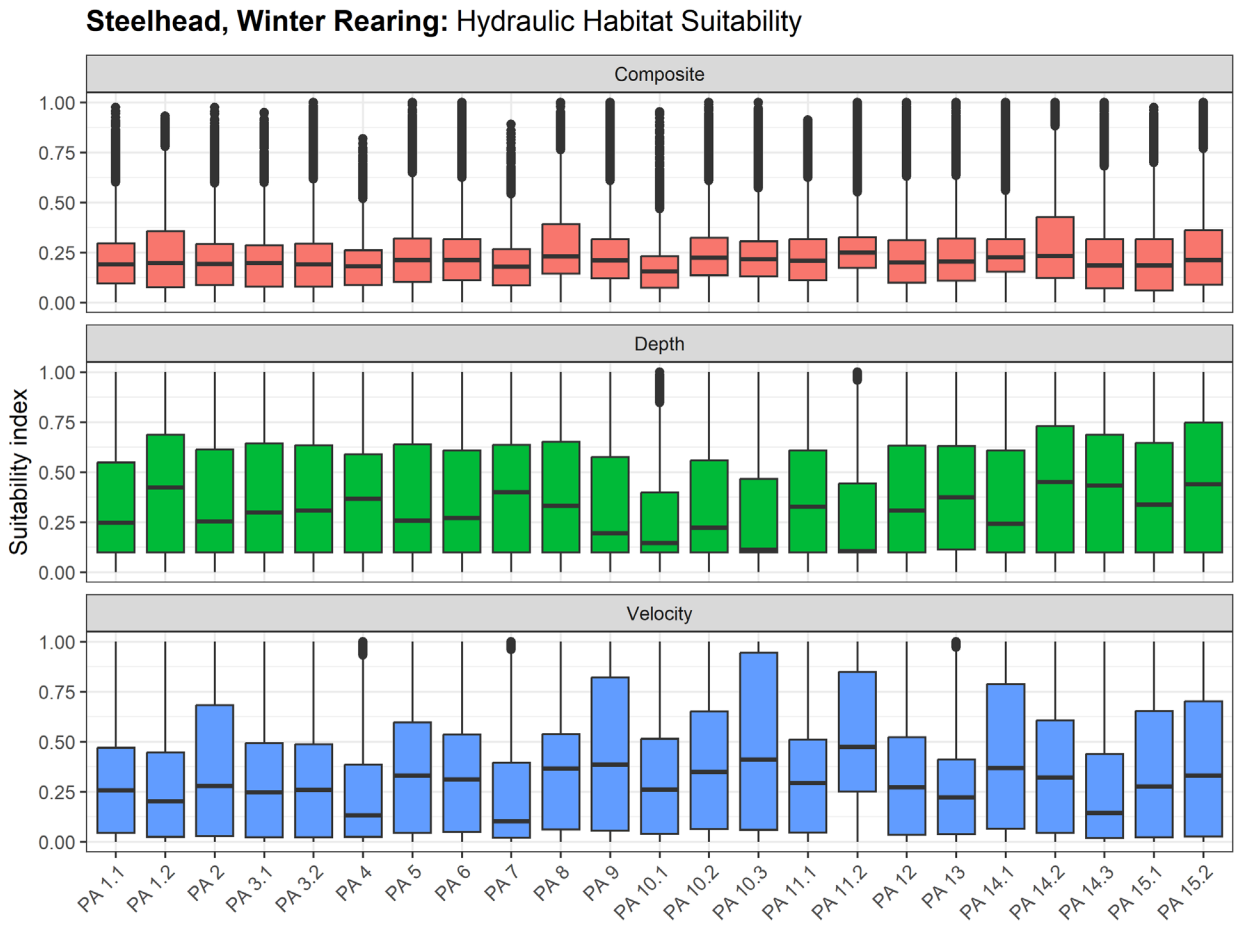


Figure 6. Box plots of composite, depth, and velocity suitability values for juvenile steelhead winter rearing summarized by project area, in PA 1.1-15.2 of the Tucannon River.

Juvenile bull trout winter rearing

Composite suitability scores for juvenile bull trout winter rearing were generally lower than juvenile Chinook salmon and steelhead (Figure 7, Table S5). Average composite scores across project areas for bull trout were approximately 0.2, compared to roughly 0.25 for Chinook salmon and steelhead. Velocity suitability scores for juvenile bull trout winter rearing rarely exceeded 0.5, whereas depth suitability scores were broadly distributed between 0.1 and 0.75, with an average near 0.45.

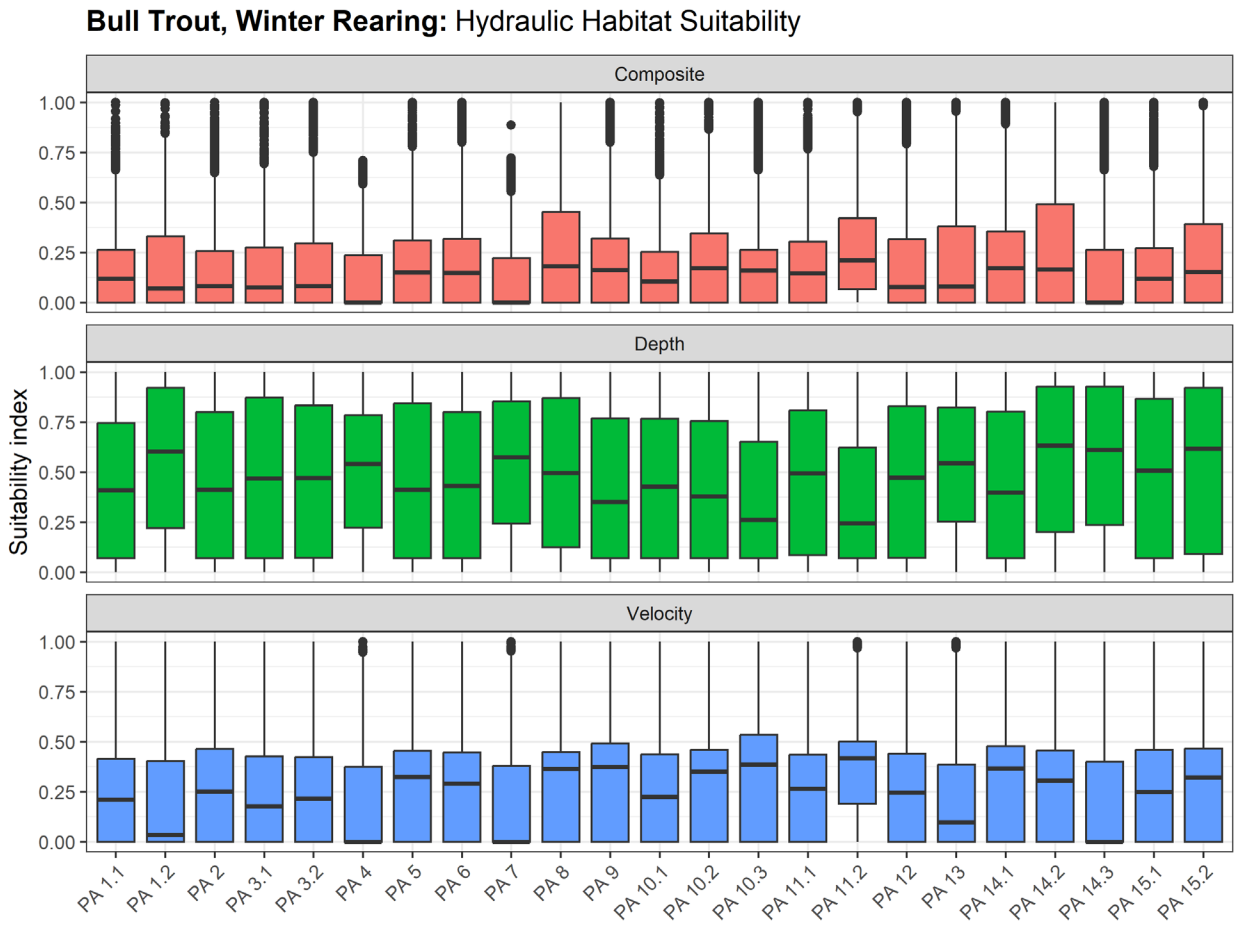


Figure 7. Box plots of composite, depth, and velocity suitability values for juvenile bull trout winter rearing, summarized by project area, in PA 1.1-15.2 of the Tucannon River.

Floodplain connectivity and HHS modeling

Increased floodplain connectivity was positively related to velocity suitability but exhibited no relationship with depth suitability (Table 3, Figure 8). Juvenile winter rearing velocity suitability was positively associated with the area of floodplain connected within a project area ($\beta = 0.015$, $p = 0.003$). In addition, juvenile steelhead winter rearing exhibited higher velocity suitability than juvenile Chinook salmon winter rearing ($\beta = 0.306$, $p < 0.001$), whereas velocity suitability for juvenile bull trout did not differ significantly from Chinook salmon ($\beta = -0.057$, $p = 0.524$). The velocity suitability model demonstrated relatively poor explanatory power, accounting for 30.1% of the variation in velocity suitability (pseudo-$R^2 = 0.301$).

In contrast, juvenile winter rearing depth suitability showed no meaningful relationship with the area of floodplain connected within a project area ($\beta = -0.002$, $p = 0.516$). However, juvenile steelhead exhibited lower depth suitability than juvenile Chinook salmon ($\beta = -0.304$, $p < 0.001$), while juvenile bull trout exhibited higher depth suitability relative to Chinook salmon ($\beta = 0.179$, $p = 0.004$). Among the three juvenile winter hydraulic suitability models, the depth model

provided the strongest fit, explaining 47.1% of the variation in depth suitability (pseudo-R^2 = 0.471).

Composite suitability increased with the area of floodplain connected within a project area and this relationship was statistically significant (β = 0.007, p = 0.034). Composite suitability did not differ significantly between juvenile steelhead and Chinook salmon winter rearing (β = 0.082, p = 0.141), whereas juvenile bull trout exhibited lower composite suitability than Chinook salmon (β = −0.178, p = 0.002). The composite suitability model explained 27.8% of the variation in composite suitability (pseudo-R^2 = 0.278), representing the weakest fit among the three juvenile winter suitability models.

Table 3. Results of beta regression models evaluating relationships between floodplain connectivity (area of connected floodplain by project area) and hydraulic habitat suitability indices (composite, depth, and velocity) for juvenile winter rearing life stages in PA 1.1-15.2 of the Tucannon River. Coefficients are reported on the logit scale. Species effects are presented relative to the reference category (Chinook salmon).

Model	Term	Coefficient	S.E.	p-value
Juvenile winter rearing composite suitability	(Intercept)	-1.351	0.061	<0.001
	Floodplain Area Con	0.007	0.003	0.034
	Species – Steelhead	0.082	0.056	0.141
	Species – Bull Trout	-0.178	0.058	0.002
Juvenile winter rearing depth suitability	(Intercept)	-0.215	0.066	0.001
	Floodplain Area Con	-0.002	0.004	0.516
	Species – Steelhead	-0.304	0.063	<0.001
	Species – Bull Trout	0.179	0.062	0.004
Juvenile winter rearing velocity suitability	(Intercept)	-1.090	0.094	<0.001
	Floodplain Area Con	0.015	0.005	0.003
	Species – Steelhead	0.306	0.086	<0.001
	Species – Bull Trout	-0.057	0.089	0.524

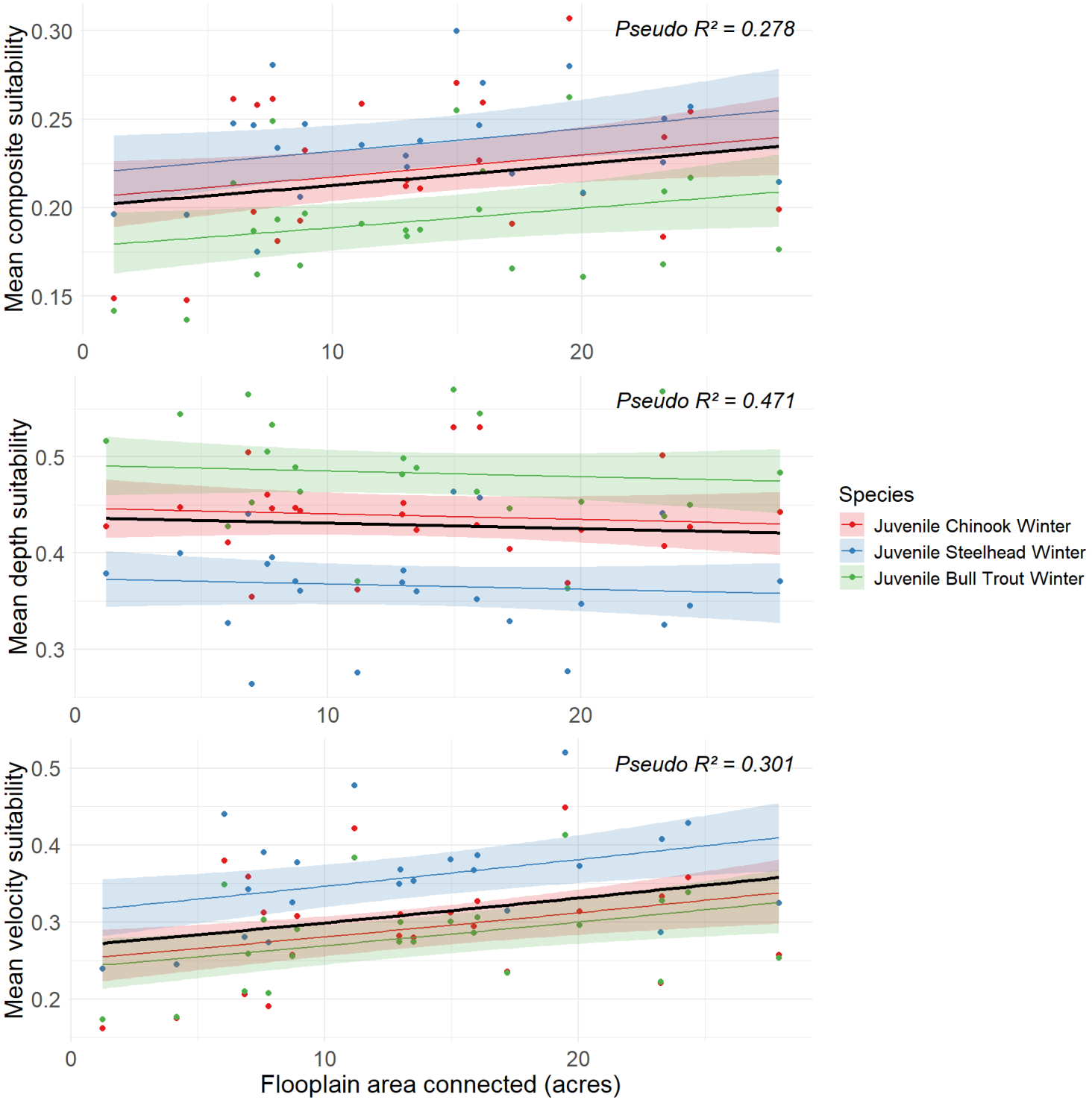


Figure 8. Scatter plots showing the relationship between the proportion of connected floodplain within each project area and mean depth, mean velocity, and mean composite suitability scores for juvenile Chinook salmon, steelhead, and bull trout winter rearing for the Tucannon River PA 1.1-15.2.

For Chinook salmon summer rearing, changes in floodplain connectivity predicted no changes in suitability (Table 4, Figure 9). Across all three suitability metrics, connected floodplain area was not a significant predictor of hydraulic suitability (composite: $\beta = -0.001$, $p = 0.737$; depth: $\beta = -0.001$, $p = 0.796$; velocity: $\beta = 0.004$, $p = 0.390$). In contrast, consistent differences were observed between summer life stages. Juvenile Chinook salmon summer rearing exhibited lower composite ($\beta = -1.155$, $p < 0.001$), depth ($\beta = -1.123$, $p < 0.001$), and velocity ($\beta = -0.773$, $p < 0.001$) suitability relative to Chinook salmon spawning across project areas 1.1–15.2.

Table 4. Results of beta regression models evaluating relationships between floodplain connectivity (area of connected floodplain by project area) and hydraulic habitat suitability indices (composite, depth, and velocity) for Chinook salmon summer life stages in PA 1.1-15.2 of the Tucannon River. Coefficients are reported on the logit scale. Life stage effects are presented relative to the reference category (Chinook salmon spawning).

Model	Term	Coefficient	S.E.	p-value
Chinook salmon summer composite suitability	(Intercept)	-0.430	0.068	<0.001
	Floodplain Area Con	-0.001	0.004	0.737
	Life stage – juvenile Chinook summer	-1.155	0.061	<0.001
Chinook salmon summer depth suitability	(Intercept)	-0.332	0.079	<0.001
	Floodplain Area Con	-0.001	0.005	0.796
	Life stage – juvenile Chinook summer	-1.123	0.069	<0.001
Chinook salmon summer velocity suitability	(Intercept)	0.253	0.074	<0.001
	Floodplain Area Con	0.004	0.004	0.390
	Life stage – juvenile Chinook summer	-0.773	0.062	<0.001

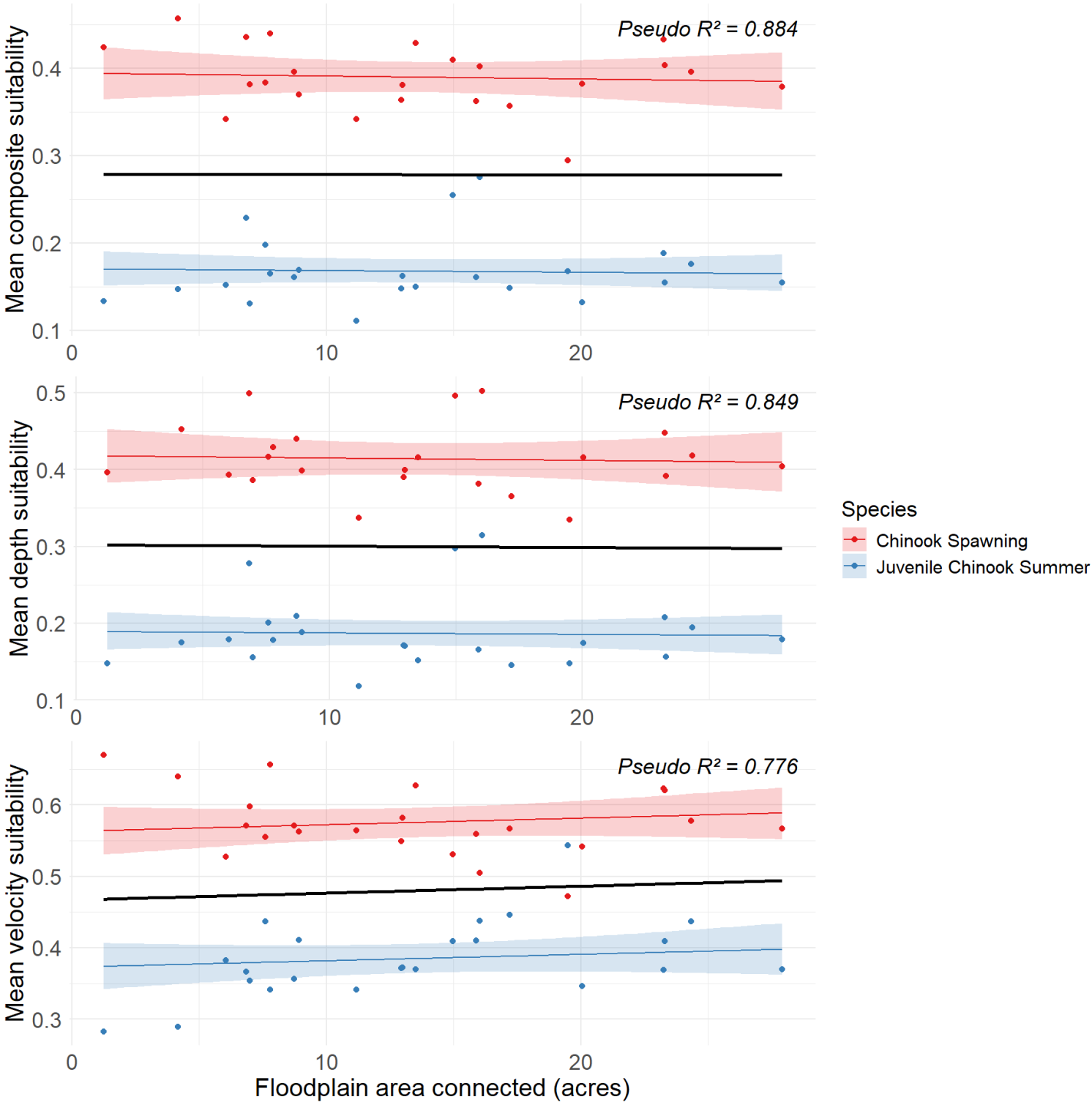


Figure 9. Scatter plots showing the relationship between the proportion of connected floodplain within each project area and mean depth, mean velocity, and mean composite suitability scores for Chinook salmon spawning and juvenile summer rearing for the Tucannon River PA 1.1-15.2.

Discussion

This technical report evaluated HHS for juvenile winter rearing Chinook salmon, steelhead, and bull trout, as well as juvenile summer rearing and adult spawning Chinook salmon within PA 1.1-15.2 of the Tucannon River. Across species and life stages, modeled hydraulic conditions were generally poor throughout the study area. Velocity suitability was consistently a primary limiting factor for juvenile winter rearing, with conditions typically faster than preferred ranges, while depth suitability was also low for most species. Depth suitability for bull trout was slightly higher than for Chinook salmon and steelhead, reflecting their preference for slightly shallower conditions. Summer rearing suitability for juvenile Chinook salmon was also limited, largely due to shallow depths, and spawning suitability for Chinook salmon, although higher than juvenile rearing suitability, remained relatively low overall.

Regression analyses indicated that the amount of connected floodplain area within a project area was only weakly associated with hydraulic suitability. Positive relationships were observed between floodplain connectivity and winter velocity and composite suitability, but model fit was relatively poor, and no clear relationship was observed for Chinook salmon summer rearing or spawning suitability. These results suggest that increasing floodplain connectivity alone is not sufficient to predict improvements in hydraulic habitat conditions. Rather, floodplain connectivity provides the spatial and geomorphic context necessary for processes to occur that generate suitable hydraulic conditions over time.

Despite the relatively weak statistical relationship between connected floodplain area and modeled suitability, reaches with limited floodplain connectivity, particularly PA 4, 7, and 13, also exhibited some of the lowest composite suitability scores across species. These reaches are largely characterized by single-thread, channelized morphology with limited side-channel or off-channel habitat. Conversely, PA 14.3 contained relatively large areas of connected floodplain but still exhibited low suitability, highlighting that connectivity alone does not ensure the development of hydraulically suitable habitat where channel complexity remains limited. Collectively, these patterns reinforce that floodplain connectivity is best interpreted as a process-enabling condition rather than a direct predictor of habitat suitability.

Decades of channel simplification, floodplain disconnection, water diversion, and altered geomorphic processes within the Tucannon River watershed have contributed to hydraulic conditions that are generally too fast and shallow for juvenile rearing and only marginally suitable for Chinook salmon spawning. Increasing floodplain connectivity expands the area available for lateral flow exchange, channel migration, and the development of multi-threaded channels, side channels, alcoves, pools, and other complex channel features. These geomorphic features create slower, deeper hydraulic environments that are more suitable for multiple juvenile life stages. Although these habitat types are sparse within PA 1.1-15.2, they exhibit the some of the highest suitability scores where they occur. Restoration strategies that increase connected floodplain area should be implemented within a broader process-based framework that promotes channel

complexity, increases channel length and reduces channel gradient, and enhances lateral habitat development, rather than relying on floodplain connectivity alone as a direct mechanism for improving hydraulic conditions.

Restoration actions that increase lateral connectivity should also prioritize the creation and maintenance of deeper, low-velocity mainstem habitats such as pools, alcoves, and backwaters, which may provide important overwintering habitat not fully replicated by side-channel environments alone. In addition, seasonal floodplain inundation can provide velocity refugia and favorable growth conditions for fry and early parr (Jeffres et al. 2008), life stages that were not evaluated in this assessment due to limited suitability information. Regardless, these patterns further support the value of restoration strategies that increase floodplain connectivity and promote the geomorphic processes responsible for creating and maintaining diverse off-channel and mainstem habitat conditions.

At the same time, restoration strategies that redistribute flow laterally should be implemented with consideration for potential tradeoffs with adult migration conditions. Excessive reductions in mainstem depths during summer migration periods, particularly in reaches influenced by water diversion, could increase the likelihood of hydraulic passage constraints for adult Chinook salmon and bull trout. Process-based restoration approaches should balance efforts to increase floodplain connectivity with the need to maintain adequate migration corridors in the primary channel, ensuring that connectivity benefits are achieved without constraining fish passage or concentrating flow into less suitable habitats.

Beyond hydraulic suitability, increased floodplain connectivity supports a range of ecological processes that benefit salmonids across life stages. Regular floodplain inundation promotes riparian vegetation development, increases large wood recruitment, enhances channel complexity, and supports groundwater recharge and hyporheic exchange (Singh et al. 2018). These processes can moderate stream temperature extremes and create localized thermal heterogeneity that provides seasonal refugia (Poole and Berman 2001; Weber et al. 2017). Because high-quality salmonid habitat reflects the interaction of hydraulic, geomorphic, thermal, and biological processes, restoration actions that expand connected floodplain area and promote natural channel dynamics are likely to produce the greatest long-term ecological benefit.

Hydraulic habitat suitability analyses provide important insight into species- and life stage-specific constraints, but they represent only one component of overall habitat quality. Results from this assessment should therefore be interpreted alongside the biological and geomorphic appendices included in this report to support integrated, watershed-scale restoration planning and prioritization.

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Supplemental Tables and Figures

Table S1. Juvenile Chinook salmon summer rearing mean and median hydraulic habitat suitability (HHS) values by Project Area.

	Mean HHS			Median HHS		
Project Area	**Composite**	**Depth**	**Velocity**	**Composite**	**Depth**	**Velocity**
PA 1.1	0.14	0.14	0.45	0.07	0.06	0.37
PA 1.2	0.22	0.27	0.36	0.13	0.16	0.30
PA 2	0.12	0.17	0.34	0.00	0.10	0.28
PA 3.2	0.15	0.20	0.35	0.05	0.11	0.31
PA 3.2	0.15	0.17	0.37	0.05	0.09	0.31
PA 4	0.13	0.14	0.28	0.08	0.10	0.24
PA 5	0.16	0.18	0.41	0.05	0.07	0.34
PA 6	0.15	0.16	0.41	0.07	0.07	0.34
PA 7	0.14	0.17	0.28	0.10	0.12	0.24
PA 8	0.19	0.19	0.44	0.10	0.09	0.38
PA 9	0.14	0.17	0.38	0.05	0.08	0.31
PA 10.1	0.12	0.15	0.35	0.04	0.08	0.30
PA 10.2	0.15	0.15	0.41	0.10	0.08	0.35
PA 10.3	0.10	0.11	0.34	0.03	0.05	0.28
PA 11.1	0.14	0.14	0.37	0.10	0.10	0.32
PA 11.2	0.16	0.14	0.54	0.04	0.03	0.52
PA 12	0.14	0.16	0.37	0.05	0.07	0.30
PA 13	0.16	0.17	0.34	0.11	0.11	0.30
PA 14.1	0.17	0.19	0.44	0.11	0.10	0.37
PA 14.2	0.25	0.29	0.41	0.16	0.17	0.34
PA 14.3	0.18	0.20	0.37	0.12	0.11	0.31
PA 15.1	0.15	0.16	0.37	0.08	0.08	0.32
PA 15.2	0.27	0.31	0.44	0.18	0.18	0.36

Table S2. Juvenile Chinook salmon winter rearing mean and median hydraulic habitat suitability (HHS) values by Project Area.

	Mean HHS			Median HHS		
Project Area	**Composite**	**Depth**	**Velocity**	**Composite**	**Depth**	**Velocity**
PA 1.1	0.19	0.40	0.23	0.17	0.30	0.09
PA 1.2	0.19	0.50	0.20	0.14	0.33	0.05
PA 2	0.20	0.42	0.31	0.17	0.30	0.11
PA 3.2	0.19	0.45	0.25	0.17	0.30	0.09
PA 3.2	0.19	0.44	0.25	0.17	0.30	0.09
PA 4	0.14	0.43	0.16	0.00	0.30	0.00
PA 5	0.23	0.44	0.30	0.23	0.30	0.17
PA 6	0.22	0.43	0.29	0.21	0.30	0.14
PA 7	0.14	0.45	0.17	0.00	0.30	0.00
PA 8	0.26	0.46	0.31	0.27	0.30	0.22
PA 9	0.26	0.41	0.38	0.25	0.30	0.24
PA 10.1	0.25	0.35	0.36	0.26	0.30	0.24
PA 10.2	0.24	0.41	0.33	0.25	0.30	0.19
PA 10.3	0.26	0.36	0.42	0.26	0.30	0.28
PA 11.1	0.21	0.42	0.28	0.20	0.30	0.12
PA 11.2	0.30	0.37	0.45	0.32	0.30	0.36
PA 12	0.21	0.44	0.28	0.18	0.30	0.10
PA 13	0.18	0.45	0.19	0.15	0.30	0.07
PA 14.1	0.25	0.43	0.36	0.26	0.30	0.22
PA 14.2	0.27	0.53	0.31	0.24	0.36	0.15
PA 14.3	0.18	0.50	0.22	0.05	0.34	0.01
PA 15.1	0.21	0.45	0.31	0.18	0.30	0.11
PA 15.2	0.26	0.53	0.32	0.23	0.35	0.17

Table S3. Chinook salmon spawning mean and median hydraulic habitat suitability (HHS) values by Project Area.

	Mean HHS			Median HHS		
Project Area	**Composite**	**Depth**	**Velocity**	**Composite**	**Depth**	**Velocity**
PA 1.1	0.35	0.36	0.57	0.33	0.29	0.65
PA 1.2	0.43	0.50	0.57	0.42	0.53	0.65
PA 2	0.38	0.41	0.54	0.36	0.39	0.63
PA 3.2	0.39	0.44	0.57	0.36	0.42	0.65
PA 3.2	0.38	0.40	0.57	0.36	0.37	0.63
PA 4	0.42	0.39	0.67	0.46	0.39	0.73
PA 5	0.37	0.40	0.56	0.33	0.33	0.64
PA 6	0.36	0.38	0.56	0.33	0.32	0.63
PA 7	0.46	0.45	0.64	0.50	0.46	0.72
PA 8	0.38	0.41	0.56	0.37	0.38	0.61
PA 9	0.34	0.39	0.53	0.30	0.35	0.61
PA 10.1	0.38	0.38	0.60	0.36	0.34	0.69
PA 10.2	0.40	0.39	0.62	0.42	0.34	0.70
PA 10.3	0.34	0.33	0.57	0.31	0.26	0.69
PA 11.1	0.43	0.41	0.63	0.47	0.41	0.71
PA 11.2	0.29	0.33	0.47	0.23	0.21	0.47
PA 12	0.36	0.39	0.55	0.34	0.33	0.64
PA 13	0.44	0.43	0.66	0.47	0.41	0.74
PA 14.1	0.39	0.42	0.58	0.39	0.39	0.67
PA 14.2	0.41	0.50	0.53	0.40	0.51	0.60
PA 14.3	0.43	0.45	0.63	0.47	0.43	0.71
PA 15.1	0.38	0.40	0.58	0.39	0.35	0.67
PA 15.2	0.40	0.50	0.51	0.39	0.51	0.57

Table S4. Juvenile steelhead winter rearing mean and median hydraulic habitat suitability (HHS) values by Project Area.

	Mean HHS			Median HHS		
Project Area	**Composite**	**Depth**	**Velocity**	**Composite**	**Depth**	**Velocity**
PA 1.1	0.22	0.33	0.31	0.19	0.25	0.26
PA 1.2	0.24	0.44	0.28	0.20	0.42	0.20
PA 2	0.20	0.34	0.37	0.19	0.25	0.28
PA 3.2	0.20	0.37	0.32	0.20	0.30	0.25
PA 3.2	0.21	0.37	0.32	0.19	0.31	0.26
PA 4	0.19	0.38	0.24	0.18	0.37	0.13
PA 5	0.24	0.36	0.38	0.21	0.26	0.33
PA 6	0.24	0.35	0.37	0.21	0.27	0.31
PA 7	0.19	0.40	0.24	0.18	0.40	0.10
PA 8	0.28	0.39	0.39	0.23	0.33	0.37
PA 9	0.24	0.32	0.44	0.21	0.19	0.39
PA 10.1	0.17	0.26	0.34	0.16	0.15	0.26
PA 10.2	0.25	0.32	0.41	0.22	0.22	0.35
PA 10.3	0.23	0.27	0.48	0.22	0.11	0.41
PA 11.1	0.23	0.36	0.35	0.21	0.33	0.29
PA 11.2	0.28	0.27	0.52	0.25	0.10	0.48
PA 12	0.23	0.37	0.35	0.20	0.31	0.27
PA 13	0.23	0.39	0.27	0.21	0.37	0.22
PA 14.1	0.25	0.34	0.43	0.23	0.24	0.37
PA 14.2	0.30	0.46	0.38	0.23	0.45	0.32
PA 14.3	0.22	0.44	0.28	0.19	0.43	0.15
PA 15.1	0.22	0.38	0.37	0.19	0.34	0.28
PA 15.2	0.27	0.46	0.38	0.21	0.44	0.33

Table S5. Juvenile bull trout winter rearing mean and median hydraulic habitat suitability (HHS) values by Project Area.

	Mean HHS			Median HHS		
Project Area	**Composite**	**Depth**	**Velocity**	**Composite**	**Depth**	**Velocity**
PA 1.1	0.16	0.45	0.23	0.12	0.41	0.21
PA 1.2	0.18	0.57	0.21	0.07	0.60	0.04
PA 2	0.16	0.45	0.29	0.08	0.41	0.25
PA 3.2	0.16	0.49	0.25	0.08	0.47	0.18
PA 3.2	0.17	0.48	0.25	0.08	0.47	0.22
PA 4	0.14	0.52	0.17	0.00	0.54	0.00
PA 5	0.19	0.46	0.29	0.15	0.41	0.32
PA 6	0.19	0.46	0.28	0.15	0.43	0.29
PA 7	0.13	0.54	0.17	0.00	0.57	0.00
PA 8	0.25	0.50	0.30	0.18	0.50	0.37
PA 9	0.21	0.43	0.35	0.16	0.35	0.37
PA 10.1	0.16	0.45	0.26	0.11	0.43	0.23
PA 10.2	0.20	0.44	0.33	0.17	0.38	0.35
PA 10.3	0.19	0.37	0.38	0.16	0.26	0.39
PA 11.1	0.18	0.49	0.27	0.15	0.49	0.27
PA 11.2	0.26	0.36	0.41	0.21	0.24	0.42
PA 12	0.18	0.48	0.27	0.08	0.47	0.25
PA 13	0.19	0.53	0.20	0.08	0.55	0.10
PA 14.1	0.21	0.45	0.34	0.17	0.40	0.37
PA 14.2	0.25	0.57	0.30	0.17	0.63	0.31
PA 14.3	0.16	0.57	0.22	0.00	0.61	0.00
PA 15.1	0.18	0.50	0.30	0.12	0.51	0.25
PA 15.2	0.22	0.55	0.30	0.15	0.62	0.32

RSI Resource Specialists INC.
20340 Empire Ave. Ste E8
Bend, OR 97703
(541) 771-6911

Memorandum

Date: September 11th, 2024
From: Gabriel Williams, Resource Specialists Inc. (gabe@rsiengr.com)
Re: Wooten Wildlife Area Dam Review

DRAFT

Overview

This memorandum lays out the efforts undertaken by Resource Specialists Inc.(RSI) to determine overall operation, safety, spatial impact, correction options, and cost to repair or decommission eight impoundments on the Wooten Wildlife Area. The rating matrix contained in this memorandum summarizes each of the categories for each of the lakes in comparison to each other and a discussion of each category is contained below. In the chart a high rating equates to a high negative rating while low relates to a positive rating. Some lakes received no rating for repair and/or decommissioning cost due to either not being a need for repairs and/or decommissioning not being a management option.

Operational Overview/Concerns

The Operational Overview/Concerns category contains general information on operations, field observations by staff, and summary of discussions had on-site. Key points of note typically include how the lake was affected by the 2020 flood, fill/drain details, annual instream disturbance requirements. Lakes which are more prone to flood effects and are difficult to drain and/or fill received a high rating.

Dam Safety Concerns

Dam safety concerns are a combination of Washington State review notes of safety issues and RSI's field observations of safety concerns. Typical observed issues were insufficient dam top width, over-steepened slopes, large trees growing in dam fill, high seepage rates, and non-functioning outlet/drainpipes. Additional weighting was given to safety correction measures which could lead to additional deficiency discoveries and unexpected repair cost increases. An example of this would be a tree removal operation which requires the rootwad to be removed with the tree. This removal could create a new leak in the dam which would require a repair of that dam section. Drainpipe repairs often result in additional unexpected work being required once the dam is opened for the installation of the new pipe. Lakes with these issues or with issues that could lead to complete dam failure received a high rating. Dam top width and slope corrections/repairs are typically activities which don't result in the discovery of additional deficiencies and thus do not typically contribute to a high rating.

Hydrologic / Topographic Concerns

Each of the impoundments were analyzed to determine how impactful the impoundments are on the natural hydraulic function of the Tucannon River and floodplain. Valley wide cross-sections through the impoundments were used to determine how much of the cross-sectional floodplain each of the structures occupy. Many of the lakes occupy more than 50% of the valley cross-sectional area. Even given similar

cross-section occupation, not all structures influenced the hydrologic function proportionately. To better evaluate overall impacts, a 2D hydraulic model (HEC-RAS) was used to determine at which flows each structure became engaged by the river and at which flows each structure had significant (flooding) engagement by the river. Flow depths and velocities were examined once floodwaters began to interact with the dam structure in order to determine how impactful high flow events could be as it relates to dam safety. This was determined by looking at both the flow rate (cfs) that river started to engage the dam, and what the water velocity at that engagement is in proximity to the structure. Given similar flow rate interaction, lakes where the velocity of the water at the dam was higher were given a higher rating. This is due to the fact that higher velocity at the toe slope of the dam has a greater erosive potential and can quickly lead to dam failure.

Correction Options/Cost

This section of the review focused on the needed correction work and the perceived urgency of that work. Most earthen dams leak to some degree and some of the existing leakage observed in several dams was deemed as not needing immediate corrective action, however other leakage was deemed to be a hazard that should be corrected in the near-term. Leakage which originated around the drainpipe or other similar infrastructure is deemed to need immediate repair to maintain the structural stability of the dam. Deer Lake in particular is concerning due to the settling of the soil over the top of the existing drain pipe which is a strong indicator that the pipe is leaking within the dam and eroding the core of the dam. The correction work directly feeds into the estimated cost of repairs and when the level of observed urgency is included, the resulting rating is provided. Lakes which require no corrective repairs received no rating.

Decommissioning Cost

This cost is an estimate of decommissioning which means the full removal of the structure and the return of the floodplain to its historical natural state. Stuff and more details.

Rating Matrix Summary Table

Beaver and Watson Lakes are analyzed jointly due to their proximity and shared hydrology. Each rating is relative based on overall conditions of all impoundments and is based on best professional judgement.

Additional information and figures detailing the analysis are provided in the individual impoundment assessments. The summary ratings of all impoundments is provided in the table below.

RATING MATRIX	Beaver & Watson Lakes	Big 4 Lake	Blue Lake	Curl Lake	Deer Lake	Rainbow Lake	Spring Lake
Operational Overview/Concerns	●	●	○	○	◉	○	○
Dam Safety Concerns	●	●	○	○	●	○	◉
Hydrologic / Topographic Concerns	◉	●	○	●	●	◉	◉
Corrections Cost	◉	●	○		●		●
Decommissioning Cost	●	●			●		◉
Rating (high, medium, low) ● ◉ ○							

DRAFT

Beaver and Watson Lakes

Size: 2.0 acres (Beaver), 6.5 acres (Watson)

Constructed: 1953 (Beaver), 1954 (Watson)



Figure 1 - Lake Overview

Operational Overview/Concerns

Both lakes are filled from a common intake on the Tucannon River. The inlet structure utilizes a wing dam which needs to be modified frequently for low-water intake. The lakes are filled seasonally starting in mid-February with subsequent dewatering from a bottom drain in Watson on or after November 30. A spring creek feeds the lakes from the SE with year-round flow.

During the 2020 flood event both lakes began dry with the bottom drain open; water overtopped the diversion structure and both lakes were subsequently filled to a point very close to overtopping the dam on Watson. During the flood event water was running through the parking area and filled the vault toilet with water. Beaver Lake serves as a sediment catch basin for Watson Lake. As such, significant sedimentation has occurred within Beaver Lake.

Dam Safety Concerns

The inlet and outlet structures are composed of CMP pipe, all likely original from construction. The 50-year lifespan of the CMP has been exceeded and the current piping is likely in poor condition.

The top width of both dams is narrow with many areas less than six feet in width. The backside of Watson shows signs of erosion.

No emergency spillway is in place for either dam increasing the likelihood of failure during a flood event.

The back of Watson has large cottonwood trees growing into the dam. The roots of the large vegetation can cause issues with overall dam stability.

A significant amount of seepage was observed on the backside of Watson. Continuous seepage has the potential of carrying away fine sediment from the core of the dam and eventually leading to piping and failure of the dam.

There is significant flow through the outlet pipe when the slide gate is in the closed position. The likely source of the leakage is through a compromised section of the CMP.

Measurements from the LiDAR data show several areas where the backside slope of the dam on Watson Lake exceed a 2(H):1(V) slope. The frontside of the Watson dam also has several areas that exceed a 3(H):1(V) slope.

Hydrologic / Topographic Concerns

Watson Lake has a significant footprint within the floodway of the Tucannon River. The positioning of the dam and lake have artificially confined the bounds of the Tucannon River by obstructing more than 60% of the historic floodplain.

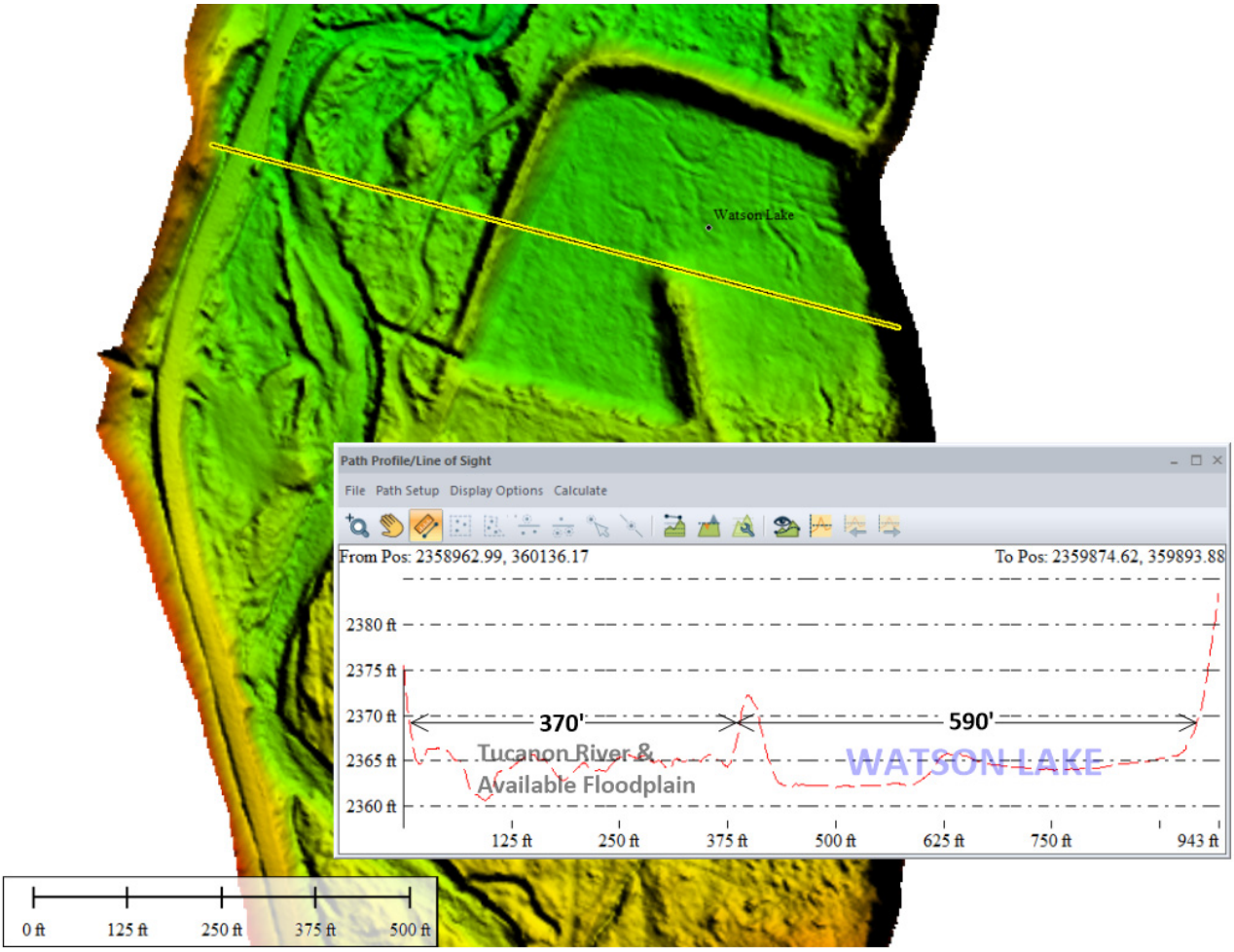


Figure 2 - Watson Lake valley floor cross-section

Hydraulic Modeling Results

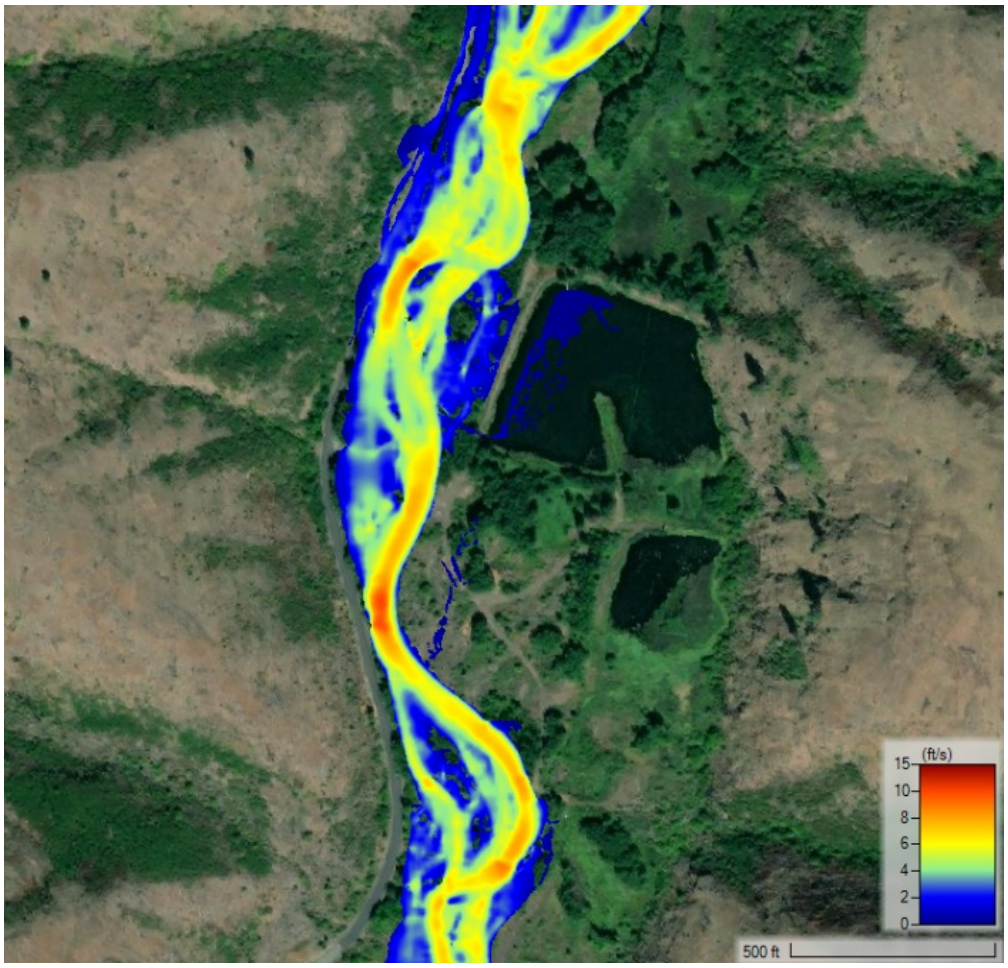


Figure 3 - HEC-RAS modeling results showing velocity at 2500 CFS

At 2500 cfs, the toe of the western dam on Watson begins to be exposed to floodwaters. This situation can rapidly compromise the integrity of the slope as material is removed by the river.

At a 25-yr event (3627 CFS), Watson Lake begins to capture floodwaters from upstream (Figure 4). The floodwaters would likely overwhelm the outlet and lead to overtopping and failure of the structure.

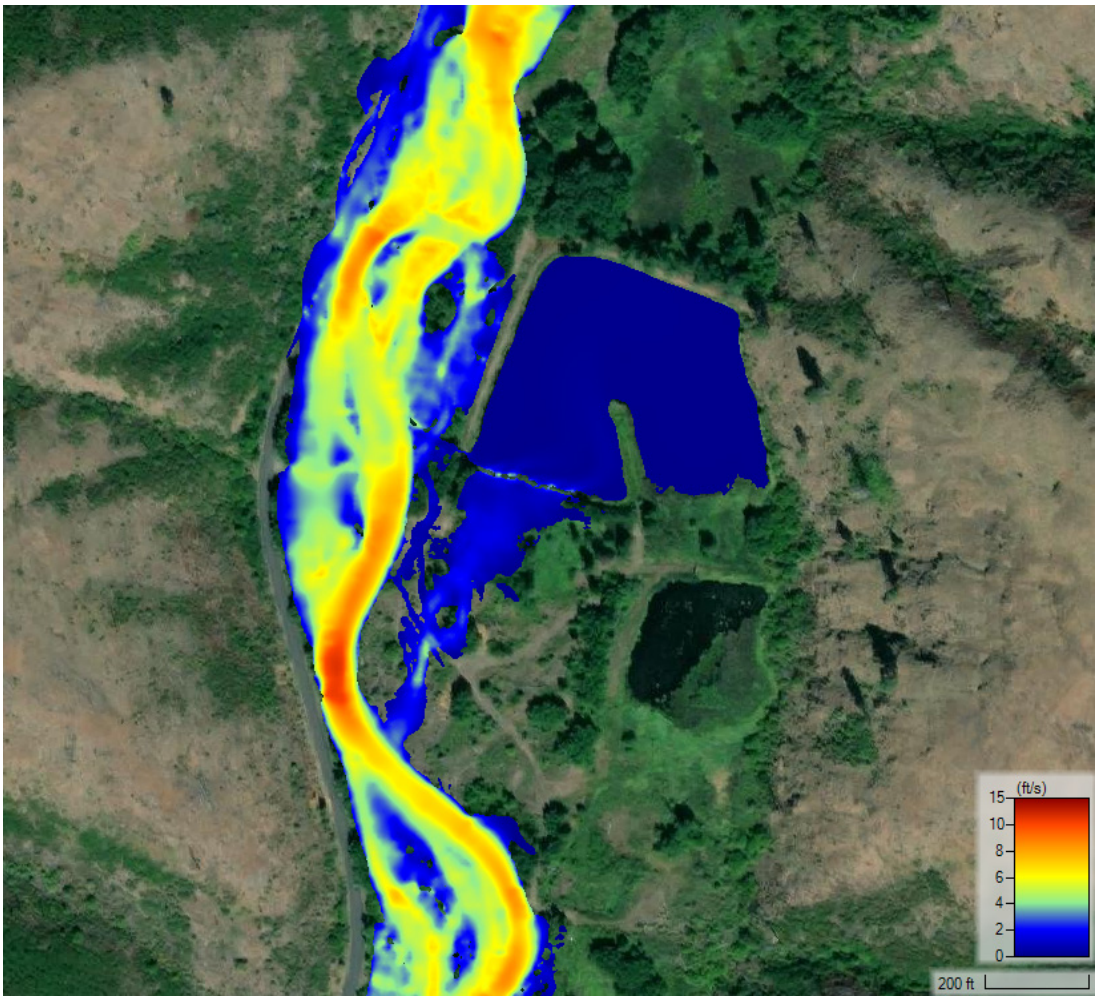


Figure 4 - Velocity at a 25-YR event (3627 cfs)

Flood events at the 2-yr (665 CFS), 25-yr (3,627 CFS), and 100-yr (6,498 CFS) events were modeled in HEC-RAS and the inundation extents and cross-sections are shown in Figure 5 and Figure 6 respectively.

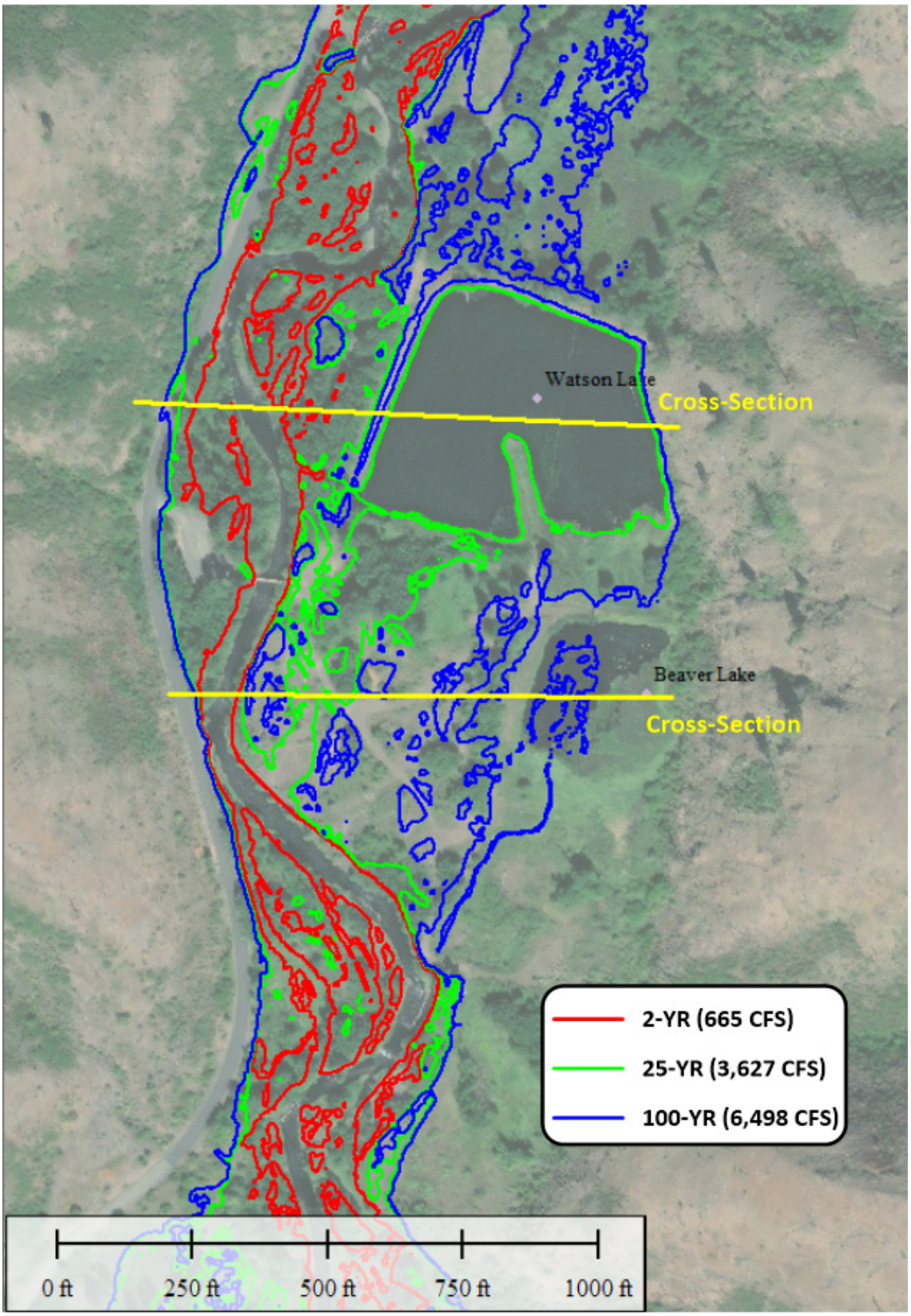


Figure 5 - Flood inundation extents from hydraulic modeling

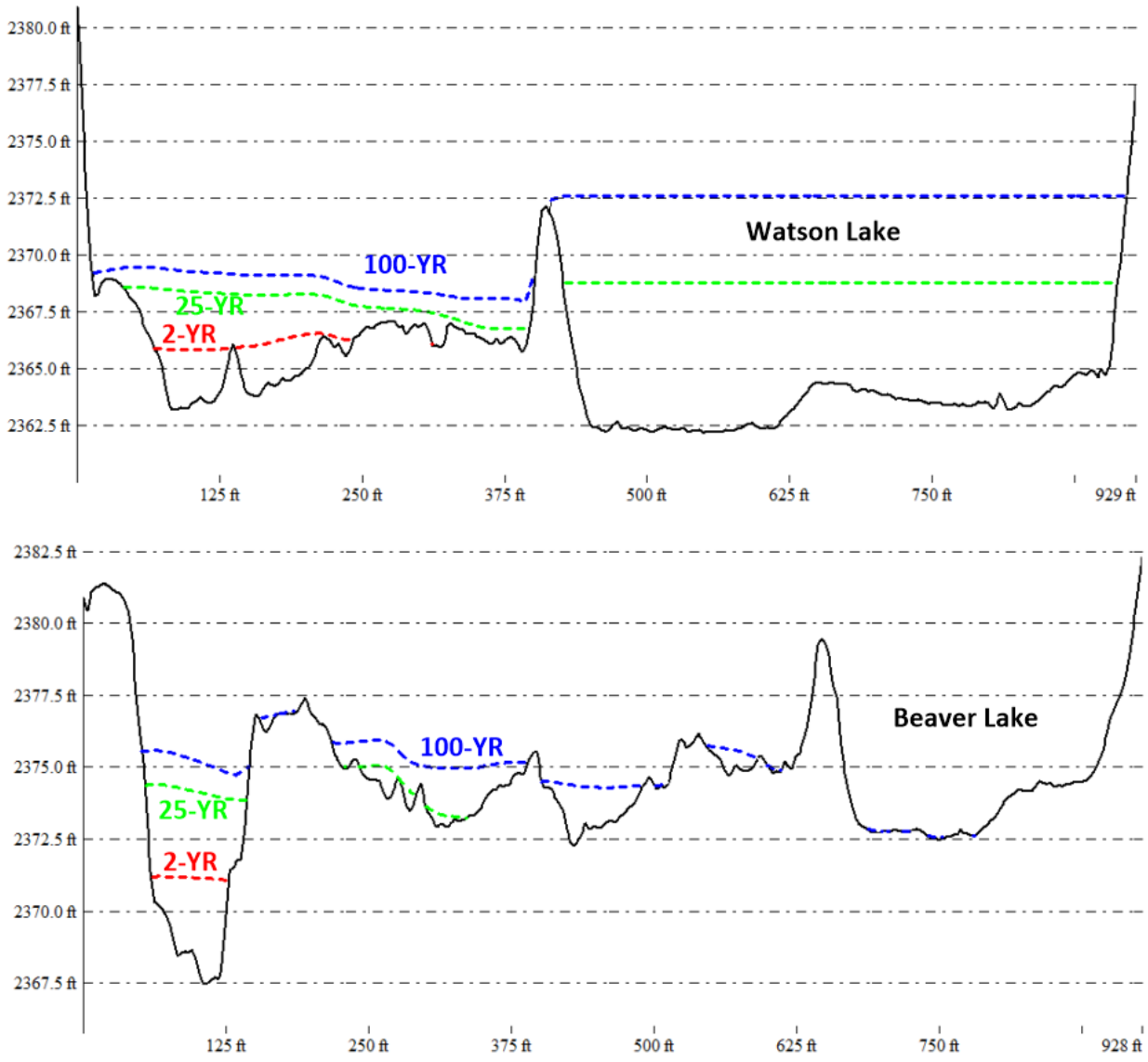


Figure 6 - Cross-sections showing terrain and water surface elevations

Watson Lake is more susceptible than Beaver Lake to floodwater interaction during high flow events in the Tucannon River.

Correction Options

Corrective action at the dams would need to involve replacing all CMP infrastructure that is past its usable lifespan. This would involve trenching through the existing dam to remove the outlet pipe and replacing the headworks. Inlet infrastructure is not as critical and can be replaced on an as-needed basis. The extensive vegetation on the backside of Watson Lake dam should be removed and the area impacted by the root systems will need to be excavated and recompacted. The dam on Watson Lake should be expanded in order to reduce the back and front slopes to a maximum of 2(H):1(V) and 3(H):1(V) respectively.

Estimated cost of repairs: $375,000

Decommissioning both ponds would involve substantial regrading and a robust revegetation plan. Estimated cost of decommissioning: $250,000

Rating Matrix

The matrix below visually summarizes the categories above. The ratings are based on comparisons between all lakes with high representing the greatest negative (concern/impact/cost) and low representing the least negative (concern/impact/cost).

RATING MATRIX	
Operational Overview/Concerns	●
Dam Safety Concerns	●
Hydrologic / Topographic Concerns	◉
Corrections Cost	◉
Decommissioning Cost	●
Rating (high, medium, low) ● ◉ ○	

Big 4 Lake

Size: 2.1 acres

Constructed: 1954



Figure 1 - Lake Overview

Operational Overview/Concerns

Big 4 Lake is situated just off of the main active channel of the Tucannon River. The flooding in 2020 had significant impacts and resulted in the inability to utilize the inlet structure due to stream re-alignment, resulting in the lake being dewatered. The river is also actively eroding at the base of the western dam. Historically, the lake was filled in mid-February and then drained after November 30th.

Dam Safety Concerns

The inlet and outlet structures are likely composed of CMP pipe and past their usable lifespan. With the inability to fill the lake from the river, the safety concerns are reduced. A high flow event has the potential to fill the impoundment and subsequently breach the western dam

Field observations suggest that the dam has substantial leaking/piping through the core.

The LiDAR data shows an area where the Tucannon River is impinging on the base of the dam.

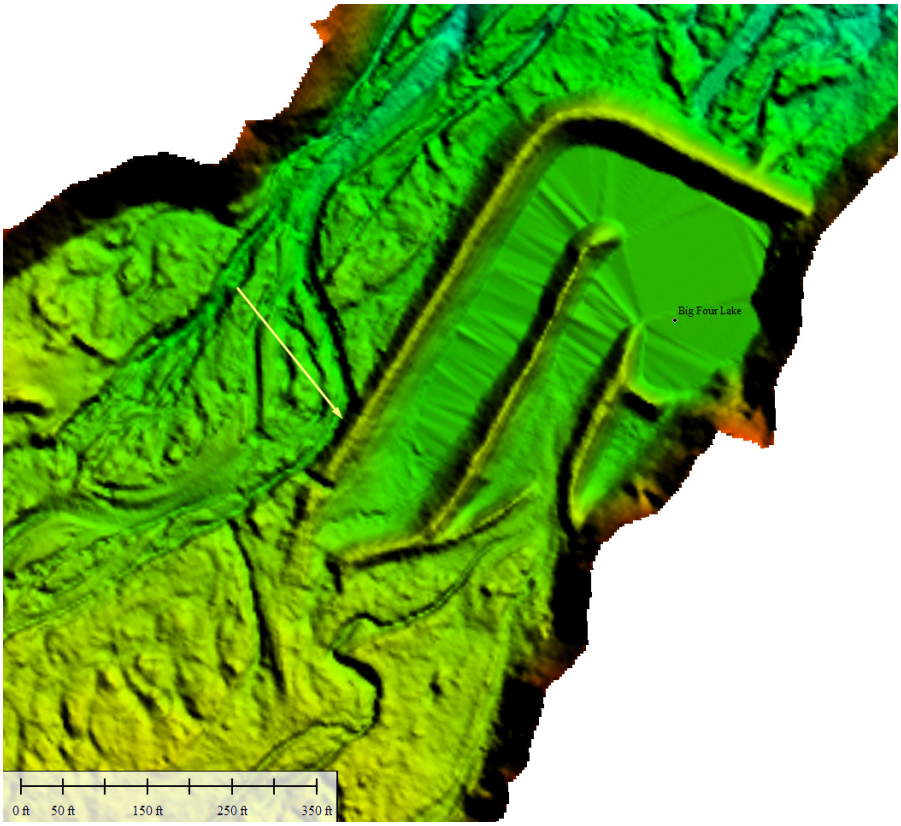


Figure 2 - LiDAR of Big 4 Lake and surrounding area. Arrow highlighting area of immediate concern.

Measurements from the LiDAR data show several areas where the backside slope of the dam exceed a 2(H):1(V) slope. The frontside of the dam also has several areas that exceed a 3(H):1(V) slope.

Hydrologic / Topographic Concerns

Big 4 Lake has a significant footprint within the floodway of the Tucannon River. The positioning of the dam and lake have artificially confined the bounds of the Tucannon River by obstructing almost 60% of the historic floodplain.

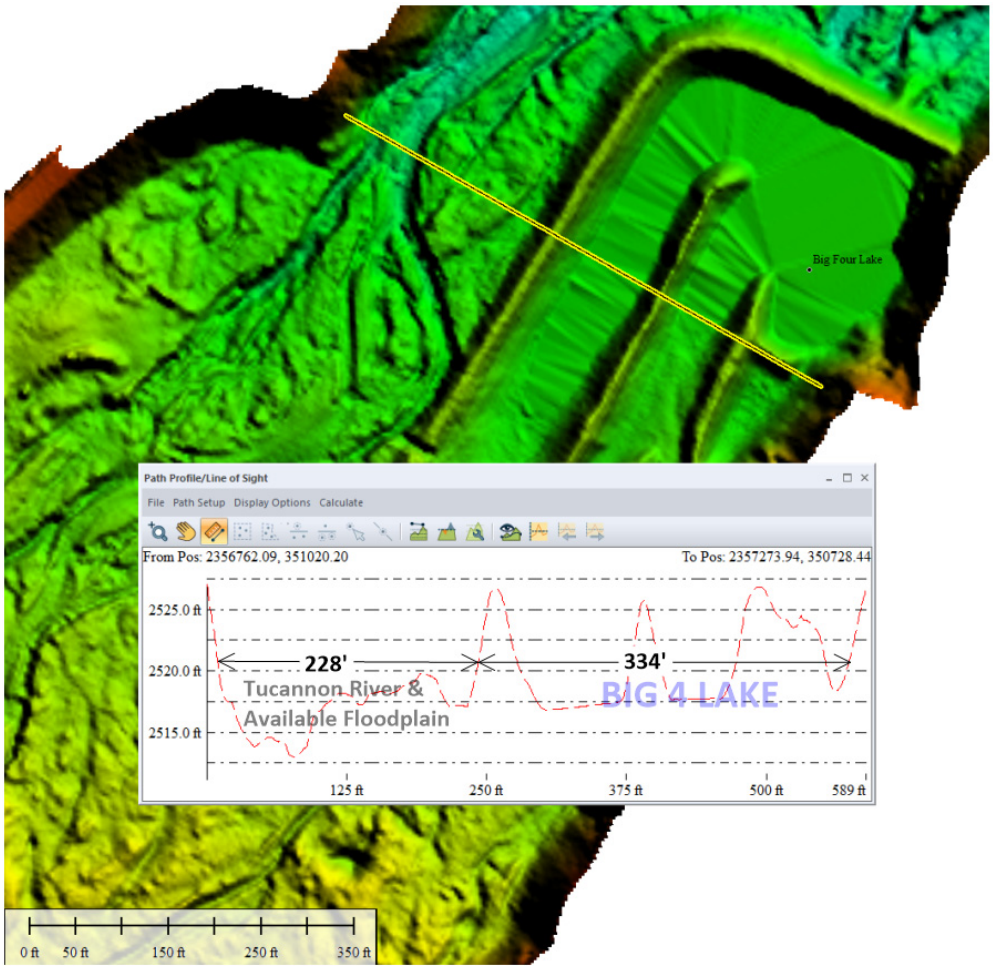


Figure 3 – Big 4 Lake valley floor cross-section

Hydraulic Modeling Results



Figure 4 – HEC-RAS simulation showing velocity at 600 cfs

With the current channel configuration, even minor event flows are putting significant erosive pressure on the western dam. Compacted earthen dams are not composed of large diameter material and are highly susceptible to erosion when subjected to continuous flowing water. Hydraulic modeling shows elevated velocities (> 3ft/s) at the base of the dam at normal spring flow levels of ~ 600 cfs.

Flood events at the 2-yr (665 CFS), 25-yr (3,627 CFS), and 100-yr (6,498 CFS) events were modeled in HEC-RAS and the inundation extents and cross-section are shown in Figure 5 and Figure 6 respectively.

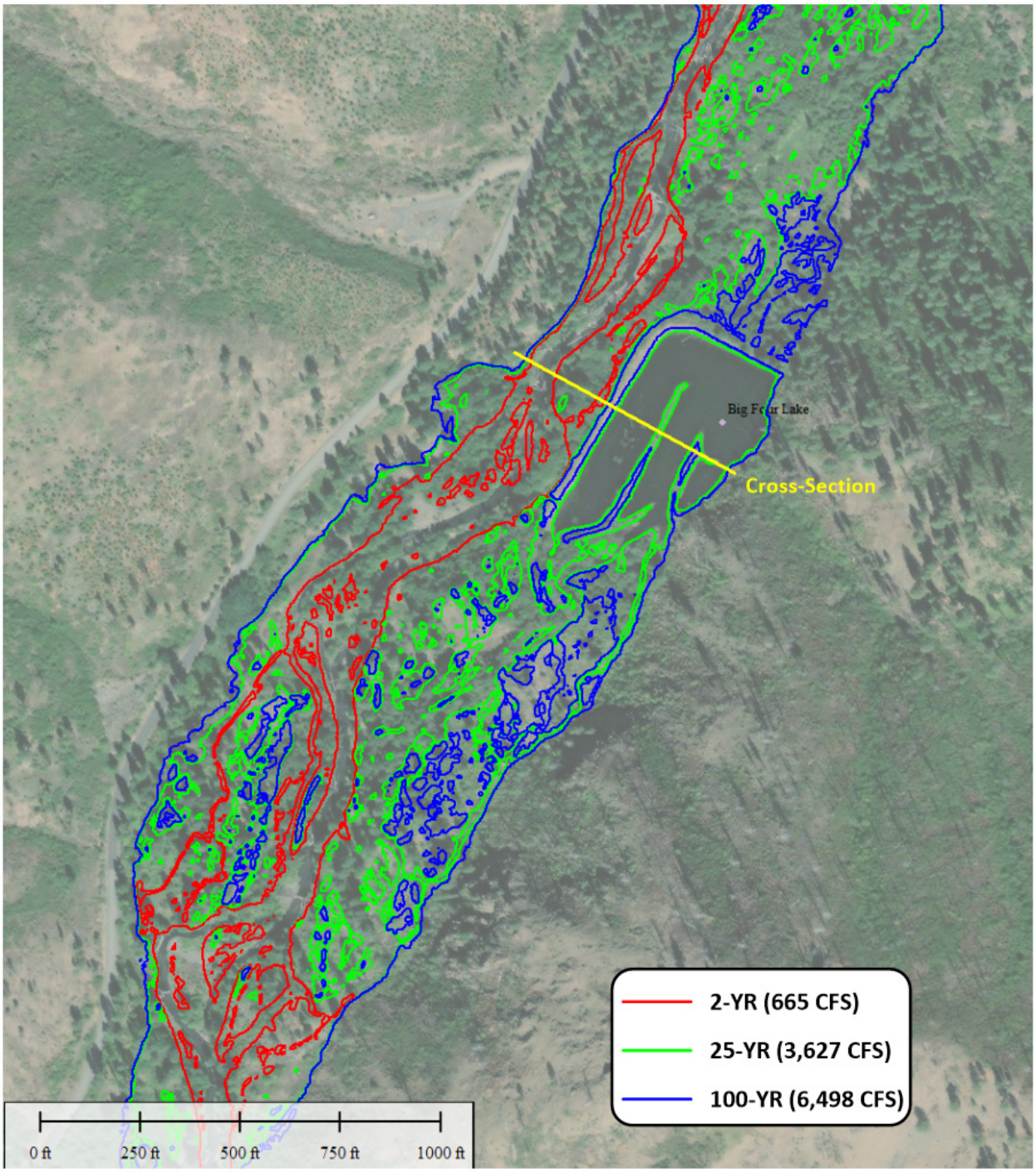


Figure 5 - Flood inundation extents from hydraulic modeling

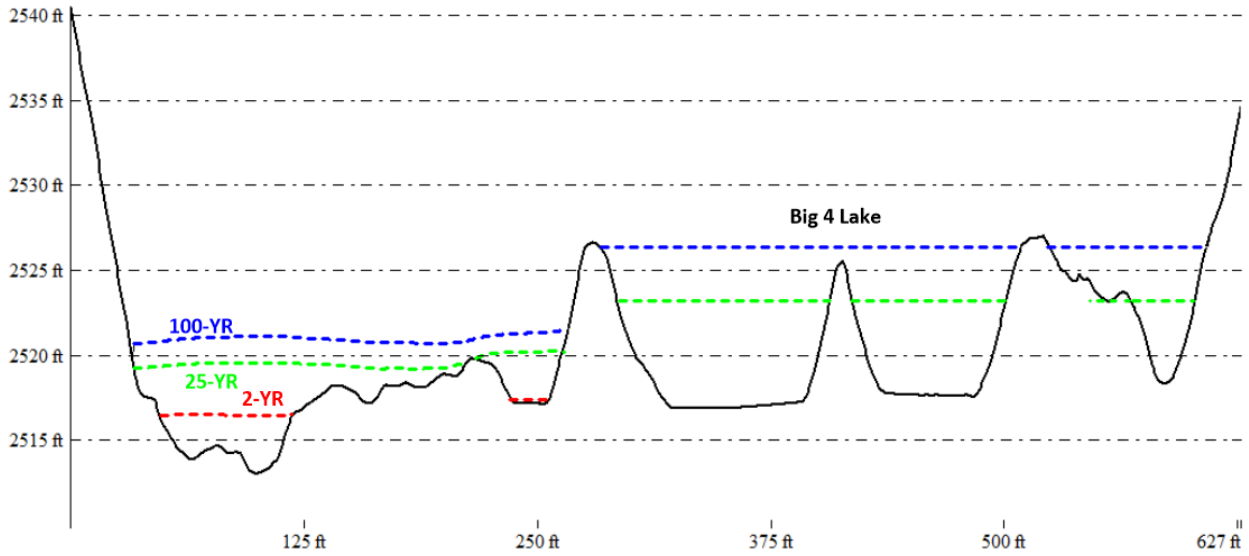


Figure 6 - Cross-section showing terrain and water surface elevations

Flood events flow into Big 4 Lake from the south and could rapidly lead to overtopping of the dam.

Correction Options

Any corrective actions are complicated by lack of access to the lake. All heavy equipment would need to be routed through (or over) the Tucannon River.

Fixing Big 4 Lake would involve addressing several problems. All CMP infrastructure that is past its usable lifespan would need replacing. The area where the river is eroding the toe of the dam would either need to be reinforced on the river side or completely relocated. The overall dam footprint would need to be expanded in order to reduce the back and front slopes to a maximum of 2(H):1(V) and 3(H):1(V) respectively.

Estimated cost of repairs: $500,000

Decommissioning would involve substantial regrading and a robust revegetation plan. Estimated cost of decommissioning: $175,000

Rating Matrix

The matrix below visually summarizes the categories above. The ratings are based on comparisons between all lakes with high representing the greatest negative (concern/impact/cost) and low representing the least negative (concern/impact/cost).

RATING MATRIX	
Operational Overview/Concerns	●
Dam Safety Concerns	●
Hydrologic / Topographic Concerns	●
Corrections Cost	●
Decommissioning Cost	●
Rating (high, medium, low) ● ◉ ○	

Blue Lake

Size: 2.3 acres

Constructed: 1954



Figure 1 - Lake Overview

Operational overview/concerns

Unlike the majority of the other lakes in the valley, Blue Lake is solely spring fed. There is a top drain culvert along with a retrofitted bottom drain culvert that was installed in the mid-90s. Access to the south and south-west side of the lake is limited.

Dam Safety Concerns

There are areas of the dam where the backslide slope is steeper than 2(H):1(V). The top drain culvert is situated such that there is minimal freeboard. A new outlet was installed in 1997.

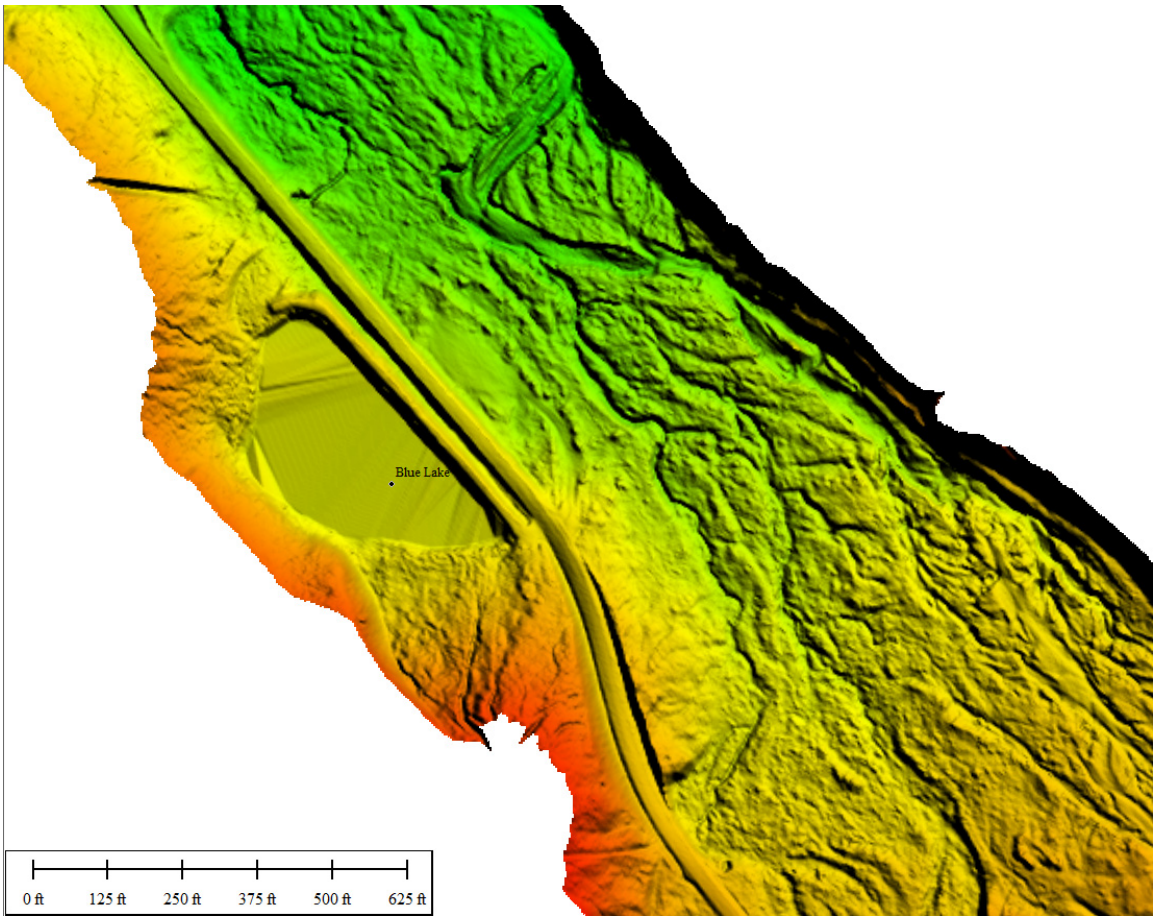


Figure 2 - LiDAR of Blue Lake and surrounding area.

The LiDAR shows the lake well removed from the Tucannon River floodway. Cross-sectional analysis shows a top width being 8-10 feet and mild over steepening on the backside slope.

Hydrologic / Topographic Concerns

Blue Lake is separated from the Tucannon River floodway by the road. The topographic layout of the lake causes little to no impact to floodwaters within the river.

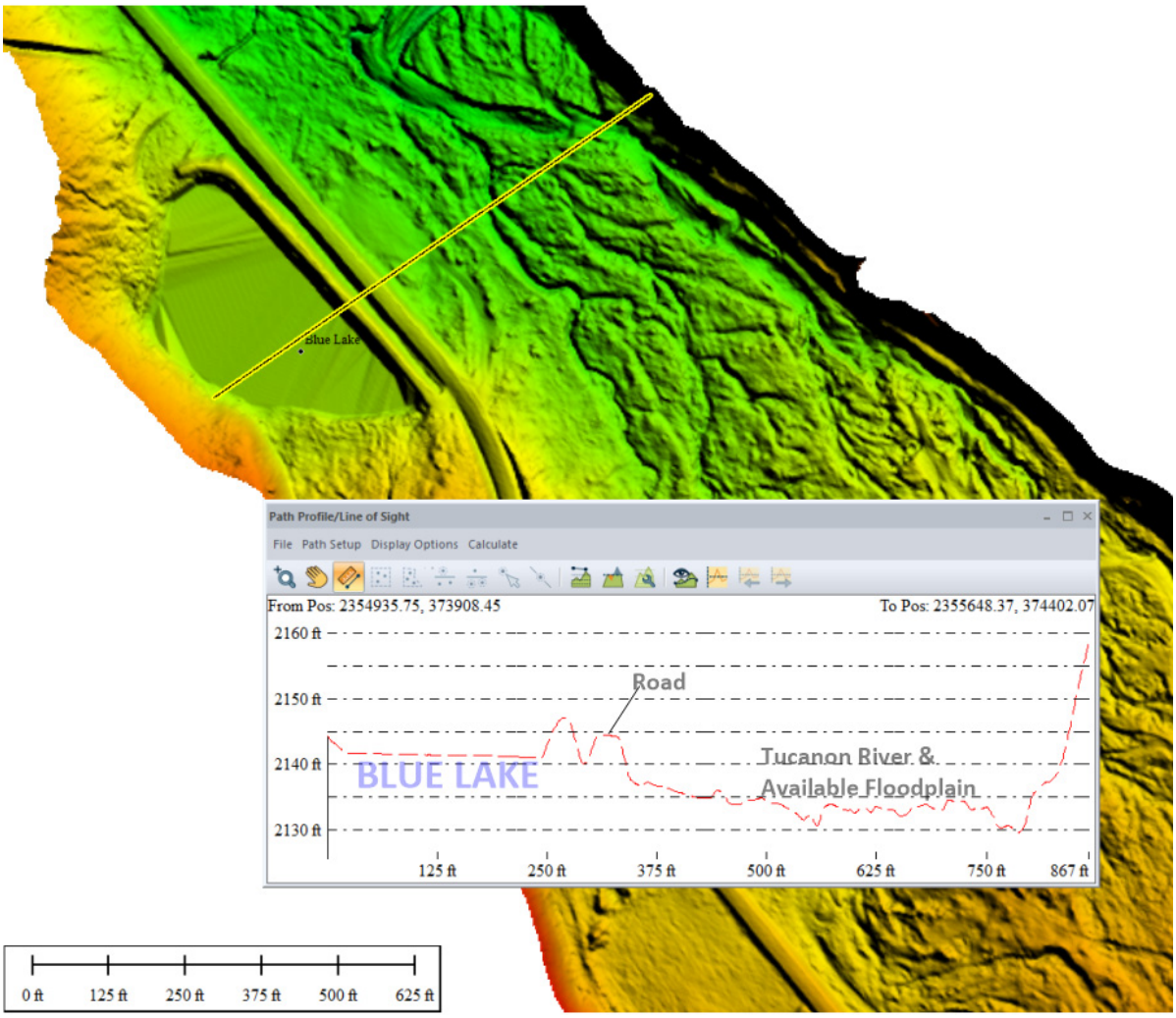


Figure 3 - Blue Lake valley floor cross-section

Hydrologic Modeling Results

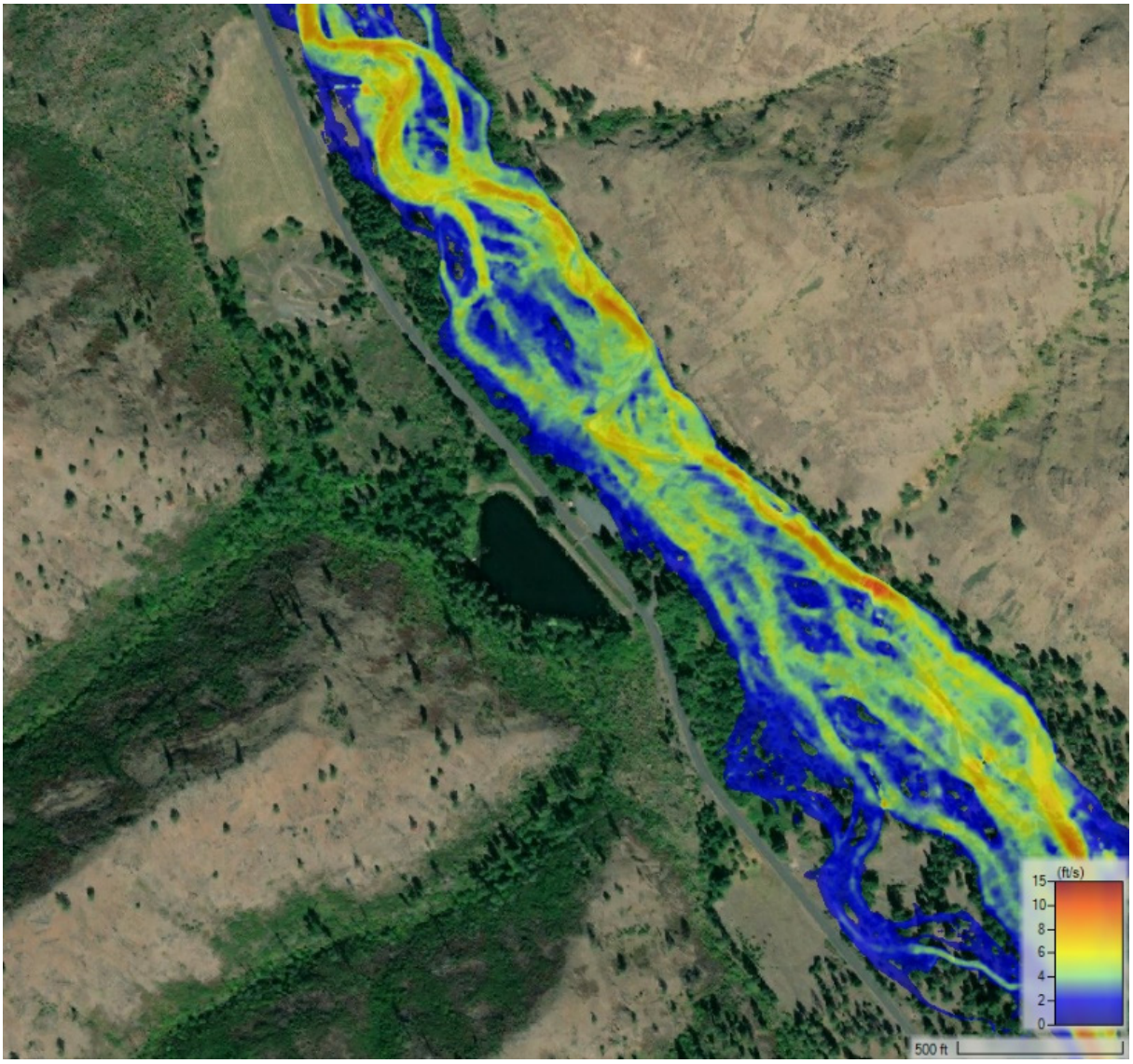


Figure 4 - HEC-RAS flow simulation showing velocity at 4,200 cfs

A flood event of 4,200 cfs was modeled and showed no interaction with Blue Lake or the road.

Flood events at the 2-yr (665 CFS), 25-yr (3,627 CFS), and 100-yr (6,498 CFS) events were modeled in HEC-RAS and the inundation extents and cross-section are shown in Figure 5 and Figure 6 respectively.

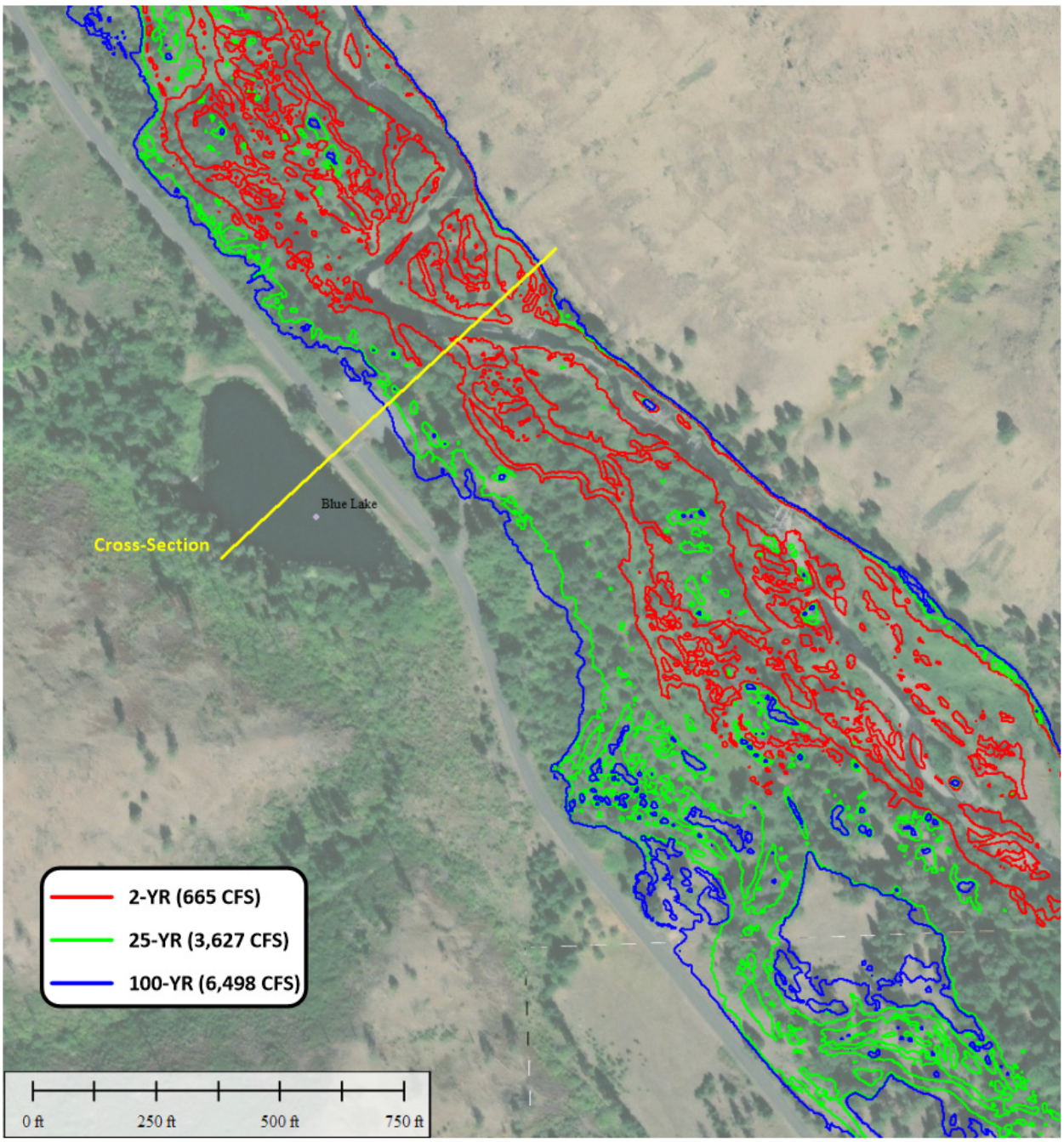


Figure 5 - Flood inundation extents from hydraulic modeling

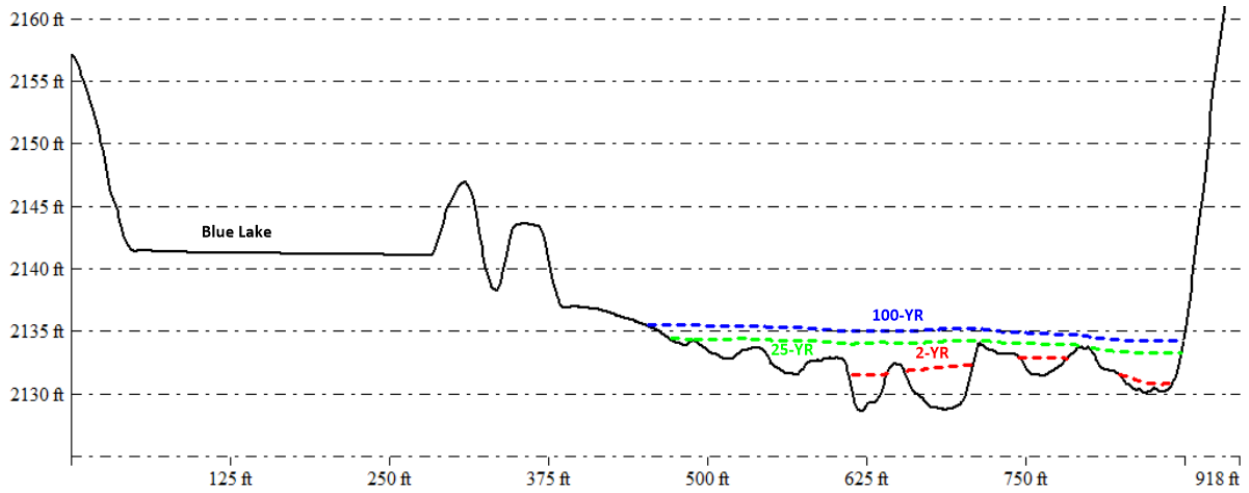


Figure 6 - Cross-section showing terrain and water surface elevations

Blue Lake is perched a significant distance vertically from the floodplain and is isolated from flood events occurring in the Tucannon River.

Correction Options

Blue Lake remains full by way of two springs fed by two separate drainages to the west. A significant rain event could result in inflows that would overwhelm the top outlet on the lake.

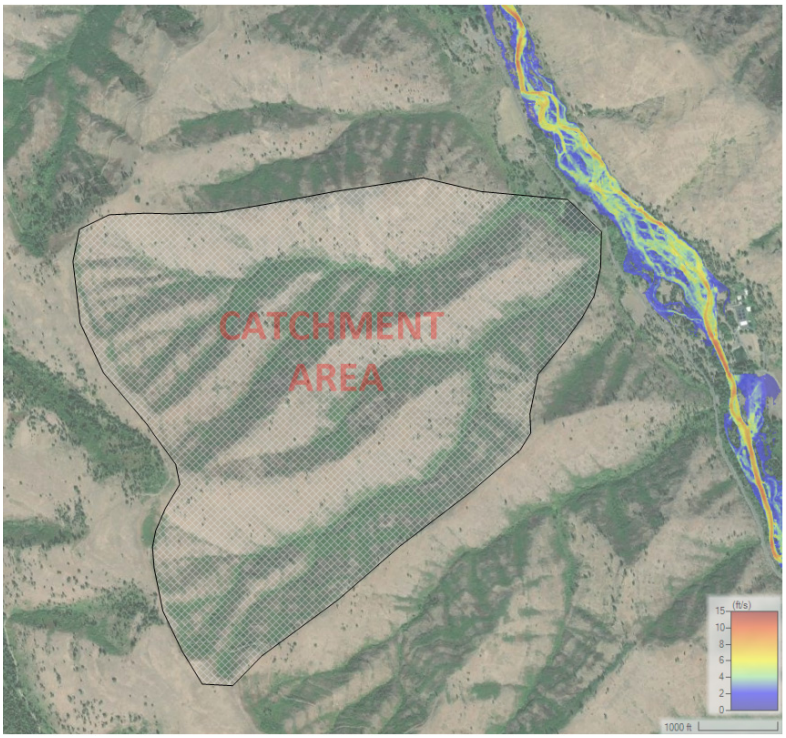


Figure 7 - Approximate catchment area of Blue Lake

Estimated cost of repairs: $90,000

Rating Matrix

The matrix below visually summarizes the categories above. The ratings are based on comparisons between all lakes with high representing the greatest negative (concern/impact/cost) and low representing the least negative (concern/impact/cost).

RATING MATRIX	
Operational Overview/Concerns	○
Dam Safety Concerns	○
Hydrologic / Topographic Concerns	○
Corrections Cost	○
Decommissioning Cost	
Rating (high, medium, low) ● ● ○	

Curl Lake

Size: 2 acres

Constructed: 1984

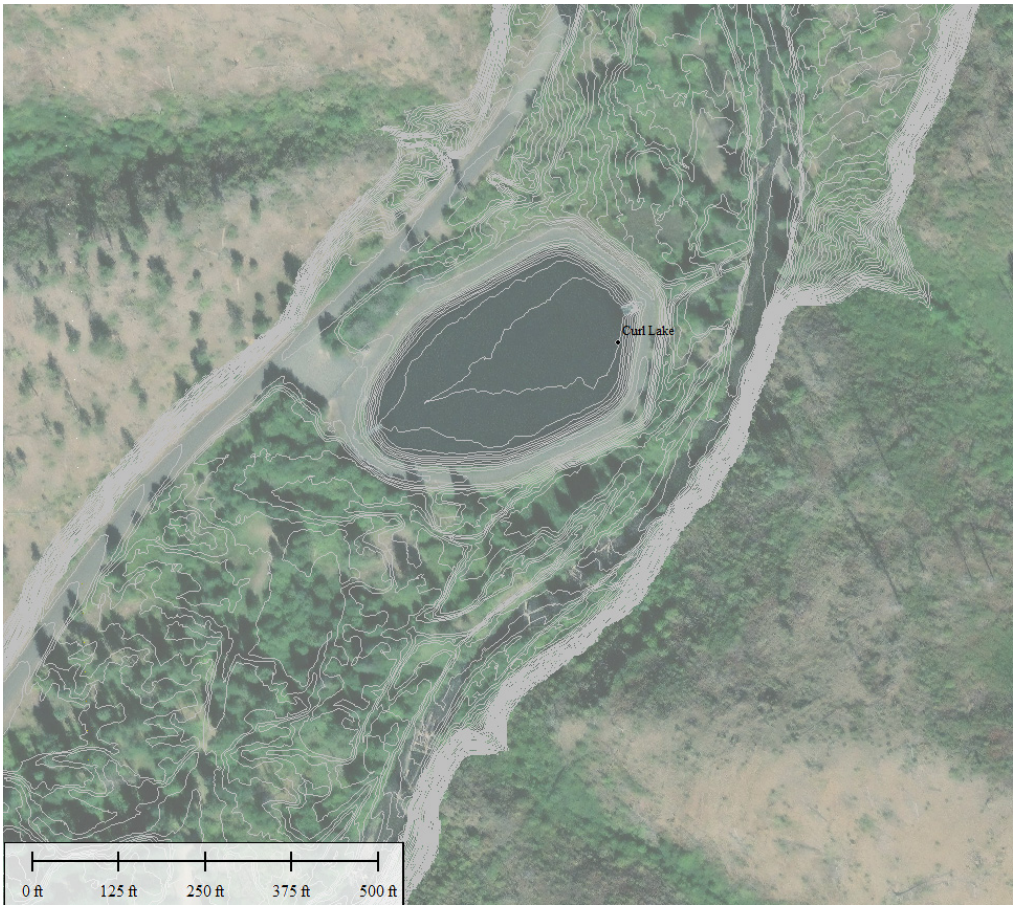


Figure 1 - Lake Overview

Operational Overview/Concerns

Curl Lake was built fairly recently in 1984 and the infrastructure associated with the impoundment is in good working condition. The lake is fed from a diversion off the Tucannon River starting in February and subsequently drained on, or after, October 31st. Past repairs of the structure include the repair of the inlet wing dam after the 2020 floods, and repairing of a sink hole in the dam in 2005.

Dam Safety Concerns

The inlet and outlet structures are all in good usable condition. With the inability to fill the lake from the river, the safety concerns are reduced. No areas of dam erosion from leaking were observed during the field visit. The top width and side slopes of the structure are within recommended ranges. Vegetation on the dam is limited to mostly grasses which improve soil stability.

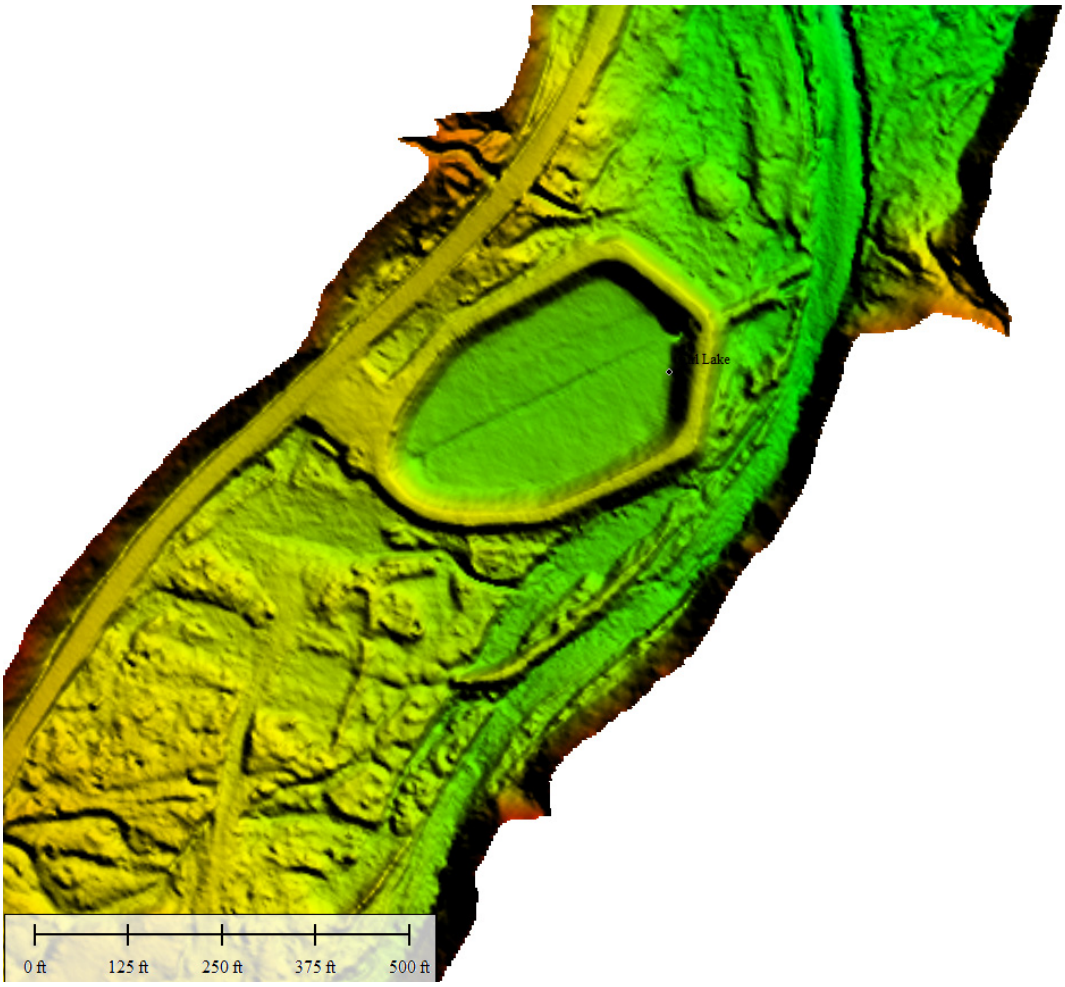


Figure 2 - LiDAR of Curl Lake and surrounding area.

The LiDAR shows an area along the southern dam that may be exposed to high flow events within the Tucannon River.

Hydrologic / Topographic Concerns

Curl Lake has a significant footprint within the floodway of the Tucannon River. The positioning of the dam and lake have artificially confined the bounds of the Tucannon River by reducing the floodway width to just 100 feet at the pinch point.

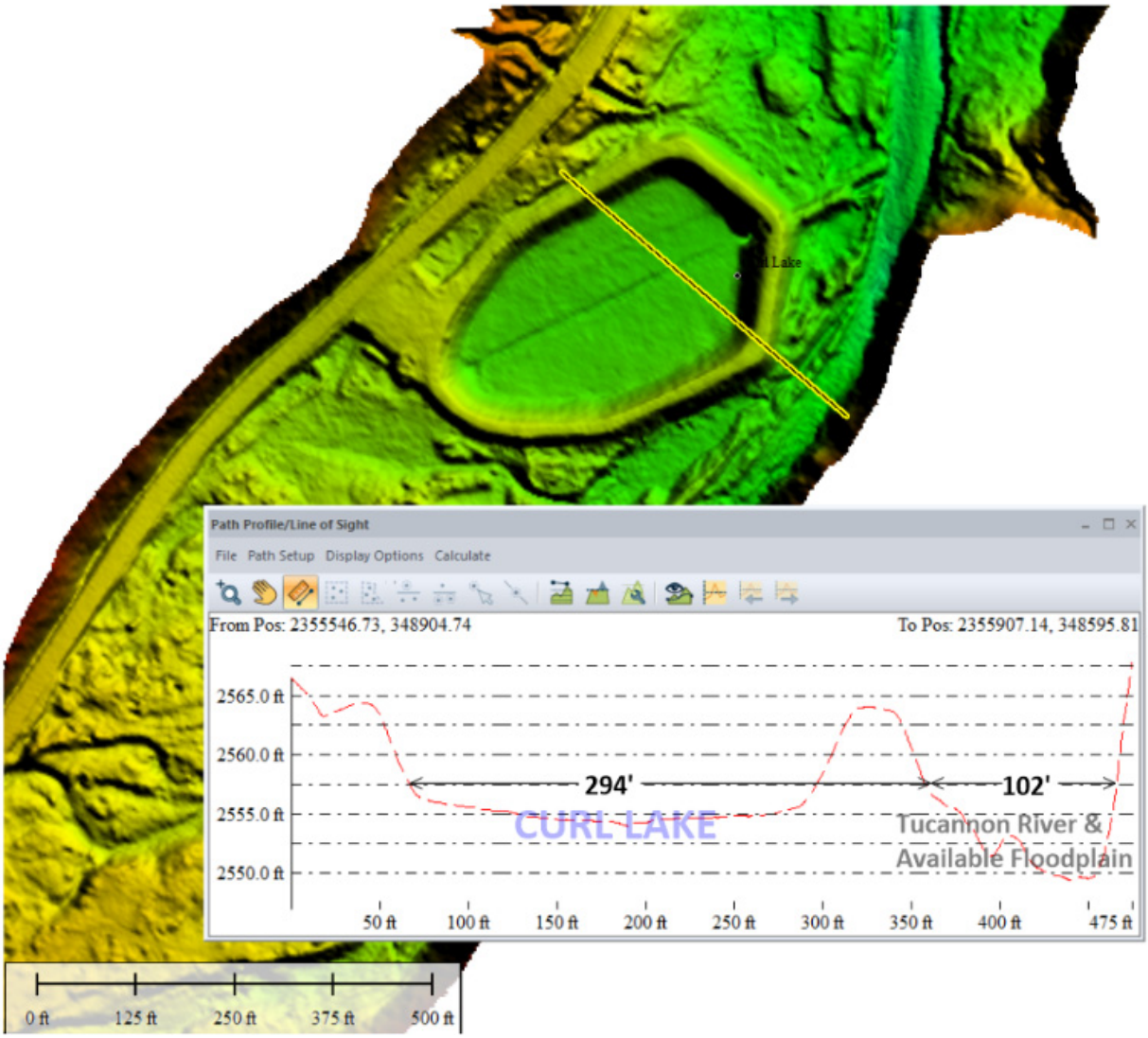


Figure 3 - Curl Lake valley floor cross-section

Hydrologic Modeling Results

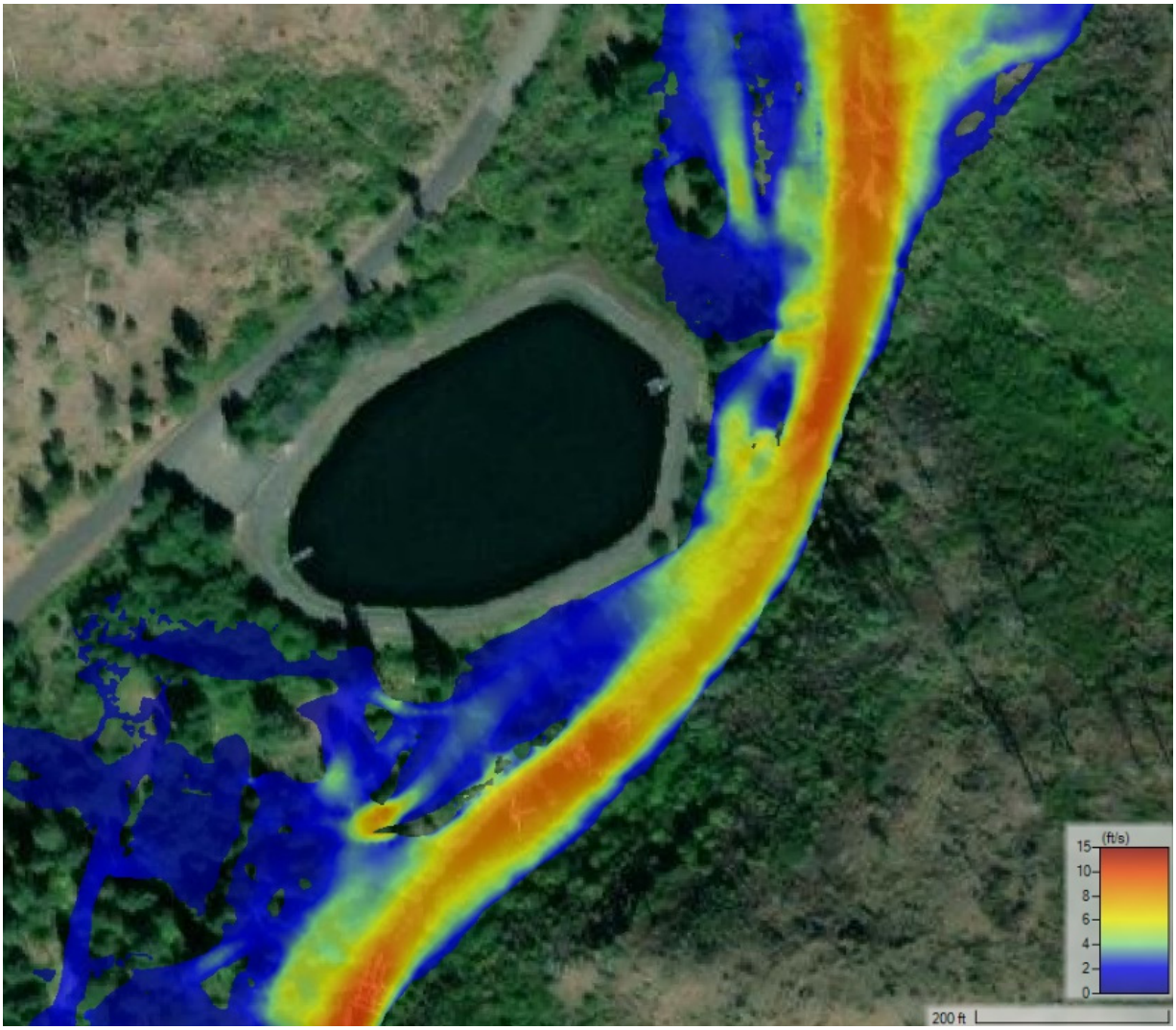


Figure 4 - HEC-RAS flow simulation showing velocity at 4,000 cfs

The southern dam has the highest likelihood of being impacted by a high flow event in the Tucannon River. A high point along the river bank just upstream of the lake provides significant protection from high flows and serves to divert the majority of the river's energy away from the structure. Water begins to pond in the low area to the south of the lake when flows in the river reach about 600 cfs. Significant flood events near 4,000 cfs have the potential to start eroding the toe of the dam slope in multiple locations.

Flood events at the 2-yr (665 CFS), 25-yr (3,627 CFS), and 100-yr (6,498 CFS) events were modeled in HEC-RAS and the inundation extents and cross-section are shown in Figure 5 and Figure 6 respectively.

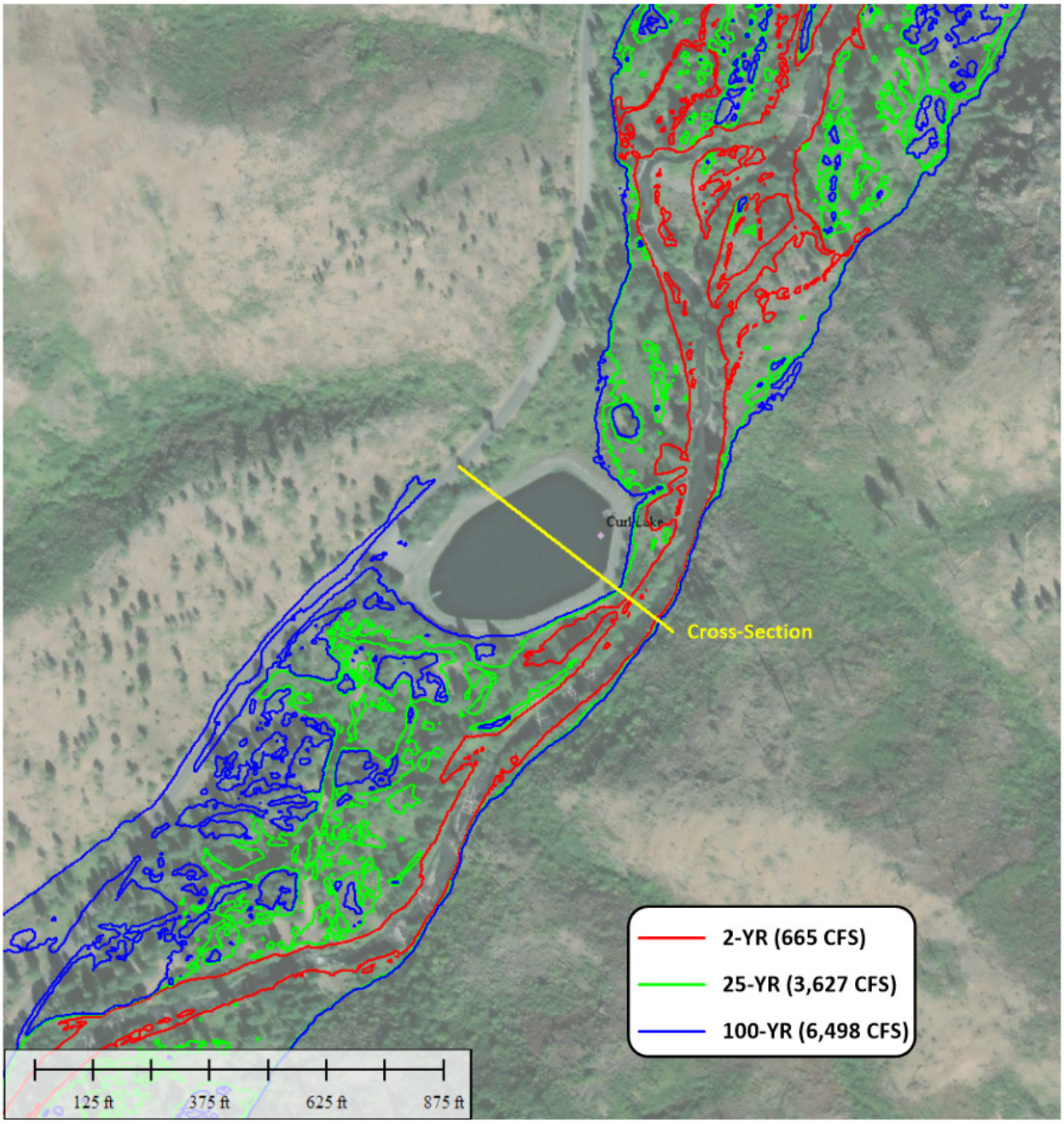


Figure 5 - Flood inundation extents from hydraulic modeling

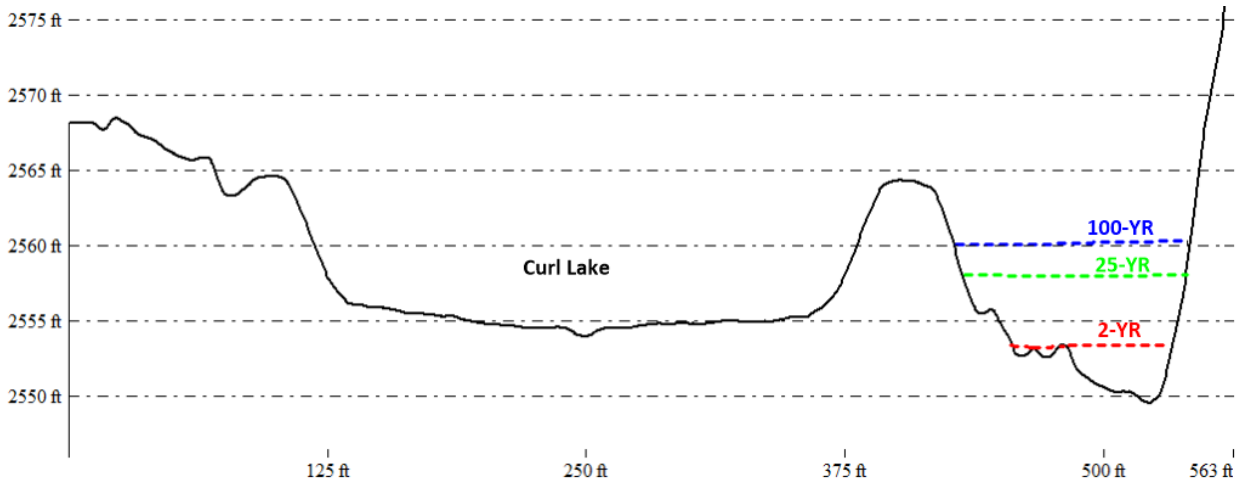


Figure 6 - Cross-section showing terrain and water surface elevations

Curl Lake dam experiences significant interaction with the Tucannon River during high flood events.

Correction Options

Curl Lake appears to be functioning well with no identifiable issues to be addressed at this time.

Rating Matrix

The matrix below visually summarizes the categories above. The ratings are based on comparisons between all lakes with high representing the greatest negative (concern/impact/cost) and low representing the least negative (concern/impact/cost).

RATING MATRIX	
Operational overview/concerns	○
Dam Safety Concerns	○
Hydrologic / Topographic Concerns	●
Corrections Cost	
Decommissioning Cost	
Rating (high, medium, low) ● ● ○	

Deer Lake

Size: 4.4 acres

Constructed: 1955



Figure 1 - Lake Overview

Operational Overview/Concerns

The inlet structure is located approximately 1-mile upstream from the lake. The planned operation for the lake is to fill it seasonally starting in February and subsequently draining on, or after, November 30th. Issues with the bottom drain have hampered this operational plan. The flooding in 2020 resulted in uncontrolled flow into the lake. The lake was not drained at the time and the excess flow overtopped the dam on the north side of the lake. The dam has had issues with leaking

Dam Safety Concerns

The intake structure looks to be in good usable condition. The outlet structure leaks and there is ground settlement in the area from either erosion or collapse of the pipe. Large springs are present on the downstream side of the dam suggesting substantial leaking/piping. Operation of the bottom drain pipe is unsatisfactory and prevents draining at the end of the year.

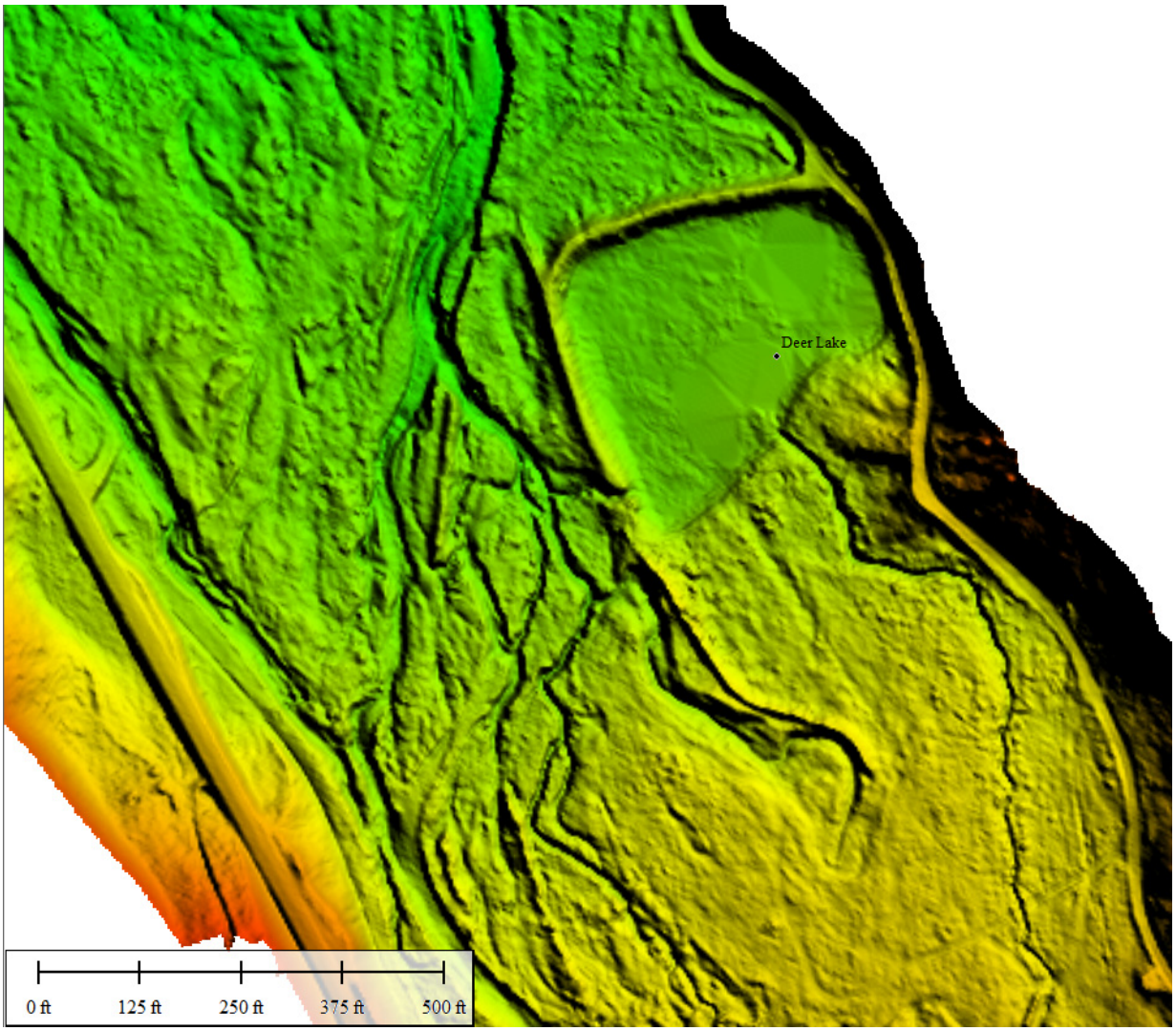


Figure 2 - LiDAR of Deer Lake and surrounding area.

The LiDAR shows areas of erosion on the backside of the northern dam, likely occurring during the overtopping in 2020.

Hydrologic / Topographic Concerns

A small artificial levee is present to the south of the lake and is visible as a southerly extension of the western dam (see Figure 2).

The lake has a significant impact on the floodway of the Tucannon River, taking up nearly 50% of the valley floor width.

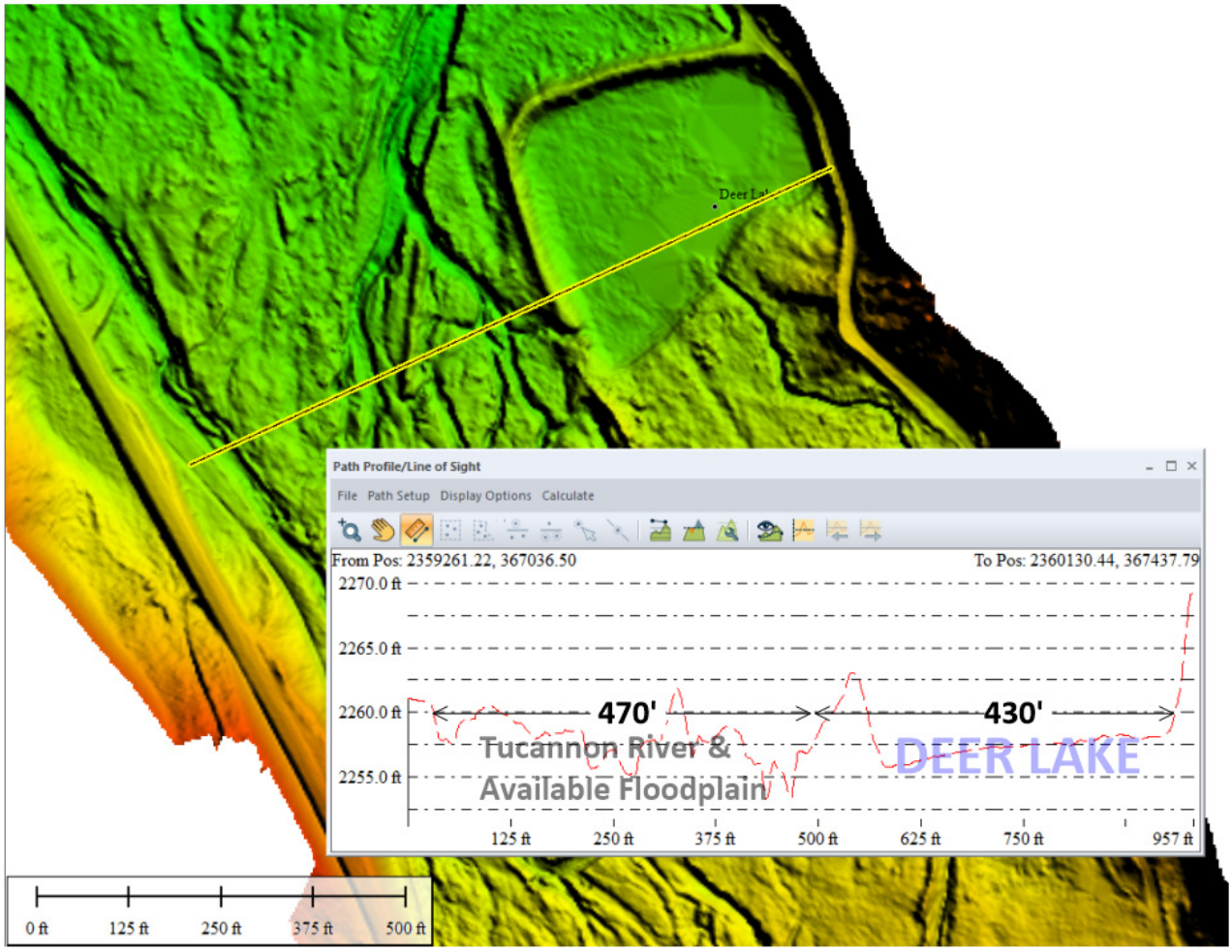
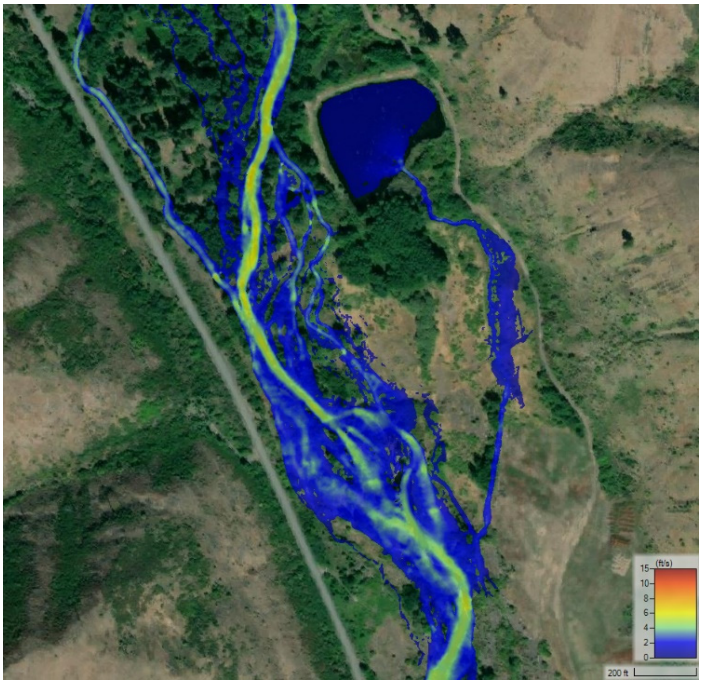


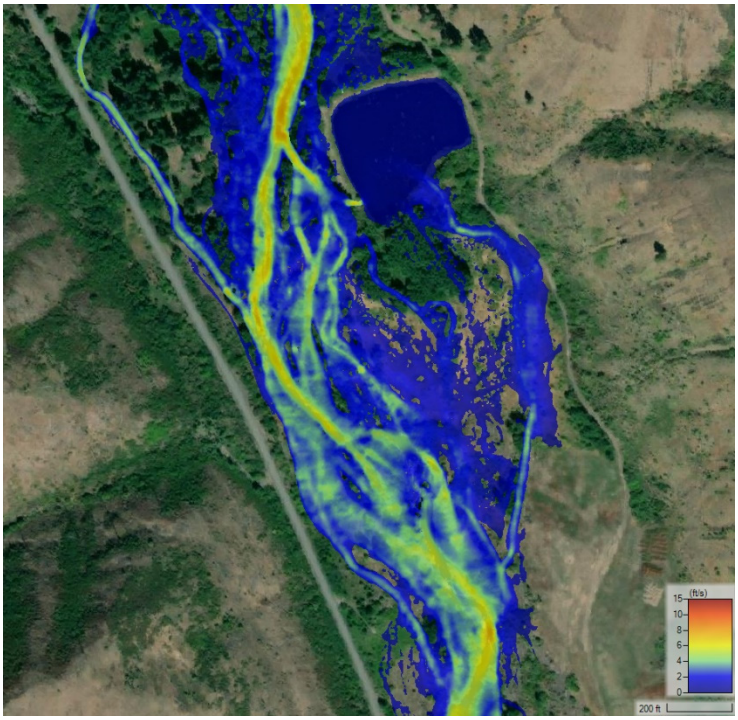
Figure 3 - Deer Lake valley floor cross-section

Hydraulic Modeling Results



Deer Lake begins to be at risk of accepting floodwaters as flows approach 1,000 cfs in the Tucannon River.

Figure 4 - HEC-RAS flow simulation showing velocity at 1,000 cfs



At larger events, the amount of additionally captured water begins to become substantial and additional flow begins to overtop the backside of the dam (Figure 5).

Figure 5 - HEC-RAS flow simulation showing velocity at 2,100 cfs

Flood events at the 2-yr (665 CFS), 25-yr (3,627 CFS), and 100-yr (6,498 CFS) events were modeled in HEC-RAS and the inundation extents and cross-section are shown in Figure 6 and Figure 7 respectively.

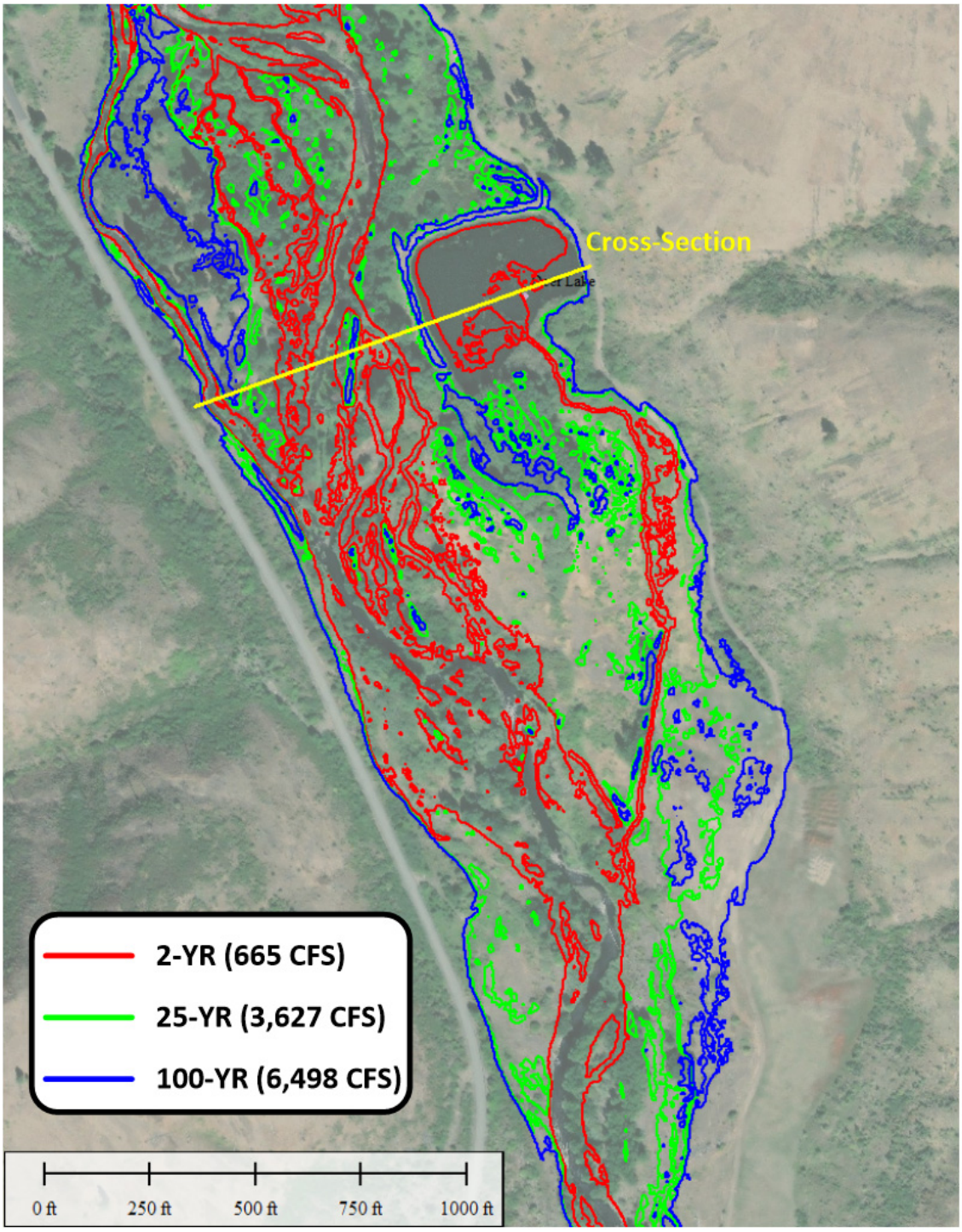


Figure 6 - Flood inundation extents from hydraulic modeling

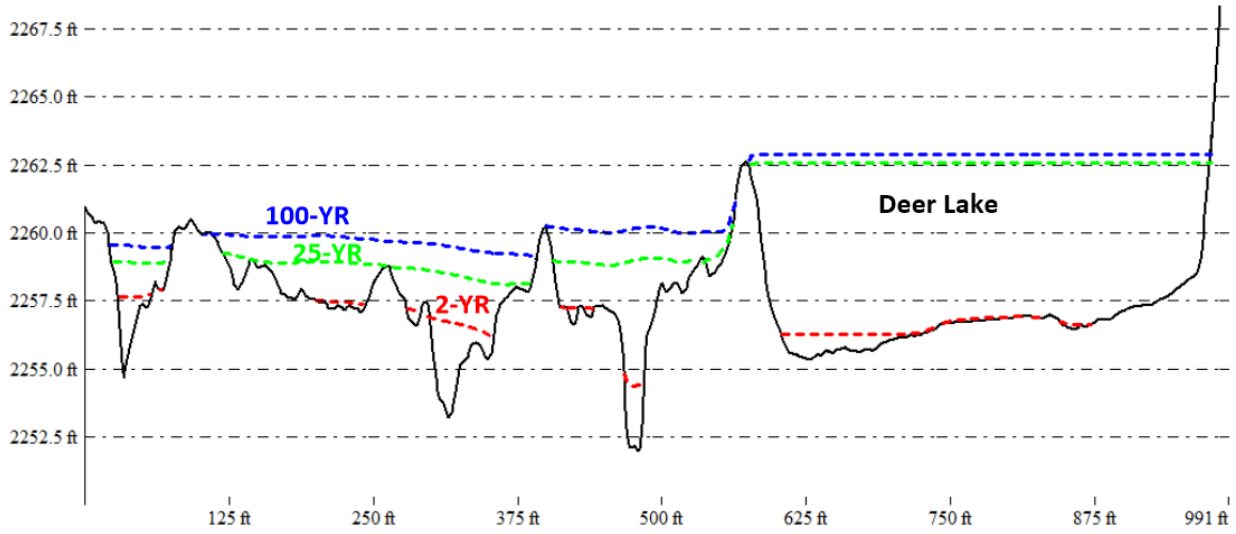


Figure 7 - Cross-section showing terrain and water surface elevations

Correction Options

There are several areas of concern with Deer Lake that require corrective action in the near future. The dam exhibits significant leaking. Piping through the dam is a condition that does not generally improve over time. Excessive piping can transport significant amounts of material out of the core of the dam and over time lead to an unsafe condition. The outlet pipe requires fixing. The top width of the dam does not meet dam safety standards. The backside of the north dam should be repaired from the erosion during the 2020 flood.

Fixing of the outlet would likely require excavation of the existing pipe and replacing it with a HDPE pipe and associated headworks. Minor expansion of the dam is recommended to expand the top width. It is also recommended to further investigate ways of limiting the amount of floodwaters captured by the lake during high water events. If no work is done to limit inflows during high events, a substantial spillway should be employed to deal with excess inflow during flood events.

Estimated cost of repairs: $650,000

Decommissioning would involve substantial regrading and a robust revegetation plan. Estimated cost of decommissioning: $175,000

Rating Matrix

The matrix below visually summarizes the categories above. The ratings are based on comparisons between all lakes with high representing the greatest negative (concern/impact/cost) and low representing the least negative (concern/impact/cost).

RATING MATRIX	
Operational overview/concerns	●
Dam Safety Concerns	●
Hydrologic / Topographic Concerns	●
Corrections Cost	●
Decommissioning Cost	●
Rating (high, medium, low) ● ● ○	

Rainbow Lake

Size: 7 acres

Constructed: 2018 / 2019.



Figure 1 - Lake Overview

Operational Overview/Concerns

The lake underwent construction to reshape the lake in 2018 and 2019. The lake provides water to the Tucannon Fish Hatchery and unlike the other managed lakes in the valley it remains filled year round.

Dam Safety Concerns

There are currently no known dam safety concerns at Rainbow Lake. No known damage was sustained to the dam or related infrastructure during the high water event in 2020.

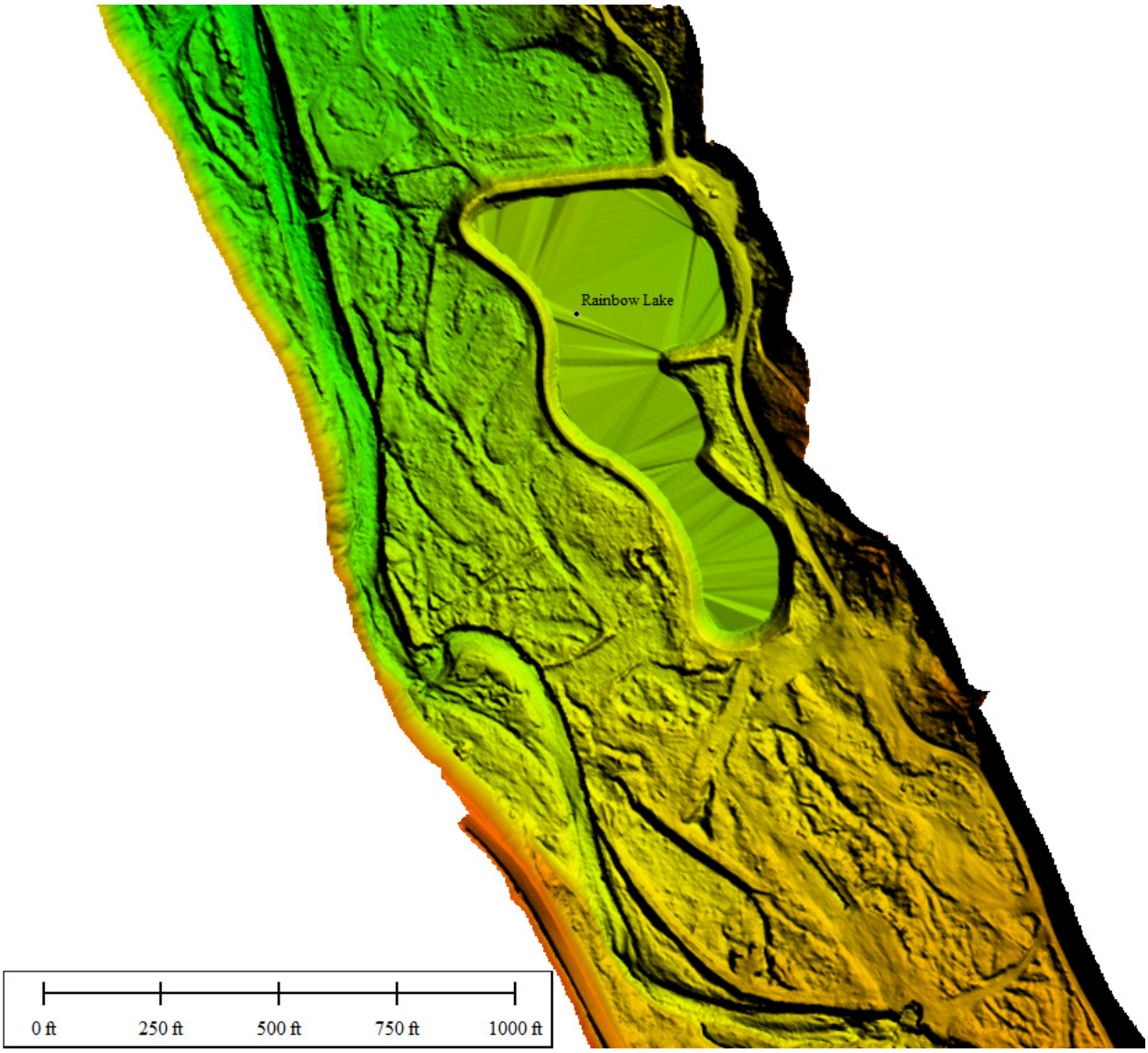


Figure 2 - LiDAR of Rainbow Lake and surrounding area.

The LiDAR shows areas no obvious areas of concern. Dam top width and side slopes are within recommended parameters.

Hydrologic / Topographic Concerns

Rainbow Lake is situated in an area where the Tucannon River is single thread and moderately incised. The lake footprint takes up about 50% of the floodplain width at the northern end of the lake.

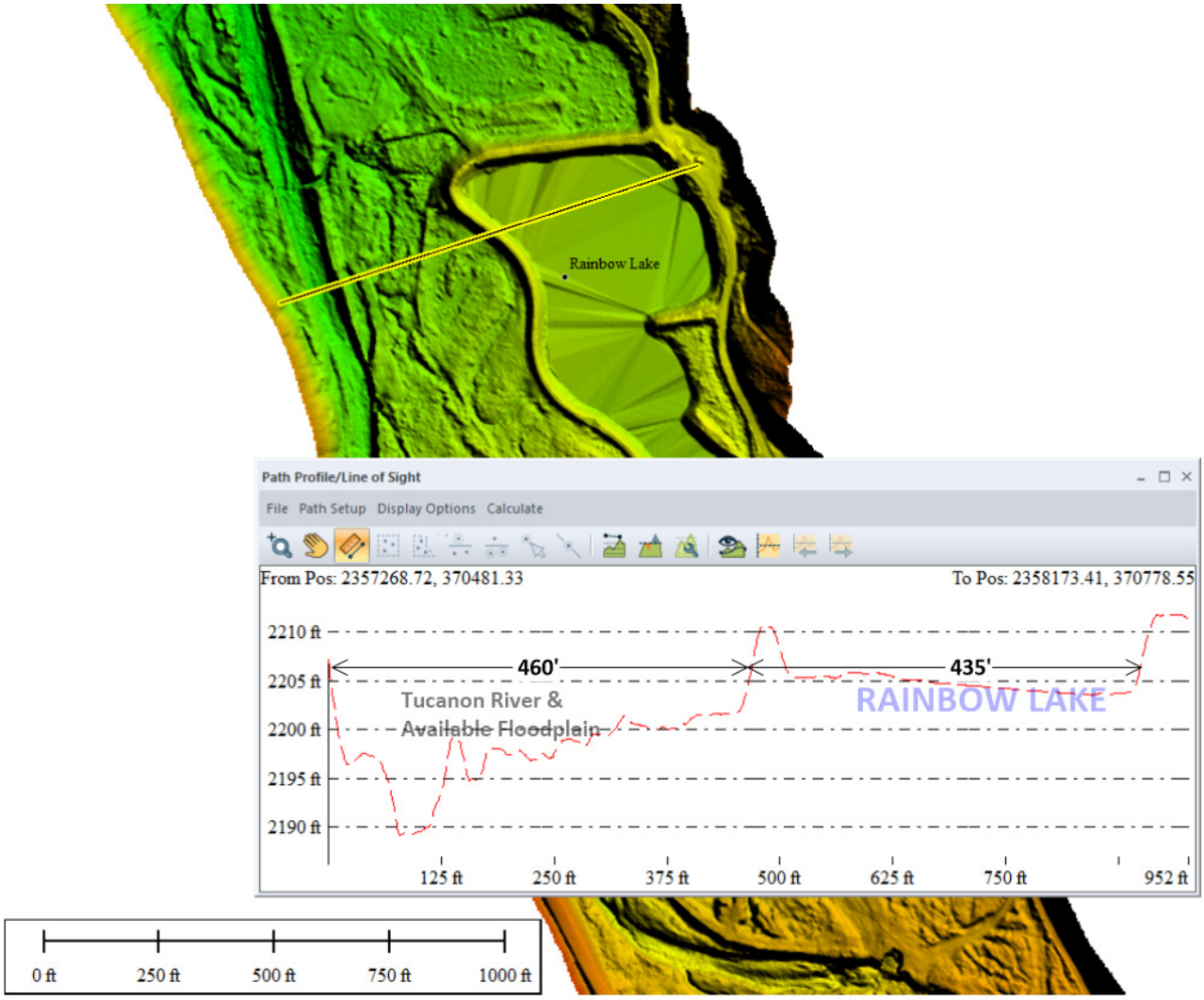


Figure 3 - Rainbow Lake valley floor cross-section

Hydraulic Modeling Results

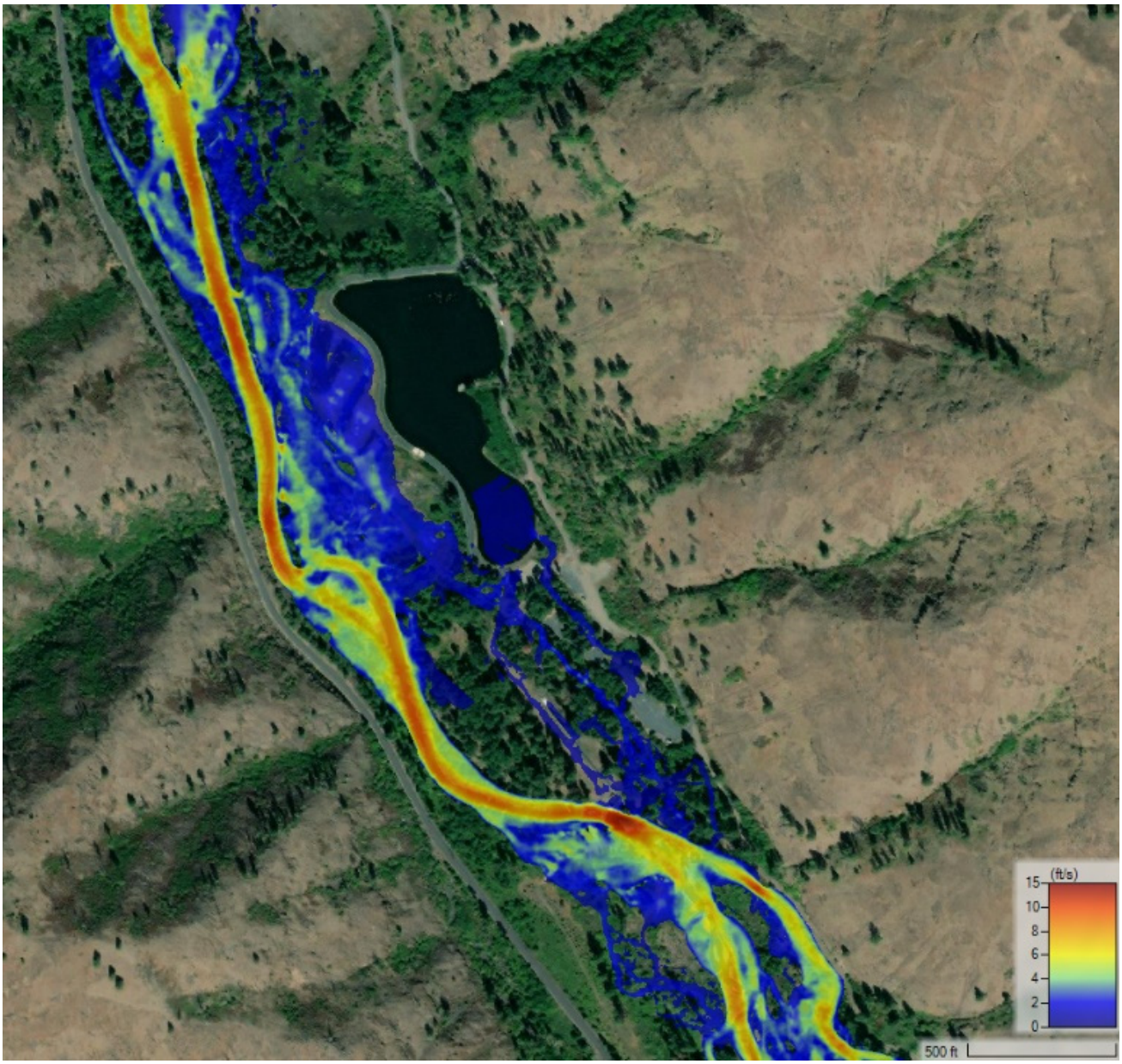


Figure 4 - HEC-RAS flow simulation showing velocity at 4,200 cfs

Water begins to pond along the toe of the western dam at approximately 1,600 cfs, but has minimal depth and velocity. Water begins to be routed into the southern portion of the lake at a flow level of approximately 4,200 cfs.

Flood events at the 2-yr (665 CFS), 25-yr (3,627 CFS), and 100-yr (6,498 CFS) events were modeled in HEC-RAS and the inundation extents and cross-section are shown in Figure 5 and Figure 6 respectively.

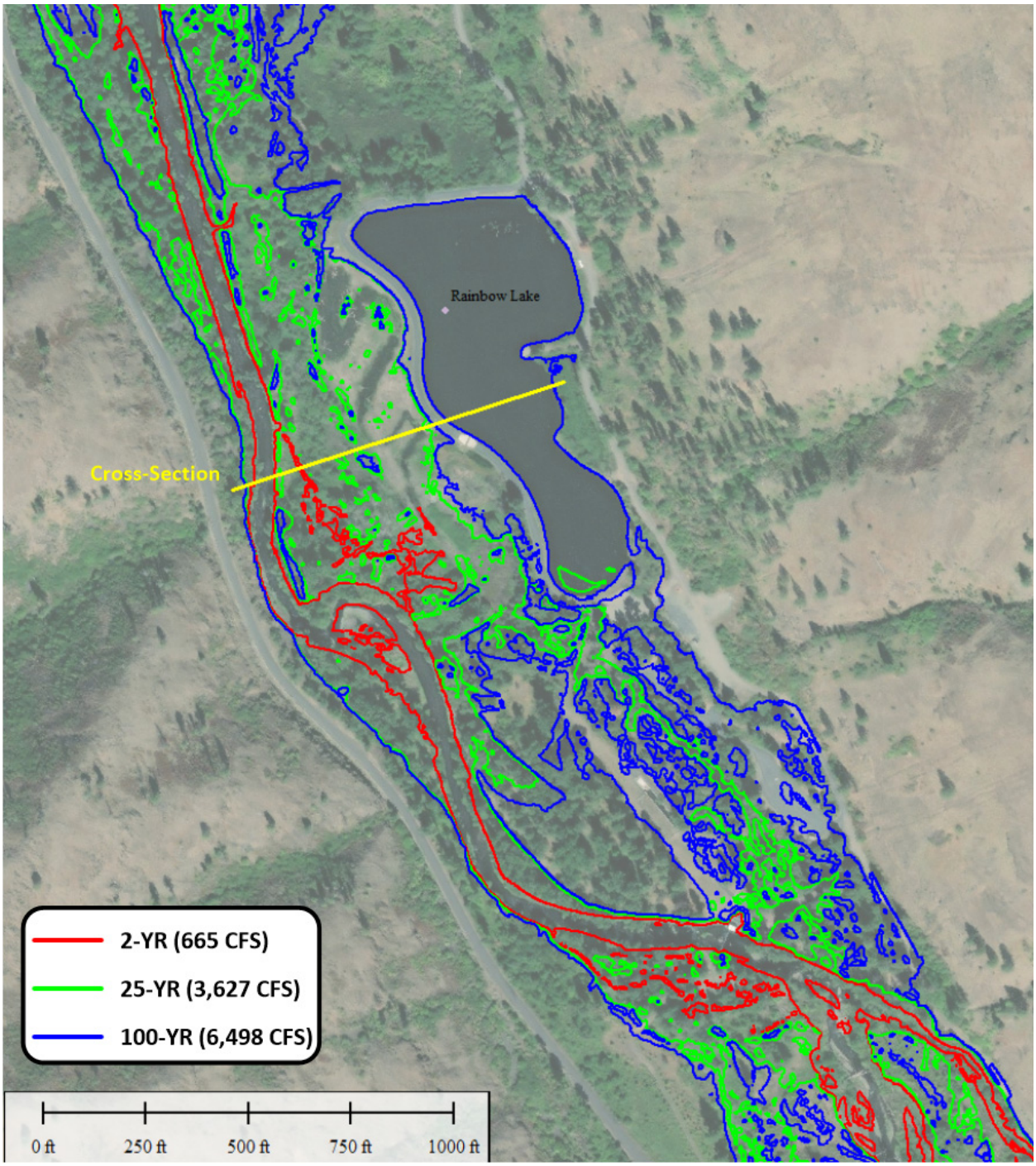


Figure 5 - Flood inundation extents from hydraulic modeling

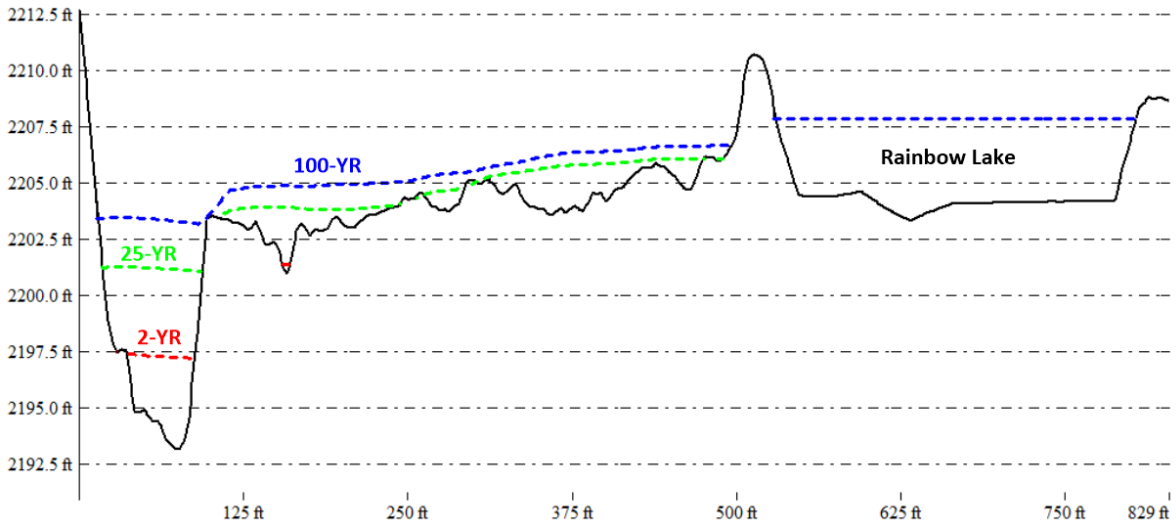


Figure 6 - Cross-section showing terrain and water surface elevations

A 100-yr event will route a significant amount of water into Rainbow Lake and could potentially lead to an unsafe condition.

Correction Options

Rainbow Lake went through significant modifications during the construction in 2018 and 2019. There no known safety issues with Rainbow Lake or the dam at this time.

Rating Matrix

The matrix below visually summarizes the categories above. The ratings are based on comparisons between all lakes with high representing the greatest negative (concern/impact/cost) and low representing the least negative (concern/impact/cost).

RATING MATRIX	
Operational overview/concerns	○
Dam Safety Concerns	○
Hydrologic / Topographic Concerns	●
Corrections Cost	
Decommissioning Cost	
Rating (high, medium, low) ● ● ○	

Spring Lake

Size: 6 acres

Constructed: 1955

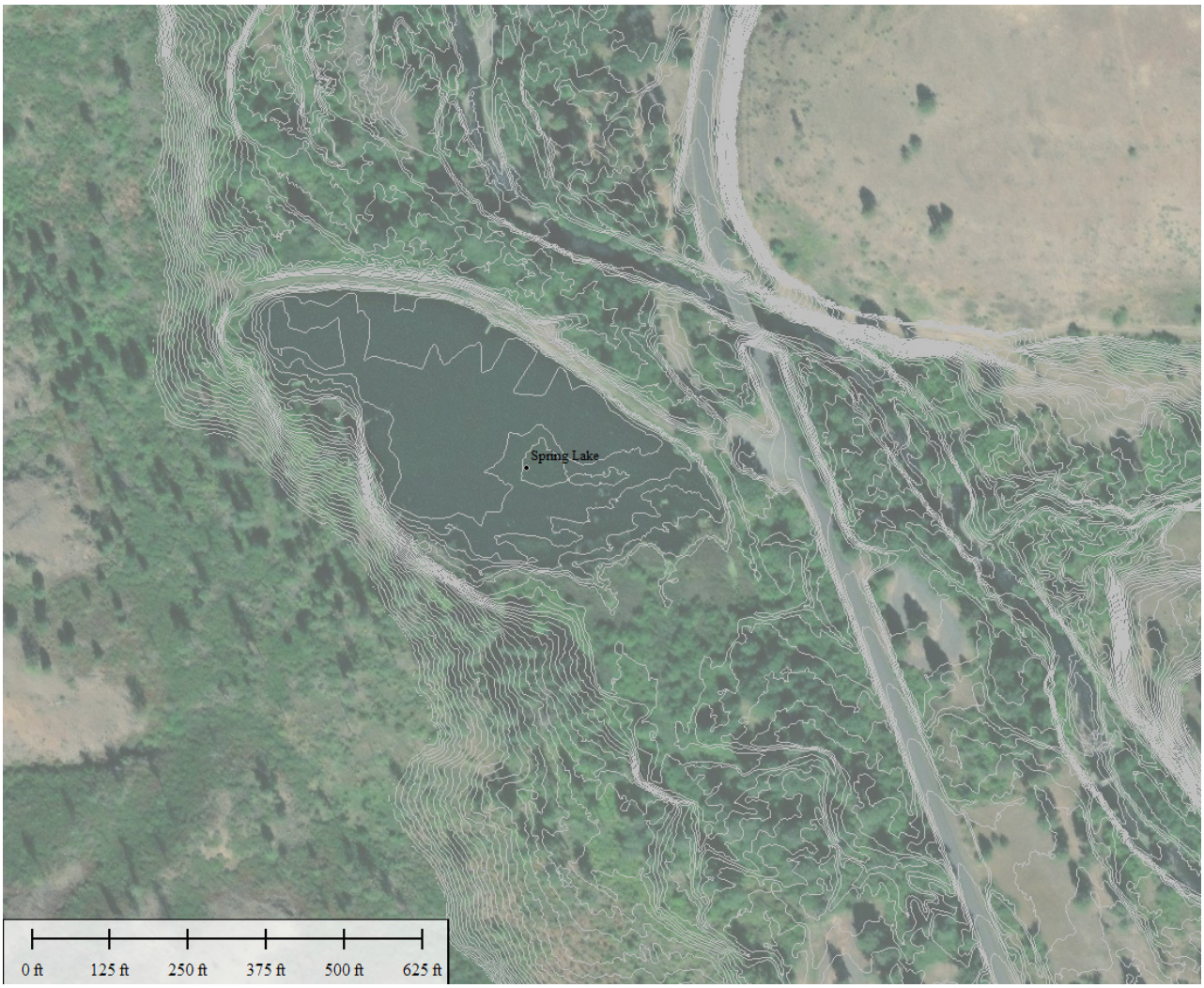


Figure 1 - Lake Overview

Operational Overview/Concerns

Spring lake is the most downstream lake of concern in the Tucannon valley. Water for the lake is supplied from local runoff and springs; there is no diversion from the Tucannon River. There is water in the lake year round.

Dam Safety Concerns

There is a bottom drain gated structure but it has not been functional in 15+ years. The remnants of the gate valve can be seen sticking out of the lake. There is an existing seep in the dam that has been observed for the past 15 years.

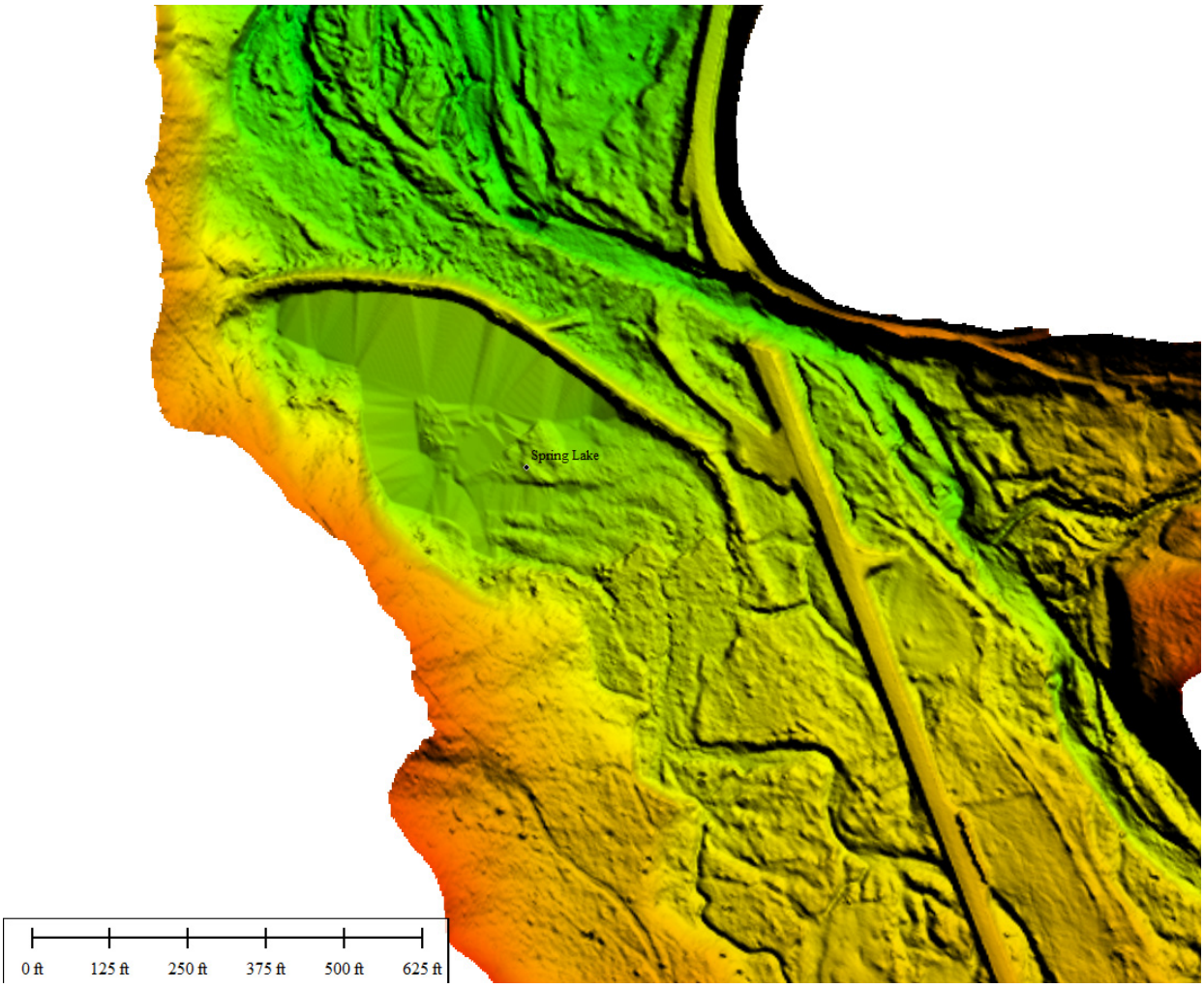


Figure 2 - LiDAR of Spring Lake and surrounding area.

Cross section examination shows a minimally adequate top width (10-12') and an acceptable backside slope. Only seven vertical feet are visible in the LiDAR cross section, however the slopes on the upstream side of the dam are much closer to a 2(H):1(V) than the recommended 3(H):1(V) on upstream dam slopes. The upstream slopes are shallower than backside slopes to accommodate for the fully saturated sediments in a rapid drawdown scenario. Care should be taken to not dewater the lake too rapidly or upstream slope failure may occur.

Hydrologic / Topographic Concerns

The road serves to protect the upper portion of the lake from floodwaters. The road crossing over the Tucannon River artificially constrains the river and reduces the chance of channel migration in the area around the lake and dam.

Downstream of the bridge, the Tucannon River is significantly channelized. The footprint of the lake takes up about 55% of the valley on a cross-sectional basis on the downstream side of the bridge.

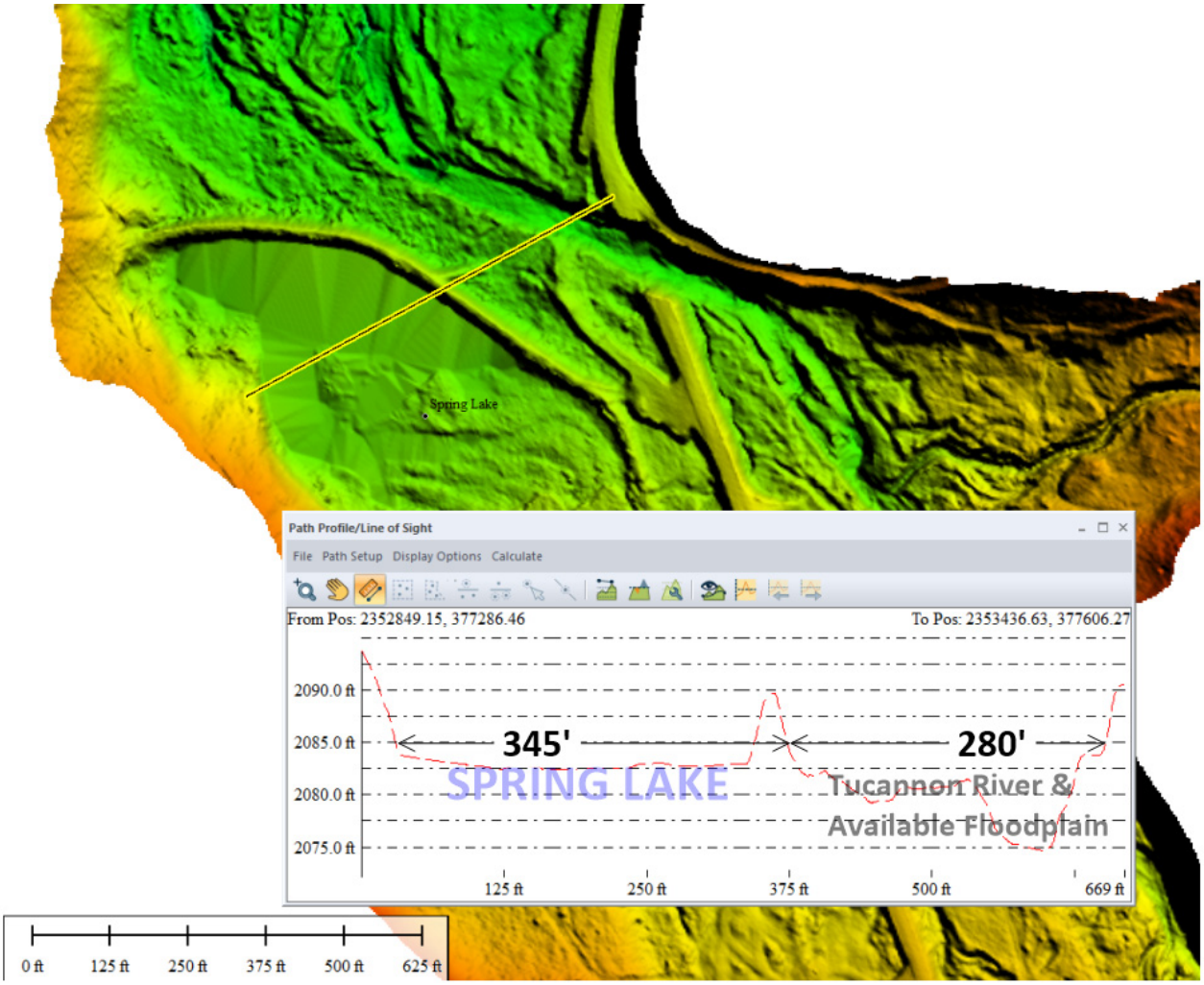


Figure 3 - Spring Lake valley floor cross-section

Hydraulic Modeling Results

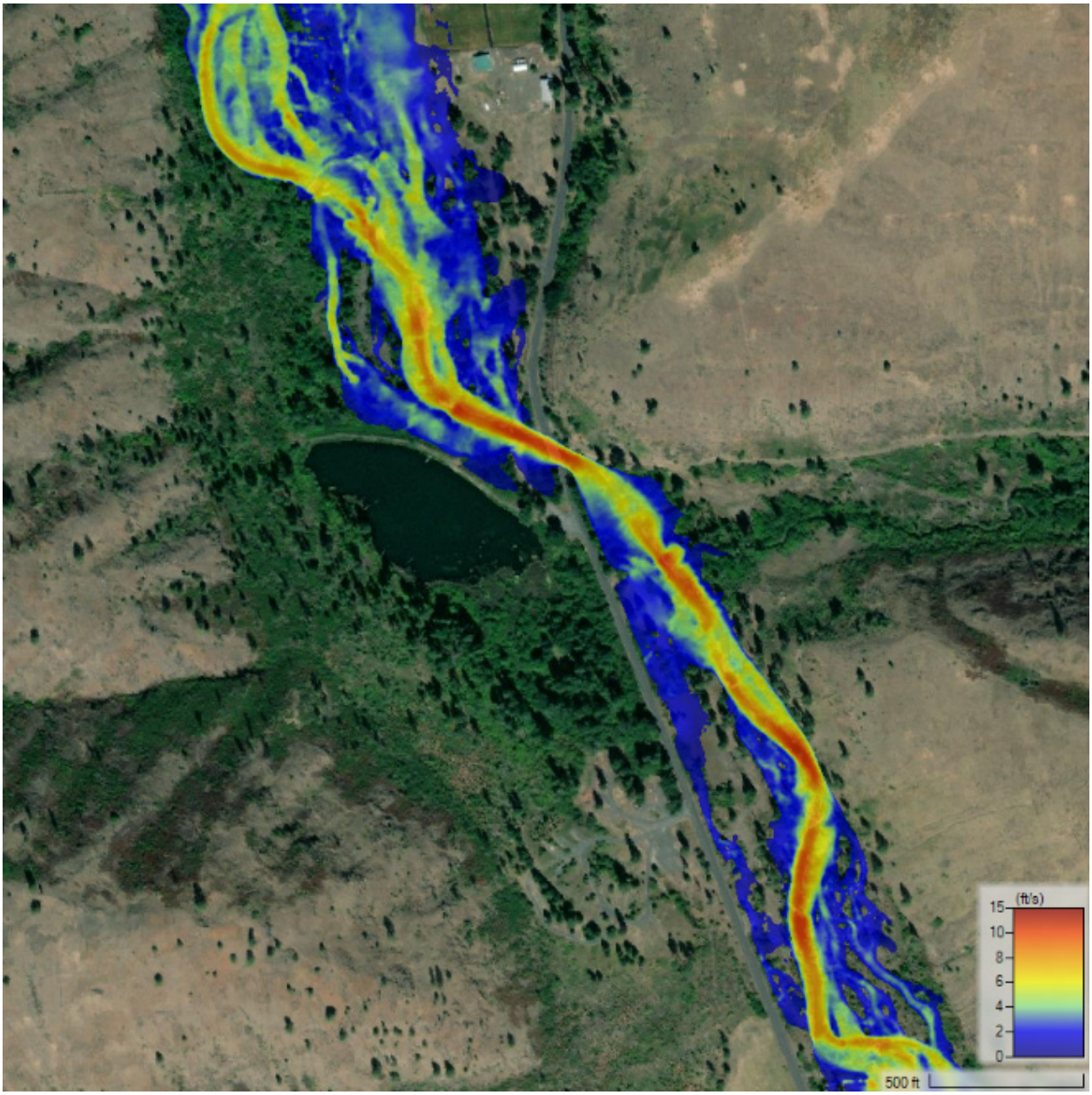


Figure 4 - HEC-RAS flow simulation showing velocitgy at 4,200 cfs

Flood waters begin to pool at the backside of the dam at a flood event of ~ 1,800 cfs, but velocities are minimal. Velocities remain low for any floodwaters on the backside of the dam, even up to a discharge level of 4,200 cfs.

Flood events at the 2-yr (665 CFS), 25-yr (3,627 CFS), and 100-yr (6,498 CFS) events were modeled in HEC-RAS and the inundation extents and cross-section are shown in Figure 5 and Figure 6 respectively.

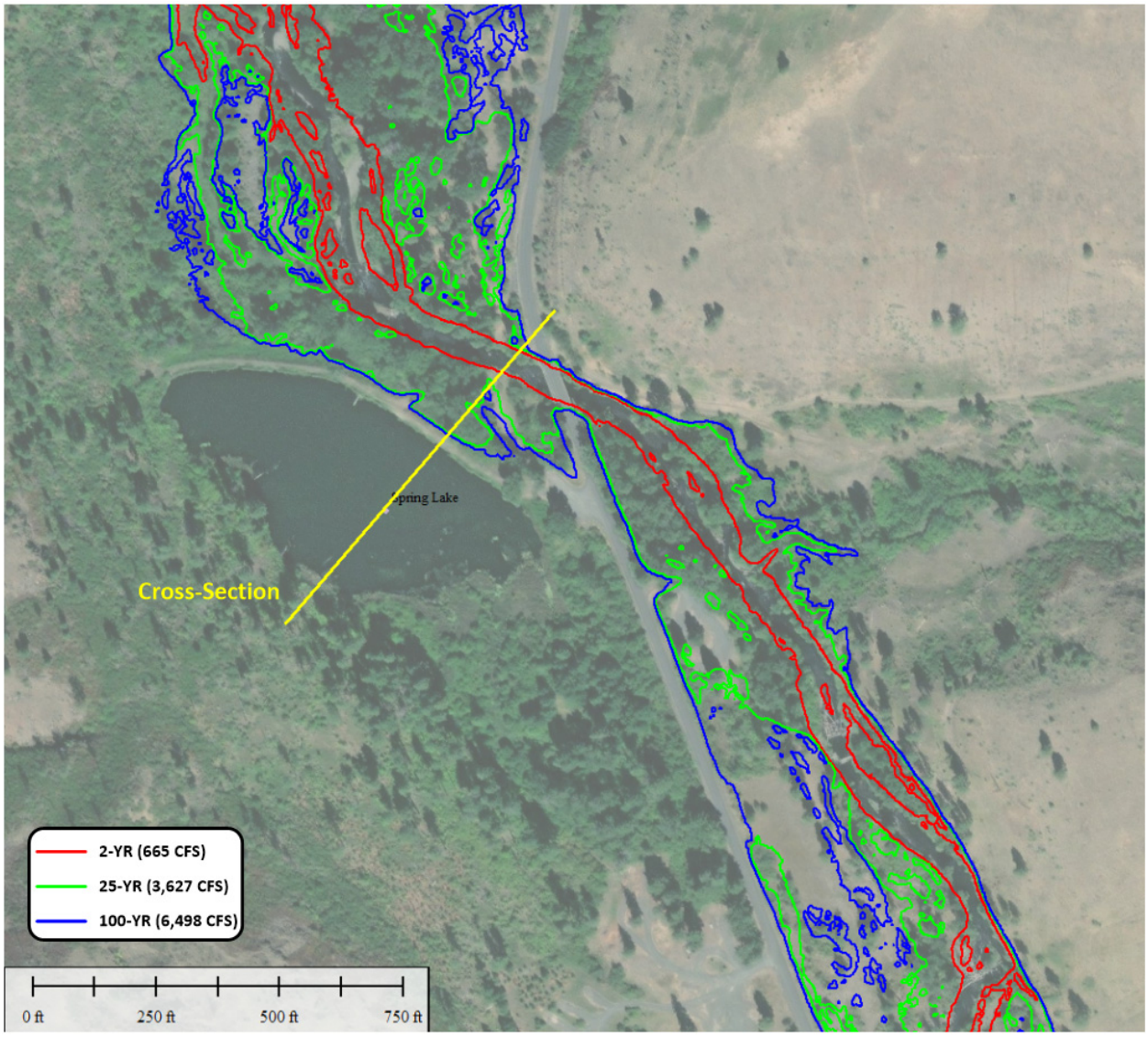


Figure 5 - Flood inundation extents from hydraulic modeling

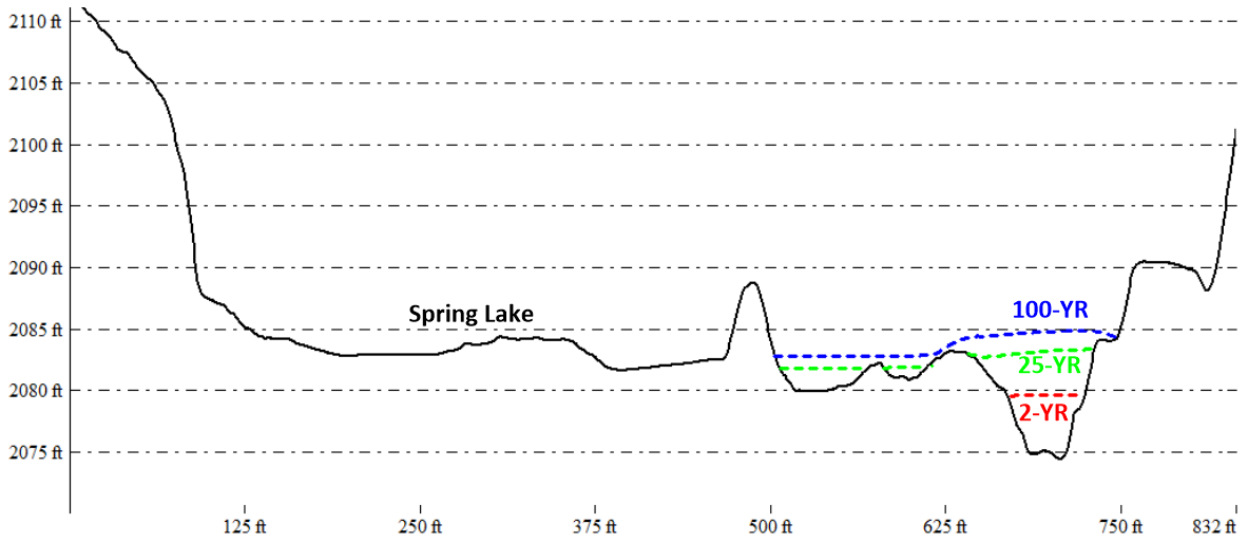


Figure 6 - Cross-section showing terrain and water surface elevations

Spring Lake is protected from floodwaters in the Tucannon River by the elevated roadway to the East. There is approximately 2.5 feet of freeboard on the roadway during a 100-yr event.

Correction Options

The dam on Spring Lake has been leaking for over 15 years. Significant springs are visible on the back side of the dam in multiple locations. The outlet pipe and headworks are non-functional.

Fixing the leaks and outlet pipe would require a significant amount of dam core removal and recompaction.

Drainage area analysis and design of an appropriate sized spillway would reduce the hazard potential of the dam.

Estimated cost of repairs: $325,000

Decommissioning would involve substantial regrading and a robust revegetation plan. Estimated cost of decommissioning: $100,000

Rating Matrix

The matrix below visually summarizes the categories above. The ratings are based on comparisons between all lakes with high representing the greatest negative (concern/impact/cost) and low representing the least negative (concern/impact/cost).

RATING MATRIX	
Operational Overview/Concerns	○
Dam Safety Concerns	●
Hydrologic / Topographic Concerns	●
Corrections Cost	●
Decommissioning Cost	●
Rating (high, medium, low) ● ● ○	

WOLF WATER RESOURCES

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Portland, OR 97214
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Technical Memorandum

Date:	JANUARY 23, 2024
To:	Kris Fischer, Confederated Tribes of the Umatilla Indian Reservation (CTUIR)
From:	Joe Rudolph, PWS – Wolf Water Resources (W2r) Jeremiah Green – Wolf Water Resources (W2r) Luke Russell – Wolf Water Resources (W2r) Nick Legg, PG – Wolf Water Resources (W2r)
Project:	Tucannon River PA 5-15 Assessment and Conceptual Design
Subject:	Wetland and OHWM Determination

Introduction

The memorandum (memo) documents a wetland mapping and ordinary high water mark (OHWM) determination for the Tucannon River Project Area (PA) 5-15 Assessment and Conceptual Design Project (the Project). The Project is along an approximately nine-mile reach of the Tucannon River coinciding with the W.T. Wooten Wildlife Area owned by Washington Department of Fish and Wildlife (WDFW). In collaboration WDFW and Nez Perce Tribe (NPT), the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are completing a multi-purpose assessment of floodplain opportunities on the W.T. Wooten Wildlife Area. The assessment will identify integrated restoration and management strategies for the floodplain areas W.T. Wooten Wildlife Area and complete conceptual designs for the project areas that exist within this footprint.

The Project's goal is to create an assessment that will inform planning and prioritization of a comprehensive restoration strategy for the project reach. These restoration actions will require permitting under Clean Water Act (CWA) Section 404 and 401. The project team expects to obtain a Section 404 permit through the Nationwide Permit #27 for Aquatic Habitat Restoration, Establishment, and Enhancement Activities.

To fulfill regulatory requirements, Wolf Water Resources (W2r) has assisted the project team by completing a wetland determination aimed at mapping the extent of likely jurisdictional wetlands and waters within the Project area and specifically restoration actions that may result in a direct impact. Identifying wetland and ordinary high water mark (OHWM) boundaries will allow the project team to calculate the project impacts necessary to facilitate the Corps' review of the Project. Therefore, W2r scientists determined wetland and OHWM boundaries through a desktop analysis

that was field verified through vegetation, hydrology, and OHW observations. This memorandum summarizes site conditions based on desktop analyses and field verification observations. Approximate wetland areas are shown in Attachment 1.

Landscape Context

The Project area is located in southeast Washington on the W.T. Wooten Wildlife Area in Columbia County between river miles 36.25 through 46.25 on the Tucannon River. This stretch of the Tucannon River floodplain includes a series of artificial lakes within the floodplain, degrading habitat for Chinook salmon, steelhead, bull trout, lamprey, and mussels. Confinement of the river and its energy has also threatened the longevity and function of these lakes for fishing use. With eroding levees, malfunctioning water intakes, sedimentation, and dam safety issues, many of these lakes provide diminishing recreational value, a growing maintenance backlog, and, in some cases, limited options for repair. Recognizing the alignment in diminished recreational values, increased costs, and ecosystem impacts, this project is an opportunity to build a future where reconnected floodplains support thriving ecosystems for aquatic and upland species, recreational users have access to functioning and well-maintained lakes (that are feasibly managed), ecosystems and infrastructure are buffered to the impacts of climate change, and communities maintain access to Tucannon headwaters and its full suite of natural and cultural values.

Wetland Determination Methods

The proposed Project encompasses a 1075.4-acre area. The entire Project area was assessed for wetlands to gather a baseline understanding of Project area conditions and potential impacts associated with construction access and staging.

Desktop Assessment

Prior to the field investigation, W2r staff reviewed National Wetland Inventory (NWI) data, Natural Resources Conservation Service (NRCS) soil data, topographic LiDAR data, and 2019-2021 NAIP imagery for the study area to determine hydrologic conditions most likely to sustain wetlands.

A Local Wetland Inventory (LWI) was not available for this area. The National Wetland Inventory shows the potential for riverine, freshwater emergent, freshwater forested/shrub, and freshwater pond wetlands to be present within the project area.

The NRCS lists nineteen different soils within the project area, none of which are considered hydric.

Using 2020 LiDAR sourced from the Washington State Department of Natural Resources, a relative elevation model was created to identify low-lying areas where wetland hydrology is likely present. Using the hydro-smoothed LiDAR, we sample elevations from within the channel to represent a low-flow water surface elevation. We interpolated the surface from these water surface elevations covering the Project area and subtracted the interpolated water surface from the true elevation. This yields the elevation of the floodplain relative to the stream's approximate baseflow water-surface

elevation. From there a relative elevation of 2.5 feet above water surface was used to define initial wetland boundaries that were later field verified and refined by W2r staff.

Field Verification

On September 26th and 27th, 2023, W2r scientists Jeremiah Green and Luke Russell conducted a wetland field investigation at the Project area to field verify the presence or absence of wetlands identified during the desktop analysis. During the field investigation, vegetation communities and geomorphic position were observed and documented. Observed wetlands were Cowardin and hydrogeomorphic (HGM) classified and wetland extents were estimated. Wetland field indicator data were used to refine the initial desktop-based wetland boundaries. Ground-level color photographs were taken to demonstrate site conditions within the study area.

Mapped Wetlands and Waters

Artificial Wetlands

Within the study area there are eight artificial lakes that are created and maintained by water diverted from the Tucannon River. Currently, the lakes are used for recreational purposes but many of them pose dam safety issues and significant impacts to the river and floodplain processes. The ponds are shallow, permanently flooded and are considered depressional wetlands according to HGM classification and Cowardin classified as palustrine emergent and/or palustrine unconsolidated bottom wetlands. An example of a PEM/PUB classified wetland is shown in Figure 1.



Figure 1. Beaver Lake is a PEM/PUB classified wetland near RM 42.25.

Pond adjacent wetlands

Each artificial lake has adjacent wetland complexes with hydrology originating from a consistent waterflow seeping through pond berms. These wetlands occur on both the upstream and downstream margins of the lakes. On the upstream side, the lakes act as local hydrological controls that support wetland formation. On the downstream side, seepage through confining berms and levees supports wetlands. These wetland complexes contain dominant vegetation of Himalayan blackberry (*Rubus armeniacus*), reed canary grass (*Phalaris arundinacea*), cattail (*Typha latifolia*), and

red alder (*Alnus rubra*). The pond adjacent wetlands have an HGM classification of depressional and palustrine emergent in Cowardin classification. An example of these pond-adjacent wetlands is shown in Figure 2.



Figure 2. A wetland complex adjacent to Curl Lake. Each pond has adjacent wetlands due to berm seepage.

Riverine wetlands

The desktop analysis, based on the REM +2.5' mapping approach, was generally accurate in predicting riverine wetlands within the floodplain. Cowardin classifications are palustrine forested, palustrine emergent, and palustrine shrub-scrub. These wetlands are hydrologically connected to the water table of the adjacent river during high flow events.

Hillslope seep wetlands

There are numerous instances of groundwater emerging from the steep slopes of the Tucannon hillsides and near tributary alluvial fans. In many cases depressional wetlands were observed at the slope toe and floodplain edge. These wetlands typically have well-developed shrub or herb layers but lack closed tree canopies. An example of plant communities in a hillside seep wetland is shown in Figure 3.



Figure 3. Hillside slope wetland near RM 45.



In total, approximately 69.1 acres of wetlands were mapped within the study area. Five wetland types were identified based on Cowardin classification. Acreages for each of these wetland types are referenced in Table 1.

The OHWM boundary was developed based on a combination of 2019-2021 National Agriculture Imagery Program (NAIP) and 2020 LiDAR sourced from the Washington State Department of Natural Resources.

Table 1. Cowardin classified wetland types found in the Project area.

Cowardin classification	Acreage
Palustrine emergent	29.7
Palustrine emergent/Unconsolidated bottom	17.3
Palustrine forested	14.3
Palustrine scrub-shrub	3.3
Palustrine unconsolidated bottom	4.5

Conclusion

In support of this voluntary restoration project, W2r determined wetland and OHWM boundaries through a combination of LiDAR data and drone imagery. Site observations were used to validate or refine the desktop analysis. Identifying these boundaries will assist the Project design team in designing a project that will result in an increase in aquatic resource functions and services. This will also allow the Project team to calculate Project impacts to facilitate the Corps' review of the Project for CWA permitting under NWP #27.

Disclaimer

This report documents the observations, best professional judgment, and conclusions of the investigators. This wetland determination is not comprehensive. Varying sources of wetland hydrology limit predictability of wetland hydrogeomorphic classification. Additional fieldwork will be required once projects are better defined. It is correct and complete to the best of our knowledge. It should be considered a precursor to a Preliminary Jurisdictional Determination (PJD) of wetlands and other waters and used at your own discretion unless reviewed and approved in writing by the Corps.

Reference

USDA. (2023). Web Soil Survey. Retrieved September 4, 2023, from

https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

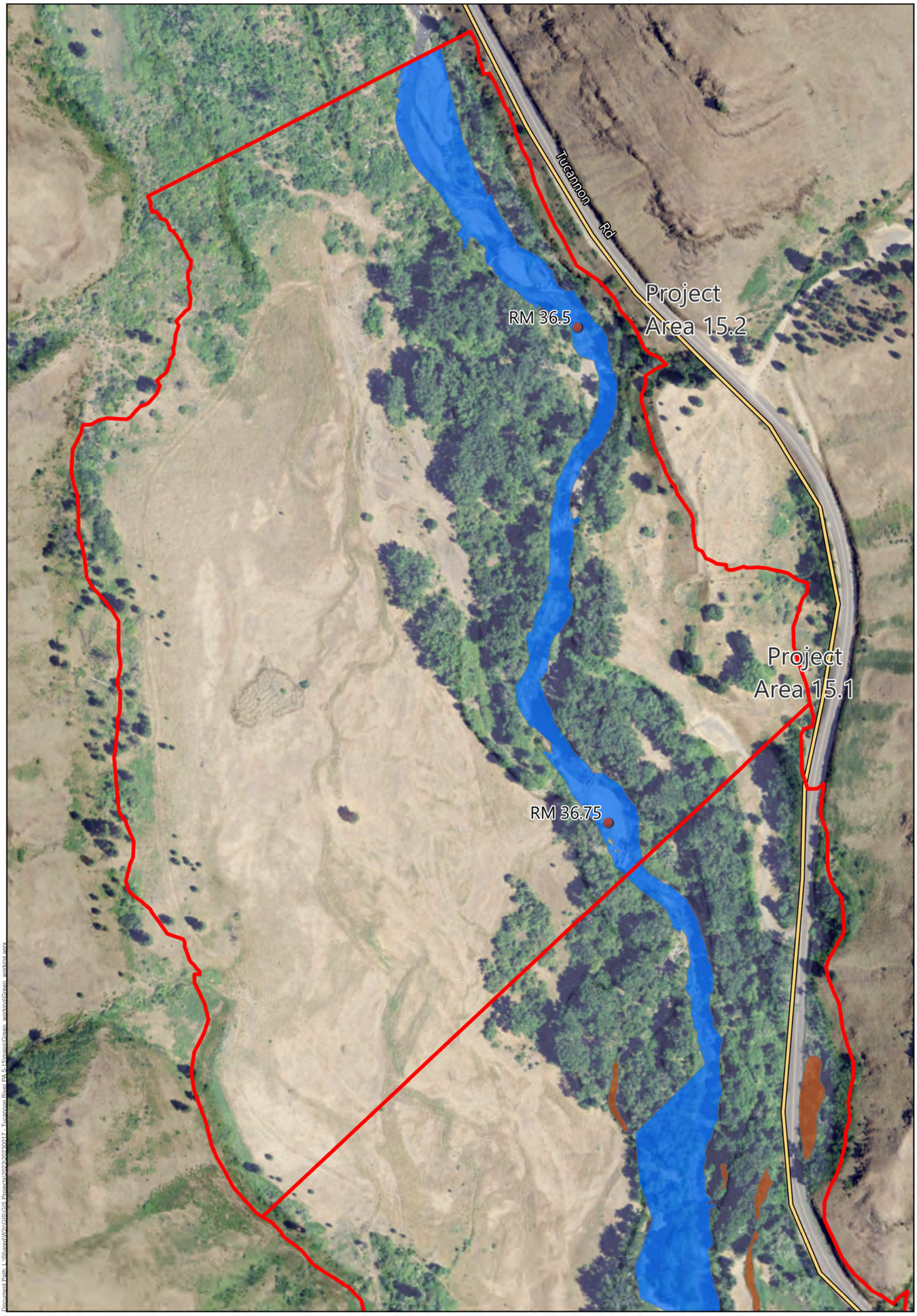
USFWS. 2023. National Wetland Inventory. Retrieved September 4, 2023, from https://www.fws.gov/program/national-wetlands-inventory

Attachment

Attachment 1- Approximate Wetland Features

Attachment 1

Approximate Wetland Features and Background Maps



Tucannon River

Wetland Determination

Map 1 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

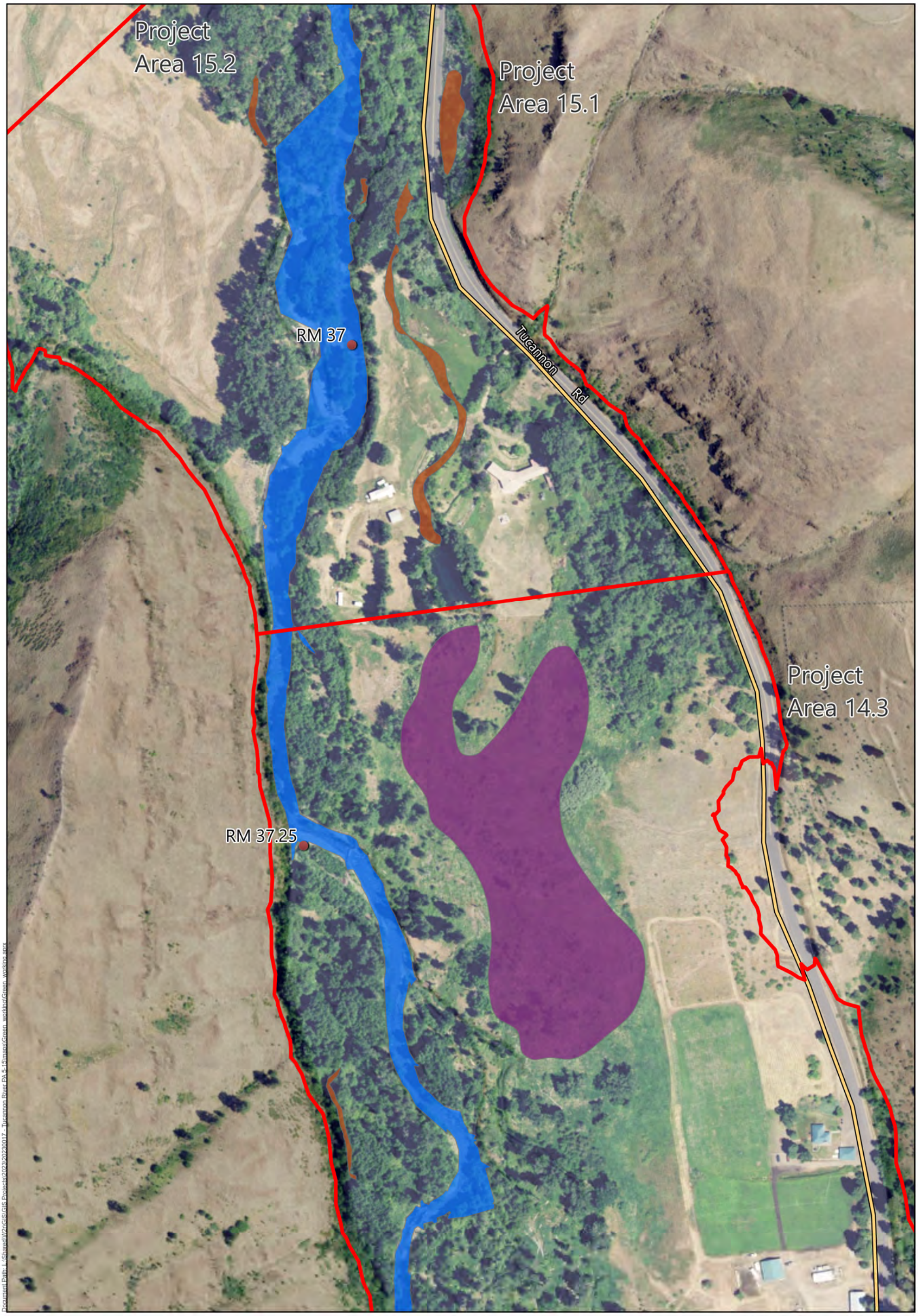
***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 2 of 18

0 100 200 400 Feet

N

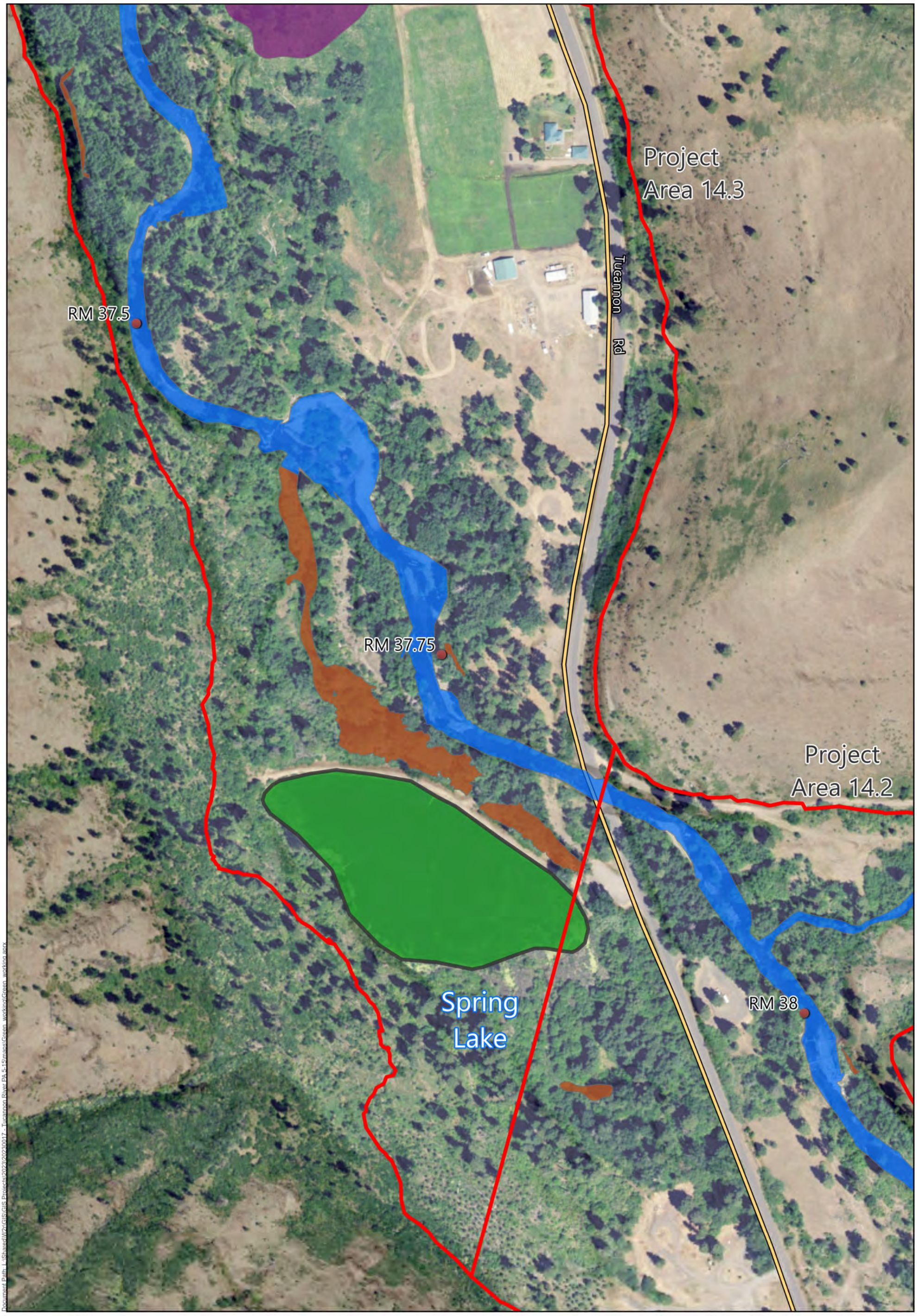
*Wetlands (Cowardin classification)

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

*The wetlands shown are preliminary in nature.

WOLF WATER RESOURCES



Tucannon River

Wetland Determination

Map 3 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 4 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

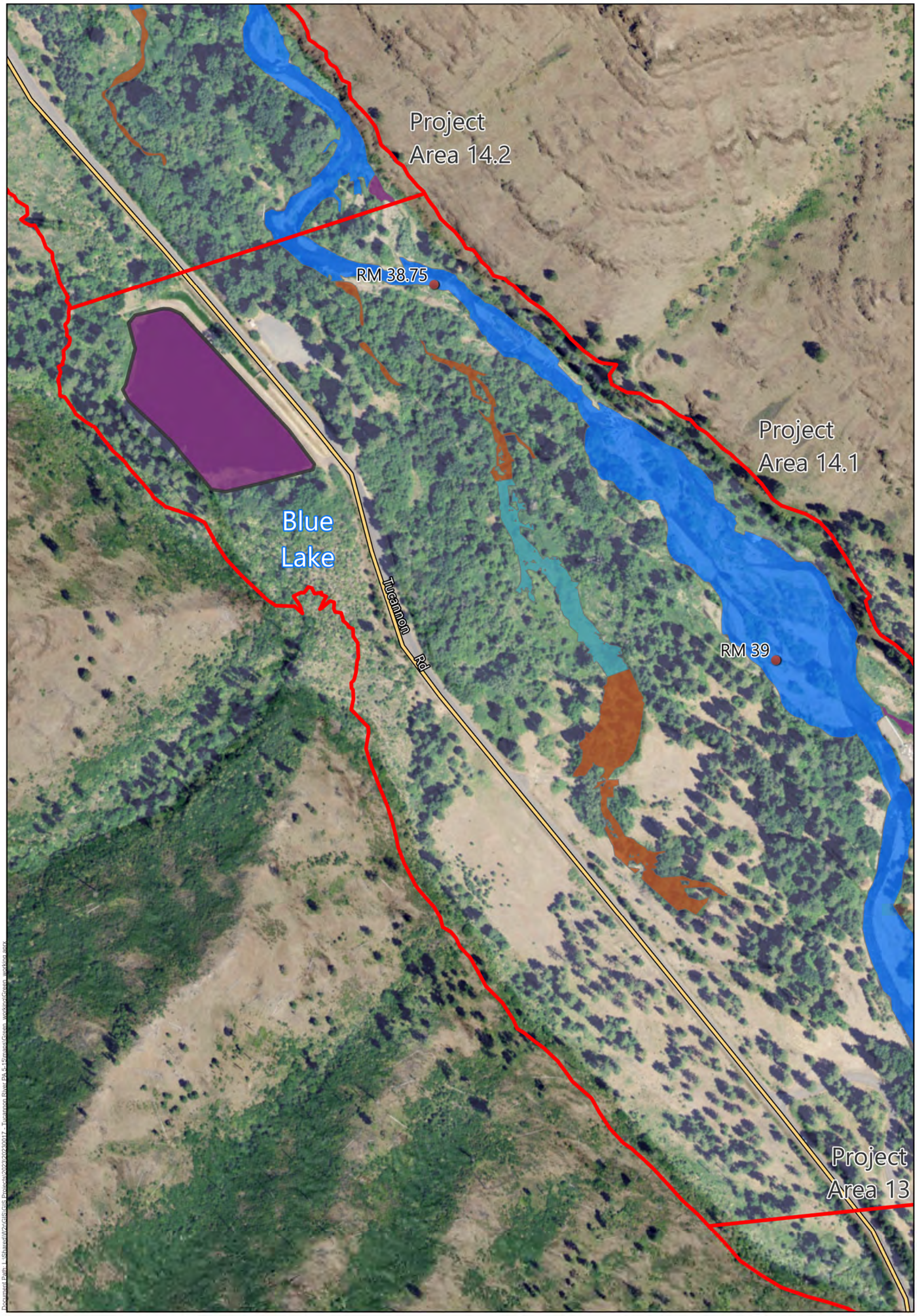
***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- River Mile
- OHW
- Road
- Lake

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 5 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES

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RM 39

Project
Area 14.1

RM 39.25

Tucannon Rd

Project
Area 13

RM 39.5

Rainbow
Lake

Tucannon River

Wetland Determination

Map 6 of 18

0 100 200 400 Feet

N

*Wetlands (Cowardin classification)

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

*The wetlands shown are preliminary in nature.

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 7 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

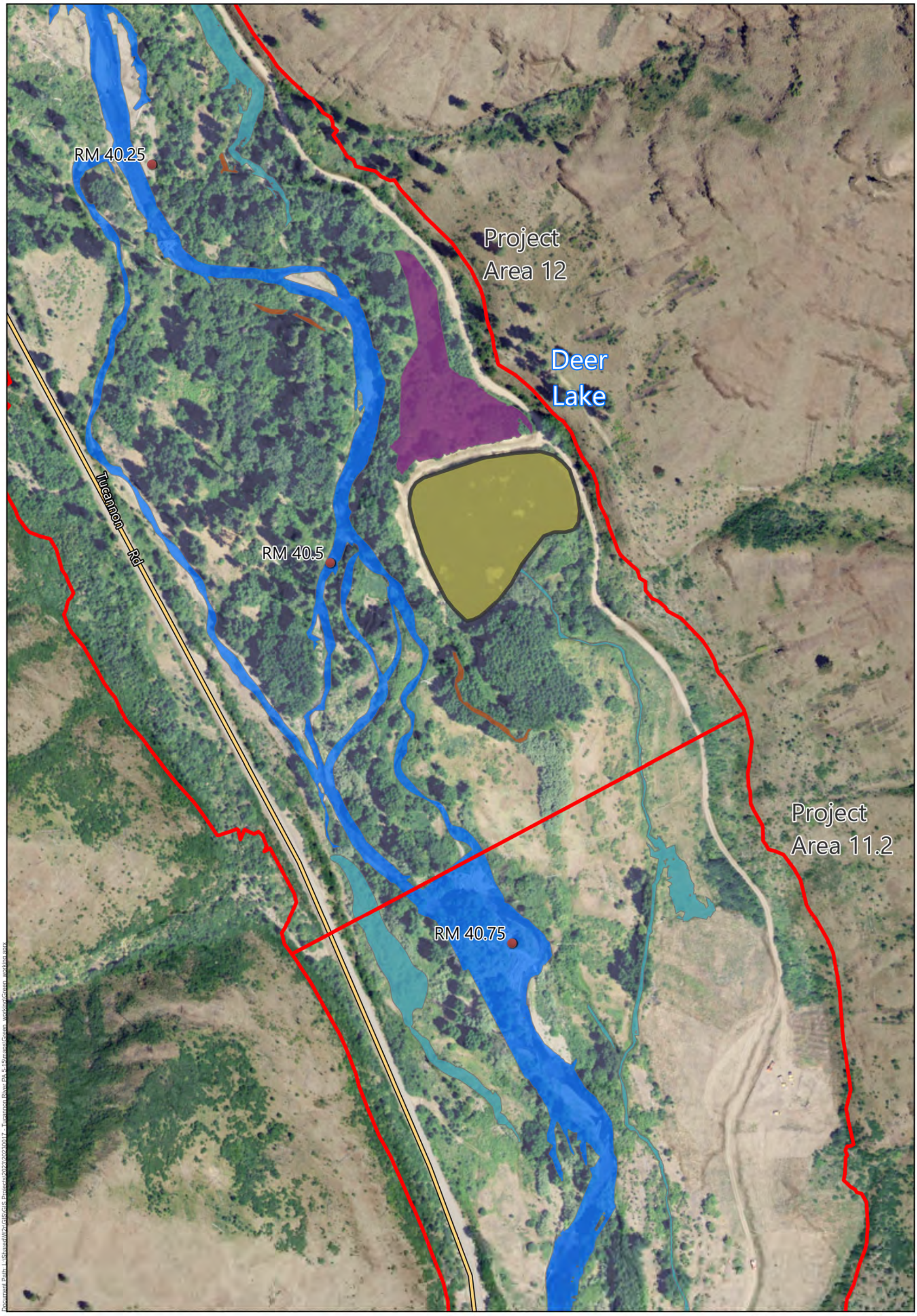
***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- River Mile
- OHW
- Road
- Lake

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 8 of 18

0 100 200 400 Feet

N

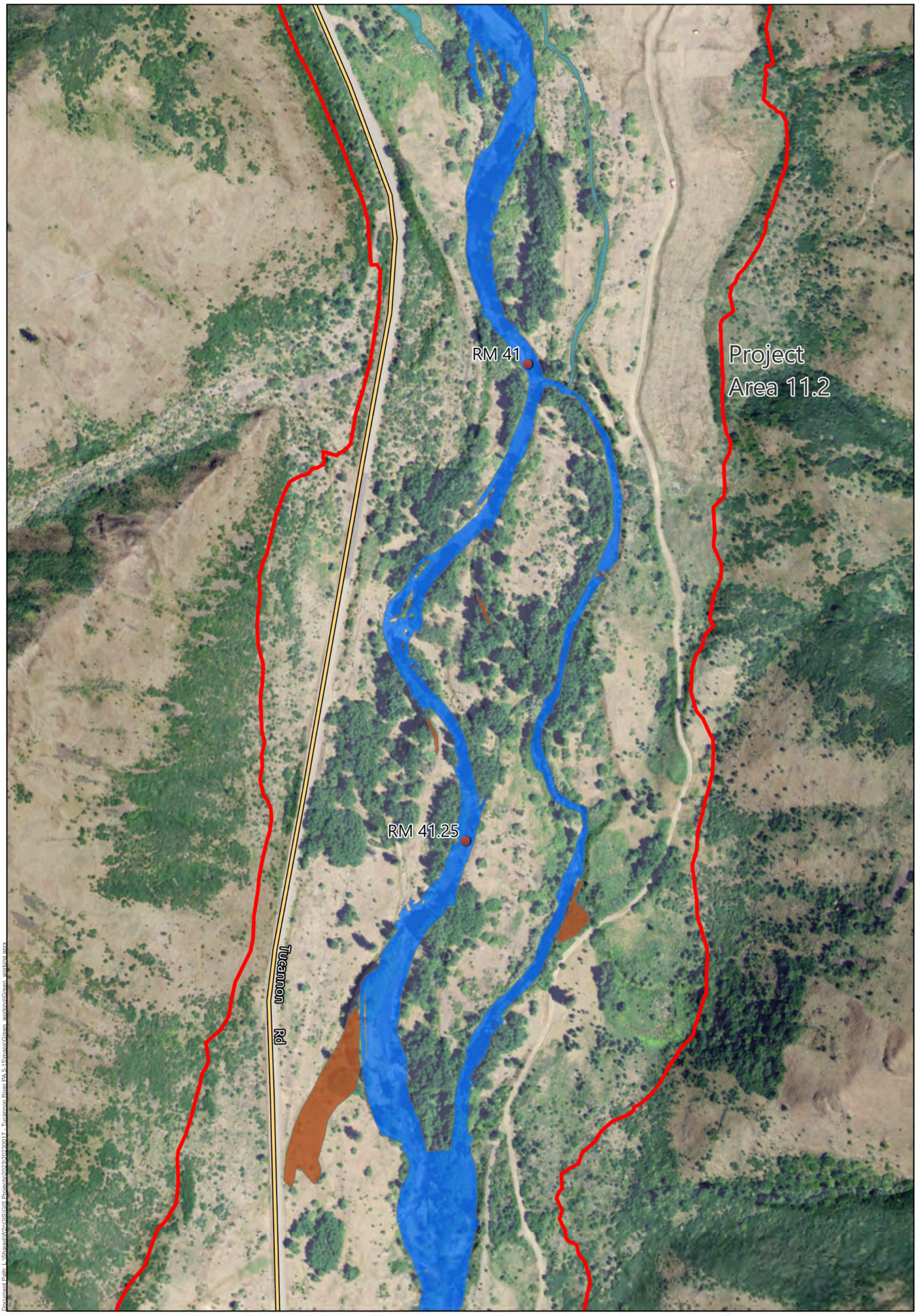
*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES



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Tucannon River

Wetland Determination

Map 9 of 18

0 100 200 400 Feet

N

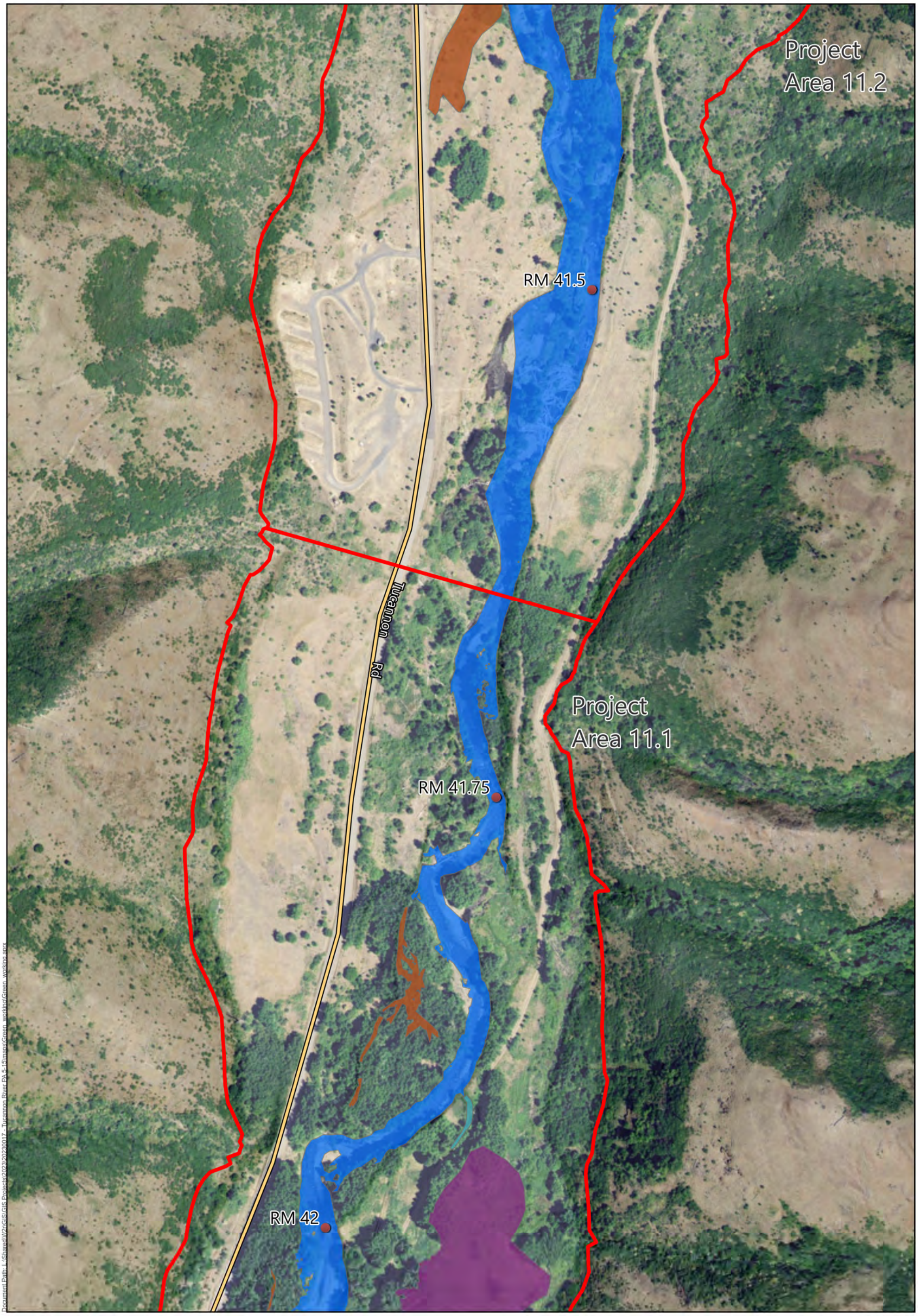
*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES



Tucannon River

Wetland Determination

Map 10 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

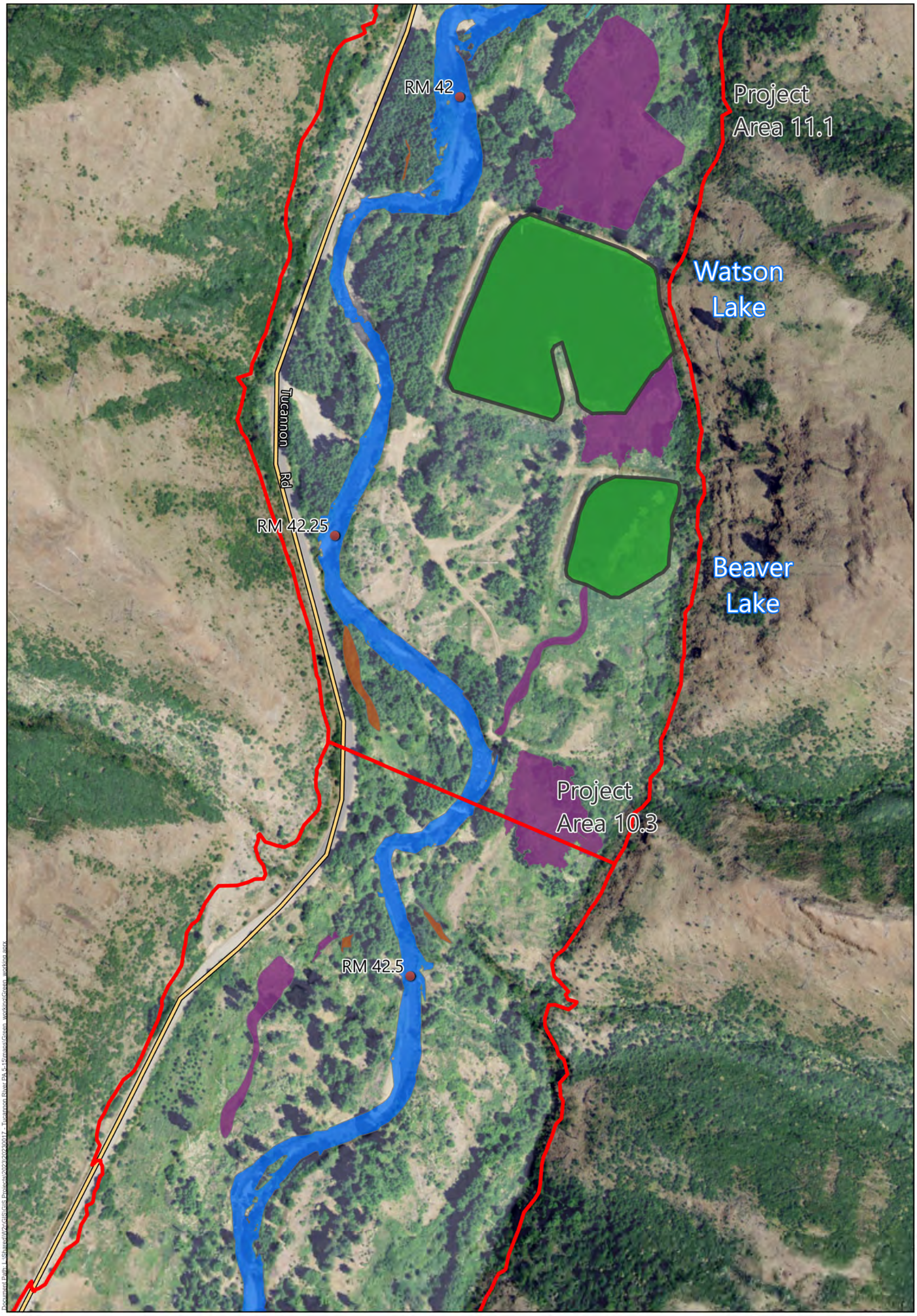
***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- River Mile
- OHW
- Road
- Lake

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 11 of 18

0 100 200 400 Feet

N

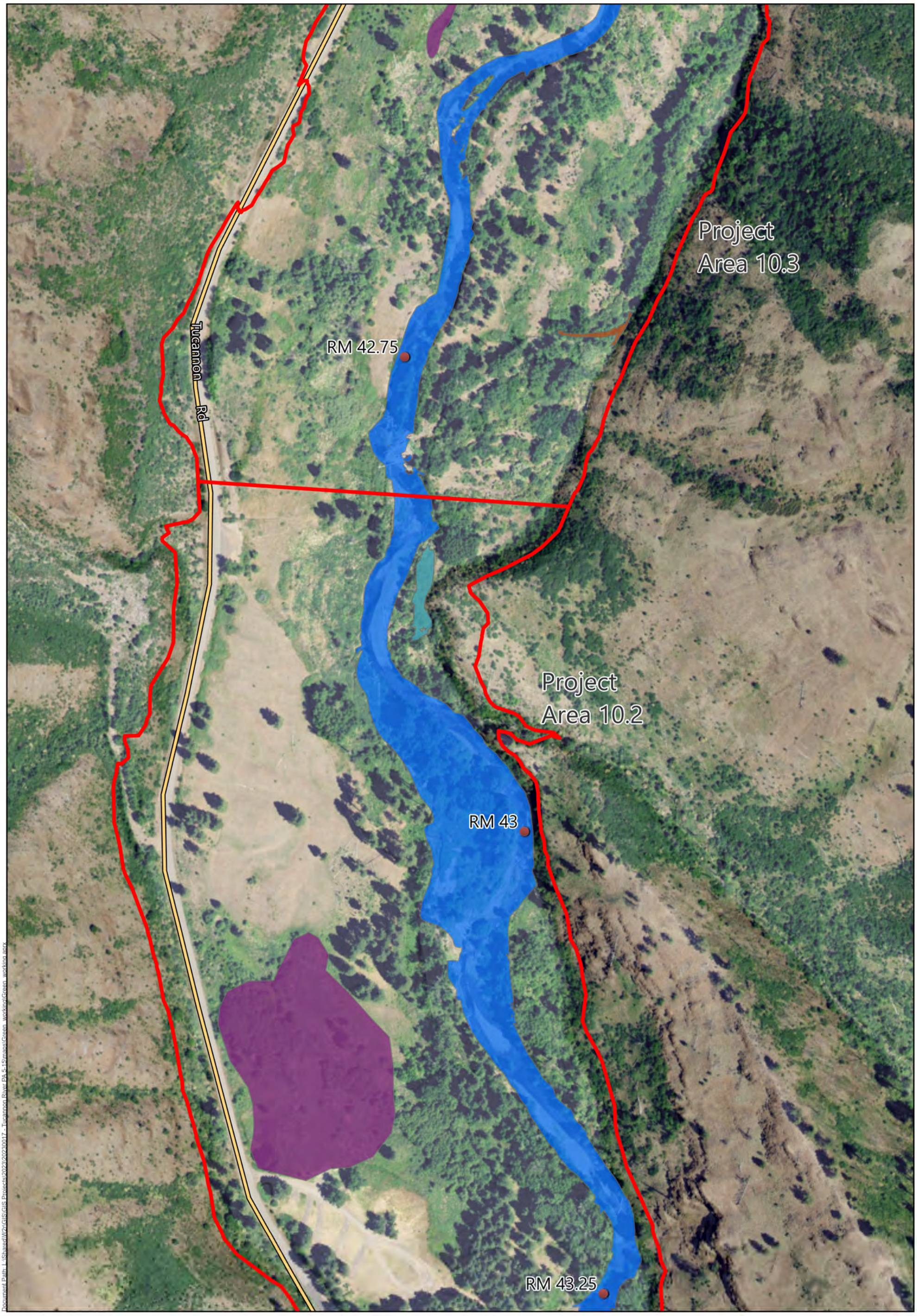
*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES



Tucannon River

Wetland Determination

Map 12 of 18

0 100 200 400 Feet

N

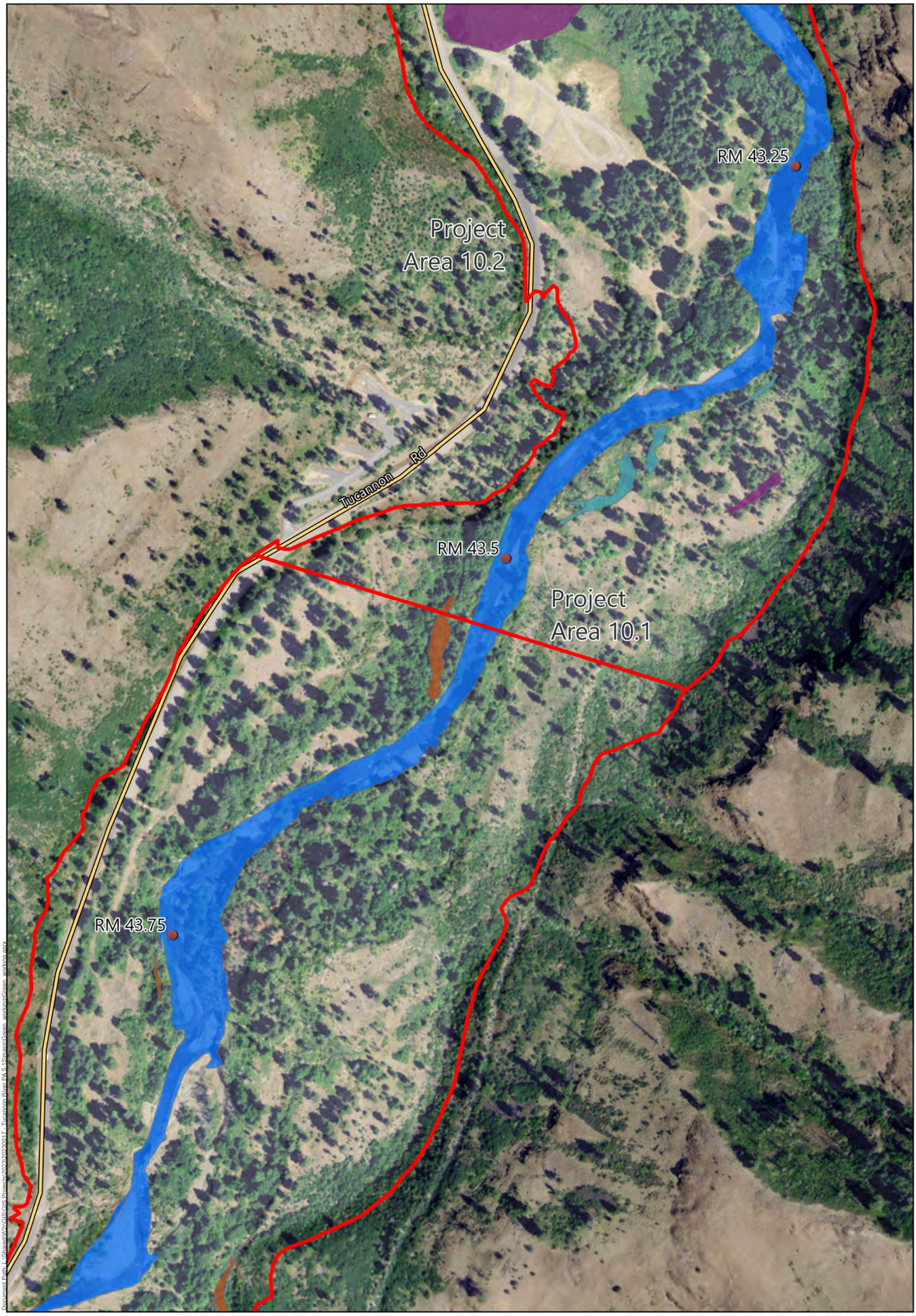
*Wetlands (Cowardin classification)

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom
- Project area
- OHW
- Lake
- River Mile
- Road

*The wetlands shown are preliminary in nature.

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 13 of 18

0 100 200 400 Feet

N

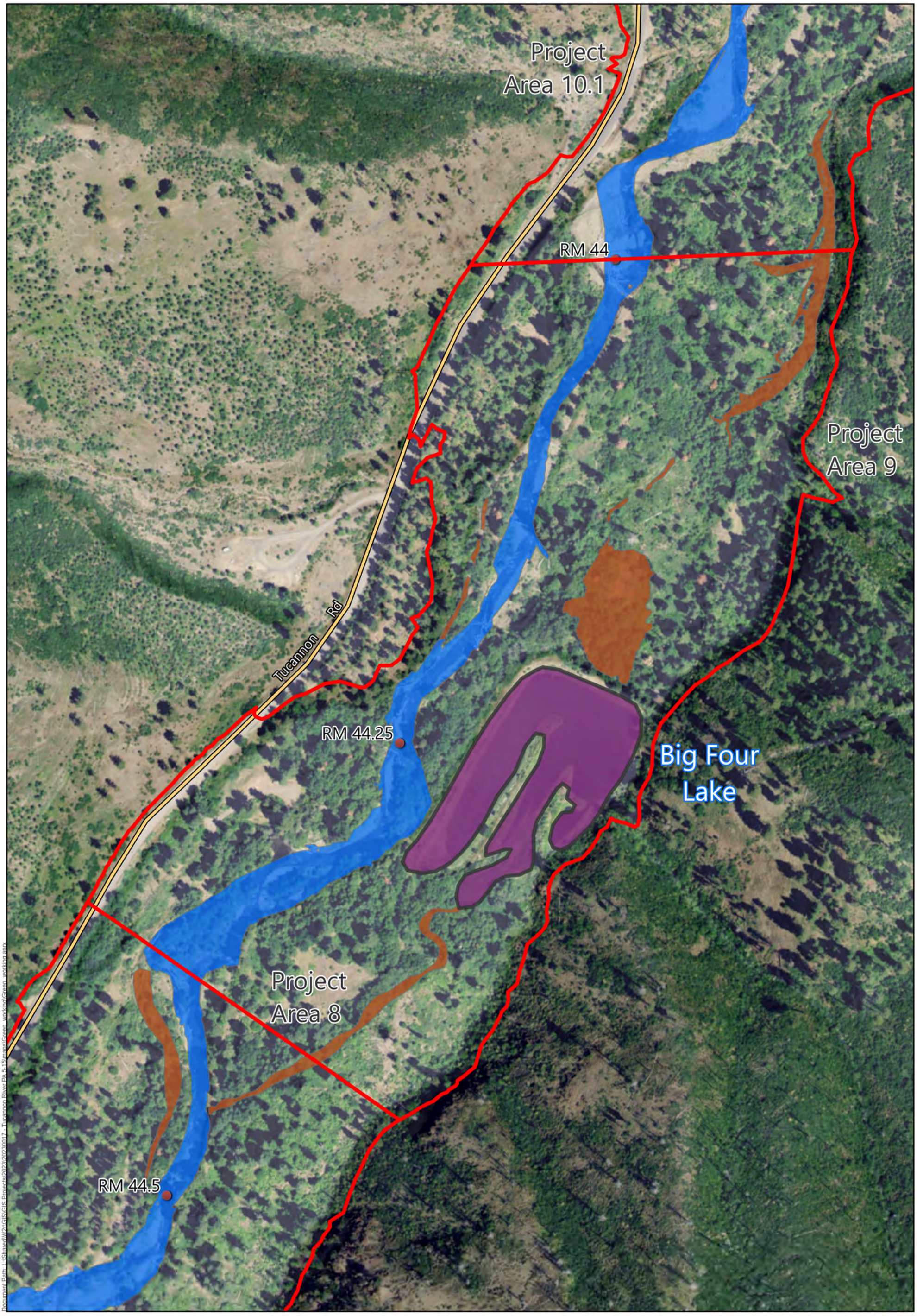
*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES



Tucannon River

Wetland Determination

Map 14 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

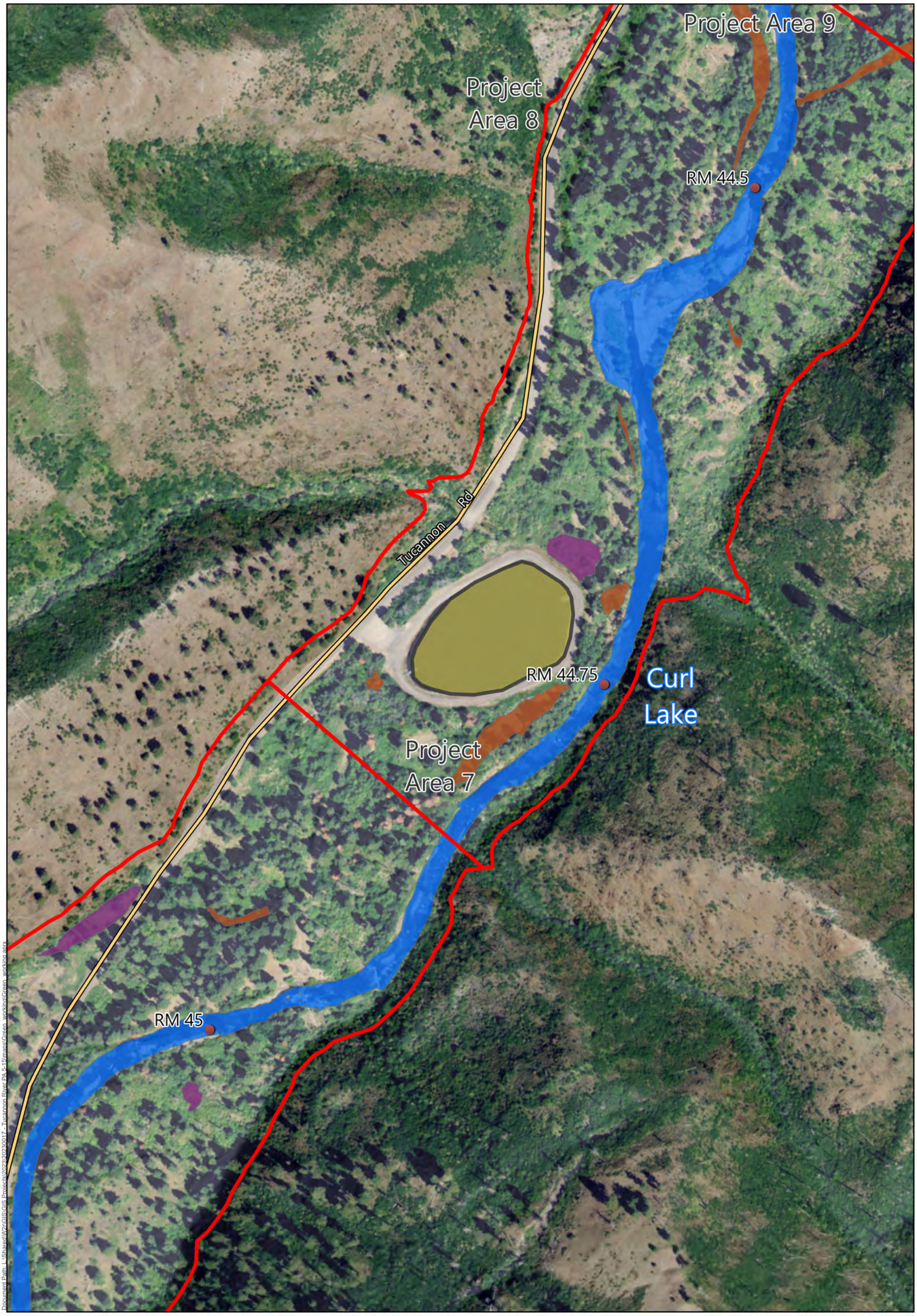
***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES

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Tucannon River

Wetland Determination

Map 15 of 18

0 100 200 400 Feet

N

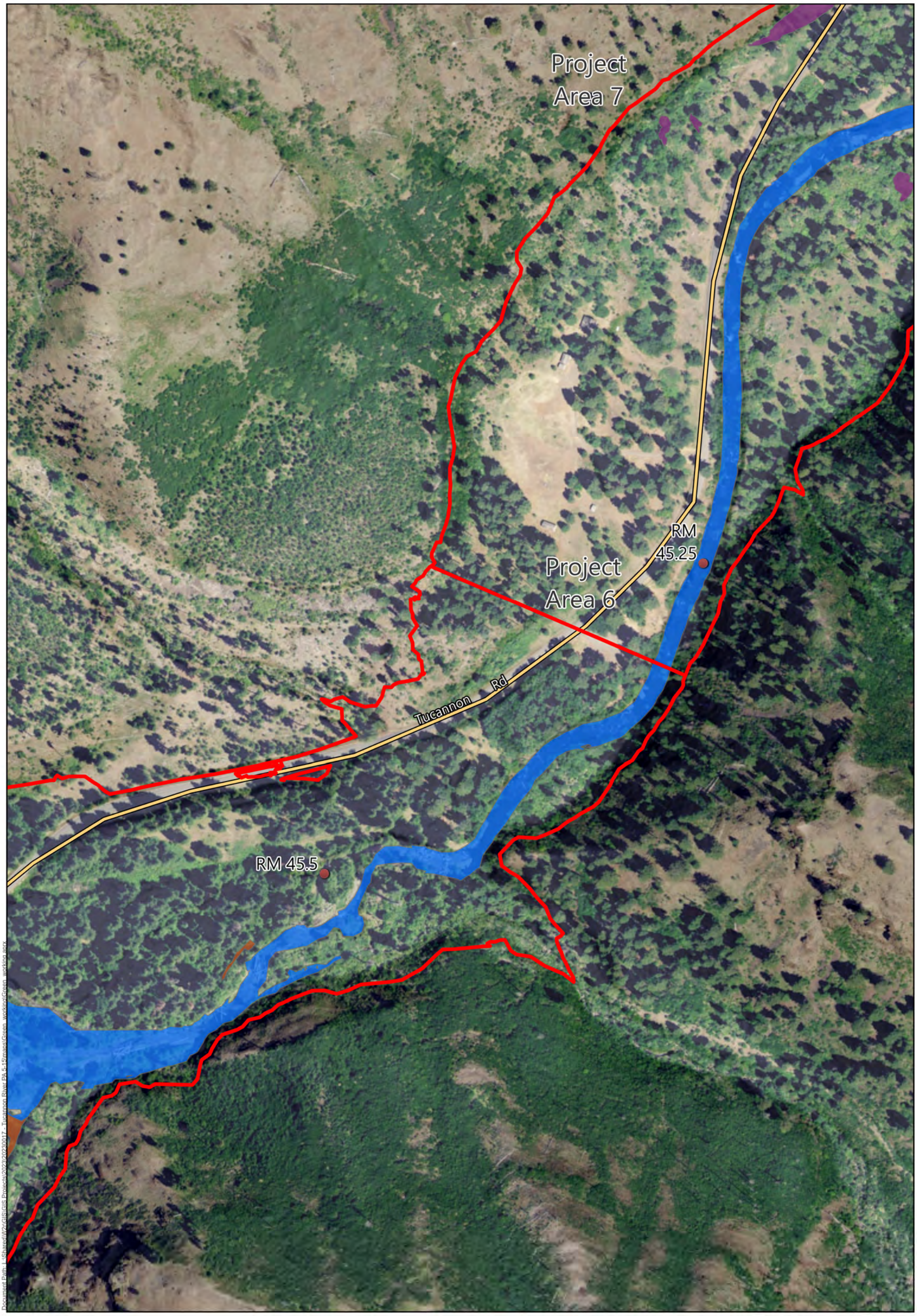
*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES



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Tucannon River

Wetland Determination

Map 16 of 18

0 100 200 400 Feet

N

*Wetlands (Cowardin classification)

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

*The wetlands shown are preliminary in nature.

WOLF WATER RESOURCES

Project Area 6

RM 45.5

Tucannon Rd

RM 45.75

RM 46

Project Area 5

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Tucannon River

Wetland Determination

Map 17 of 18

0 100 200 400 Feet

N

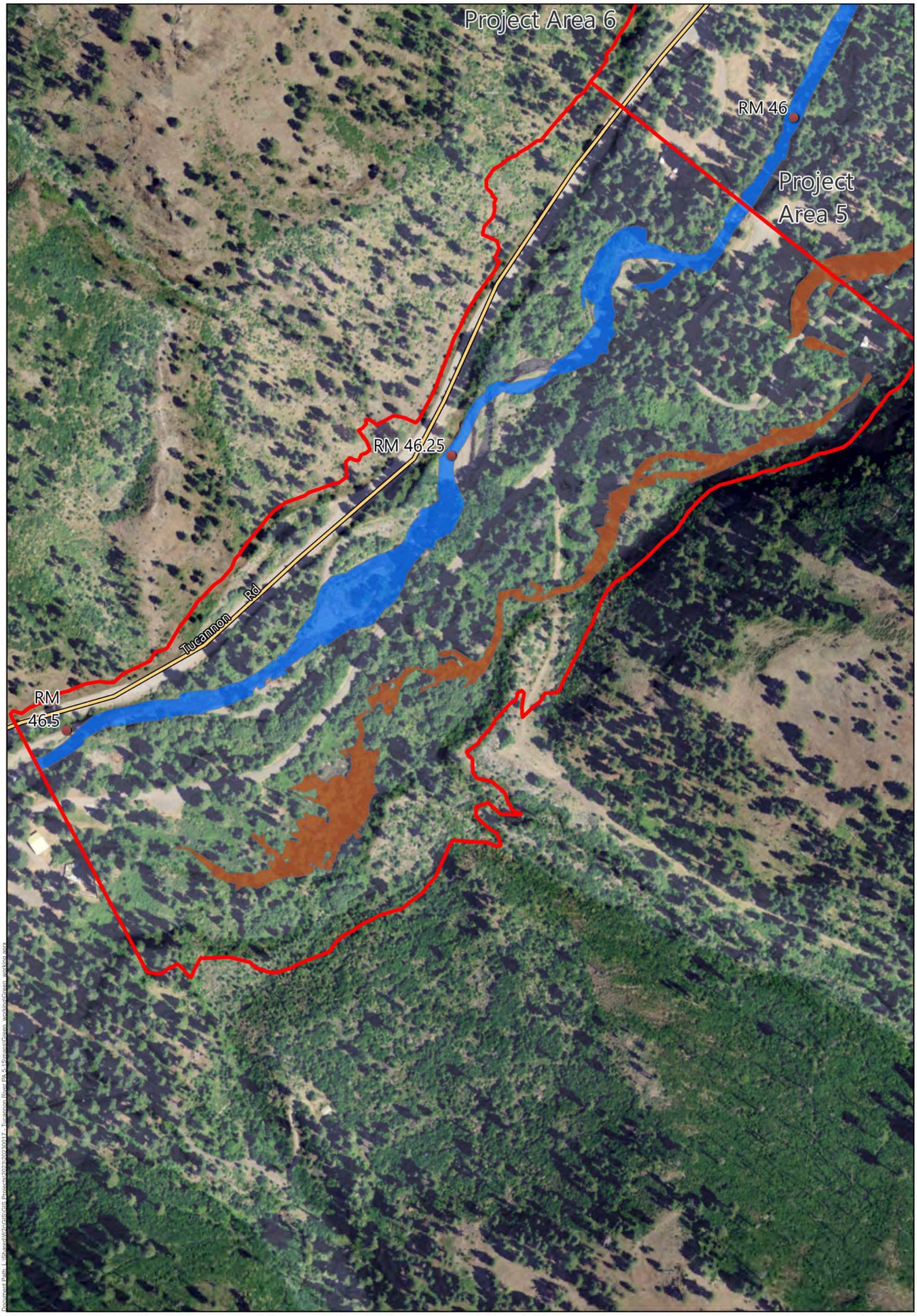
*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- River Mile
- OHW
- Road
- Lake

WOLF WATER RESOURCES



Tucannon River

Wetland Determination

Map 18 of 18

0 100 200 400 Feet

N

*The wetlands shown are preliminary in nature.

***Wetlands (Cowardin classification)**

- Palustrine forested
- Palustrine emergent
- Palustrine scrub-shrub
- Palustrine unconsolidated bottom
- Palustrine emergent/Palustrine unconsolidated bottom

- Project area
- OHW
- Lake
- River Mile
- Road

WOLF WATER RESOURCES

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Tucannon River

PA 5-15 Report

Washington Department of Fish and Wildlife
Nez Perce Tribe
Confederated Tribes of the Umatilla Indian Reservation

