January 2021
Tucannon Basin Habitat Restoration

Geomorphic Assessment and Restoration Prioritization

Prepared for Columbia Conservation District

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Habitat Restoration Prioritization and Conceptual Restoration Plans

Prepared for
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ABBREVIATIONS

1D	one-dimensional
2D	two-dimensional
CCD	Columbia Conservation District
cfs	cubic foot per second
CHM	Canopy Height Model
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWT	Coded-Wire Tag
DEM	digital elevation model
Ecology	Washington State Department of Ecology
ELJ	engineered log jam
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
ICTRT	Interior Columbia River Technical Recovery Team
LFH	Lyons Ferry Hatchery
LiDAR	Light Detection and Ranging
LSRCP	Lower Snake River Compensation Plan
LWM	large woody material
MaSA	major spawning area
MPG	major population group
NMFS	National Marine Fisheries Service
PA	project area
PIT	Passive Integrated Transponder
RM	river mile
SRSRB	Snake River Salmon Recovery Board
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife

1 Introduction

The Tucannon River is a tributary to the lower Snake River and supports Endangered Species Act (ESA)-listed summer steelhead, spring Chinook salmon, fall Chinook salmon, and bull trout, which have all been identified as aquatic focal species in the *Tucannon Subbasin Plan* (CCD 2004). Intensive restoration efforts in the Tucannon Basin in the last decade have been aimed at restoring salmonid populations and beneficial geomorphic processes. Sponsors of restoration in the basin include the Columbia Conservation District (CCD), the Snake River Salmon Recovery Board (SRSRB), and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). This Geomorphic Assessment and Restoration Prioritization report is the sequel to the *Tucannon River Geomorphic Assessment and Habitat Restoration Study* (Anchor QEA 2011a) and provides an assessment of current geomorphic conditions and restoration opportunities in the basin as well as an analysis of implemented restoration projects.

The restoration opportunities identified through this assessment represent the most effective restoration actions, based on current scientific data, to restore the geomorphic and ecological processes to the Tucannon River and floodplain to the highest extent possible. There are other interests and needs in the basin that represent constraints on the opportunities identified, but documents, such as the Wooten Wildlife Floodplain Management Plan (WDFW 2014), exist to express additional goals and interests. Therefore, this assessment does not make a specific attempt to identify those outside interests or the constraints they may have on restoration actions. Any restoration project that is pursued further will need to consider the constraints of individual interests in the basin and factor them in through collaboration and discussion with stakeholders.

The goals and objectives for this report were designed to address the goals and objectives for restoration within the Tucannon Basin. The limiting factors to salmonid survival in the Tucannon Basin were established in the *Tucannon Subbasin Plan* and include fine sediment, lack of woody debris, lack of key pool habitats, compromised riparian habitat, anthropogenic confinement of the floodplain, high summer water temperatures, and inadequate summer stream flow (CCD 2004). In response to these limiting factors in the Tucannon Basin, Anchor QEA developed the following basin goals and restoration objectives, shown in Table 1-1 and referenced throughout the report. Some of these goals address the limiting factors directly, while others, such as increasing storage of in-channel bedload sediment, are meant to help restore the impaired fluvial processes that are impacting the limiting factors. How these goals affect the limiting factors is discussed more in Sections 6, 7, and 8.

Table 1-1
Basin Goals and Restoration Objectives

Programmatic Goal	Restoration Goals and Objectives	Reference Section
Improve floodplain connectivity	The available 5-year recurrence floodplain is connected at the 2-year event	Appendix F and Section 10
Develop a high-functioning riparian corridor	The available riparian zone, as defined in Section 10 and Appendix K, will be vigorously growing with native deciduous species	Appendix K and Section 10
Increase channel complexity at low-winter flows	Low-winter flow complexity to levels of current 90th percentile of basin	Appendix G and Section 10
Increase channel complexity during spring and winter peaks	Mean-winter and 1-year flow complexity to levels of current 90th percentile of basin	Appendix G and Section 10
Increase quantity of pools	Increased pool frequency	Not included in this document due to incomplete data
Improve quality of pools	Large, deep, channel-spanning pools	Not included in this document due to incomplete data
Increase temporary storage of in-channel bedload sediments	No river segments significantly above the excess transport capacity regression line	Appendix H and Section 10

Note: Table 8-1 of this assessment provides more details on specific targets and assessment methods for each of these goals.

The analyses of this assessment were created to provide the information needed to meet the habitat targets and goals of the objectives. To that end, analyses were developed with the following goals:

1. Use the available data to measure the key components of the habitat targets and basin goals including:
    a. Floodplain Connectivity: measure the existing connected floodplain and potential floodplain targets and determine floodplain potential.
    b. Channel Complexity: Measure channel complexity at a variety of flow conditions and determine which reaches are complex and which are not.
    c. Transport Capacity: Determine where the rivers of the Tucannon Basin have too much stream power for the maintenance of natural geomorphic processes of sediment transport.
    d. Gravel Augmentation Plan: Determine and target reaches and project areas that would receive most geomorphic benefit from additional gravel supply.
2. Prioritize areas for restoration and identify restoration opportunities that can provide the most benefit and uplift to habitat for the focal species through restoration of natural geomorphic processes.
3. Provide the data on key components of habitat targets for future evaluation, target setting, and accomplishment tracking for each of these key metrics.

2 Basin Overview

The Tucannon Basin is located in Columbia and Garfield counties in the southeast corner of Washington State (Figure 2-1). The main channel is approximately 58 miles long and drains approximately 503 square miles from its headwaters in the Blue Mountains and Umatilla National Forest, to the mouth of the Snake River approximately 20 miles upstream of the Lower Monumental Dam. Several major tributaries drain into the main channel, the largest (by basin area) being Pataha Creek, which enters the main channel at river mile (RM) 12.3. Pataha Creek is approximately 56 miles in length with a long, narrow watershed draining 185 square miles. The second and third largest tributaries (by basin area) are Kellogg Creek (35 square miles) and Willow Creek (30 square miles). A full list of the Tucannon tributaries and their known fish use is shown in Table 2-1.

The river's headwaters are within the Umatilla National Forest and Wenaha-Tucannon Wilderness, and the upper watershed drains densely forested valleys with minimal anthropogenic impacts outside of historical logging and recreation. Downstream of its confluence with the Little Tucannon River, the Tucannon River has been anthropogenically confined by roads and levees. Habitat quality in this reach has been limited by channel confinements, which have reduced complexity, and by man-made floodplain lakes that limit channel migration and divert water. Restoration activities in this reach in the last decade have prioritized restoring large wood, promoting pool formation, and increasing floodplain connectivity.

Continuing downstream to the confluence with Pataha Creek, agricultural impacts become the dominant impact on habitat quality. Fields and their associated levees have encroached on much of the floodplain and confined the channel, causing incision and reducing complexity and connectivity. Removal of riparian forests has resulted in decreased shading, high summer temperatures, sedimentation, and loss of woody debris. The combination of reduced riparian forests and water withdrawals has altered the hydrologic regime to cause increased peak flows and reduced summer baseflows. Successful restoration efforts in this reach along with landowner outreach and cooperation have reformed agricultural practices to reduce sediment runoff and reduce irrigation withdrawals while restoring riparian forests (SRSRB 2011).

The lower Tucannon reach and the Pataha watershed are heavily influenced by agriculture as well as the towns of Starbuck and Pomeroy. Pataha Creek is highly incised and has an undeveloped road network that confines the channel and contributes fine sediment. High temperatures caused by a lack of riparian trees and irrigation withdrawals are a primary concern in the lower basin. The Tucannon River confluence with the Snake River is not included in the prioritization of this assessment, but concerns about predation and temperature are also major concerns here. More information about habitat and attraction flows in this area could also be useful for future assessments.

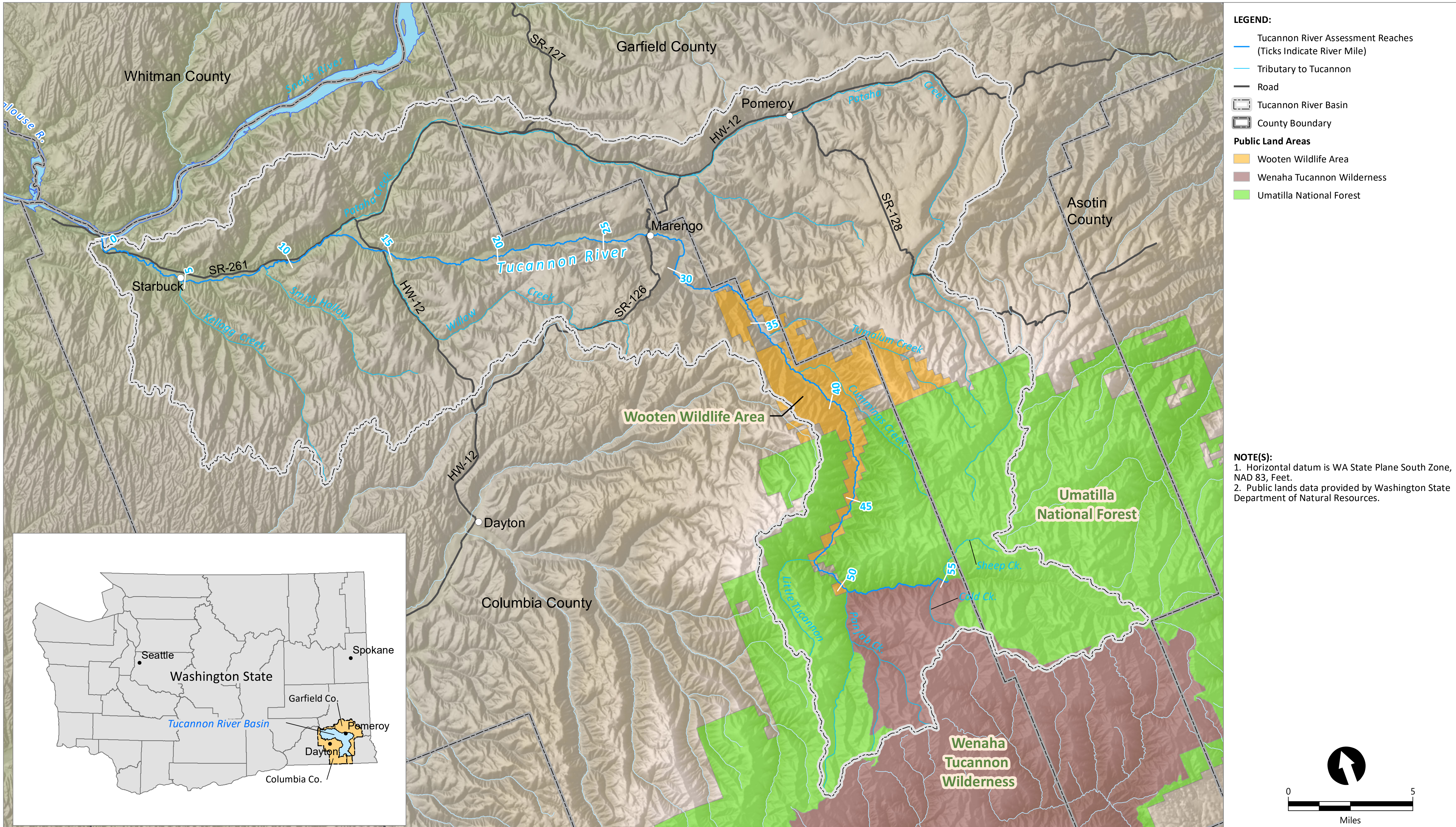

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Figure 2-1
Basin Vicinity and Site Map
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Two dams that blocked fish passage were historically present in this reach, the De Ruwe Dam at RM 16 and the Starbuck Dam at RM 5.5. Only the Starbuck Dam remains, and a fish ladder was constructed in 1992 to provide fish passage (SRSRB 2011). Restoration actions to reduce grazing, limit sediment runoff, and restore riparian forests have improved conditions in this reach, but high sediment loads, lack of key habitat, and high temperatures remain limiting factors.

2.1 Perennial Waterways in the Tucannon Basin

In 2018, the Tucannon Technical Work Group summarized perennial tributaries of the Tucannon River for the purpose of assimilating available information into the 2019 Conceptual Restoration Plan. Although the majority of habitat restoration has occurred in the Tucannon River mainstem, some work has also occurred in the tributaries. Much of this work has been focused on forest and land management and includes: the Forest Management Plan (Pomeroy District), Conceptual Restoration Plan (Natural Resources Conservation Service), and forest management (Washington Department of Natural Resources and Washington Department of Fish and Wildlife). Many of the tributaries have been the target of fish passage restoration work.

While the focus of this restoration plan is on the mainstem Tucannon River, the tributaries in the basin do provide valuable habitat that should not be ignored. Although current fish use within the tributaries of the Tucannon River are not available, local experience and field biologists have identified stream reach extents where salmon and steelhead have been noted over the past 20 years, which is reflected in Table 2-1, although these extents are estimates and future evaluation of fish presence in the tributaries may be warranted. Habitat restoration actions within the tributaries will develop a more robust population structure for aquatic species and aid in building resiliency within the population particularly for steelhead and bull trout within the basin. Tributary improvements also add to the increased resilience of the basin as a whole by slowing flows within the upper basin, increasing floodwater retention, changing peak flow timings, and reducing flood power. Table 2-1 provides basic flow and known fish presence extents for the tributaries in the Tucannon Basin for spring Chinook salmon and steelhead. This information can be used to help identify where tributary restoration will be most valuable as opportunities arise. More detailed information on the state of the tributaries to the Tucannon River can be obtained from the SRSRB.

Table 2-1
Tucannon Tributaries and Fish Presence[1]

Stream Name	Chinook Presence (miles)	Steelhead Presence (miles)	Perennial Flow Extent (miles)	Primary Land Ownership
Kellogg Creek	None	1.94	1.94	Private
Smith Creek	None	0.42	0.42	Private
Pataha Creek	None	52.3	56.3	Private/Public
Hartsock Creek	Unknown	Unknown	0.52	Public
Tumalum Creek	None	6.2	1	Private/Public
Cummings Creek	None	11.03	11.03	Public
Blue Lake Creek	Unknown	Unknown	0.61	Public
Waterman Canyon Creek	Unknown	Unknown	1.08	Public
Big 4 Canyon Creek	0.74	0.74	1.89	Public
Grub Canyon Creek	Unknown	Unknown	0.89	Public
Hixon Creek	0.8	0.8	1.82	Public
Little Tucannon River	None	4.03	6.03	Public
Cow Canyon Spring	Unknown	Unknown	0.2	Public
Panjab Creek	2.52	8.38	8.38	Public
Meadow Creek	None	5.59	5.59	Public
Meadow Creek Tributary	Unknown	Unknown	2.23	Public
Turkey Creek	None	2.19	2.19	Public
Panjab Creek Tributary	Unknown	Unknown	1.49	Public
Tucannon Above Panjab[2]	5.06	9.53	11.78	Public
Cold Creek	Unknown	Unknown	1.93	Public
Sheep Creek	None	None	0.7	Public
Bear Creek	Unknown	Unknown	2.66	Public

Note:

1. The fish presence miles listed here are rough estimates based on field observations; further evaluation of fish use in the tributaries may be warranted.
2. The upstream boundary of this assessment is at Tucannon RM 50.17 and the Panjab Creek Confluence is at RM 50.34. The distances listed above begin at RM 50.17 and include the 0.17-mile section of the Tucannon River between the end of the assessment and the confluence with Panjab Creek.

Bull trout migrate throughout the mainstem, but their critical habitat is located in the mid- to upper-river cold-water tributaries including Cummings Creek, Hixon Creek, the Little Tucannon River, Panjab Creek, Cold Creek, Sheep Creek, and Bear Creek (USFWS 2010). Relative to the other species, the tributary habitat is more important to steelhead and bull trout, which can spawn and rear in smaller tributaries than the spring Chinook salmon. Of the four salmonid species in the basin, fall Chinook salmon use the tributaries the least and their spawning and brief rearing activities are mainly relegated to the lower mainstem Tucannon River (USFWS 2002).

2.2 Land Cover and Vegetation

A majority of the watershed downstream of Tumalum Creek (RM 35.5) is under cultivation, primarily consisting of grain crops (Figure 2-2). The valley floor is occupied primarily by livestock pastures and some cultivated crops downstream of the National Forest boundary at RM 41, except for a vegetated riparian buffer along the margins of the channel. The watershed upstream of Tumalum Creek is typically covered in evergreen forest, with scrub/shrub on the steeper, southwest-facing slopes. The valley floor is forested, with sparse undergrowth in the floodplain until upstream of Panjab Creek (RM 50.2), where tree and undergrowth density increase significantly (USDA 1984). The riparian corridor typically contains interspersed evergreen and deciduous trees with dense undergrowth.

As is true throughout the western Rocky Mountains, the Tucannon Basin is a wildfire-maintained ecosystem and was managed to minimize wild fire, which had the effect of increasing fuel loads and potentially leading to a more significant burn cycle over the past 60 years. Large forest fires in 2005 (School Fire), 2006 (Columbia Complex Fire), 2010 (Hubbard Fire), 2014 (Grizzley Fire), and 2015 (Hartsock Fire) impacted the upper basin, including the floodplain and riparian corridor (USFS 2008).

2.3 Regional Geology

The Tucannon Basin consists primarily of Miocene-aged Columbia River Basalt flows of the Grande Ronde, Wanapum, and Frenchman Springs members with recent Quaternary river alluvium along the valley floor (Figure 2-3). Basalt is exposed at the surface upstream of Tumalum Creek (RM 35.5) and along the valley walls and gullies down from Tumalum Creek to RM 18. Downstream of RM 18, including within the Pataha and Willow Creek subbasins, the basalt is overlain by loess deposits (fine sand and silt) of the Palouse Formation. In these areas, bedrock is only exposed in gullies and along valley slopes. The valley walls in much of the lower basin downstream of RM 18 are composed of Quaternary flood outburst deposits consisting of stratified sand, gravel, and cobble. Alluvial fans line the valley floor at the mouths of tributaries; the fans tend to be large and wide in locations where tributaries drain loess-dominated subbasins, and small and narrow in basins where mainly bedrock is exposed.

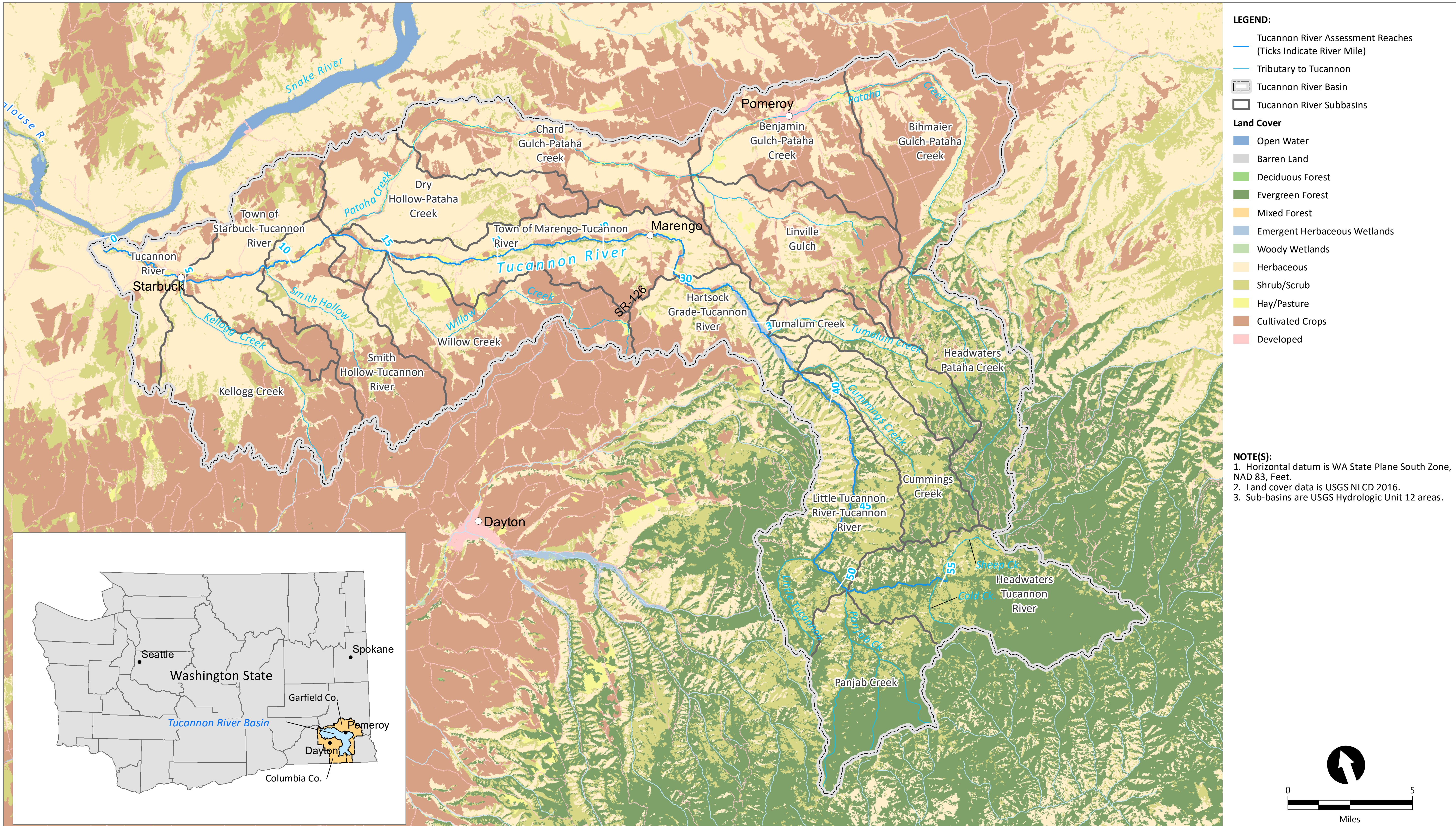

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Figure 2-2
Landcover Units and Subbasins
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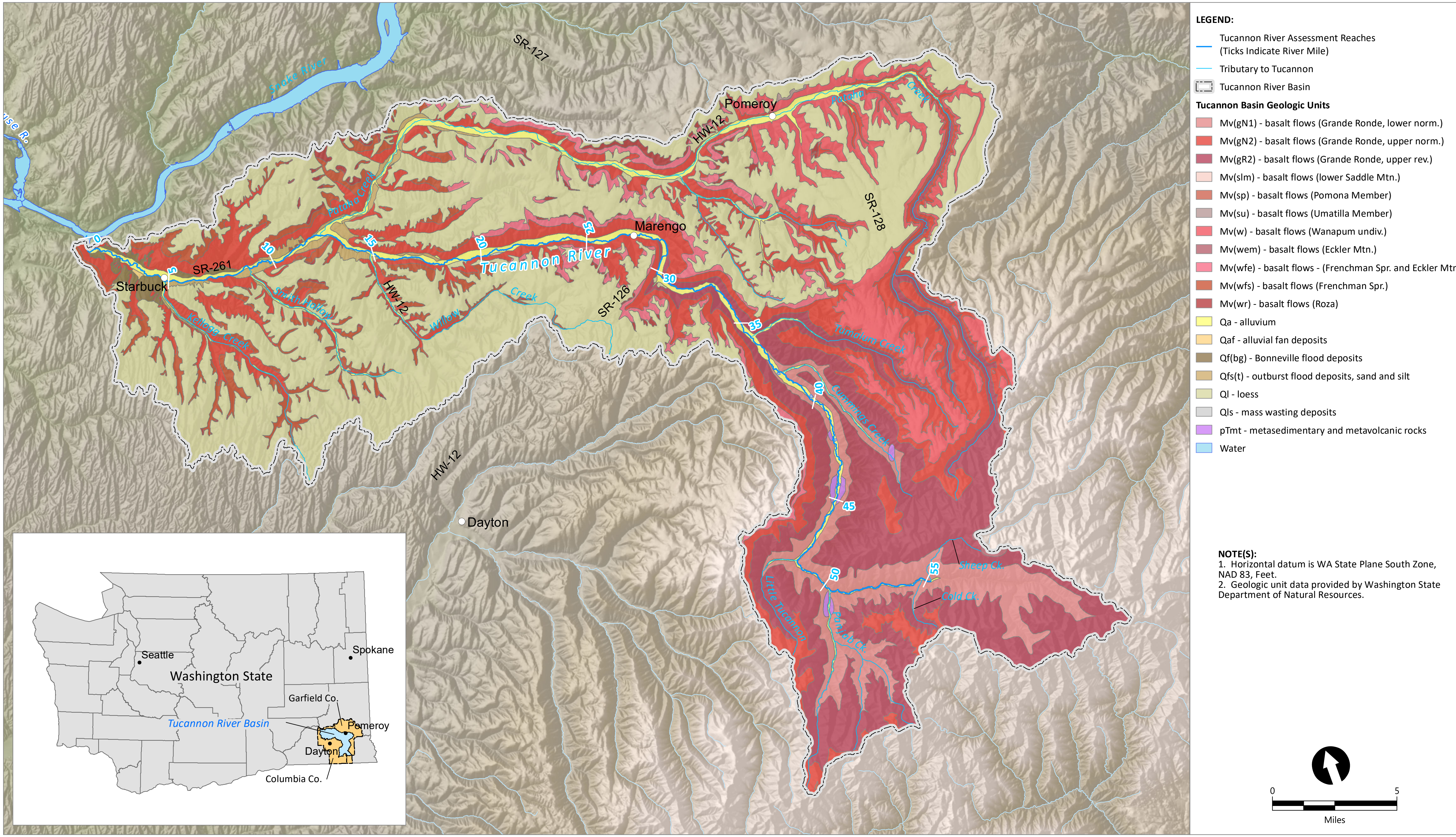

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Figure 2-3
Basin Geology
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2.4 Overview of Basin-Scale Geomorphic Processes

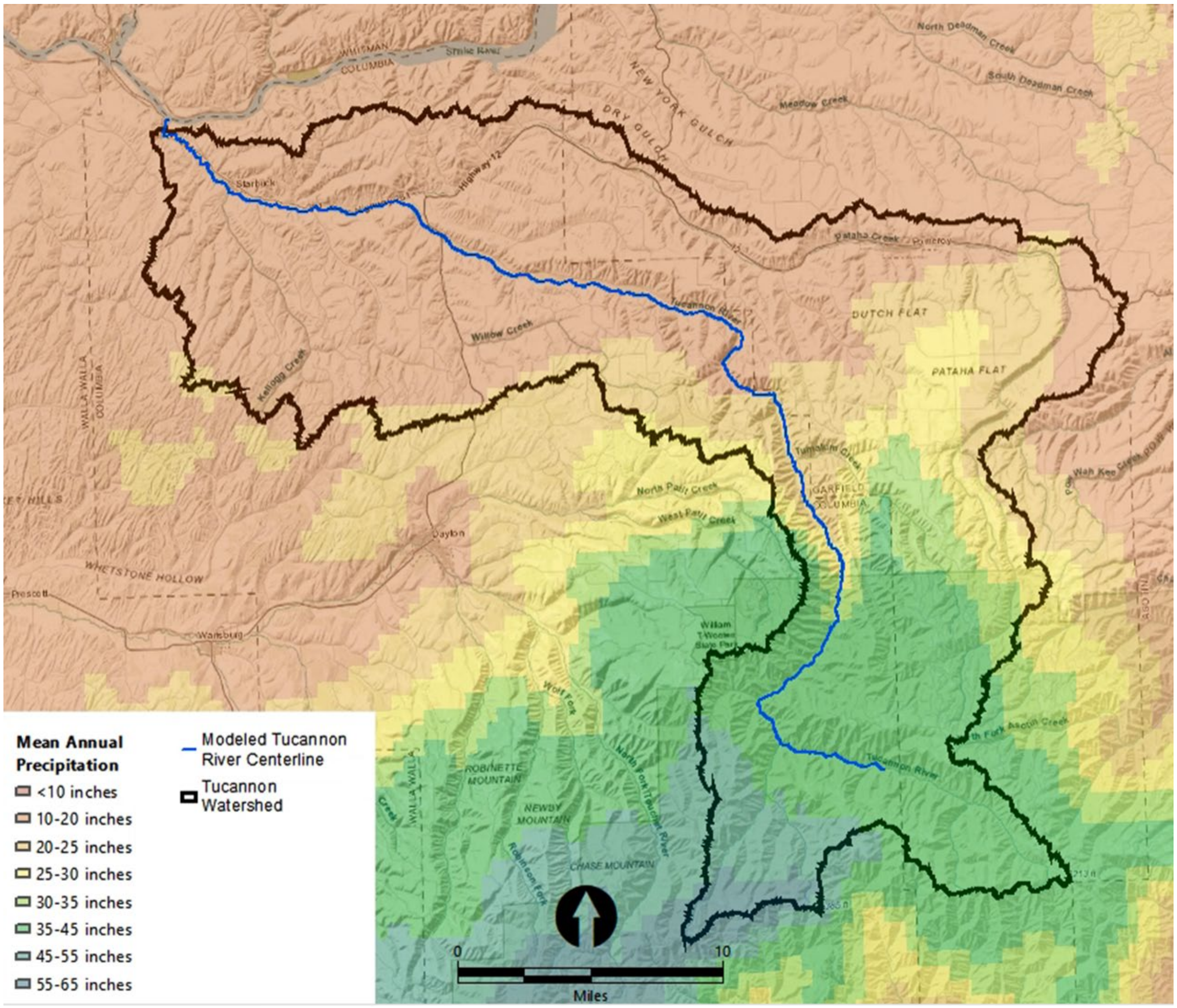
The Tucannon River and its tributaries comprise a steep mountain system in an arid setting. The surrounding peaks at the headwaters in the Blue Mountains reach 6,300 feet, and the mouth at its confluence with the Snake River (63 miles downstream) lies at 540 feet. The geometry of the basin appears to be geologically controlled, paralleling a northwest-southeast trending feature for the first 10 miles, before turning north and exiting the mountains another 10 miles downstream. The river loses about half of its elevation in its upper portion where it is likely actively incising the terrain. Downstream of the turn, the gradient slackens, and the valley floor widens. There are abundant relic channels in this reach that show a history of avulsion, deposition, and channel reorganization. Upland sediment sources in the mountain reaches include sheet and rill erosion on non-forested slopes, shallow landslides from steep valley walls, and debris flows (USDA 2002). As the river transitions into the loess-dominated landscape of the Columbia Basin downstream of its confluence with Tumalum Creek (RM 35), the valley floor becomes wider still where the river has had more room to migrate and more sediment to deposit. Anthropogenic influence in this reach and the lower portion of the mountain reaches has disconnected much of the river from its floodplain, halting geomorphic and hydrologic processes like deposition, channel migration, and groundwater recharge.

2.5 Precipitation and Runoff Overview

The basin climate is primarily continental, with some marine influences. Precipitation occurs primarily in the winter months as frontal storms pass over the basin. Frontal and convective storms occur in late spring through early summer. In the dry, late summer months, precipitation is primarily from convective events (Hecht 1982).

Mean annual precipitation data for the basin were summarized in the *Tucannon Subbasin Plan* (CCD 2004) and updated data were available geospatially from Oregon State University through the PRISM climate model (OSU 2019), as shown in Figure 2-4. Precipitation data remained largely unchanged from the precipitation data calculated in the previous assessments (Anchor QEA 2011a, 2011b, 2012a, 2012b). The distribution of precipitation in the Tucannon Basin is highly dependent on elevation. Mean annual precipitation ranges from 10 inches at lower elevations to more than 40 inches at higher elevations. Runoff from precipitation events varies distinctly with antecedent moisture conditions and the extent and type of ground freezing. At higher elevations, much of the mean annual precipitation falls in the form of snow, with a basin mean annual snowfall of 65 inches (CCD 2004). The snow pack typically melts during the months of March, April, May, and June, with occasional rain on snow events in December through February causing rapid snowmelt below the freezing elevation.

Figure 2-4
Mean Annual Precipitation Distribution, Tucannon Basin



Note: Precipitation data were drawn from the Oregon State University PRISM climate model (OSU 2019) and represent the 30-year (1981 to 2010) annual average.

This precipitation pattern often means that the basin experiences multiple unique discharge peaks in a water year—one peak typically occurs as the result of a winter storm and the other as the result of spring snowmelt. For the period of record, 32 of the maximum annual discharges occurred in December, January, or February, while only 18 maximum annual discharges occurred in March, April, or May. The spring peak discharge is often similar in magnitude to the winter storm peak discharge, although with a much longer duration driven by the length of the spring snowmelt. Additionally, because the hydrologic regime in the basin is primarily driven by snow melting events, the majority of the basins flow and most perennial tributaries originate from the upper basin. So even though some tributary catchments that are larger in area are located in the lower basin, they are often intermittent because they do not extend up to elevations were precipitation is enough to support perennial flow. Although there is not much information on the potential to modify or increase flow duration in some of the ephemeral catchments, holding back and slowing flow through channel and floodplain restoration could be a way to increase the amount of time surface flow occurs in these basins.

Peak flow basin hydrology for the Tucannon River was developed for input to the basin-scale hydraulic model and for use in reach delineation. Information on hydrology in the Tucannon Basin included discharge gages on the Tucannon River (U.S. Geological Survey [USGS] 13344500) and Pataha Creek (Washington State Department of Ecology [Ecology] 35F050) and spatially distributed rainfall data. Figure 2-5 shows major tributaries, gage locations, and subbasin areas in the Tucannon Basin. Distributing hydrologic inputs throughout the basin required the use of some standard flood frequency analysis methods along with basin scaling techniques and gage discharge correlations (USGS 2018; Thomas et al. 1994). A thorough description of the methodology and hydrologic results are discussed in Appendix C.

The lack of hydrologic gage sites in the upper basin, limited historical record, and local climate conditions (e.g., wet and drought year regime) created uncertainties in the flood magnitude and frequency analysis. Therefore, this assessment used a range of discharge values along the main channel that employ different methodologies for flow estimation and proportioning (USGS 2001). The values used for this study are provided in Table 2-2.

Notable flood events recorded at the Starbuck gage include those in water years 1916 (February 10, 1916) at 5,740 cubic feet per second (cfs); 1930 (February 2, 1930) at 6,000 cfs; 1963 (February 3, 1963) at 4,700 cfs; 1965 (December 22, 1964) at 7,890 cfs; 1996 (February 9, 1996) at 5,580 cfs; and 2020 (February 7, 2020) at 3,410 cfs. These events are all approximately at or larger than the 10-year return period event. The flood of record (7,890 cfs) is slightly less than the 50-year return period event. Both the 1965 and 1996 water year floods had documented channel changes and floodplain inundations associated with them. During the 1965 flood, the levee in the town of Starbuck was overtopped and flooded the town with approximately 2 feet of water (USACE 2010). Several major channel avulsions were documented, and, in some cases, post-flood “restoration” was performed to re-establish a desirable channel configuration.

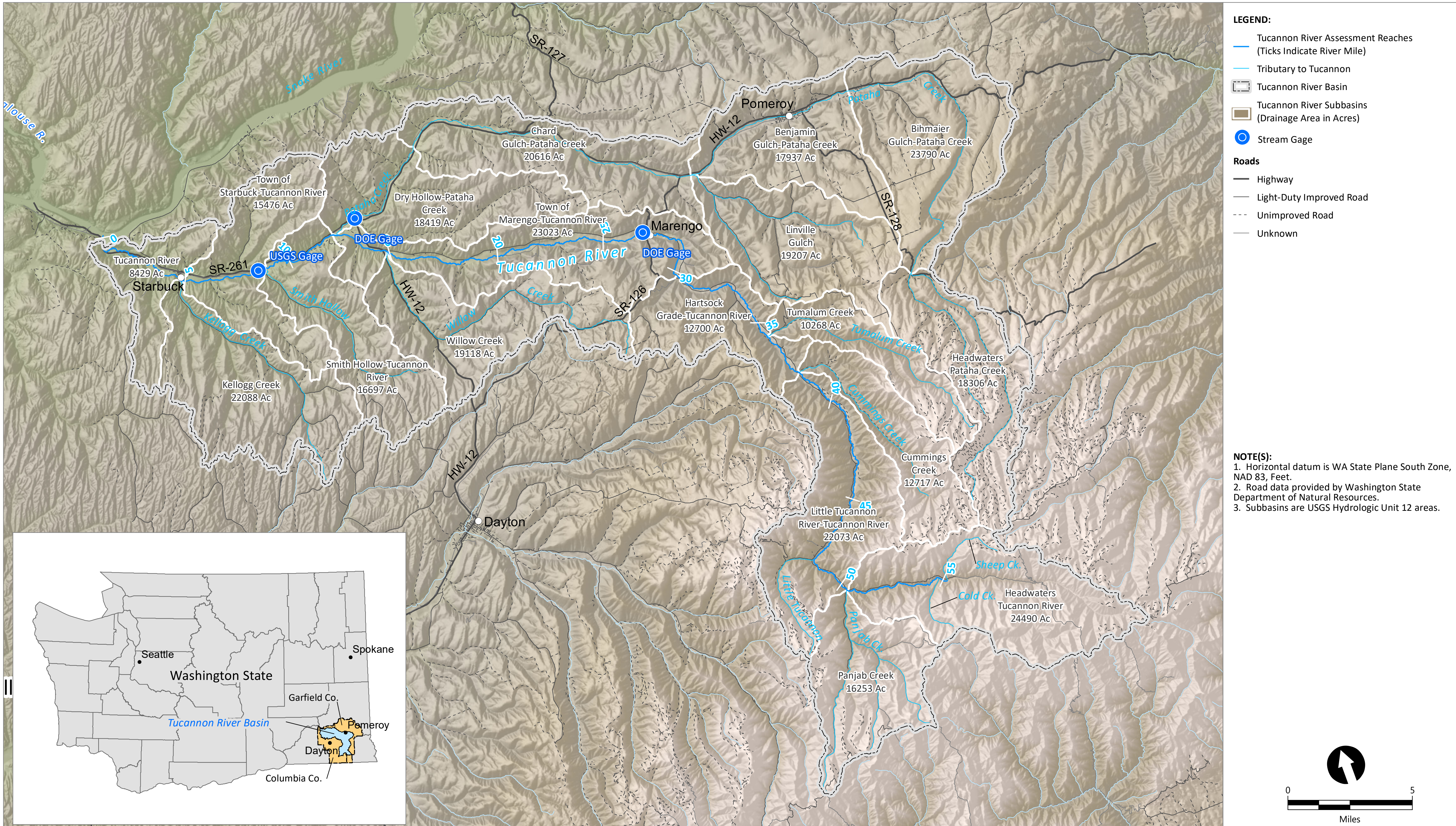


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Figure 2-5
Subbasin Areas and Stream Gages
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Table 2-2
Flood Discharges Values (cfs)

Flow Change (RM)	Tributary/ Location Name	Return Period (years)							Maximum Avg. Winter Flow[2]
		1	2	5	10	25	50	100	
4.9	Kellogg Creek	595	1,548	2,728	3,869	5,861	7,850	10,379	323
8.8	Smith Hollow[1]	552	1,435	2,528	3,585	5,431	7,275	9,619	300
12.4	Pataha Creek	532	1,383	2,437	3,457	5,237	7,014	9,275	289
14.9	Willow Creek	367	956	1,683	2,388	3,617	4,845	6,406	200
35.8	Tumalum Creek	367	954	1,573	2,231	3,327	4,418	5,799	199
38.1	Cummings Creek	348	906	1,474	2,090	3,106	4,117	5,411	189
48.3	Little Tucannon River	284	738	1,192	1,691	2,512	3332	4,367	154
50.4	Panjab Creek	267	694	1,109	1,574	2,334	3,094	4,058	152
55.14	Above Panjab	168	436	723	1,026	1,545	2,072	2,745	145

Notes:

1. For the purposes of modeling, the discharge downstream of Smith Hollow was assumed to be equivalent to the discharge at the Starbuck gage.
2. The highest monthly average flow during the months of January to May at the Starbuck gage.

2.6 Anthropogenic Impacts

Primary anthropogenic impacts in the basin include agriculture and forestry, infrastructure including roads, levees, bridges, and dams, and biological impacts such as hatcheries and invasive plants. Land use in the basin including irrigated agriculture and forestry have impacted hydrology by removing riparian forests, increasing runoff, and reducing groundwater storage. Agriculture and infrastructure within the floodplain have reduced habitat complexity and connectivity by confining the channel and disconnecting the river from its floodplain. Historical removal of riparian forests and wood have also simplified the channel. Anthropogenic confinements including levees and riprap have caused increased transport capacity, reducing gravel storage and limiting pool formation. Dams within the basin have reduced fish passage and changed sediment transport regimes. Anadromous salmon in the Tucannon River also have to pass the four lower Columbia River dams and two of the lower Snake River dams, causing a multitude of threats including fish passage barriers, thermal stress, and predation during both legs of the journey. Finally, biological impacts of hatcheries have affected salmonid life cycles and survival, and proliferation of invasive plants has reduced the ability of riparian forests to provide sufficient shade and woody debris. Altogether, the salmonids of the Tucannon and Snake River basins are further threatened by the effects of climate change including increased water temperatures, increased peak flows, and reduced summer low flows.

The basin was settled in the mid-19th century and has since been heavily influenced by agriculture, forestry practices, and other developments that have typically increased fine sediment loading, degraded riparian areas, and limited natural geomorphic processes such as large woody material (LWM) recruitment and floodplain connectivity. Native bunchgrass in the lower part of the basin that once minimized soil erosion has been replaced by grain crops, and some native floodplain and riparian areas were cleared and replaced with pastures (Beckham 1995).

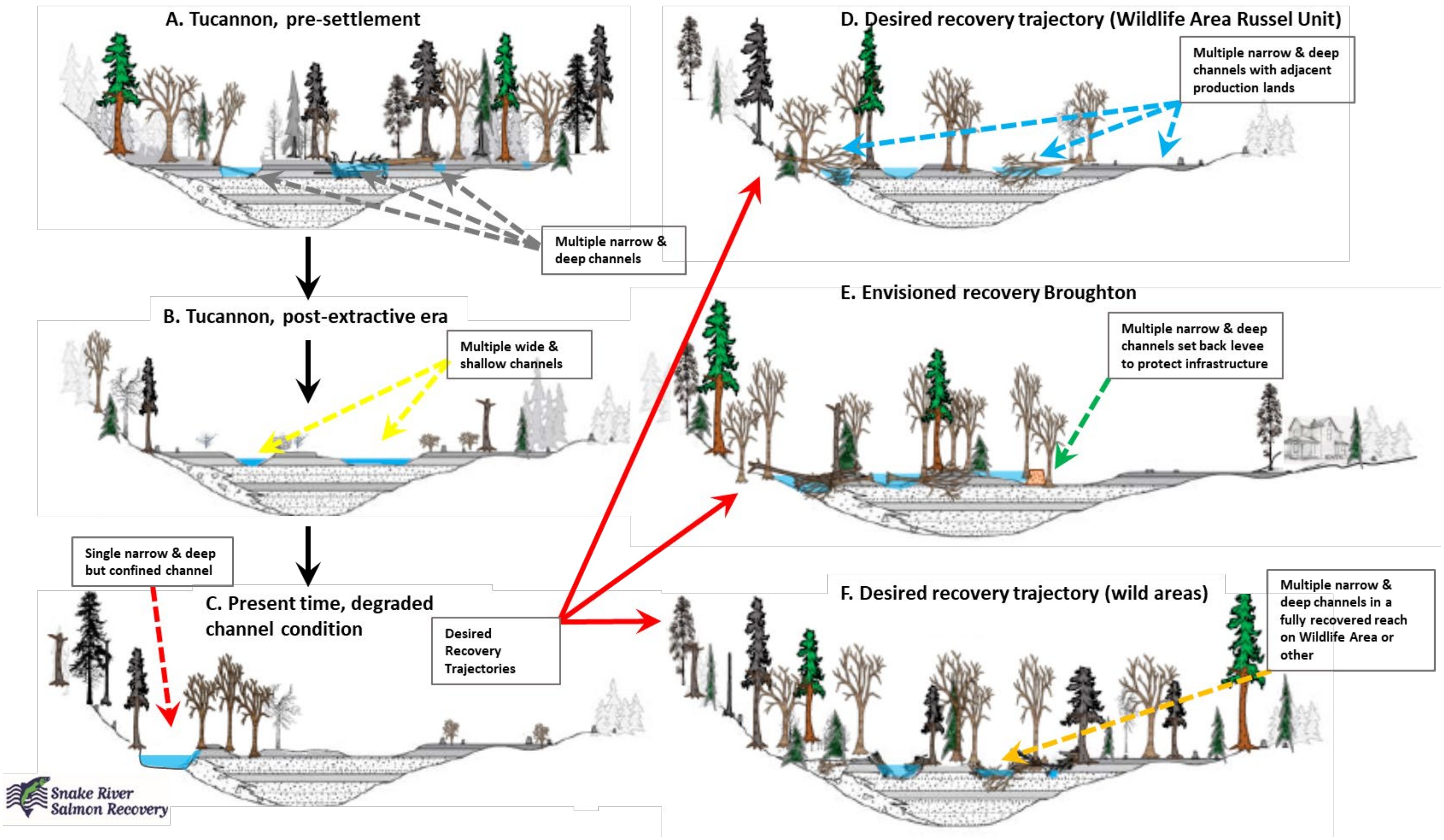
LWM volume and riparian cover have been significantly reduced from past conditions, through the lower 50 miles of the basin. Channel wood-clearing and straightening practices were common in the Pacific Northwest in the early 19th century and have been known to occur in the Tucannon Basin from the mouth upstream to Camp Wooten (RM 46.5) and beyond. Removal of mature trees from both main channel and tributary riparian zones has decreased the average size and density of riparian trees. This clearing of mature vegetation has contributed to a reduction in the volume of key wood pieces (more than 6 meters long and 0.3 meter in diameter) available for recruitment to the system. Riparian tree removal has also reduced shading and increased water temperatures. Although a riparian buffer exists throughout a majority of the valley, historical accounts and photography indicate that the density of mature trees and undergrowth was much heavier before extensive settling occurred; riparian trees were likely cut down for firewood and the undergrowth was grazed upon by livestock (Beckham 1995). Logging in the upper basin also likely contributed to reduction of the riparian zone; logging practices may have involved channel clearing, straightening, and otherwise reducing channel complexity for easier transport of materials. Timber harvesting of the Tucannon River valley in the upper watershed continued to occur until the 1980s (SRSRB 2006). Following the floods of 1964 and further in 1996, the channel was carved out and shaped in many reaches to increase flood conveyance. Channel modification and straightening have reduced channel length and increased stream power over time, further diminishing the channels ability to recruit and maintain key wood pieces within the channel. These channel modifications have also led to an increase in stream power and armoring of larger bed material, limiting geomorphic change.

Starbuck Dam, Tucannon Falls, and the Hatchery Dam are all passable by adult salmonids, but may act as partial barriers to some individuals and specifically out-migrating juveniles (SRSRB 2006). Fish ladders have been installed at both dams, but long-term removal of the Starbuck Dam presents a long-term opportunity to fully remove this barrier and its impacts on fish passage and sediment transport. Historically, the Starbuck and De Ruwe dams were barriers to fish passage and major causes of the decline of salmonid populations throughout the 20th century.

Figure 2-6 illustrates the effects of anthropogenic actions on an idealized cross section of the Tucannon River floodplain and riparian forests. Section A depicts the pre-settlement, undisturbed condition, with multiple low-volume channels and mature riparian forest dispersed across the majority of the valley bottom. Section B illustrates changes that had occurred through the period of degradation with wide, shallow river channels and severely reduced riparian vegetation. Section C illustrates the existing condition of the majority of the Tucannon River, with a single, over-widened channel and excessive conveyance capacity, man-made confinement features, and minimal recovery of riparian habitat. Sections D, E, and F illustrate desired recovery trajectories for three different land types that all benefit salmon and steelhead. Section D illustrates working lands where occasional flooding is possible. Section E illustrates working lands with setback levees to protect infrastructure. Section F illustrates a full wild land restoration.

Historical irrigation and water use practices in the Tucannon Basin have created major impacts to aquatic habitat. Diversion of water for irrigation leads to a base flow that is lower than natural conditions, which greatly increases water temperatures during the dry season. However, present water conservation efforts have contributed over 10 cfs to base flow conditions.

Construction of dams in the lower basin adversely affected salmonid populations by creating fish passage barriers, reducing mainstem base flow in the summer, and by entrainment of juveniles. The De Ruwe Dam, which washed out in the 1964 flood, and the Starbuck Dam (RM 6.4) upstream of the town of Starbuck did not have sufficient fish passage features and thus blocked passage of adults into the upper watershed. The Starbuck Dam is still in place and it is believed that the dam does not currently act as a barrier for upstream migration of focal aquatic species (SRSRB 2006). The hatchery weir and bedrock falls partially formed through anthropogenic influences have both been partially addressed to restore some fish passage.



This model illustrates an idealized cross section of the Tucannon River floodplain and riparian forests over time since pre-settlement. Sections A and B illustrate changes that had occurred through the period of degradation with wide, shallow river channels, and Section C illustrates a modified condition with a single, narrow channel that has confinement and recovering riparian habitat. Sections D and E illustrate desired recovery trajectories for three different land types that all benefit salmon and steelhead. Section D illustrates working lands where occasional flooding is possible, Section E illustrates working lands with infrastructure protection setback levee, and Section F illustrates a full wild land restoration. Source: Kris Buelow, Snake River Salmon Recovery Board, via email communication.

Figure 2-6
Tucannon Conceptual Stream Model

Restoration for salmon and other aquatic and riparian species has been occurring in the basin for several decades. In the floodplain, programs that work to establish native vegetation on private and public lands have made strides towards reestablishing a portion of the historical riparian cover. This assessment is focused on the in-channel processes and does not make an attempt to directly assess the state of the riparian vegetation, although some inferences may be made as riparian vegetation and wood availability plays a large role in channel complexity. Additionally, many in-channel restoration projects have occurred in the river; those that have taken place since the previous assessments are examined in more detail in this assessment. Other in-channel restoration projects are typical for the time period including large rock and boulder vanes and barbs, as shown in Figure 2-7, as well as some anchored large wood. While not directly addressed in this assessment, these projects have had an undeniable effect on the habitat conditions and geomorphic processes of the basin.

Figure 2-7
Rock Weir Restoration in Project Area 5

3 Tucannon Fish Recovery Targets and Pressures

The Snake River Salmon Recovery Plan for Southeast Washington (SRSRB 2011) identifies recovery targets and actions that need to occur to meet recovery goals and future broad sense goals. Although the restoration partners have been working on recovery efforts since the ESA listings of spring Chinook salmon, fall Chinook salmon, summer steelhead, and bull trout in the basin, there are still many data gaps even given the best available science and information we have learned from additional efforts and experience (discussed further in Section 11). For additional details, please refer to the Recovery Plan and associated efforts.

3.1 Goals for Spring/Summer Chinook Salmon

According to the Recovery Plan, spring/summer Chinook in the Tucannon Basin are considered to be an intermediate population within the Lower Snake River major population group (MPG). The minimum abundance threshold is 750 and the productivity threshold is 2.10. The Interior Columbia River Technical Recovery Team (ICTRT) recommends that the Tucannon population be at a "very low risk" level of abundance and productivity (<1%) for the MPG to meet delisting criteria. To meet spatial structure and diversity criteria, natural rates and levels of spatially mediated processes must be maintained to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial arrangement of the population. Natural patterns of variation must also be maintained to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007). Restoration goals were also established in the Recovery Plan for natural-origin returning adults; that goal for was 2,400. Comparatively, although historical abundances are not available, the Nez Perce Tribe ecological goal, established in phase 1 of the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory Committee, is 22,000.

3.2 Goals for Steelhead

According to the Recovery Plan, summer steelhead in the Tucannon Basin are considered to be an intermediate population within the Lower Snake River MPG. The minimum abundance threshold is 1,000 and the productivity threshold is 1.20. To meet spatial structure and diversity criteria, natural rates and levels of spatially mediated processes must be maintained to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial arrangement of the population. Natural patterns of variation must also be maintained to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007). Restoration goals were also established in the Recovery Plan for natural-origin returning adults; that goal for was 1,823 to 3,400. Comparatively, the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory estimated 1960s abundance for steelhead at 3,400 and the Nez Perce Tribe ecological goal is set at 15,000.

3.3 Goals for Bull Trout

Recovery goals and metrics for bull trout are similar to, but not the same as, goals for steelhead and Chinook salmon. The U.S. Fish and Wildlife Service (USFWS), which has regulatory authority for bull trout, developed a goal and objectives for bull trout recovery throughout its range (USFWS 2002). The goal for all populations is:

> . . . ensure the long-term persistence of self-sustaining, complex interacting groups (or multiple local populations that may have overlapping spawning and rearing areas) of bull trout distributed across the species' native range.

The USFWS recognized that recovery of bull trout will also require reducing threats to the long-term persistence of populations, maintaining multiple interconnected populations of bull trout across the diverse habitats of their native range, and preserving the diversity of bull trout life history strategies (e.g., resident or migratory forms, emigration age, spawning frequency, local habitat adaptations).

To recover bull trout, the USFWS identified four objectives:

- Maintain current distribution of bull trout within core areas as described in recovery unit chapters and restore distribution where recommended in recovery unit chapters.
- Maintain stable or increasing trend in abundance of bull trout.
- Restore and maintain suitable habitat conditions for all bull trout life history stages and strategies.
- Conserve genetic diversity and provide opportunity for genetic exchange.

3.4 Goals for Fall Chinook Salmon

According to the ESA Recovery Plan for Snake River fall Chinook salmon (NMFS 2017), all fall Chinook salmon in the Snake River Basin are defined as a single MPG within the evolutionarily significant unit (ESU). The Tucannon River was identified as one of five major spawning areas (MaSAs) within the entire population, and was defined as the area downstream of Tucannon Falls and the adjacent inundated mainstem Snake River section associated with Little Goose and Lower Monumental Dams. The minimum abundance threshold for the entire MPG is 3,000 natural-origin fish. There is no minimum abundance threshold specific for the Tucannon River run of fall Chinook salmon. Limiting factors for fall Chinook salmon in the Tucannon River include excess sediment (from Pataha Creed), loss of habitat, and reduced habitat diversity and channel stability. Currently, productivity estimates determined by NOAA Fisheries is 1.53 for the entire MPG, of which the Tucannon River MaSA contributes. The Lower Snake River fall Chinook salmon population is currently rated as viable, at low (1% to 5%) risk of extinction with 100 years based on current abundance and productivity. The spatial structure and diversity are considered moderate risk (NMFS 2017), which is reflective of the widespread distribution of hatchery origin returns across the MaSAs. To meet spatial structure and diversity criteria, natural rates and levels of spatially mediated processes must be maintained to minimize the likelihood that populations will be lost due to local catastrophe, to maintain natural rates of recolonization within the population and between populations, and to maintain other population functions that depend on the spatial arrangement of the population. Natural patterns of variation must also be maintained to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007). Currently, the Tucannon MaSA natural-spawning population is difficult to determine due to a lack of evidence supporting natural-origin spawners. Natural-origin fish are likely present in the Tucannon River, but because approximately 50% of the hatchery-origin fall Chinook salmon produced within the Snake River Basin are unmarked/untagged, the only way to precisely determine origin requires genetic analysis. Lack of funding prevents this from occurring.

3.5 Summary of Tucannon Salmonid Fish Pressures

3.5.1 Habitat

In general, habitat pressures occur both within the Tucannon Basin, as identified in Section 6 of this report, as well as outside the basin. Collectively, this assessment identifies the Tucannon Basin habitat shortcomings and restoration. Habitat factors such as Snake and Columbia fish passage and environmental conditions are the focus of the Federal Agencies through the Federal Columbia River Power System (FCRPS) Biological Opinion (NOAA 2008), and although the impacts of the hydropower system are acknowledged in this effort they are not directly addressed within this report. This approach has been taken in relation to habitat as one of the "4 Hs" (habitat, harvest, hatchery, and hydropower)to allow the stakeholders to focus their available resources and local expertise on improving habitat conditions for the most vulnerable life stages.

3.5.2 Harvest

In general, out-of-basin harvest pressures on Tucannon natural-origin salmonids varies by species and there are data available to support this. However, there are unknowns and data gaps related to harvest, and harvest conservation measures could be bolstered to potentially provide future success.

To demonstrate this, using Tucannon hatchery spring Chinook salmon harvest—as reported on the Coded-Wire Tag (CWT) database (Regional Mark Information System)—data have been summarized to two time periods when hatchery fish were clipped or unclipped. Out-of-basin harvest used to be about 10% per year, but since marking ceased harvest is about 2% to 3%. It is believed that the decrease observed is due to the lack of marking due to the fact that the Columbia River is mark selective for spring Chinook salmon. However, not all fisheries in the Columbia River may be adequately sampled (either not sampled or not sampled at a high enough rate to appropriately expand the CWTs). For example, in Zone 6 (Bonneville Dam to McNary Dam, fishery harvest appears to be less than 1%. However, based on Passive Integrated Transponder (PIT) tag conversions of Tucannon spring Chinook salmon through this area, approximately 15% are lost annually (includes all sources of mortality such as harvest, natural mortality, predation). These discrepancies in apparent fish loss in this area need to be further explored.

It is also known that the Columbia River spring Chinook fisheries can have high harvest levels, and that upriver fish (Snake Basin) are present in higher percentages earlier in the run (Sorel 2018; Sorel 2020). When so few fish return, any harvest impact is important. The only conservation measures that are taken in the Columbia River fishery are to comply with ESA take permits (Columbia River Policy C-3620). If fish abundance gains are made, there are no conservation mechanisms in place for recovery success if those gains are lost through harvest.

3.5.3 Hatchery Considerations

As stated in the Recovery Plan, it is important to understand that management of adult returning hatchery-origin fish in the Tucannon River (spring Chinook salmon and steelhead) is complicated and co-managers are not necessarily in agreement on all hatchery management actions listed within the Recovery Plan. Some studies have shown that excess hatchery-origin adults spawning in the wild may reduce natural population productivity (e.g., Araki et al. 2008). However, this issue is still considered a critical uncertainty and, as such, proper management actions are still in development until additional information is obtained.

For steelhead, in the Tucannon, the co-managers have shifted to an endemic stock. It is important to understand this management change as it relates to Tucannon steelhead abundance (for details, see Section 4.1).

To date, the hatchery program for spring Chinook salmon has been deemed critical for maintaining population viability at this point in time because the natural population has generally been below the replacement level. As such, managers have made drastic stop-gap decisions to collect all returning adults that reach the Tucannon hatchery intake weir to Lyons Ferry for holding. This was done to mitigate for high pre-spawn mortality of adults left in the river during the summer prior to the onset of spawning. Fish collected and not needed for broodstock have been returned to the upper basin above the hatchery trap each year. It is important to note that approximately 30% of the annual return remains below the adult trap to spawn.

3.5.4 Hydroelectric Installations

Tucannon salmon and steelhead populations are directly impacted by at least six hydroelectric dams (and up to eight, considering fish that overshoot the Tucannon River). As noted in the Recovery Plan, these efforts are being worked on by the Federal Agencies through the FCRPS Biological Opinion (NOAA 2008). Some of the key impacts from hydropower, as identified in the Recovery Plan, include the following:

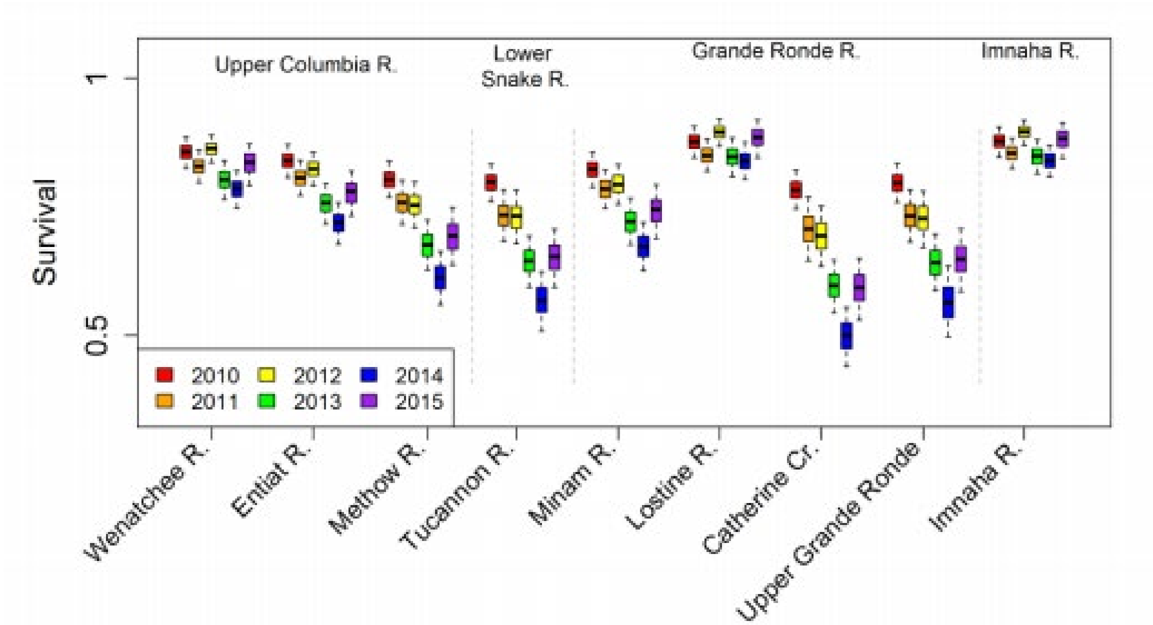
- Stocks are negatively impacted by flow regulation from dams in the upper Columbia and Snake rivers. Spring flows are lower and summer flows are generally higher.
- There is major loss of spawning and rearing habitat above Hells Canyon Dam, and loss or alteration of habitat for spawning and rearing in the lower Snake River (for Snake River fall Chinook primarily).
- Flow impacts are attributable to Dworshak and Hells Canyon dams.
- Some of the mainstem dams prevent fish that have overshot their natal tributary from returning to that tributary, as adequate adult passage is generally lacking and limited to going through the turbines, back down the fish ladders, or through the juvenile bypass facilities. For Tucannon steelhead, from PIT tags the overall impact may be as high as 40% to 50% of the overall annual return, while for spring Chinook salmon the impact, while once thought high as well, appears to be in the 5% to 10% range. In the 2020 FCRPS Biological Opinion (NOAA 2020), to reduce the effect of steelhead overshooting, the dams have begun periods of surface spilling during months when no spill for juveniles is already planned, allowing adult steelhead to migrate back downstream.

3.5.5 Predation

Extensive research on predation and efforts at predator control, including piscivorous fish, avian predators, and marine mammals, have been undertaken in the Columbia Basin for decades, and will continue. Population year specific survival declined between 2010 and 2015 by more than 18% (shown in Figure 3-1) while marine mammal population increased in the mouth of the Columbia River over the same time likely impacting early migrating Chinook salmon population the greatest (Chasco et al. 2017). Tucannon spring Chinook salmon were found to have the highest associated mortality due to increased sea lion predation of all populations evaluated (Sorel 2020). The FCRPS Biological Opinion (NOAA 2008) and the Estuary Module (73 FR 161, January 2, 2008), both of which are part of the Recovery Plan, provide extensive evaluations of these issues as threats and limiting factors as well as specific strategies and actions for both monitoring and addressing them. Of note are the recent anthropogenically increased levels of avian and marine mammal predation. Also of concern is the potential of northern pike invasion from the upper Columbia River.

Recently, however, the Washington Department of Fish and Wildlife (WDFW) has liberalized fishing regulations around non-native predatory fish in the anadromous water of the Columbia Basin, including the Snake and Tucannon rivers, with the hope of reducing predation through recreational fishing (WDFW 2020b).

Figure 3-1
Predation of Columbia River Spring Chinook



Source: Sorel et al. 2017

3.5.6 *Estuary, Ocean, and Climate Change*

The combined influence of diking and filling tidal wetlands and hydrosystem flow management have reduced habitat capacity in the Columbia River estuary, and hatchery genetic effects have reduced salmonid life history variation that helped temporally maximize utility of the productive estuarine habitat. The quantity of tidal wetlands critical for juvenile outmigrants in the lower Columbia River has been halved due to levees and filling combined with reduced inundation resulting from flow management at dams (Bottom et al. 2011). Hatchery simplification of life histories and selection for early out-migration timing has shifted peak estuary occupancy to the spring and removed much of the summer and fall estuary usage. This shortened use of the estuarine habitat is also exacerbated by estuarine habitat loss and diminished inland and upper Columbia salmonid populations, including the Tucannon population, that would arrive later in the year (Bottom et al. 2011).

Research also suggests that recent warm and unfavorable ocean conditions are an increasing threat to Columbia River salmonid populations. Extremely warm marine water temperatures initiating in 2014 and 2015 associated with a strong El Niño event reduced upwelling and primary productivity and favored less nutritious plankton populations (NWFSC 2015). Trends of warm coastal waters and reduced productivity associated with El Niño conditions and warm Pacific Decadal Oscillation periods are expected to increase in frequency and strength with climate change (NWFSC 2015). However, the effects of marine conditions will not be uniform among species with regard to Tucannon populations. Columbia River spring Chinook salmon typically migrate to Alaska while fall Chinook salmon remain on the Washington/Oregon coast, and steelhead migrate directly west in the North Pacific, all experiencing different marine conditions (NWFSC 2015).

Projected climate change effects include reduced spring snow cover and glaciation, sea surface temperature rise, increased ocean acidification, and increased marine thermal stratification and hypoxia. Climate change will affect salmon directly via mortality from heat stress during rearing and adult phases. Altered flow regimes will influence migration timing and energetics and increased flooding will reduce egg survival (NWFSC 2015). Altogether, predicted warming ocean and river conditions will continue to threaten Snake and Tucannon River salmonid populations.

4 Fish Management

4.1 Steelhead

Historical wild-origin steelhead abundance in the Tucannon River is relatively unknown but thought to have been as high as 2,000 to 3,000 adults in the 1950s. By the mid-1970s, sport harvest in the Tucannon River (which was solely supported by wild-origin steelhead) was rapidly declining (Figure 4-1), and steelhead fishing in the Tucannon River was limited or closed altogether. The Lower Snake River Compensation Plan (LSRCP) hatchery program started releasing hatchery-origin steelhead in the Tucannon River in 1983. The LSRCP hatchery program was initiated in the early 1980s to compensate for fish losses from the construction and operation of the four lower Snake River dams. The hatchery stock(s) originally used were from out-of-basin hatchery programs (Wells and Wallowa) and were later termed the Lyons Ferry Hatchery (LFH) stock once they started returning to the hatchery for broodstock. Shortly after hatchery releases started, steelhead sport harvest in the Tucannon River was quickly re-established (Figure 4-1). In addition, estimating the number of steelhead spawning in the Tucannon River started in the mid-1980s as part of the monitoring and evaluation program funded by the LSRCP hatchery program. The average number of wild and LFH hatchery-origin spawners from 1987 to 1999 was estimated at 238 and 404, respectively, with wild-origin steelhead continuing to decline over that period.

In 1997, all Snake River Basin steelhead populations were listed under the ESA as threatened. Following the ESA listing, and due to the apparent low or declining number of wild-origin steelhead in the Tucannon River, the National Marine Fisheries Service (NMFS) questioned WDFW about the continued use of the LFH stock in the Tucannon River. From that, WDFW was requested to develop a new stock from "localized" adult steelhead (i.e., wild-origin returns that could have either wild or LFH stock parents), with the eventual goal of replacing the LFH stock from the basin. In 2000, with agreement from co-managers, WDFW began a 5-year "test" program to: 1) collect broodstock; 2) rear successfully at the hatchery; 3) return adults to support sport harvest; and 4) assist in the recovery of wild-origin steelhead.

The new "test" program produced 50,000 smolts, but because they were derived from wild-origin fish they could not be marked for harvest. Concurrently, the LFH stock releases were reduced by 60,000 (down to 100,000 total smolt release) to offset the additional hatchery production in the river. Some drop-off in sport harvest was expected but was deemed acceptable by the co-managers because returns to the Tucannon River were exceeding the hatchery return goals. By 2005, there still was not enough information to determine if the "test" program was successful. As such, WDFW and the co-managers agreed to continue testing the program for another 5 years.

In 2009, NMFS requested updates to the Hatchery and Genetic Management Plans (a required ESA document that allows hatchery programs where listed species are involved) for both the LFH and

Tucannon River steelhead stocks. Prior to re-submittal of these two plans, NMFS indicated they would not issue an ESA Permit for the continued propagation/release of any LFH stock steelhead into the Tucannon River. However, by 2010, enough information was available to determine that the "test" program was successful in returning adults to support not only the sport fishery, but also to maintain a conservation component of the program to help support the depressed wild-origin population (Figure 4-1). Concurrent with the decision to implement the Tucannon River stock program, releases of LFH stock steelhead in the Tucannon River were ceased (last release in 2010).

A key component of the Tucannon River stock implementation plan (50,000 smolts for conservation, 100,000 smolts for sport harvest) was the need for additional rearing space at the LFH. The LFH was designed for production of a few separate stocks of fish, with large rearing vessels that can hold multiple release locations. As such, elimination of the LFH stock releases did not free up additional rearing space for the Tucannon River stock. When the initial decision was reached to proceed with the Tucannon River stock, WDFW and the co-managers were promised that additional rearing space in the form of 20-foot circular tanks would be in place within a year (ready for rearing in 2011), with no gap in overall smolts released.

Due to a variety of factors, the additional rearing space at the LFH has yet to be realized. Because of that, there was no harvestable steelhead (adipose fin clipped) released into the Tucannon River from 2011 to 2013, which is reflected in the lower harvest estimates since then (Figure 4-1). Other program changes have occurred in the meantime, and currently WDFW has attempted to fulfill full production of this stock (Figure 4-2), although efforts have been hampered by low adult returns and disease outbreaks in the hatchery, which has limited overall smolt production. The LSRCP hatchery program is currently funding engineers to design additional rearing capabilities at the LFH, which will benefit Tucannon River steelhead and other stocks reared at the LFH.

Current Status: Determining the status of steelhead returning to the Tucannon River is difficult because fish return over many months, and spawn during periods of higher stream flows with poor visibility, so operation of adult traps or conducting redd surveys are often ineffective. Recently, instream PIT tag arrays have been deployed throughout the basin, and these have been used to estimate total escapement to the Tucannon River (Figure 4-3). Wild-origin steelhead continue to remain at relatively depressed levels, yet a large number of out-of-basin steelhead (both hatchery- and wild-origin) are present in fairly large numbers, which has complicated management of the population. Furthermore, the overshoot of Tucannon River steelhead to areas above Lower Granite Dam is hampering overall efforts to recover this stock or make the hatchery program successful. Overall impacts to the Tucannon River steelhead population from overshooting is difficult to quantify, but generally only 40% to 50% of the Tucannon River stock that cross Ice Harbor Dam make it back to the Tucannon River.

Figure 4-1
Estimated Harvest of Wild- and Hatchery-Origin Summer Steelhead in the Tucannon River (1967 to 2017)

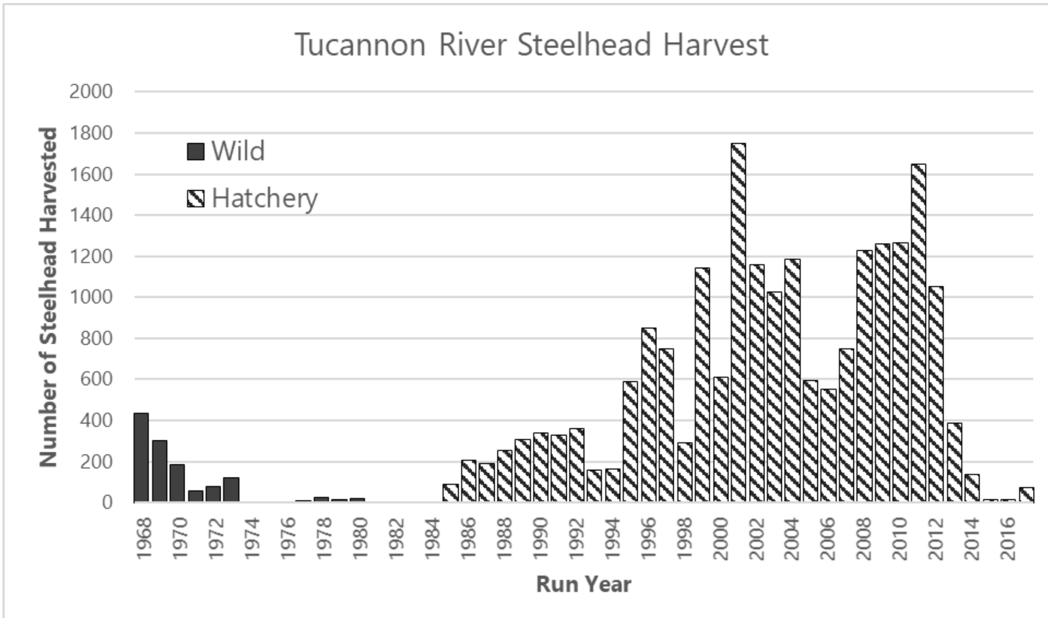


Figure 4-2
Number of Hatchery-Origin Steelhead from Either LFH or Tucannon River Stocks Released into the Tucannon River (1983 to 2019)

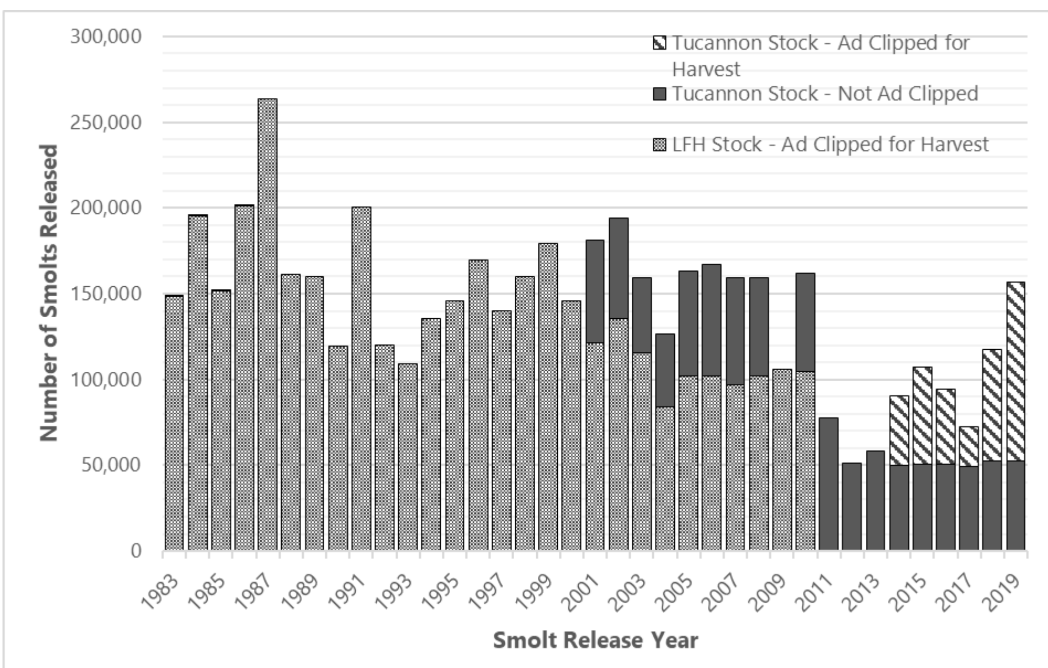
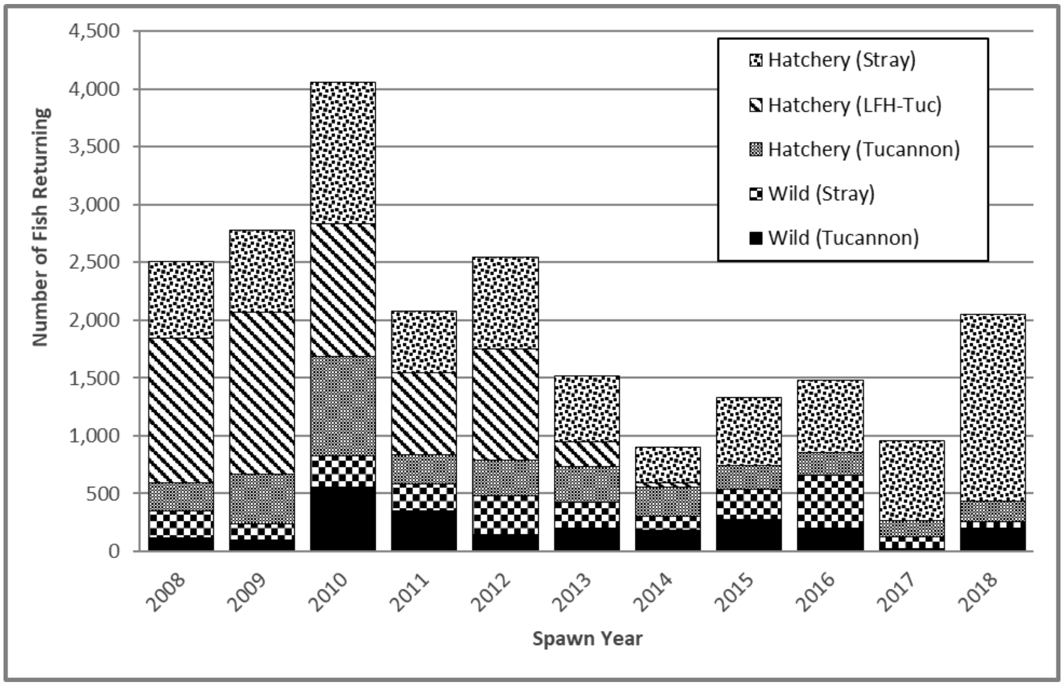


Figure 4-3
Estimated Number of Wild- and Hatchery-Origin Steelhead (Multiple Stocks) that Escape to the Tucannon River (2007 to 2018 Spawn Years)



4.2 Spring Chinook Salmon

Historical spring Chinook salmon abundance in the Tucannon River is relatively unknown; some rough estimates suggest the river could have supported as many as 30,000 adults, but by the 1950s estimates suggest this was less than 5,000 (Johnson 1995; CBPTF 2019). Based on expanded index redd surveys from 1958 to 1984, the natural population was in a slow decline (Figure 4-5). With completion of the four lower Snake River dams, the LSRCP hatchery program started releasing hatchery-origin spring Chinook salmon in the Tucannon River in 1987; the first broodstock collections began in 1985. The spring Chinook salmon hatchery program was initiated with natural-origin returns, and then both hatchery- and natural-origin fish have been used for broodstock annually since 1989. While originally meant for harvest mitigation, there has yet to be a spring Chinook salmon sport fishery in the Tucannon River since the LSRCP hatchery program began. The original goals of the program were to produce 132,000 smolts annually, released at 15 fish per pound, with an assumed 0.87% smolt to adult survival rate, which would return approximately 1,152 adults to the Tucannon River.

Monitoring of the first hatchery returns in the late 1980s suggested that smolt to adult survival of hatchery fish was only about one-quarter of what was expected. In addition, it was determined that the natural population (those juveniles that rear in the Tucannon River) were below replacement levels, and the population would continue to decline (see Appendix B for more information). In 1992, all spring/summer Chinook salmon in the Snake River basin were ESA-listed as "endangered," including the Tucannon spring Chinook salmon stock. The listing status was downgraded in 1995 to "threatened." The Tucannon salmonid survival assessment report (Crawford et al. 2019) identified survival and normalized-for-time survival in different reaches of the Tucannon River (both for spring Chinook salmon and steelhead). The information on survival from this effort has provided support for working on habitat related to over-winter survival and work in the lower Tucannon River.

Hatchery returns up to ESA listings, while not as high as expected, were at least above replacement levels and would help slow or stabilize the overall decline of spring Chinook salmon in the Tucannon River. A few different rearing strategies were tried to increase survival, but before results could be obtained, record low returns of both hatchery- and natural-origin fish occurred in 1994 (140 fish) and 1995 (54 fish), as shown in Figure 4-5. In addition, major floods in 1996 and 1997 destroyed most of the natural production from those 2 years. Moreover, an 80% loss of the hatchery egg take occurred in 1997 due to a malfunction of a water chiller that cold shocked the eggs. Because of the lower than expected adult returns in 1996 and 1997, the losses to both natural and hatchery production, and the natural population being below replacement levels, WDFW initiated a captive broodstock program with 1997 brood year fish to prevent the potential extirpation of the population. The captive broodstock program duration was planned for 5 brood years, with the intent to provide a demographic boost to the population (in adult returns) in coming years, but to lessen the overall effect of this extreme hatchery intervention. The captive program generally went as planned, yet due to some unknown factors following the release of juveniles from the program, they never returned as many adults as expected (Figure 4-5).

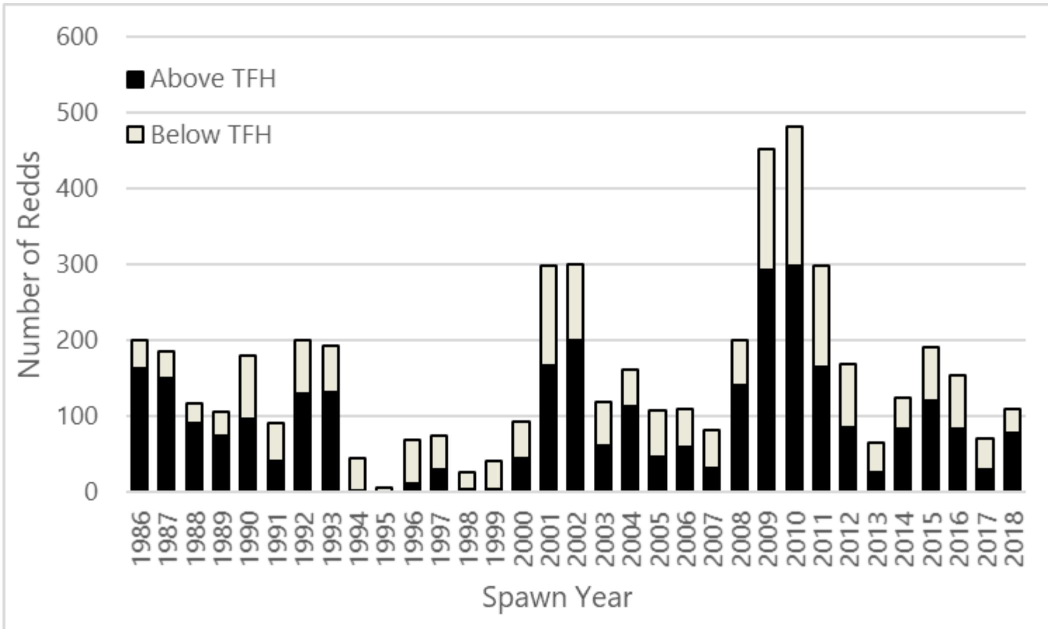
Over this time period, natural-origin fish generally remained below replacement, and hatchery-origin fish helped to maintain the population at somewhat decent returns. Hatchery smolt releases were moved to Curl Lake in 1998 to: 1) potentially increase smolt to adult survival; and 2) shift the spawning distribution of hatchery fish in the river to areas where spawning densities for spring Chinook salmon were historically the highest prior to hatchery intervention. In addition, in 2002, none of the hatchery fish were adipose fin clipped anymore so they would not be harvested in downriver mark selective fisheries, allowing for a greater escapement of adults to the spawning grounds. However, hatchery fish overall continued to perform poorly (in spite of these and a few other alternative rearing strategies), and survival was still well below the assumed smolt to adult survival goal that was used to size the hatchery program in 1985. As a result, in 2006, the managers (state, tribal, and federal) agreed to increase the program size to 225,000 smolts (Figure 4-6). They also began a size at release study (15 fish per pound vs. 9 fish per pound) to see if that would help increase the survival of hatchery fish.

For a short period in the mid-2000s, smolt to adult survivals increased for both hatchery- and natural-origin fish, but this was mainly attributed to favorable ocean and out-migration conditions (Figure 4-5). In 2013 and continuing over the next few years, WDFW documented high pre-spawn mortality over the summer; the direct cause has yet to be determined. Due to the high pre-spawn mortality, WDFW and the co-managers made the decision to hold all, or a portion of, the fish that would normally be passed upstream of the adult trap be transported and held at the LFH. These fish would then be outplanted to the river just prior to spawning (late August). To date, holding and outplanting of adults occurred in 2015, 2016, 2018, 2019, and 2020.

In 2016, WDFW initiated nutrient enhancement in the upper Tucannon Basin by putting out salmon carcasses from the Snake River fall Chinook salmon program at the LFH. It is anticipated the approximately 1,200 carcasses will be returned to the stream annually for the foreseeable future. The added nutrients over time are expected to increase the overall productivity of the ecosystem, which may increase survival of the juvenile spring Chinook salmon in the river.

Current Status: Overall returns have dropped from the levels observed in the mid-2000s but have been around 500 total fish the last few years (Figure 4-5). Hatchery fish, while released at a larger size and in greater numbers than the original program, continue to perform poorly, and discussions are underway to try alternative release strategies in the future. Natural-origin fish remain below the replacement level in most years and continue to be assisted by the hatchery program to ensure some natural production occurs. Historical redd distribution of spring Chinook salmon throughout the Tucannon River is shown in Figure 4-4. It is still unknown if the high pre-spawn mortality over the summer months experienced a few years ago is still occurring. Because of this uncertainty, and the expected low returns in the next few years due to poor ocean conditions, the holding and outplanting strategy used recently will likely continue until it can be determined that the high pre-spawn morality is not an issue. Monitoring activities on this population include pre-spawning and spawning ground surveys; adult trapping (broodstock and other needs); smolt monitoring and PIT tagging wild spring Chinook salmon at the smolt trap; adult trap passage/delay; and, depending on funding, juvenile parr PIT tagging to determine over-winter survival, movements, and habitat use.

Figure 4-4
Historical Redd Distribution in the Tucannon River Above and Below the TFH Adult Trap on the Tucannon River



Source: WDFW 2020a, Table 8

Figure 4-5
Estimated Number of Wild- and Hatchery-Origin Spring Chinook Salmon that Returned to the Tucannon River (1958 to 2018 Spawn Years)

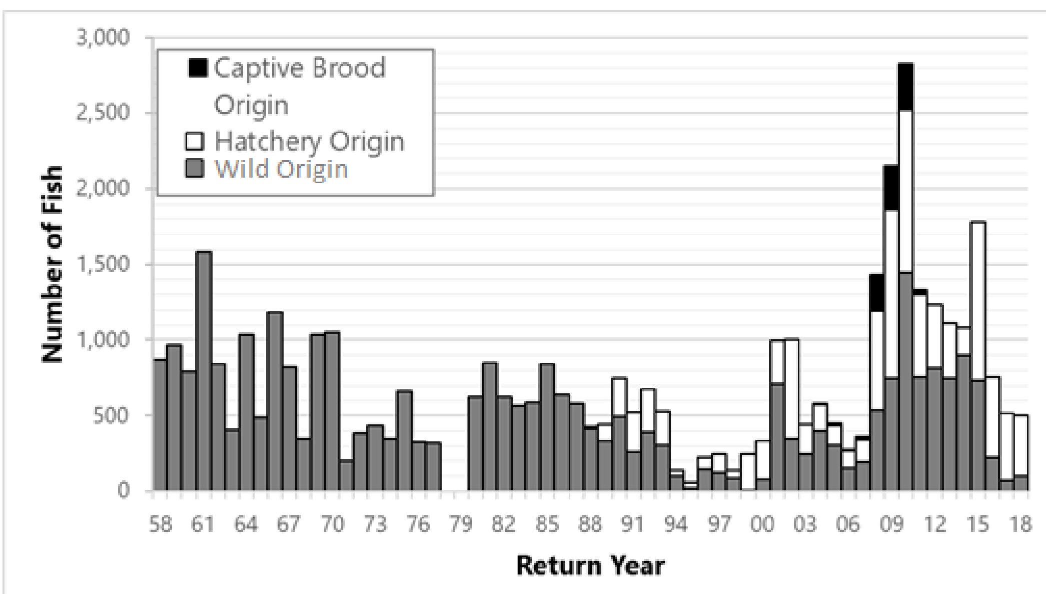
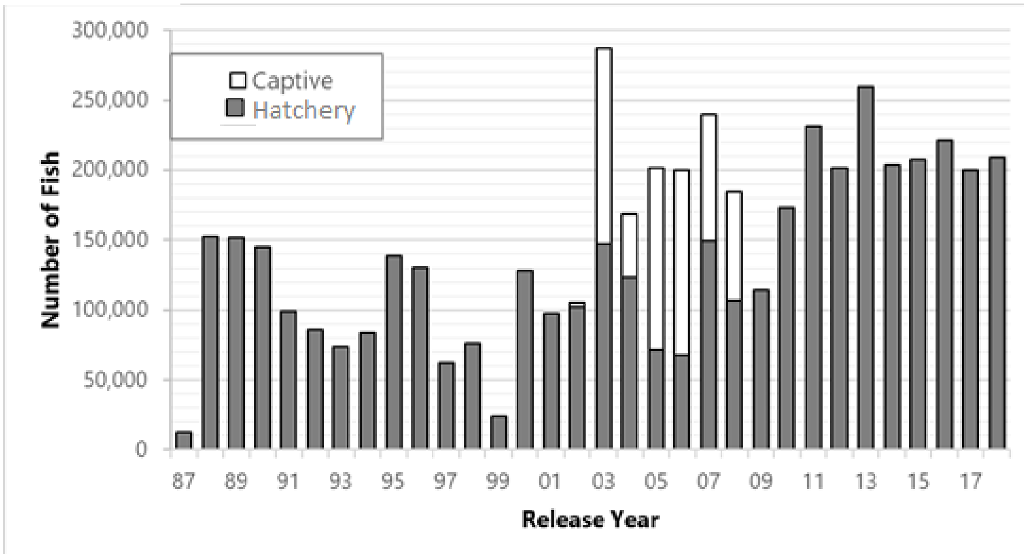


Figure 4-6
Number of Hatchery-Origin Spring Chinook Smolts Released into the Tucannon River (1985 to 2018)



4.3 Fall Chinook Salmon

Historical fall Chinook salmon abundance in the lower Tucannon River was relatively unknown until redd counts began in the late 1980s under the LSRCP hatchery program. Fall Chinook salmon in the Tucannon River are part of the much larger Snake River fall Chinook salmon population, all of which were ESA-listed as "threatened" in early 1990s. With completion of the four lower Snake River dams, the LSRCP hatchery program at the LFH started releasing hatchery-reared fall Chinook salmon in the Snake River, but no releases have ever been programed for the Tucannon River. Currently, 80% of the total fall Chinook salmon hatchery production in the Snake River basin is released upstream of Lower Granite Dam. Based on redd surveys and carcass recoveries, the majority of fall Chinook salmon spawning in the Tucannon River are hatchery-origin, with most originating from the on-station releases of fall Chinook salmon at the LFH, although some strays from the Umatilla River hatchery program have also been found. About 95% of the fall Chinook salmon spawning in the Tucannon River takes place from the Highway 12 bridge downstream to the mouth. Redd counts are highly correlated with the overall return of fall Chinook salmon to the Snake River basin (Figure 4-7). Besides redd and carcass surveys, the only other monitoring of fall Chinook salmon occurs at the smolt trap just upstream of the Highway 261 bridge. Natural smolt production (Figure 4-8) of fall Chinook salmon from the Tucannon River has been shown to be highly variable, with the largest factors in determining production being high stream flows that can scour redds and sediment input (Pataha Creek) that can smother the redds. No additional population monitoring or management actions are planned for fall Chinook salmon in the Tucannon River at this time.

Figure 4-7
Estimated Number of Fall Chinook Salmon (Hatchery- and Natural-Origin) Returning to the Snake River Basin (1938 to 2017) and the Number of Fall Chinook Redds Estimated in the Tucannon River (1986 to 2017)

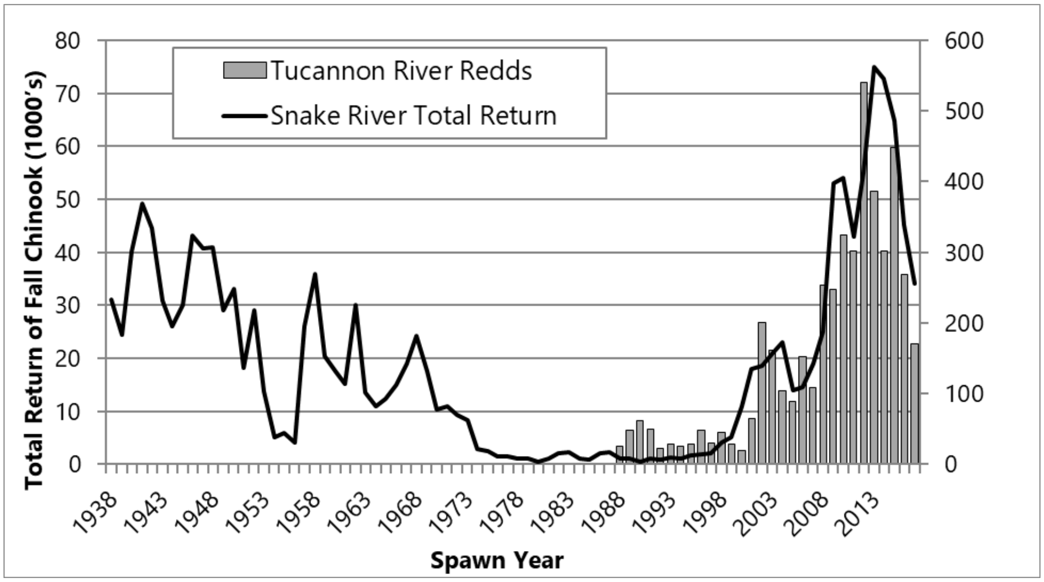
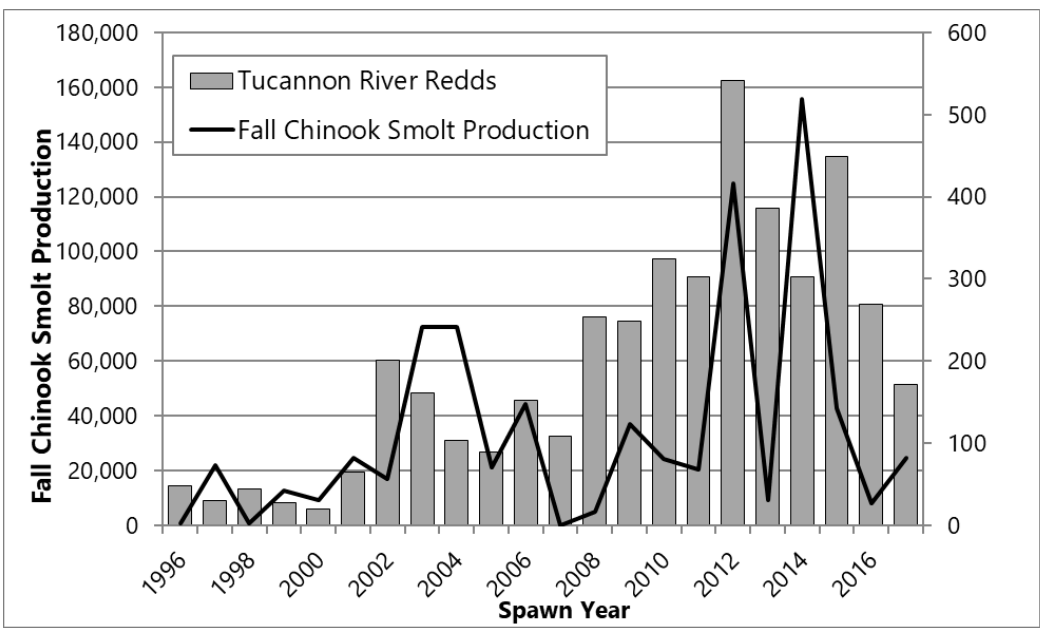


Figure 4-8
Estimated Number of Fall Chinook Redds and Subsequent Smolts Migrating from the Tucannon River the Following Spring (1996 to 2017 Spawn Years)



4.4 Bull Trout

Bull trout in the Columbia Basin were ESA-listed as threatened in 1998. The Tucannon River bull trout population is part of the Lower Snake River geographic area of the Mid-Columbia Recovery Unit (USFWS 2015). Bull trout life histories present in the Tucannon River include resident, fluvial, and adfluvial forms. Migratory bull trout move upstream from the lower Tucannon and Snake rivers into the upper Tucannon River in the spring and early summer, with nearly identical run timing at the Tucannon Fish Hatchery adult trap to that of spring Chinook salmon. Critical habitat in the Tucannon Critical Habitat Subunit, as designated by the USFWS, includes the mainstem Tucannon River, Little Tucannon River, and Cummings, Hixon, Panjab, Cold, Sheep, and Bear creeks (USFWS 2010). Juvenile rearing is primarily thought to occur in the mainstem Tucannon River upstream of Tumalum Creek to the headwaters and the tributaries listed above. The lower and middle Tucannon River provide over-wintering habitat and a migratory corridor for adults and sub-adults to the spawning and rearing areas upstream in the watershed.

Historically, the bull trout population in the Tucannon River was considered healthy based on redd surveys; however, redd survey data, and adult trap data (Figures 4-9 and 4-10) from the mid-2000s suggested a population decline (USFWS 2010). However, since that time, redd numbers and bull trout captures at the Tucannon Fish Hatchery adult trap increased to previous levels. Due to lack of available funding, redd surveys following 2014 have been discontinued. WDFW continues to trap bull trout at the Tucannon Fish Hatchery trap. Currently, the only monitoring is to conduct PIT tagging of all bull trout captured annually at the Tucannon Fish Hatchery adult trap. Re-detection of bull trout with PIT tags is being used to monitor: 1) the proportion, arrival, and departure of spawners at the Tucannon/Panjab fork; 2) the upstream and downstream movement and travel time of bull trout in the Tucannon and Snake rivers at other PIT tag array locations; and 3) passage and passage delay at the Tucannon Fish Hatchery adult trap.

Figure 4-9
Total Number of Redds during Bull Trout Spawning Survey in the Tucannon Basin (1994 to 2014)

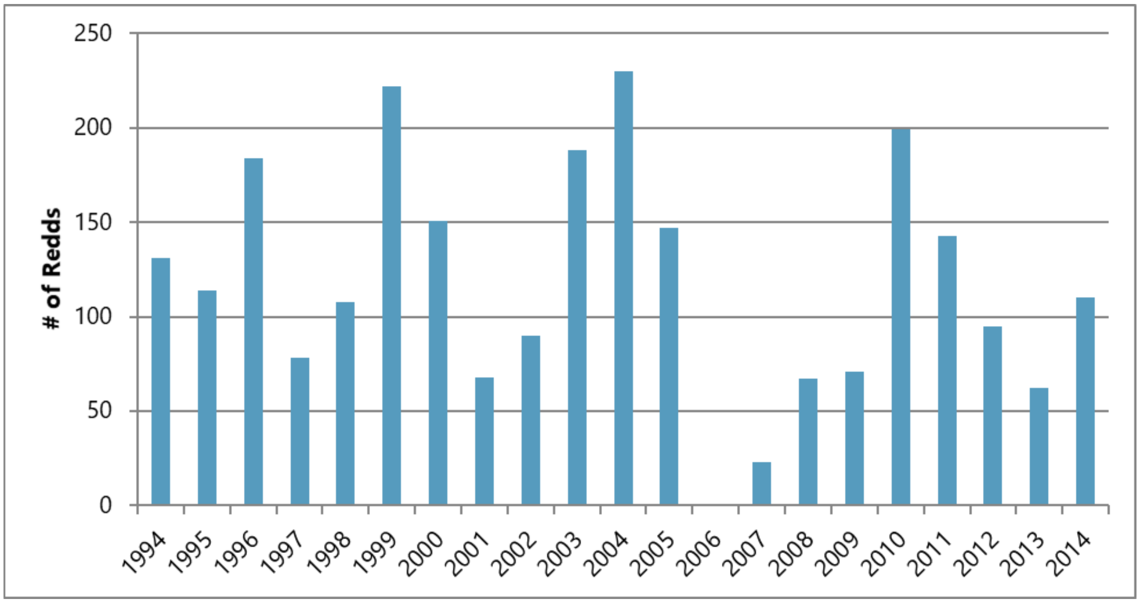
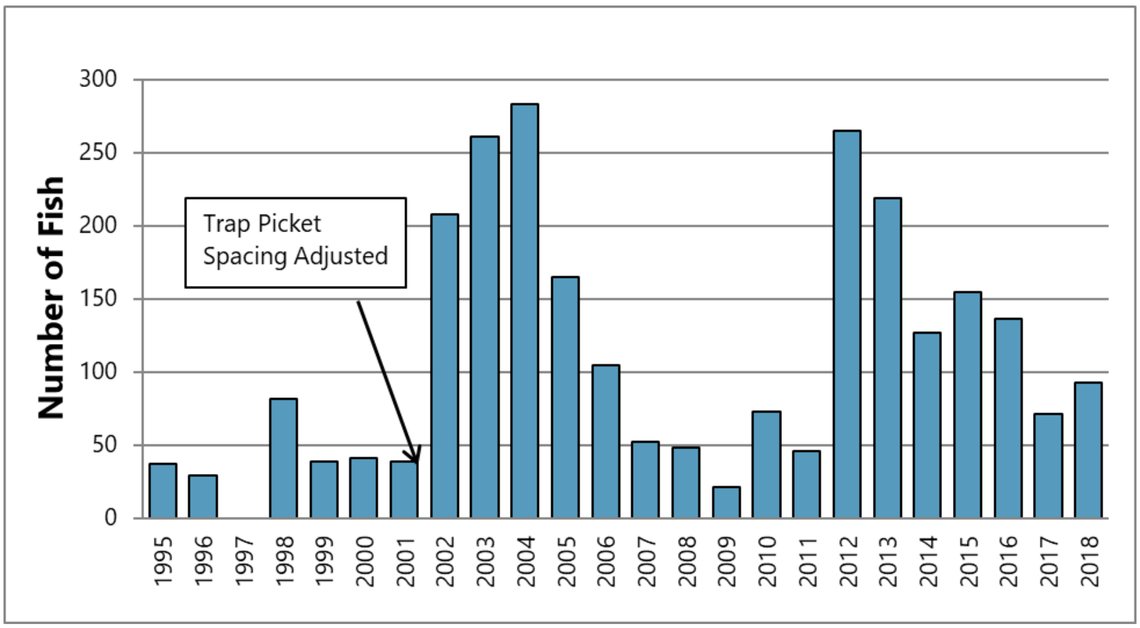


Figure 4-10
Bull Trout Captured at the Tucannon Fish Hatchery Adult Trap (1995 to 2018)



Note: Years prior to 2002 do not represent all fish that likely passed through the trap/weir due to larger picked spacing between the panels.

5 Fish Habitat, Life Cycle, and Distribution

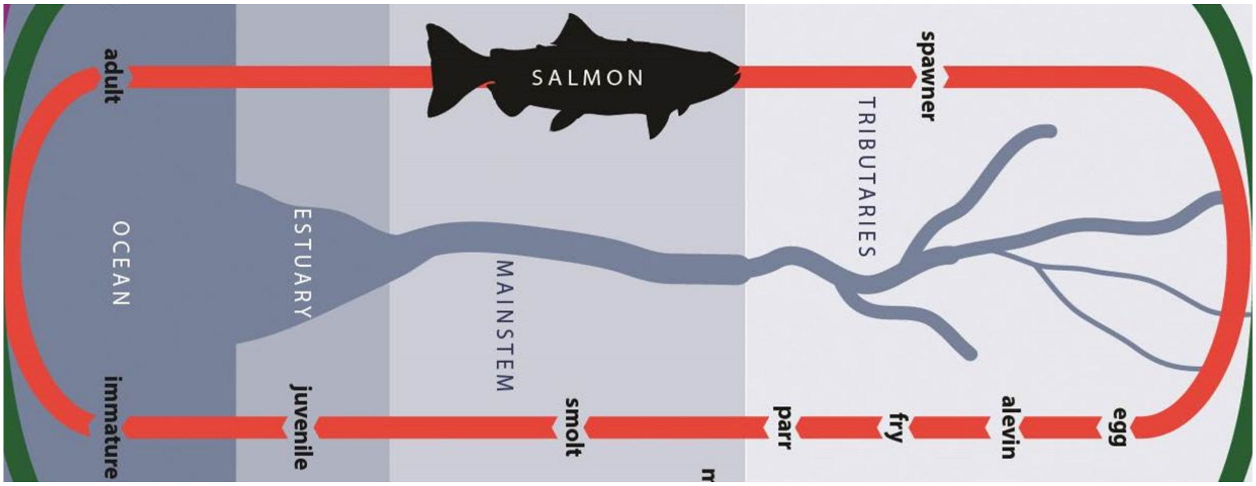
The Tucannon River supports four ESA-listed Snake River Basin salmonid populations throughout all or a portion of their life stages. Summer steelhead, spring Chinook salmon, fall Chinook salmon, and bull trout were identified in the Tucannon Subbasin Plan as aquatic focal species (CCD 2004). Collectively, these species use the main channel from the mouth to the headwaters, as well as major tributaries including Pataha Creek. The following information is summarized from the Tucannon Subbasin Plan (CCD 2004) and the Snake River Salmon Recovery Plan (SRSRB 2006), and revised to include new information from recent data being collected by WDFW and others in the basin (SRSRB 2011; Gallinat and Ross 2010; Crawford et al. 2019). This information has been updated to reflect the current status as of 2018, through email communication with WDFW (WDFW 2019). Table 5-1 shows the spatial distribution of steelhead and Chinook salmon in the mainstem of the Tucannon River, with darker shades of gray indicating higher densities of fish present during their respective life stages. Information on bull trout was not sufficient to provide distribution data as reported for the other focal species.

Natural Tucannon River summer steelhead, spring Chinook salmon, and fall Chinook salmon all express anadromous life cycles, where they spend at least a portion of their life span in fresh water (the Tucannon, Snake, and Columbia rivers for this group) followed by a part in the brackish Columbia River estuary and the Pacific Ocean. The time spent in each ecosystem varies by each species and within species depending on environmental conditions (e.g., stream temperature, ocean productivity). Bull trout within the Tucannon River are potamodromous, meaning they are migratory without going to the ocean, spending their life in fresh water.

This is simplified life cycle for salmon indicating the life stages of Chinook salmon for the Tucannon River. Figure 5-1 tracks a typical life cycle of Tucannon salmon beginning with adults spawning in 2019. Starting with the adult life stage, salmon enter the Columbia River from March to April 2019, enter the Tucannon River in May to June 2019, and finally spawn in the Tucannon River in September 2019. The eggs remain in the gravel from September 2019 to February 2020, hatching into alevins, and leaving the gravel in April to May 2020 as fry. Salmon fry live in the Tucannon River and become parr between June and July 2020. Parr will remain in the Tucannon River until the spring freshet between April and June 2021 when they migrate down the Columbia River to its estuary to undergo smoltification, preparing themselves for the ocean environment. They feed in the productive, brackish estuarine environment prior to entering the marine environment. The smolts will spend some time acclimating to saltwater conditions in the mild, brackish estuary environment, while feeding on the bountiful food production of the Columbia River estuary. The Tucannon River spring Chinook salmon eventually enter the Pacific Ocean and will remain in the ocean ranging as far as the Gulf of Alaska before returning to the Tucannon in 2022 (as jacks) or in 2023 to 2024 (as adults).

Figure 5-1
Tucannon River Salmon Life Cycle

Spawn 2019



Ocean 2022–2024 **Smolt 2021** **Rear 2020**

Table 5-1
Distribution of Steelhead, Chinook Salmon, and Bull Trout in the Mainstem Tucannon River

Geographic Area	From (RM)	To (RM)	Summer Steelhead				Spring Chinook				Fall Chinook			Bull Trout			
			Spawning	Summer Juvenile Rearing	Winter Juvenile Rearing	Adult Holding	Spawning	Summer Juvenile Rearing	Winter Juvenile Rearing	Adult Holding	Spawning	Juvenile Rearing	Adult Holding	Spawning	Summer Juvenile Rearing	Winter Juvenile Rearing	Adult Holding
Mouth	0	0.7												Note: Migratory and resident fish. Distribution data are limited.			
Lower Tucannon	0.7	4.8															
	4.8	5.5															
	5.5	8.7															
	8.7	12.3															
Pataha-Marengo	12.3	16.5															
	16.5	18.6															
	18.6	22.8										Note: Juveniles out-migrate as subyearlings					
	22.8	26.6															
Marengo-Tumalum	26.6	35.6															
Tumalum-Hatchery	35.6	37.8															
	37.8	41.9															
Hatchery-Little Tucannon	41.9	44.6															
	44.6	45.6															
	45.6	48.1															
Mountain	48.1	50.2															
Wilderness (Panjab to Sheep Creek)	50.2	56.0															
	53.0	56.0															
Wilderness (Sheep Creek to Headwaters)	56.0	59.0															
	59.0	62.0															

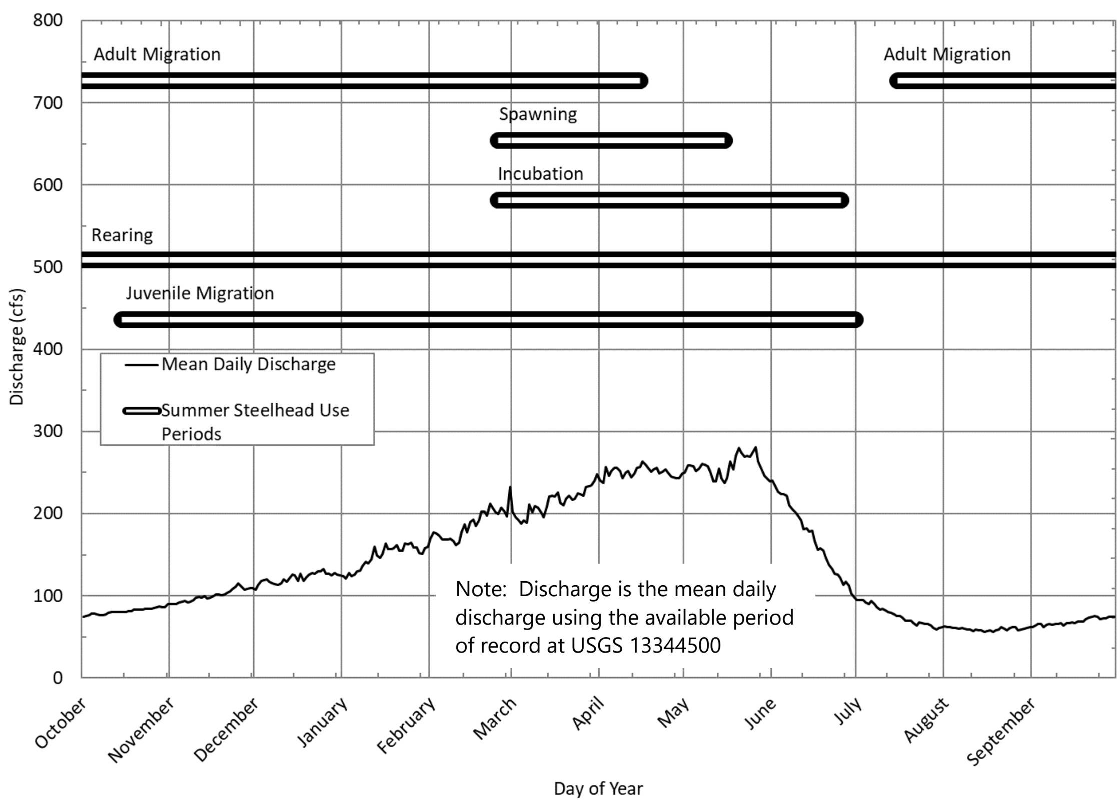
Notes:

1. Distribution data have been collected by WDFW, updated in 2018, and conveyed via email communications for this report.
2. Darker shades of gray indicate higher densities of fish present during their respective life stages.

5.1 Summer Steelhead

Summer steelhead in the Tucannon River are part of the Snake River Basin steelhead ESU, which was listed as threatened in 1997. Summer steelhead enter the Tucannon River as early as July and begin spawning in late February to early March with spawning continuing to late May (Figure 5-2). Spawning occurs in the mainstem Tucannon River from the mouth (RM 0.0) upstream to the Tucannon River headwaters, as well as within Cummings Creek and in the lower portions of Panjab, Sheep, Little Tucannon, and, in some years Tumulum Creek; the greatest concentration of steelhead spawning is typically found in the mainstem river between Tucannon Falls (RM 16.5) and Beaver/Watson Lake at approximately RM 42. Juveniles also rear throughout the mainstem river but are typically found in the greatest numbers between approximately RM 18 and School Canyon (approximately RM 45).

Figure 5-2
Mean Annual Hydrograph and Typical Timing of Life History Stages for Summer Steelhead in the Tucannon Basin



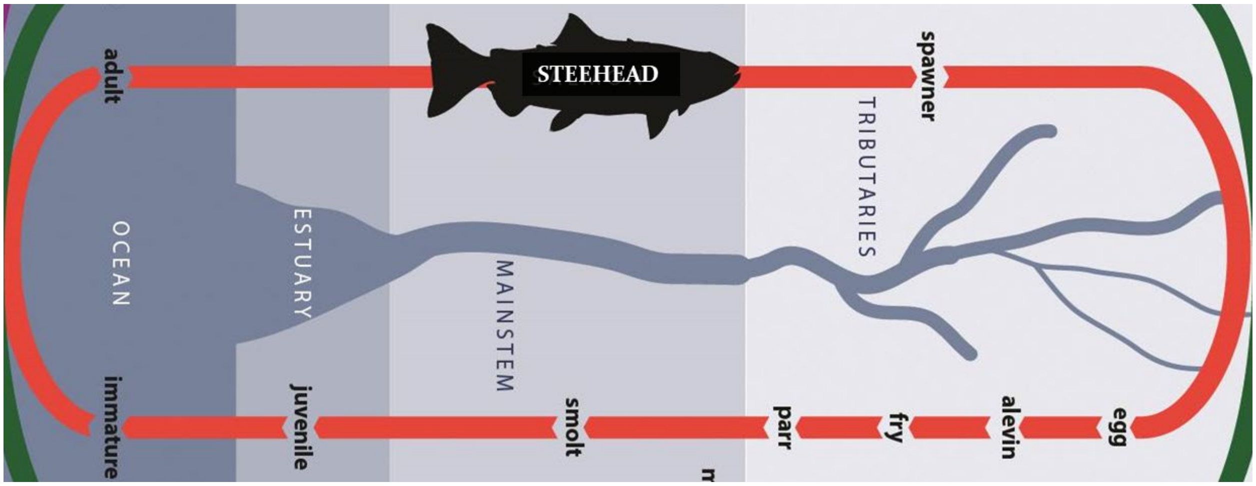
In the Tucannon River, it is believed that the steelhead exhibit both anadromous and resident life histories where some steelhead progeny remain in the Tucannon River and complete their life cycle without leaving the river. The number and proportion of these fish is not known; however, and a recent study looking into spring Chinook salmon and summer steelhead survival and distribution (Crawford et al. 2019) indicates that the number of residual fish may be limited. Although not directly investigating juvenile steelhead age structure within the basin, the random sampling method included developing an age structure model indicating the vast majority of aged steelhead to be age 0 to age 1 (98.66%), with few fish being age 2 (1.33%) or older. The study found steelhead emigration from spawning and rearing, varied with juvenile parr spending between 1 and 3 years within the Tucannon River before smolting (Crawford et al. 2019). Tucannon steelhead complete their anadromous life cycle on average in 3 to 6 years following the egg stage, spending 1 to 3 years in the ocean.

The WDFW study investigated juvenile steelhead survival within the Tucannon River downstream to Monumental Dam on the Snake River in 2016 and 2017 using both brood years (Crawford et al. 2019). Fish movement was completed using PIT tags and modeled survival based on instream detections at four in-basin tag receives during the seaward migration through 2018. Tagged fish have been observed leaving the upper basin in the mid to late fall using the middle and lower river basin to over-winter before entering the Snake River in the spring.

The Tucannon River steelhead exhibit an anadromous life cycle that for some individuals can take up to 7 years to complete. Figure 5-3 portrays the Tucannon steelhead anadromous life cycle, beginning with adult spawning in the Tucannon River between March and May of 2019. Alevins emerge from the gravel and become fry between June and July 2019. Fry grow to become parr, remaining for one to two winters or from August 2019 to April 2021, and then smolt and emigrate into the Snake River and then the Columbia River. The smolts can remain in the Columbia River estuary or directly enter the Pacific Ocean where they mature from sub-adults into adults. As adults they will spend between 1 and 3 years in the ocean before reentering the Columbia River between June and September of 2021 to 2025. The longer steelhead adults remain in the ocean, the larger they will be at spawning. The wild steelhead population remains in the Columbia River and Snake River from late summer until winter and early spring before arriving in the Tucannon River and spawning in the late winter or early spring.

Figure 5-3
Tucannon River Steelhead Life Cycle

Spawn 2019

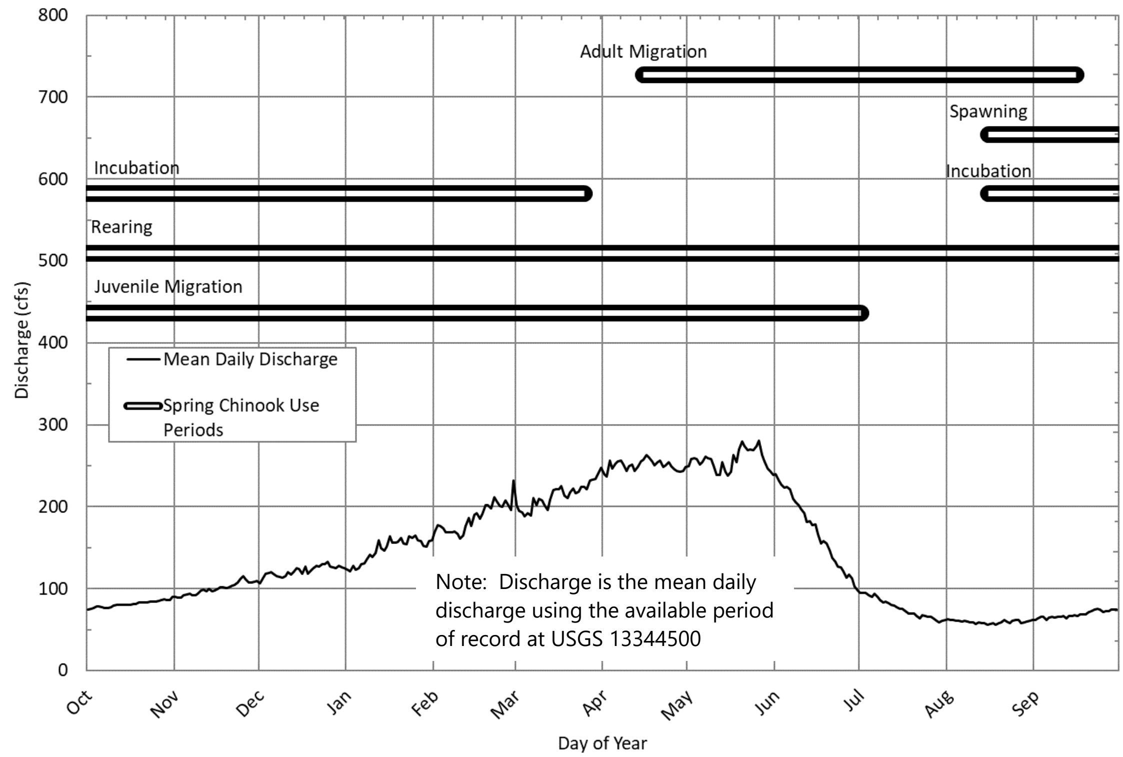


Ocean 2021–2025 **Smolt Spring** **Rear 2020–2022**

5.2 Spring Chinook Salmon

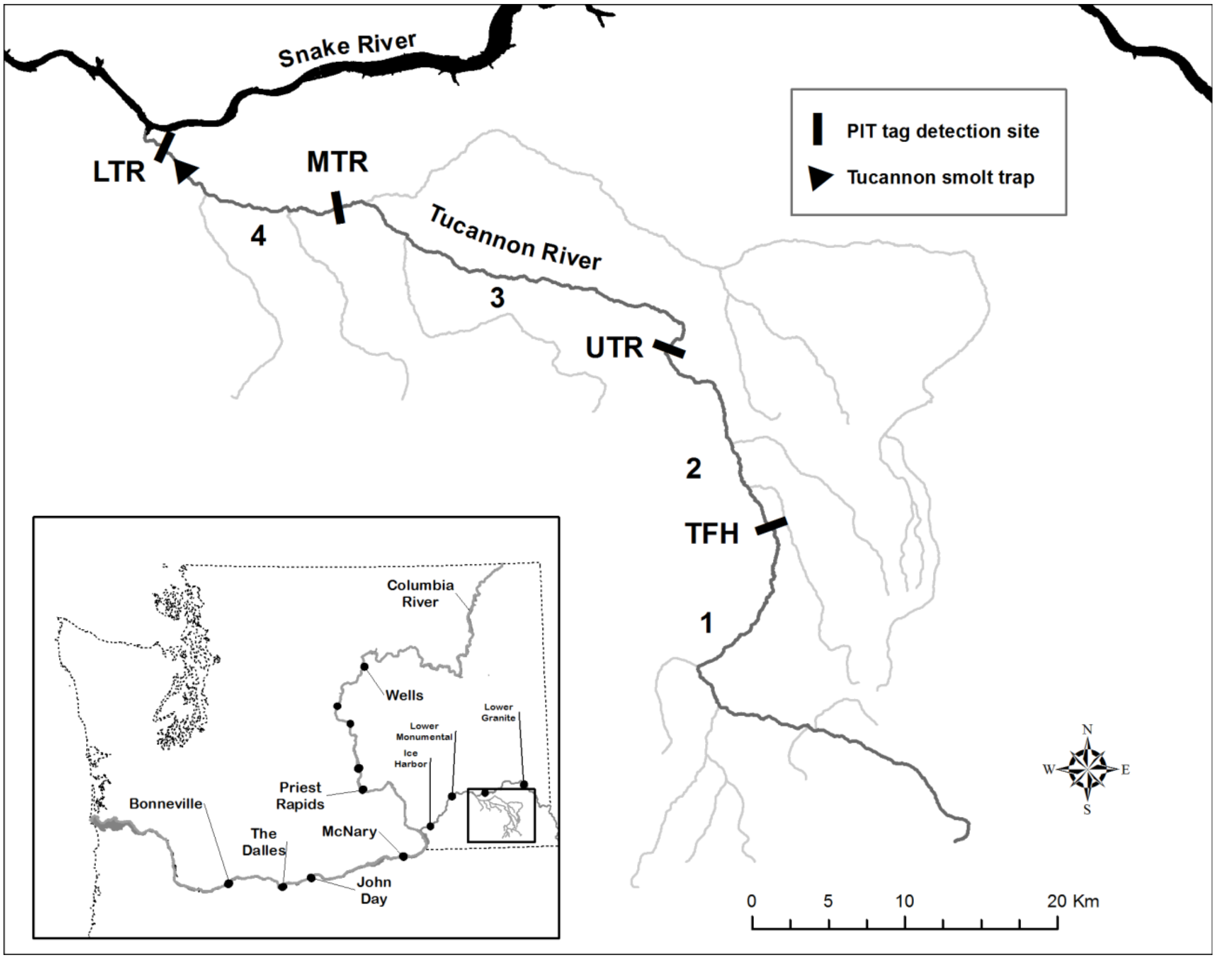
Spring Chinook salmon in the Tucannon River are part of the Snake River spring/summer Chinook salmon ESU that was ESA-listed as endangered in 1992 but downgraded to threatened in 1995. Spring Chinook salmon enter the Tucannon River beginning as early as mid-April and can enter as late as mid-September, although generally 90% of the run enters the lower river between May 1 and June 30 (Figure 5-4). Spawning occurs from mid-August to the end of September, almost exclusively in the main channel from approximately King Grade (RM 22.9) to the mouth of Sheep Creek near RM 55 (Gallinat and Ross 2017). The greatest densities of spawners are between Cummings Creek (RM 38) and the Little Tucannon River (approximately RM 48.1). Summer rearing of juveniles occurs from approximately Tucannon Falls (RM 16.5) to the headwaters, with the highest densities located between Marengo and School Canyon (approximately RM 45).

Figure 5-4
Mean Annual Hydrograph and Typical Timing of Life History Stages for Spring Chinook Salmon in the Tucannon Basin



In 2016 and 2017, WDFW investigated juvenile spring Chinook salmon migration behavior and survival within the Tucannon River downstream to Monumental Dam on the Snake River (Crawford et al. 2019). Fish observations were completed using PIT tags and instream detections at four receivers within the basin to determine emigration behavior spatially/temporally and modeled survival to the Snake River. The study found that across the two year classes that were tagged, a large proportion of parr tagged in the two upper-most river strata (labeled as TFR and UTR in Figure 5-5) emigrate seaward from the upper basin in the mid to late fall using the middle and lower river basin to over-winter before entering the Snake River. Based on outcomes from Crawford et al. (2019), the upper river (TFH, UTR) is used as over-winter habitat but is proportionally used less than the middle river (MTR) by over-wintering Chinook parr. Additionally, the study indicated reduced survival over winter in the third strata located in the middle river (between UTR and MTR, as shown in Figure 5-5).

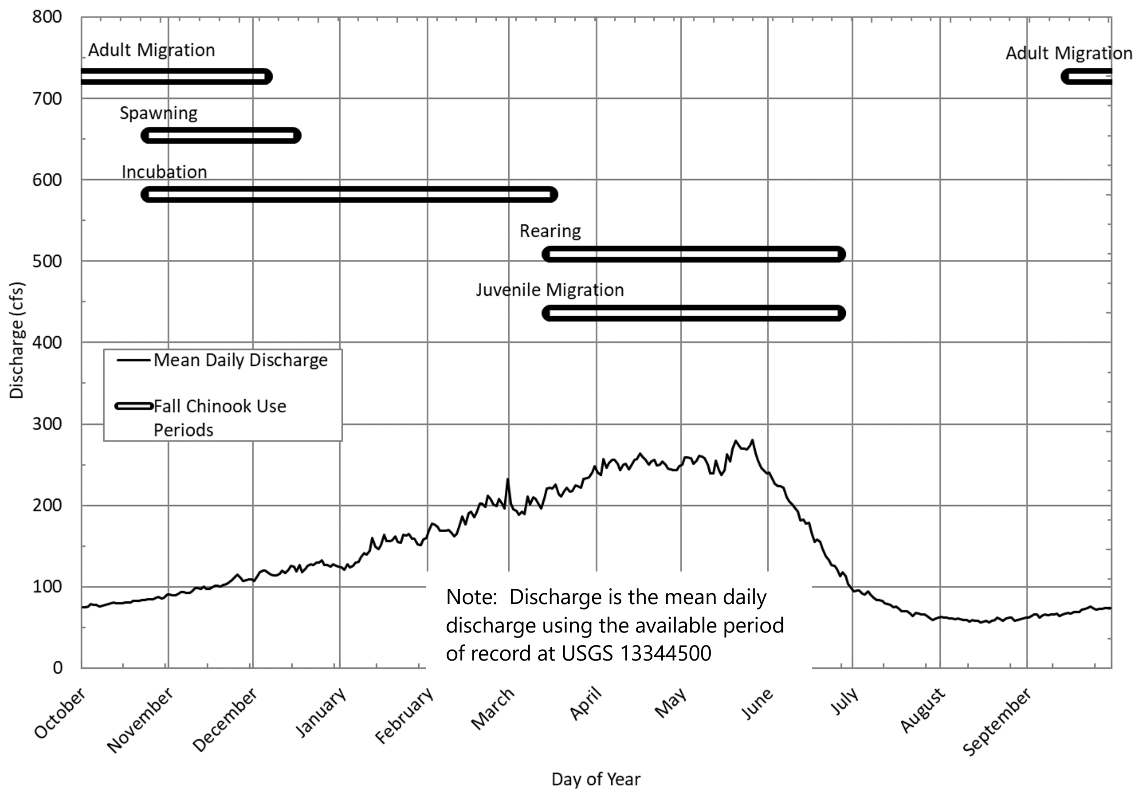
Figure 5-5
Tucannon PIT Tag Locations



5.3 Fall Chinook Salmon

Fall Chinook salmon are part of the Snake River fall Chinook salmon ESU, also listed as threatened in 1992. Fall Chinook salmon enter the lower Tucannon River beginning as early as mid-September and can continue to enter the river through early December. Spawning typically begins in late October and continues into mid-December (Figure 5-6). Fall Chinook salmon use the main channel of the river from the mouth, and have been occasionally observed spawning as high as King Grade Road (RM 22.9), but the highest concentration of spawning is generally from the mouth to around the Starbuck Dam near RM 5.5. Juvenile fall Chinook salmon do not over-winter in the Tucannon River and out-migrate shortly after emergence during early spring to early summer.

Figure 5-6
Mean Annual Hydrograph and Typical Timing of Life History Stages for Fall Chinook Salmon in the Tucannon Basin



5.4 Bull Trout

Bull trout in the Columbia Basin were ESA-listed as threatened in 1998. The Tucannon River bull trout population is part of the Lower Snake River Critical Habitat Unit (USFWS 2010). Bull trout life histories present in the Tucannon River include resident, fluvial, and adfluvial forms. Migratory bull trout move upstream from the Snake River into the upper Tucannon River in the spring and early summer, with nearly identical timing to that of spring Chinook salmon. Critical habitat in the Tucannon Critical Habitat Subunit, as designated by the USFWS, includes the mainstem Tucannon River, Cummings Creek, Hixon Creek, the Little Tucannon River, Panjab Creek, Cold Creek, Sheep Creek, and Bear Creek (2010). Juvenile rearing occurs upstream of Tumalum Creek to the headwaters. The lower and middle Tucannon River are important migratory corridors to spawning and rearing areas upstream in the watershed, including the headwaters and tributary streams noted here.

Historically, the bull trout population in the Tucannon River has been considered healthy; however, data from the mid-2000s suggested some population declines (USFWS 2010). As cited by USFWS, WDFW surveys indicated the number of redds in the upper Tucannon River dropped from more than 100 in 2002 and 2003 to less than 20 in 2007. This correlated with a decline in the number of adult migratory bull trout captured at the Tucannon Fish Hatchery trap as they were moving upstream. However, since that time redd numbers increased, with an average redd count from 2008 to 2014 of 83 redds, with a high of 161 redds. Due to lack of funding, redd surveys following 2014 have been discontinued. WDFW continues to trap bull trout at the Tucannon Fish Hatchery trap, and following 2007 also rebounded and appear fairly stable, with the average number of bull trout trapped between 2008 and 2018 equaling 114, with a high of 265 and low of 21.

5.5 Other Species of Concern

Besides the four ESA-listed species, many other native aquatic species are present in the Tucannon River. Unfortunately, most of these have little to no biological information on their current status and health. Based on previous surveys by WDFW, species such as sculpins (multiple species), dace (long-nose or speckled), and red-sided shiners are plentiful throughout the basin. Other species such as whitefish, suckers, Pacific lamprey, and freshwater mussels were also once abundant within the basin, but are now thought to be critically depressed from historical levels. Previous actions within and outside the basin likely contributed to their decline, and it is hoped that habitat prescriptions described within this assessment will assist in their recovery. Although some species are currently abundant in the Snake pool between Lower Monumental Dam and Little Goose Dam including mountain whitefish (*Prosopium williamsoni*) or suckers (Catostomidae sp.), they do not seem to be migrating upriver and initiating/supporting populations. It is possible these riverine potamodromous species are unable to navigate the fish ladder at Starbuck Dam or the Tucannon Falls. Snorkel surveys conducted between 2014 and 2018 by the Action Effectiveness Monitoring project, sponsored by both the Bonneville Power Administration and Snake River Funding Board recorded observations of all fish species observed during surveys and found that both whitefish and sucker species decreased moving upstream and were absent above RM 37 and nearly absent above RM 26 (Roni 2019).

6 Limiting Factors Progression

Many efforts have been made to understand the factors negatively affecting salmon and steelhead growth and survival across varying life history stages throughout the Pacific Northwest. The priority habitat factors limiting survival and production within a given river segment, tributary, or basin change over time as conditions continue to degrade or improve. Early watershed assessments often focused on limiting factors that were directly killing fish (called imminent threats), such as dewater streams, migratory blockages, or unscreened diversions. As the imminent threats were addressed across the watershed, restoration efforts transitioned toward limiting factors that indirectly killed fish or limited their growth or survival over several life cycles or part of their life cycle. Simplified instream conditions and lack of deep pools, degraded riparian conditions, and fine sediment input from logging, farming, and other land use activities are primary factors affecting fish. In the Tucannon Basin, fine sediments and elevated summer water temperatures impacted returning adult spring Chinook survival, which led to widespread use of minimum till agriculture, riparian planting, and bank stabilization projects. These early assessments were often focused on the adult life history stage and looking at the ability of adult fish to traverse, hold, and successfully spawn in river systems.

Protection of riparian areas, improved irrigation and tilling practices, levee setbacks, and instream channel improvements, that began in the 1990s, have greatly reduced land use practices that were negatively impacting the river. This has led to significantly improved ecological conditions such that temperature and fine sediment inputs are no longer considered limiting factors. Summer water temperatures in the mid-1980s typically would reach 26°C below RM 20, making the river migratory seasonal habitat; however, since 1997 it has been recognized that steelhead spawning and rearing habitat exists to the mouth of the Tucannon River. This was based on catches of newly emerged steelhead fry captured in the rotary screw trap in May/June, and subsequent catches of parr/fingerling-sized juveniles during late summer electrofishing surveys. Riparian corridors now provide significant shading and nutrient contributions through much of the river, as well as providing floodplain stability and flood resiliency.

The following studies have evaluated limiting factors in the Tucannon River:

- The Tucannon Subbasin Plan (CCD 2004)
- Snake River Salmon Recovery Plan for SE Washington (SRSRB 2006)
- Response to ISRP comments on BiOp proposal, Tucannon River Programmatic Habitat Project (SRSRB 2011)

Table 6-1 summarizes the limiting factors considered for each of these efforts and displays how these limiting factors changed as conditions in the basin have improved and additional information has been collected.

Table 6-1
Summary of Life History Stages and Limiting Factors

Salmon Life History Stage	EDT Limiting Factors [1]	Key Limiting Factor [2]	Cause of Problem	2011 Salmon Recovery Plan Obj. [3]	2011 Programmatic Objectives [4]	2020 Prioritization Goals [5]	2020 Prioritization Objectives [5]	Expected Ecological Response [5]	Assessment Method [8]
Spring Chinook Egg-Fry	Sediment Load [A, a] Temperature [b] Channel Stability [C] Habitat Diversity [D]	Large Wood Log Jams Confinement [F] Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function	Riparian: > 40-70% max LWM: > 1 key piece/channel width Confinement: < 20-50% of Length Temperature < 4 day > 72°F Embeddedness: < 20% [G]	OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-6 [H]	Increase complexity at low-winter flows, during spring and winter peaks Reconnect abandoned floodplains Increase retention and storage of bed load gravel	Flow Complexity to levels of current 90th percentile of basin for low-winter and mean spring/winter peaks 75% of the available floodplain is connected at the 2-year event > 15% pool area	Improved habitat conditions for summer and fall juvenile rearing and winter refugia Improved extreme event refugia, riparian growth, wood material availability, bedload material availability juvenile rearing	Channel complexity at low-winter, mean-winter, and 1-year flow Channel aggradation floodplain potential, encroachment removal, and total floodplain potential Excess transport capacity, connectivity, and complexity analysis
Spring Chinook Fry-Smolt	Temperature [B] Channel Stability [C] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function		OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-5				
Spring Chinook Adult	Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Riparian Function Key Habitat (pools) Temperature	Loss of channel process and complexity		OBJ-1, OBJ-3, OBJ-4, OBJ-5	Improve quantity and quality of pools	> 15% pool area	Improved adult holding and cover	Pool frequency analysis and excess transport capacity analysis
Steelhead Egg-Fry	Sediment Load [A, a] Temperature [b] Channel Stability [C] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature Sediment [A]	Channelization, loss of floodplain and riparian, loss of channel complexity and function	Riparian: > 40-70% max LWM: > 1 key piece/channel width Confinement: < 20-50% of Length Temperature < 4 day > 72°F Embeddedness: < 20% [G]	OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-6 [H]	Increase complexity at low-winter flows, during spring and winter peaks Reconnect abandoned floodplains Increase retention and storage of bed load gravel	Flow Complexity to levels of current 90th percentile of basin for low-winter and mean spring/winter peaks 75% of the available floodplain is connected at the 2-year event > 15% pool area	Improved habitat conditions for summer and fall juvenile rearing and winter refugia Improved extreme event refugia, riparian growth, wood material availability, bedload material availability juvenile rearing	Channel complexity at low-winter, mean-winter, and 1-year flow Channel aggradation floodplain potential, encroachment removal, and total floodplain potential Excess transport capacity, connectivity, and complexity analysis
Steelhead Fry-Smolt	Temperature [B] Channel Stability [C] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function		OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-5				
Steelhead Adult	Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Riparian Function Key Habitat (pools) Temperature	Loss of channel process and complexity		OBJ-1, OBJ-3, OBJ-4, OBJ-5	Improve quantity and quality of pools	> 15% pool area	Improved adult holding and cover	Pool frequency analysis and excess transport capacity analysis
Fall Chinook Egg-Fry	Sediment Load [A] Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature Sediment [A]	Channelization, loss of floodplain and riparian, loss of channel complexity and function	Riparian: > 40-70% max LWM: > 1 key piece/channel width Confinement: < 20-50% of Length Temperature < 4 day > 72°F Embeddedness: < 20% [G] Note: The Recovery Plan identifies these objectives as habitat recovery for the Tucannon downstream of Pataha Creek but not directly for fall Chinook.	OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-6	Increase complexity at low-winter flows, during spring and winter peaks Reconnect abandoned floodplains Increase retention and storage of bed load gravel	Flow Complexity to levels of current 90th percentile of basin for low-winter and mean spring/winter peaks 75% of the available floodplain is connected at the 2-year event > 15% pool area	Improved habitat conditions for summer and fall juvenile rearing and winter refugia Improved extreme event refugia, riparian growth, wood material availability, bedload material availability juvenile rearing	Channel complexity at low-winter, mean-winter, and 1-year flow Channel aggradation floodplain potential, encroachment removal, and total floodplain potential Excess transport capacity, connectivity, and complexity analysis
Fall Chinook Fry-Smolt	Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Confinement Riparian Function Key Habitat (pools) Temperature	Channelization, loss of floodplain and riparian, loss of channel complexity and function		OBJ-1 OBJ-2 OBJ-3 OBJ-4 OBJ-5				
Fall Chinook Adult	Temperature [B] Habitat Diversity [D] Key Habitat [E]	Large Wood Log Jams Riparian Function Key Habitat (pools, spawning riffles)	Loss of channel process and complexity		OBJ-1, OBJ-2, OBJ-3, OBJ-4, OBJ-5, OBJ-6	Improve quantity and quality of pools	> 15% pool area	Improved adult holding and cover	Pool frequency analysis and excess transport capacity analysis

Notes:

[A] – Fine sediment on redds is no longer an impact to salmonid redds upstream from Patah Creek and is identified as being only an active limiting factor downstream of Patah Creek.
[a] – Diminished or disrupted bed load in some reaches has led to insufficient gravel to support riffle and pool development.
[B] – Water temperature that is too cold or too warm can reduce the survival of all salmonids in the Tucannon River and is the result of poor river channel shape and loss of connection to the floodplain, leading to reduced hyporheic flow in channel and return flow from floodplain storage.
[b] – Egg-to-Fry stage are primarily impacted by low water temperature in the Tucannon River; for example, ice impacts to redds and larvae.
[bb] – Warm temperatures increasing moving downstream below the Tucannon Fish Hatchery Weir and more so below Marengo, WA.
[C] – Channel stability in the Tucannon River is best described as the plane bed channel with bed armor and entrenchment, which has led to increased stream power and bed scour and loss of floodplain connectivity and confinement.
[D] – Habitat diversity in the Tucannon River is the extent of habitat complexity within a river segment, including side channels at base flow up to ~ 5-year return flow, pools, riffles, and off-channel habitats on the floodplain.
[E] – Key habitat is referring directly to the number of pools, spawning riffles, and off-channel rearing habitats including large wood log jams.
[F] – Floodplain and river meander confinement.
[G] – Embeddedness is a restoration objective for the lower Tucannon River below Pataha Creek and is not currently limiting above Pataha Creek.
[H] – The programmatic objective for embeddedness < 20% for all reaches above Pataha Creek is currently being met.
[1] – The limiting factors used in this table were taken from the Salmon Recovery Plan for SE WA (2011) Chapter 5 (Table 5-1).
[2] – The key limiting factors for the Tucannon River are listed in full detail in the Salmon Recovery Plan for SE WA (2011) Chapter 5 (Table 5-2).
[3] – A summary table of restoration objectives is provided in the Salmon Recovery Plan for SE WA (2011) Chapter 6 (Table 6-2).
[4] – For a full description of the Programmatic Restoration objectives, see Table 1-1 in this report.
[5] – A list and full description is provided in Table 1-2 in this report.

Working in concert with these efforts is addressing the longer term processes that the current strategies target. Addressing impaired processes such as floodplain connectivity will contribute to reversing negative trends in longer term processes, for example establishing and maturing riparian forests increasing resiliency and the natural long-term recovery of the basin. Table 6-2 summarizes the impaired processes and limiting factors as understood by the SRSRB and its restoration partners at the time of this assessment.

Table 6-2
Summary of Impaired Processes and Limiting Factors

Impaired Processes	Causes	Limiting Factors for Fish and Wildlife
Reduced in-channel structure (e.g., wood)	Past removal of wood from channel	• Low diversity of in-channel habitats • Lack of deep pools for holding or rearing • Limited quantity of off-channel habitat • Lack of cover
	Lack of large trees in the riparian zone	
	Historical channel straightening and levee building	
	Much of the existing wood is highly mobile	
Modified sediment delivery and transport	Loss of in-channel structure increases transport and bed incision	• Low diversity of substrates and potential for coarsening over time • Reduced quality of spawning gravel
	Levees reduce floodplain storage and exchange	
	Reduced riparian density increases bank erosion potential (i.e., fine sediment delivery)	
	Bank armoring reduces channel migration (i.e., coarse sediment delivery)	
Reduced floodplain connectivity and function	Channel incision from reduced in-channel structure	• Limited quantity of off-channel habitats • Low diversity of off-channel habitats • Lack of high-flow refugia • Reduced groundwater recharge and discharge
	Bank armoring and other geomorphic impediments	
Reduced riparian condition and function	Past removal or harvest of riparian vegetation	• Limited cover • Low diversity of in-channel or off-channel habitats • Reduced nesting and foraging habitats • Reduced productivity of food webs • High water temperatures (primarily downstream)
	Widespread colonization by invasive species	
	Rapid bank erosion and human/animal trampling prevents maturation of riparian plantings (some locations)	

7 Restoration Strategies

The restoration opportunities presented in this report are focused on promoting natural geomorphic and ecological processes to restore ecosystem functions. Developing restoration strategies that take advantage of those opportunities and promote natural processes is vital to providing the greatest benefit to salmonid abundance and productivity in the near term, as well as long-term sustainability of project actions. In order to adequately understand how process-based restoration strategies can be used to promote the goals and objectives of this assessment, this section examines the driving geomorphic processes and the expected geomorphic response of each prioritization goal. Through understanding the driving geomorphic processes of the prioritization goals, process-based restoration strategies have been developed that are expected to induce the desired geomorphic processes to achieve the prioritization goals and objectives and promote the desired ecological response. Section 7.2 describes the general restoration strategies that may be identified as an opportunity in any given project area, along with the physical and biological benefits of each opportunity, and which analysis results were used to inform each restoration opportunity.

7.1 Consistency with Natural Geomorphic Process

In order to develop process-based restoration strategies to meet the goals of the prioritization, it is necessary to first understand the physical and ecological processes that support those goals. There are specific physical and ecological processes that support the prioritization goals and proposed restoration strategies. These restoration strategies focus on the following geomorphic processes: bedload sediment transport, floodplain connection and inundation, wood material recruitment, and channel confinement and incision. Table 7-1 shows how the goals of this prioritization are related to these geomorphic processes, which are discussed in more detail in the following section. Additionally, Table 7-1 provides a description of the type of response that can be expected from the advancement of the prioritization goals and how this response relates to maintaining the natural fluvial processes in the basin. Because these goals and the geomorphic processes behind them are all connected at some level, Table 7-1 lists what other goals will be affected by the driving geomorphic processes and the expected responses.

Table 7-1
Prioritization Goals and Their Driving Geomorphic Processes

Goal	Driving Geomorphic Processes	Expected Geomorphic Response
Increase complexity at low-winter flows	• Bedload sediment transport and availability • Floodplain connection and inundation • Wood material recruitment	Channel systems that change primary low-winter flow paths year to year and are resilient to catastrophic change, and incision via maintenance of multiple low-winter flow pathways.
Increase complexity during spring and mean-winter peaks	• Bedload sediment transport • Floodplain connection and inundation • Wood material recruitment	Channel systems maintain low velocity alternative channels during high-flow events by causing yearly geomorphic change to the banks and floodplain. Dynamic channels mobilize sediment stored in the floodplain and recruit wood material from riparian areas.
Reconnect disconnected and abandoned floodplains	• Bedload sediment transport and availability • Floodplain connection and inundation	Floodplains that are inundated every few years allow for greater riparian growth of native species, and therefore allow for an increase of wood material on the floodplain. Low-lying connected floodplains allow for more frequent channel avulsions and increased complexity.
Improve quantity and quality of pools	• Bedload sediment transport and availability • Wood material recruitment	Pools store water, increase hyporheic exchange, and recharge groundwater, allowing for healthy riparian areas and wood material rejuvenation in the floodplain.
Increase retention and storage of in-channel bedload sediments	• Bedload sediment transport and availability • Wood material recruitment	Bedload sediment material that is mobilized on a yearly basis allows for complex dynamic channels, changing bedforms, formation of pools with instream wood, and connection to riparian floodplains.

The most encompassing process listed in Table 7-1 is bedload sediment transport, including mobilization and availability. This process influences the availability of gravel and cobble material that is necessary for geomorphic change in the Tucannon River. It has been noted through experiential knowledge that lack of these materials often causes restoration projects to respond slowly or not at all, preventing geomorphic change from occurring. In functioning reaches of the Tucannon River, alluvium that can be mobilized with a 1- to 2-year flow event is continuously stored in and released from the floodplain and channel as channel migrations and avulsions occur through the floodplain. These migrations and avulsions are in turn caused by the deposition of similarly sized material from upstream reaches in a process that drives the complexity and geomorphic change in the Tucannon River. The availability and deposition of this material directly in the channel also raises the overall water surface in a reach and allows for more frequent floodplain inundation. Therefore, the transport and availability of this material through either upstream channel dynamics or gravel augmentation is essential to all of the goals of this prioritization.

The process of floodplain connection and inundation is similarly essential in that it allows for connection and recharge of groundwater and healthy riparian growth. Many native riparian species depend on this semi-annual source of water in the Tucannon River ecosystem, and therefore this process drives wood material rejuvenation and eventual recruitment. Regular access to the floodplain allows for geomorphic change such as bank erosion, meander bar building, and channel migration. Because of this, the goal of reconnecting disconnected and abandoned floodplains is also tied indirectly to the goals of increasing low-winter flow, mean-winter flow, and 1-year flow complexity.

Closely tied to the processes of floodplain connection and bedload transport is the process of wood material rejuvenation and recruitment. Shallow groundwater in connected floodplains (supplemented by the Tucannon River) supports the growth of floodplain forests which are the source of large wood recruitment into the Tucannon River. As geomorphic changes occur, this wood is recruited into the active channel along with easily transportable gravel material, eventually causing more geomorphic change, and complexity. When adequate sediment is available, large wood also aids in the creation of pools. In this way the process of wood material rejuvenation and recruitment is a crucial step in the long-term maintenance of the goals of complexity for low-winter, mean-winter, and yearly flows, as well as the formation of pools and in-channel complexity.

7.2 Habitat Restoration Actions

The fundamental tenet of the strategies for restoration opportunities identified in this assessment is that promoting geomorphic change and channel mobility allows for the natural creation and maintenance of beneficial habitat conditions, both in channel and in the larger riparian area. Enhancing habitat may be accomplished by undertaking a variety of treatment actions within the main channel, along the banks, and within the riparian zone and floodplain. In the previous sections, driving geomorphic processes and expected responses were related to the goals and objectives of this prioritization. Restoration strategies presented here have been conceptualized and developed to directly influence those driving geomorphic processes and bring about the expected geomorphic change for each prioritization goal. Table 7-2 presents the restoration strategies that will be identified for each goal based on the driving geomorphic processes. For each of the project area cut sheets in Appendix J, these restoration strategies will be discussed for use in the specific circumstances of the project area, using the assessment results in Table 7-2 as key indicators for when these restoration strategies should be employed. Each project area presents its own unique set of circumstances, limitations, and requirements, so not every one of the restoration strategies indicated by the assessment results may be used for the individual project area. However, the strategies listed in this table present a range of conceptual strategies that could be used to address the driving geomorphic processes. These strategies and how they will influence the driving geomorphic processes are discussed in greater detail in the following sections.

Table 7-2
Restoration Strategies for Geomorphic Processes and Goals

Goal	Driving Geomorphic Processes	Assessment Result Indicators	Restoration Strategies
Increase complexity at low-winter flows (~130 cfs)	• Bedload sediment transport and availability • Floodplain connection and inundation • Wood material recruitment	• Standardized Complexity Evaluation at Low-Winter Flow	• Gravel augmentation for channel dynamics • Address encroaching features • Reconnect/develop side channels • Develop instream structure (wood) • Riparian zone enhancement for wood recruitment
Increase complexity during spring and winter peaks (~1,000 cfs ??)	• Bedload sediment transport • Floodplain connection and inundation • Wood material recruitment	• Standardized Complexity Evaluation at Mean-Winter Flow • Standardized Complexity Evaluation at 1-year Flows • Excess Transport Capacity	• Gravel augmentation for channel dynamics • Address encroaching features • Reconnect/develop side channels • Develop instream structure (wood) • Riparian zone enhancement for wood recruitment
Reconnect disconnected and abandoned floodplains	• Bedload sediment transport • Floodplain connection and inundation • Channel confinement and incision	• Channel Aggradation • Encroachment Removal • Excess Transport Capacity	• Channel aggradation to reverse incision • Address encroaching features • Reconnect/develop side channels
Improve quantity and quality of pools	• Bedload sediment transport • Wood material recruitment	• Pool Frequency Analysis • Excess Transport Capacity	• Gravel augmentation for channel dynamics • Address encroaching features • Develop instream structure (wood) • Riparian zone enhancement
Increase retention and storage of in-channel bedload sediments	• Bedload sediment transport • Channel confinement and incision • Wood material recruitment	• Excess Transport Capacity • Channel Aggradation	• Gravel augmentation • Address encroaching features • Develop instream structure (wood) • Riparian zone enhancement for wood recruitment • Modify or remove obstructions

7.2.1 Project-Specific Gravel Augmentation

The availability of bedload material that can be mobilized on a 1- to 2-year basis in the Tucannon River has been identified as a primary factor in the success of restoration projects in the Tucannon Basin. Restoration actions and natural LWM that do not have access to a supply of bedload material mobilized on a 1- to 2-year basis are often associated with slow or delayed geomorphic change based on local observations. Oftentimes channels that do not have access to this material are, therefore, plane-bed, homogenous, and incised. Incised and plane-bed channels in turn transport material extremely effectively further limiting in-channel structural complexity. Minimizing structural complexity exacerbates the problem in a feedback loop where there is not enough transportable material to cause complexity and not enough complexity to retain transportable material in the channel. As discussed previously, this feedback loop has drastic effects on every one of the goals for this prioritization: complex channel systems cannot occur, channels become incised and floodplains become disconnected, pools do not form, and sediment is not retained in the system.

Within the Tucannon Basin, it is now recognized that the solution to this problem cannot only be found in any one restoration strategy. In the past, adding woody material to force geomorphic change has been attempted as a restoration strategy for reaches experiencing this feedback loop. However, some of these restoration strategies have not performed on the desired time frame, possibly due to the lack of mobile gravel/cobble material. Instead, it is now believed by local experts and restoration practitioners that both the addition of LWM and the addition of mobile gravel bedload material is necessary to promote geomorphic change and "jumpstart" natural processes. To provide a reliable source of this gravel bedload material and accelerate improvements, gravel augmentation is identified as a restoration opportunity for suitable areas within the basin. Gravel augmentation has historically been used to supplement salmonid spawning habitat (Merz et al. 2004; Zeug et al. 2013) but has increasingly been recognized as having a positive effect on juvenile rearing habitat associated with floodplain connectivity and complexity (Sellheim et al. 2016). However, just as adding wood structure alone did not always produce desired results, gravel augmentation is a restoration strategy that should always be performed in tandem with the development of instream structure and addition of LWM. Without instream structure to trap and retain some of this sediment and promote geomorphic change, gravel augmentation will, at best, be a temporary boost to complexity and connectivity. At worst, augmented gravel could be washed through the targeted restoration area without causing any change. By supplementing gravel material and developing instream structure, the physical processes of sediment deposition and mobilization can jumpstart geomorphic change and help maintain functional geomorphic process over time.

While all of the restoration strategies affect the natural processes occurring in the river, and therefore can and often do affect project areas outside of the immediate target, gravel augmentation in particular has far-reaching effects that exceed the bounds of one or two project areas. Section 9 develops an overarching plan for strategically implementing gravel augmentation in the Tucannon Basin, based on the metrics and analysis results developed for this prioritization. It describes how to consider gravel augmentation as one element in a larger restoration strategy for a site, and how to integrate it into a basin-wide strategy. Appendix L lays out a comprehensive plan for long-term gravel augmentation at specific sites.

7.2.2 Reconnect Side Channels and Disconnected Habitat

Off-channel habitat provides critical holding and rearing habitat for juvenile salmonids during moderate to high flows and often provides preferred habitat conditions at lower flows. Several disconnected features are present in the Tucannon River floodplain, including off-channel wetlands that are wetted during part of the year and become disconnected at lower flow periods, disconnected side channels, and floodplain areas.

Encouraging reconnection of these features will increase habitat complexity by providing off-channel habitat and increased connectivity with the channel where disconnected features become cut off or create stagnant conditions during the dry season. Reconnecting these areas will allow fish to move in and out of these features for longer periods of time and enhance water quality conditions, particularly during low flows.

Actions for reactivating disconnected habitat may include earthwork to establish hydraulic connections with the main channel, aggradation of the main channel to provide more consistent connection or installation of LWM to backwater flows in the main channel or assist in keeping pathways to the main channel accessible.

Side channels often provide preferred rearing habitat during low flows and provide hydraulic refuge and cover during high flows (see Appendix J for specific locations). Encouraging multiple flow paths will increase habitat complexity by diversifying the planform, dissipating stream energy, distributing sediment load, and providing hydraulic complexity. Diverse floodplain and side channel networks often have multiple flow paths at various elevations across the valley bottom. Therefore, different channels are accessed at different water surface elevations. In this manner, off-channel habitat is accessed in different areas of the channel network under changing flow regimes providing a multitude of habitat during a large range of flow conditions.

7.2.3 Address Encroaching Features

Tens of thousands of linear feet of levees confine the mainstem Tucannon River and prevent or limit a surface water connection to the adjacent floodplain (see Appendix J for specific locations). In these areas, levee removal and/or setback may be used to increase the active floodplain area, thereby promoting floodplain and side channel connectivity and more natural channel migration processes. In a majority of the locations identified, working outside the limits of existing irrigation areas will allow widening of the floodplain corridor without significant changes to agricultural practices by working outside the limits of existing irrigation areas as much as possible.

Removing levees and promoting floodplain connectivity encourages geomorphic processes while dissipating velocities during high flows as floodwaters are distributed onto the floodplain. This also allows fine sediment to deposit on the floodplain, promoting ecological processes. Decreased channel velocities may also lessen erosive energy along the banks in areas of concern for landowners. Allowing the channel to migrate throughout a wider corridor will encourage development of complex channel and planform geometry, distributing energy and sediment load. It will be important to consider the reach-scale effects of widening the floodplain, particularly at the downstream end of confined reaches. For example, creating an unconfined floodplain below a tightly confined section will likely result in a large amount of sediment deposition and channel migration.

7.2.4 Develop Instream Structure – Wood Placement

Instream habitat complexity is correlated to hydraulic complexity created by the channel geometry, bedforms such as gravel bars and pools, hardpoints such as bedrock, and perhaps most importantly to the presence of LWM. The primary biological function of LWM in rivers and streams is to provide complexity that creates hydraulic refuge and cover for adult and juvenile salmonids.

In natural systems, riparian trees often enter a watercourse as the result of erosion, windfall, disease, beaver activity, or natural mortality. However, in most Pacific Northwest river systems, including the Tucannon River, LWM has been removed from the river channels and cleared from riparian areas. In addition, a significant quantity of natural LWM that would otherwise be recruited from riparian areas has been removed by logging and agricultural practices. Anthropogenic activities in the basin have decreased the number, size, and volume of LWM being introduced to the river through natural processes. Therefore, installing LWM is necessary to supplement existing conditions, recognizing that it will take decades of riparian planting and development to begin to provide natural replenishment rates. In the long term, the added channel and bank roughness created by wood structures will help retain additional mobile wood and sediment, diversifying hydraulic and bedform complexity and contributing to increased floodplain connectivity and functionality of floodplain processes over time. For the Upper Tucannon River Major Spawning Area, the Snake River Salmon Recovery Plan recommended at least two pieces of LWM per channel width (SRSRB 2006). Installation of rock structures is also considered as an option to add instream complexity, particularly in areas where bedrock already interfaces with the channel.

7.2.4.1 LWM Placements

LWM placements that are suitable for placement in the Tucannon River include single-log placements or multiple-log assemblies with rootwads that are installed in the channel bed or bank to create beneficial fish habitat and desired geomorphic effects. These features emulate natural tree fall of mature riparian trees and provide a base for mobile wood to accumulate. The different types of LWM placements have varying levels of engineering and construction effort and range in magnitude of physical and biological benefit. LWM is generally considered more mobile than the engineered log jams described in the next section. However, after the 2020 flow events, much of the placed wood is believed to have traveled less than a few hundred meters from placement and often the wood was found to be stable in the placed location.

7.2.4.2 Engineered Log Jams

Engineered log jams (ELJs) are large wood structures that can be placed in the main channel that emulate naturally occurring, stable log jams. Historically, several log jams per mile were likely present in the main channel, but they have either been cleared or are no longer able to become established due to a lack of mature riparian trees being recruited to the river, particularly in reaches where the local riparian conditions are poor. ELJs are typically placed along the bank or in the channel with the bottom of the structure at the anticipated scour depth and the top built to the approximate height of the 100-year flood water surface elevation. The structure is backfilled with streambed materials for stability, and a gravel bar deposit may be placed in the lee of the structure that emulates the natural sediment deposit that would occur. ELJs are generally designed to be more stable and less mobile during flow events compared to placed LWM with light or simple anchoring.

ELJs can create large flow stagnation areas upstream and downstream of the structure and contain a substantial amount of void space within the logs and root masses, providing considerable area for fish refuge. During high flows, the rootwads interact with hydraulic forces from the river and scour large, deep pools that provide holding areas for adults while the void space within the face of the structure is used by juveniles. In addition, these structures are able to retain mobile wood debris. Because of the hydraulic conditions and hard points created by ELJs, they may also be used as "deflectors" to influence flow direction to promote channel expansion or to activate side channels.

On a reach scale, installation of multiple ELJs can influence gravel movement and deposition to create localized pool-riffle sequences, increased hydraulic complexity, and a more stable channel profile. Sediment storage and deposition adjacent to the ELJs can create large gravel bars in the active channel allowing for colonization of riparian vegetation and eventually the development of forested islands. The overall roughening of the active channel and aggrading of the riverbed promotes rehabilitation of natural processes, which increases floodplain connectivity and promotes channel migration.

7.2.5 Riparian Zone Enhancement

Riparian habitat enhancement will involve protection of healthy riparian areas, removal of undesirable vegetation, and planting of native riparian communities on the channel banks, on higher elevation gravel bars, and in the floodplain. However, establishment of the ideal riparian buffer width may be limited by the location of agricultural fields, infrastructure, and the feasibility of irrigating and maintaining plantings. Riparian planting may also be conducted in conjunction with LWM structure placement, including ELJs.

The riparian zone provides several habitat and physical process benefits including increased bank and floodplain roughness, cover, and nutrients for instream species and wildlife. Increased roughness encourages sediment deposition and decreased channel and overbank velocities during floods. Additionally, fully developed mature riparian areas are a source of LWM to the river over time. Riparian restoration should begin with protection of existing healthy riparian areas through programs such as the Conservation Reserve Enhancement Program. Where riparian habitat has been degraded, removing invasive plants and vegetation and replacing with native species in appropriate environments should be performed. For example, cottonwoods or willows may be planted in wetter areas such as along the banks, as opposed to drier floodplain terraces. Monitoring and maintenance of plantings for at least the first few years after planting, which will greatly contribute to the success of the restoration effort, may be required for permitting approval. Eradication of invasive species such as will likely require a longer and more involved maintenance and monitoring effort. Additional monitoring of project sites and areas targeting increased floodplain connectivity may be necessary as new planting areas may be necessary as new areas of the floodplain become connected.

7.2.6 Modify or Remove Obstructions

Three primary obstructions to fish passage were identified in the mainstem Tucannon River: Starbuck Dam, Tucannon Falls, and the Hatchery Dam. Although adult fish are able to pass these features, there may be impacts to juvenile salmonids and non-game native fishes (SRSRB 2006). These features may have led the lesser density of non-game native fish in the Tucannon Basin. In addition, the hydraulic conditions created by flow obstructions can adversely affect habitat quality. Extensive sections of upstream backwater often lead to deposition of sands and gravels on the upstream side, potentially starving the channel downstream of easily transportable material and LWM. Removal of obstructions would allow for more natural sediment and woody debris transport and better allow natural evolution of the channel grade and planform. Hence, a consequence of obstruction removal would likely be some adjusting of the channel bed elevation; removal must consider the future evolution associated with this action as additional bank stabilization actions may be required.

7.2.7 Long-Term Opportunity: Road Relocation

Throughout the Tucannon Basin, multiple roads, including Highway 261 in the lower basin, exist in the riparian and active floodplain of the Tucannon River. For nearly the entire river length in this assessment, Tucannon Road and Highway 12 run parallel to the river. Other county, local, and private roads often run parallel to the river as well. Roads running parallel to the river can effectively act as well-established levees, preventing channel migration and inundation in the floodplain. Many other roads run perpendicular to the river and many bridges have been identified throughout the basin. Perpendicular roads and bridges often limit channel migration, restrict the width of the floodplain, and frequently need to be protected with riprap or other hard engineering solutions. Sometimes roads being located in the floodplain is an unavoidable situation with no reasonable alternative.

However, there are several instances in the Tucannon Basin where there are reasonable alternative locations for both parallel roads and perpendicular roads and bridges, and moving these out of the floodplain could have major benefits to the natural geomorphic processes and habitat in the river. Road relocation is not a typically funded restoration project and likely would require the right set of circumstances to be considered a viable project. However, the enormous benefit that road relocation projects could provide is too valuable not to consider. Therefore, road relocations have been identified as "long-term" opportunities, in that they may not be part of the regular set of restoration work, but should be considered if the right set of regulatory, landowner agreement, and funding circumstances arises.

Long-term opportunities to relocate roads occupying the floodplain were developed using input from the previous Conceptual Restoration Plans from 2011 and 2012 (Anchor QEA 2011a, 2011b, 2012a, 2012b) Specific opportunities for road relocation can be found in the Project Area Cut Sheets in Appendix J and in the Conceptual Restoration Maps. Roads highlighted for relocation separate the channel from substantial floodplain area and act as levees that limit channel migration. Along with the road relocation opportunities, some bridges were suggested for relocation from areas where they act as floodplain bottlenecks to areas with floodplains already confined by levees. In other cases, road relocations were suggested that would enable bridges to be removed entirely, limiting the effects of bridges on channel confinement and sediment transport continuity. In all instances where road relocation was suggested, moving the road out of the floodplain will improve floodplain connectivity, reduce channel confinement and sediment transport capacity, and help restore beneficial riparian vegetation. All these actions are projected to be costly and thus are earmarked for long-term restoration potential.

7.2.8 Other Long-Term Opportunities

In addition to the removal of in-channel barriers and road relocations, the project area specific cut sheets (Appendix J) also highlight other long-term opportunities that could have major impacts on floodplain connectivity. The Floodplain Management Plan includes conceptual reconfigurations of many of the Tucannon Lakes, which could help minimize the impacts the lakes have on the floodplain and fluvial processes. Decommissioning some of the lake, while not discussed or recommended in the Floodplain Management Plan, may in some circumstances provide the highest benefit to fish and wildlife and should be evaluated but would require a specific and unique set of circumstances to maintain fishing opportunity while wild populations recover in the basin. Projects should be considered that strike a balance between these two factors, such as the Rainbow Lake project, which moved the lake impoundment partially out of the floodplain while maintaining fishing opportunities, as well as those outlined in the Floodplain Management Plan.

Large levees associated with Camp Wooten and the town of Starbuck represent areas of significant confinement and lack of floodplain. Any opportunity to alleviate the confinement due to these levees should be considered and evaluated for feasibility if the circumstances ever allow for it. The former railroad prism also acts as a confining feature in multiple project areas including Project Area (PA) 45 where a removal of the railroad grade was proposed.

8 Tucannon Programmatic Restoration Targets and Adaptive Management

Clear restoration targets and an efficient, concise adaptive management plan are important for the tracking of restoration progress, understand what treatment are most effective, and informing future decision making that will maximize the success of restoration activities in the Tucannon Basin. This document identifies restoration targets for evaluation metrics and adaptive management decision-making protocols that will promote successful long-term river and floodplain restoration implementation. This protocol will help track restoration success and make informed decisions on achievement of restoration goals and when necessary actions are needed to help achieve goals. In addition, it includes a process to identify and mitigate potential hazards that may arise as an outcome from habitat restoration actions.

In order to evaluate the success of the Tucannon Programmatic, restoration targets must be set and an adaptive management plan needs to be implemented. Table 8-1 provides a summary of restoration targets related to each of the Programmatic' s restoration goals. Post-implementation monitoring will compare site conditions to these targets when evaluating project performance.

Table 8-1
Habitat Targets Related to Programmatic Goals

Programmatic Goal	Restoration Goals and Objectives	Target Value	Basis of Target Values	Reference Section
Improve floodplain connectivity	The available 5-year recurrence floodplain is connected at the 2-year event	2-year connected inundation = 5-year available in 2017	5-year available floodplain defined by the 2017 1D model results. 2-year connected to be updated as projects are completed.	Appendix F and Section 10
Develop a high-functioning riparian corridor	The available riparian zone, as defined in Section 10 and Appendix K, will be vigorously growing with native deciduous species	25% of riparian area at 15–40-foot height class 40% of riparian area at 40–80-foot height class	2017 LiDAR dataset analysis comparison of first returns to bare earth	Appendix K and Section 10
Increase channel complexity at low-winter flows	Low-winter flow complexity to levels of current 90th percentile of basin	Low-winter flow complexity = 0.32	2017 complexity values from LiDAR water surface elevation raster as developed for this analysis. New complexity values will be compared against only 2017 complexity values. [1]	Appendix G and Section 10

Programmatic Goal	Restoration Goals and Objectives	Target Value	Basis of Target Values	Reference Section
Increase channel complexity during spring and winter peaks	Mean-winter and 1-year flow complexity to levels of current 90th percentile of basin	Mean-winter flow complexity = 0.5 1-year flow complexity = 0.645	2017 complexity values from 2D model inundation results as developed for the analysis. New complexity values will be compared against only 2017 complexity values. [1]	Appendix G and Section 10
Increase quantity of pools	Increased pool frequency	1 pool per 7 channel widths	Channel width is based on the inundated area at 300 cfs defined by the 2017 2D model results for mean-winter flow.	Not included in this document due to incomplete data
Improve quality of pools	Large, deep, channel-spanning pools	15% of wetted channel area is pool habitat	Channel area is based on the inundated area at 130 cfs defined by the 2017 2D model results for mean-winter flow.	Not included in this document due to incomplete data
Increase temporary storage of in-channel bedload sediments	No river segments significantly above the excess transport capacity regression line	Variation of 10% or less from transport capacity regression line	Based on the regression line defined in Appendix H.	Appendix H and Section 10

Note:

1. When calculating new complexity values for a project area it is important to use only the 2017 complexity values for the other project areas in the calculation process and not an updated database of current complexity. Complexity values are "standardized" in the calculation against other values, so if an updated database is used in the calculations, target values will increase as complexity increases.

Adaptive management should be considered if project areas are not achieving restoration goals after treatments have been implemented. Guiding principles for adaptive management in the Tucannon Basin are to: 1) work within the existing streamlined data collection and monitoring activities, rapid habitat assessments, and photograph documentation, such that it is repeatable and can be reproduced in the era of retreat from programmatic monitoring programs; and 2) use a combination of on-the-ground data collection and remote sensing to conduct implementation, effectiveness, and change detection monitoring. The general adaptive management process would be as follows:

1. Project area treatment
2. Performance monitoring (minimum 5 years, or after a 5-year return event)*
3. Assessment of habitat trends and goal attainment after 5 years
4. If new site-specific fish use data are available, consider those trends along with habitat trends
5. Determination of restoration action/no action
6. Adaptive management treatment design
7. Adaptive management treatment construction
8. Performance monitoring (start the cycle over)

* If no 2-year return period event occurs during this 5-year time period, it is possible that the lower flows have not produced desired geomorphic change or process and more time may be required for monitoring and adaptive management process.

Project Area Treatment

Within this framework, treatment should be considered a comprehensive effort that has the potential to result in reach-scale geomorphic change. If a project area has only been lightly or partially treated, then additional activities could occur prior to the 5-year monitoring period. Once those additional treatments occurred, the 5-year monitoring period would begin.

Performance Monitoring

During the 5-year monitoring period, the site would be evaluated periodically using rapid habitat surveys and other visual observations. These evaluations would be streamlined and there would likely be three or more surveys conducted within the monitoring period to help understand trends in recovery. In addition, these site surveys will be mindful of and record any potential risk that may have resulted from restoration activities. It is not expected that any detailed, data-intensive monitoring activities would occur specific to individual project, but more likely that data-intensive analyses would be completed in conjunction with future Light Detection and Ranging (LiDAR) data collection.

Assessment of Habitat Trends and Goal Attainment

After the 5-year (minimum) monitoring period, a detailed evaluation would occur that would include a qualitative/quantitative assessment and comparison of site conditions to restoration targets described in Table 8-1. While the intent of this assessment would be as quantitative as possible, it is understood that some attributes may be estimated based on available data. This assessment would include the direct data comparison, present difference value, as well as a trend attribute stating whether each element was trending toward the restoration target. This assessment would also include assessment of risk and risk tolerances.

Determination of Restoration Action/No Action

Determining the need for adaptive management action would be based on the assessment and consideration of the trends in the project area. For example, a given project area may not be meeting all targets, but recent progress has been observed and it is likely that the project area will meet goals within a few years. One key habitat element that could be used as an indicator that adaptive actions should be taken would be pools. If pools are not present or are not of sufficient size and depth, it is unlikely that other habitat metrics are trending toward recovery. Not meeting pool targets 5 years after implementation would trigger adaptive management actions. Another metric evaluation that would likely trigger a need for adaptive management would be if more than half of the habitat metrics are more than 20% off target conditions and trending even or negative. In addition, risks as a result of restoration activities would be evaluated and a determination of potential actions to reduce these risks would be made.

Adaptive Management Treatment Design

Once adaptive management actions have been determined to be necessary, design for treatments should be targeted toward specific habitat conditions that are lacking while also taking a process-based geomorphic approach to design.

Adaptive Management Treatment Construction

Plan for and implement the adaptive management action. This becomes the new treatment date.

Performance Monitoring

Start the cycle over at Step 2.

Existing Monitoring Protocols to be Augmented by this Protocol

LiDAR and aerial photography surveys:

- The Tucannon Programmatic uses LiDAR to collect basin-wide datasets on a reoccurring interval of approximately 8 years or immediately following flood flow events with a greater than 25-year return interval to conduct geomorphic change analysis of floodplain and channel complexity.
- A baseline data sample was collected in 2010 prior to the majority of restoration actions being implemented in the basin.
- A follow-up data collection event occurred in 2017/2018 to support an update to the Tucannon conceptual restoration strategy.
- In February 2020 the basin experienced an approximately 25-year flood event, which triggered the collection of LiDAR in late fall 2020 for the purpose of watershed evaluation and adaptive management and learning opportunities.

Rapid Habitat Survey

The habitat Programmatic also collects habitat data and maintains a dataset on restoration projects for the purpose of implementation and effectiveness monitoring. Restoration project areas are surveyed identifying channel complexity, LWM, floodplain connectivity, and pool presence and quality, in a before/after monitoring protocol with follow-up surveys beginning following significant flows or within 3 years of project completion.

9 Gravel Augmentation Basin Plan

9.1 Introduction

Investment in restoring salmonid habitat in the Tucannon River has been extensive, and results have been immediate in some cases. In other areas, the results were less than expected. Some of this has been attributed to the lack of large, bed-moving hydrologic events. Where results have been immediate, sediment supply has been high. Where sediment supply has been lower, habitat development has been slower to evolve or has not trended in the direction desired.

Gravel augmentation has been implemented in rivers for a variety of reasons, including feeding sediment-starved reaches, providing spawning-sized materials in degraded systems, and resetting the bed elevation of a stream (Merz et al. 2004; Sellheim et al. 2016). Gravel augmentation is proposed in the Tucannon River to support and accelerate the benefits of current restoration efforts in the basin by accomplishing the following:

- Mitigate for past dredging, straightening, and channelizing of the river.
- Reintroduce materials that have been used to levee off the floodplain, or lost into the floodplain through channel incision.
- Feed materials into degraded habitats.
- Feed materials into reaches treated with wood placement to accelerate habitat benefits.
- Improve floodplain connectivity.
- Promote channel complexity.
- Promote more natural transport and temporary storage of sediments throughout the basin.
- Promote more natural patterns of channel migration and natural creation and maintenance of riverine and floodplain habitat.
- Address concerns about starving river segments below heavily treated reaches.

Gravel augmentation should be thought of as one element of the overall restoration plan for the system, and planning should consider other restoration actions in the basin. Maximizing the benefits of gravel augmentation requires integration with and consideration of other restoration activities and the integration of these efforts. The following general thoughts have helped guide the development of the conceptual restoration plan:

- Consider the needs of the entire basin.
- Effort should be most intense in the upstream areas of the restoration plan to promote the achievement of goals progressing from upstream to downstream. This could be thought of as ground zero development from upstream to downstream. With the concept of jumpstarting geomorphic processes, gravel augmentation in the upper basin should supplement the need for gravel augmentation in the mid-lower basin through reactivation of natural geomorphic processes.

- Identify locations where placement can be efficient, effective, and routine.
- Feed areas where intense wood placement has been completed.
- Be mindful of sediment needs in locations downstream from intense wood placement.
- Integrate elements of gravel augmentation into other restoration implementation and management actions.
- Treat high-energy areas.
- Consider some sites that are purely feeding material.
- Consider some sites where gravel augmentation leads to large-scale restoration by lowering the floodplain or adjacent banks, creating large off-channel areas, and resulting in a high groundwater table from valley wall to valley wall.

9.2 Purpose and Need

The purpose of augmenting the gravel supply in the Tucannon River is to maximize the immediate benefits of restoration actions on a project scale and promote natural evolution toward more historical reach-scale river conditions. Since large-scale restoration in the Tucannon River began there have been concerns about how storing sediments in treatment areas may affect downstream reaches. Specifically, will this result in channel degradation and incision downstream of treated areas. Where gravel augmentation has been a project component, immediate floodplain connectivity and channel complexity has been realized. However, some locations downstream of wood placements have remained sediment starved and at risk to headcutting through treated locations upstream. Initial reports from the high-flow event in 2020 suggest that this may have occurred in a couple locations where floodplain connectivity and complexity gains may have lapsed.

Under more historical river conditions, the Tucannon River would have abundant sediment supply, regular bar forming and channel migration, and extensive sediment sorting and temporary storage. Augmenting the gravel supply is necessary to help reduce the "hungry river" effect that coarsens the riverbed and prevents sediment sorting and temporary storage. These supplemental materials will help jumpstart restoration treatments and promote increased floodplain connectivity and channel complexity, while helping reduce excess channel capacity. Where multiple flood flow paths are available to the river and groundwater elevations are sufficient to promote vibrant vegetative growth throughout the valley bottom, food web productivity will increase, and ecosystems will thrive.

9.3 Goals and Objectives

The overall goals of the gravel augmentation plan are as follows:

- Promote and accelerate the benefits of wood placement throughout the river through temporary storage local to log jams and feeding locations downstream of wood placement sites.
- Reconnect floodplain channels and upland to flood flows.
- Promote increased groundwater table throughout the valley floor.

- Promote vegetation growth throughout the valley floor.
- Feed high-energy/sediment starved river segments.
- Provide additional spawning opportunities throughout the basin.

9.4 Materials Sourcing

Sourcing of materials for use in augmentation will come from both local and import sources depending upon the placement location and available material. We expect sources to include the following:

- Floodplain benching
- Floodplain channel creation
- Existing stockpile areas in and adjacent to the floodplain
- Maintenance or emergency management activities

9.4.1 Materials Sizing

Before using material from any floodplain sourcing site, the existing material should be evaluated for gradation and content of fines. Gravel-sized material (4 to 64 mm) is generally preferable, although some content of small cobbles could also be used. Specific limitation will likely be determined by permitting, but locations with significant fines will likely need to be sorted before use. Excess fine material can be used on the floodplain where sourcing or placement is not recommended. Similarly, source locations with an excess of large cobbles and boulders will need to have those sorted out and not placed as part of gravel augmentation. The specifics of gravel sizing and sorting will likely need to be determined on a site-by-site basis during implementation.

9.4.2 Floodplain Benching

Floodplain benching involves cutting down the existing floodplain to allow for flood inundation much more frequently than under existing conditions. This will occur in locations directly adjacent to the river as well as in locations in the floodplain that are not near the existing river but will become inundated through benching. Benching will only occur in areas that are barren and not suitable for natural regeneration of valued deciduous vegetation. The target elevation for floodplain benching is the elevation of the 2-year recurrence flow with the reach. Providing the river access to the floodplain under 2-year recurrence flows will reduce hydraulic energy, increase nutrient exchange, and diversify flow conditions.

9.4.3 Floodplain Channel Creation

Within the floodplain benching areas, side channels will be excavated to help convey flows and distribute surface water throughout the valley floor. These channels will be excavated to the approximate 300 cfs water surface elevation.

9.4.4 Existing Stockpile Areas

Several stockpile areas exist within and adjacent to the floodplain. Sourcing from the floodplain areas also enhances floodplain connectivity. These sources are ideal for augmentation areas that are essentially feeding areas. Examples of these sources include PA 15 side channel materials and remnants in the PA 14 floodplain.

9.4.5 Maintenance and Emergency Materials

Maintenance dredge materials, such as at the Hatchery Dam, should be repurposed into the river as a routine practice. In addition, materials collected through road maintenance, drainage clearing, and other activities that produce suitable riverbed materials should be reintroduced to the river within this program.

9.5 Sequencing of Material Sourcing

Sequencing the sourcing of materials is an important consideration and should be focused on achieving the maximum immediate habitat benefits and reduction in hydraulic energy. Floodplain benching should begin with the areas directly adjacent to the river to maximize the area connected as early in the process as possible. Subsequent sourcing will work progressively across the floodplain connecting additional area. Side channels should begin excavation at the upstream and downstream extents. Excavating the upstream extents will help get flood flows out onto the floodplain during much lower flow rates and disperse these flows. Excavating the lower extents creates immediate alcove habitat for use by juveniles during spring runoff.

9.6 Monitoring for Success

Successful implementation will be evaluated through visual observation of several key evaluation criteria. This will include, but may not be limited to the following:

- Complete coverage of the mainstem channel with reduced grain size allowing for suitable spawning for multiple species
- Observed flood inundation area under 2-year and lessor recurrence flows
- Emergent deciduous vegetation growth, primarily cottonwood and willow, throughout the floodplain
- Presence of wetted side channels through most or all flow regimes

It should be noted that in order for many of these changes to occur and gravel augmentation to be successful, it is likely that LWM will be necessary as well. Amounts of LWM in an evaluation reach should be considered when monitoring for the success of gravel augmentation, and evaluated for supplementation along with corrective actions to the gravel augmentation program.

9.6.1 Mainstem Channel Grain Size

Much of the current bed material in the placement locations is coarse and not suitable for spawning for steelhead and other target and non-target species. One expected outcome of this program is a reduction in grain size of the bed material in the mainstem. Placement locations will be monitored for the following:

1. Did placed materials move? This evaluation will visually estimate and record the percentage of placed materials that were mobilized during higher flows.
2. Where did the materials go? This evaluation will track the movement of material to determine the distance of downstream movement and the approximate location of the river where finer bed materials are blanketing the riverbed after higher flows.

Once material from a placement site is blanketing the riverbed downstream to the location of the next placement site, monitoring will evaluate the downstream extent of movement collectively for the sites. This approach will be used for all sites such that the extent of success can be evaluated for the gravel augmentation program as a whole.

9.6.2 Flood Inundation at the 2-year Recurrence Flow and Below

Floodplain benching will target the 2-year recurrence flow elevation from the basin-scale model developed from the 2017 LiDAR data. As benching and gravel augmentation progresses, water surface elevations for a given flow will increase and benches should have flowing water at the 2-year event and get inundated at progressively lower recurrence flows. This progression will be monitored and the approximate extent of the inundated floodplain will be documented.

9.6.3 Emergent Deciduous Vegetation Growth

Emergent vegetation throughout the floodplain is an indicator of groundwater table and will be used to evaluate the success of the program. The extent of emergent growth will be monitored and documented as progress is realized. Once emergent vegetation growth is spread throughout the valley floor, gravel augmentation through this area will be considered successful and discontinuing augmentation will be considered.

9.6.4 Presence of Wetted Side Channels

Wetted side channels will be documented and used to evaluate complexity and program success. Ideal conditions would be multiple side channels through common winter flows and some perennial side channels through much of the river during summer low flow.

10 Geomorphic Analysis Summary and Evaluation

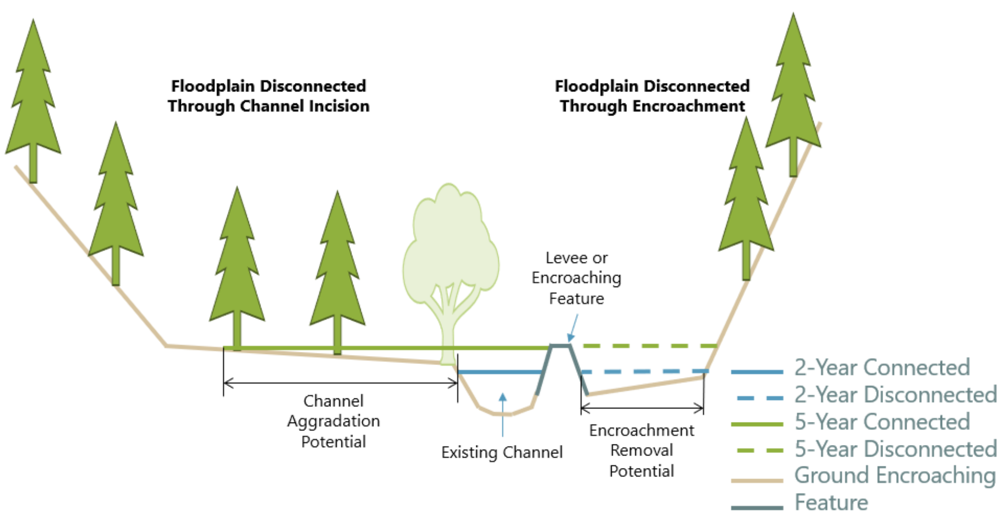
The analyses of this assessment were created to provide the information needed to meet the habitat targets and goals of the objectives. To that end the analyses were developed to use the updated data available to measure the key components of the habitat targets and programmatic objectives including Floodplain Connectivity, Channel Complexity, and Transport Capacity. The Floodplain Connectivity analysis measures the existing connected floodplain and potential floodplain targets and determines floodplain potential. The Channel Complexity analysis measures channel complexity at a variety of flow conditions and compares each project area against the range of complexity across the basin. Finally, the Transport Capacity analysis determines where the Tucannon River has too much sediment transport capacity for maintenance of natural geomorphic processes. All of these analyses were then looked at through the lens of measuring success and gaging direction. To that end these analyses provide the data for future evaluation, target setting and accomplishment tracking for each of these key metrics. The following summaries describe in more detail what these analyses are, and why they are important to the Tucannon River system and salmon recovery. Detailed instructions for performing these analyses as well as results for each project area can be found in the respective appendices.

10.1 Connectivity Analysis Summary

Increased floodplain connectivity comes with geomorphic, societal, and biologic benefits for a watershed. It can lead to increased channel complexity, reduce flood damage downstream, and improve riparian and instream habitat. With new access to floodplain area, a river is likely to establish additional channels on the floodplain that can provide flood refuge for aquatic species or that can incise and remain wetted at lower flows, increasing channel complexity and thus both riparian and instream habitat. Furthermore, greater storage capacity on the floodplain can reduce flood damage to communities downstream by flattening the curve of a flood’s hydrograph. Flood peaks farther down in the basin can be reduced by allowing more water on the floodplain in upstream areas of the basin, including the Wooten Wildlife Area, during higher flows such as 5-year return or greater. Connected floodplains provide benefit for nearly all riverine aquatic species in the form of hyporheic and riparian habitat, high-flow refugia, nutrient influx, and woody material supply. Additionally, connected floodplains, and the resilient ecosystems they support provide the material for instream wood, which in turn are key pieces of geomorphic processes associated with the functioning and resilient river system. In this analysis floodplain connectivity refers to floodplains that are connected hydraulically to the river through periodic inundation at 1- to 5-year return intervals, hyporheic flows, and groundwater connectivity. In other words, it looks only at the hydraulic connection of the floodplain to the river channel, but as described above, hydraulic connections in the floodplain are the building blocks for riparian ecosystems and geomorphic processes that provide multiple habitat benefits.

Confining features along the banks of the Tucannon River and on the floodplain have influenced hydraulic conditions during large floods, affecting local and reach-scale geomorphic processes such as sediment mobility and channel migration. Confining features may be both natural and influenced by anthropogenic activities. Inspections of aerial photography, LiDAR, and field reconnaissance were used to identify confining features within the study area. These features include bedrock along the valley wall, alluvial fan deposits, bank armoring (e.g., riprap), levees and pond berms, and road prisms. Additionally, the Tucannon River can be disconnected from the floodplain through channel incision and downcutting. Channel incision is often associated with encroaching features such as levees or bedrock valley walls because straightened channels provide more stream power for sediment transport. Channel incision is often the beginning of a cycle of sediment starvation. Appendix F of this report discusses channel incision in more detail, as well as a possible root cause and where it might be happening. The following connectivity analysis discusses the potential benefits of reversing this trend of channel incision, as well as the benefit of removing encroaching features and increasing the total area of connected floodplain.

Figure 10-1
Conceptual Cross Section of Floodplain and Floodplain Potential



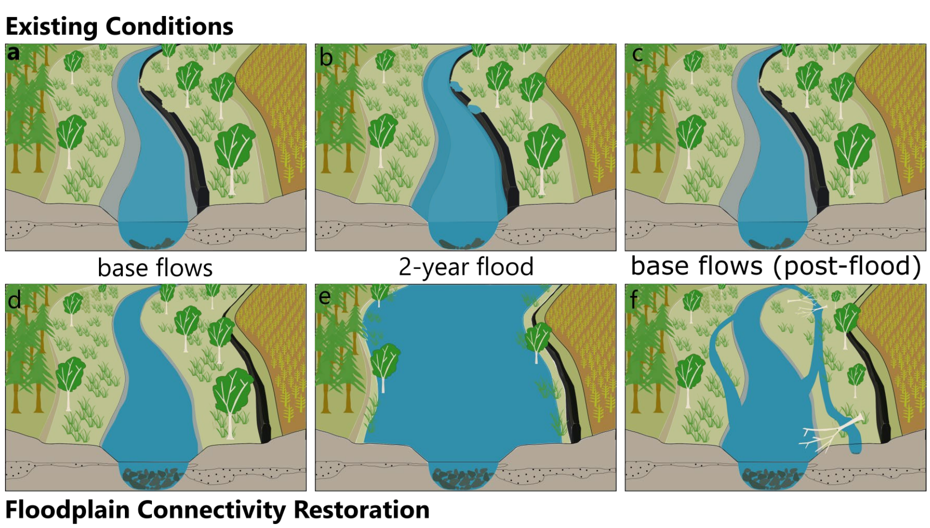
The purpose of this analysis is to describe the floodplain connectivity of a reach in a way that can be compared to the other reaches in the system and help inform potential restoration actions. The analysis focused on three characteristics of the floodplain:

1. The area of floodplain currently accessed and connected at a given flow event
2. The area that could potentially be accessed given the removal of encroaching features
3. The area that could be accessed given sediment deposition and reversal of channel incision

Figure 10-1 provides a conceptual valley cross section showing these three floodplain characteristics. The existing floodplain and potential floodplains are represented as lengths in this cross section but will be discussed as 2D (areas) for this assessment as the concept in Figure 10-1 is applied along the length of the valley for each assessment reach.

Removal of encroaching features and channel bed aggradation (or reversing channel incision) were identified as restoration actions that have the potential to provide the most benefit to floodplain connection. Figure 10-2 demonstrates how they can accomplish this goal. Panels a-c illustrate how encroaching features and channel incision can limit the river's connectivity with the floodplain by constraining the river to a narrower, deeper channel. Panels d-f illustrate the potential geomorphic response to the restoration efforts. Since these two metrics are directly related to floodplain connectivity, representations of them are easy to compute using the available data and analysis. It should be noted that these restoration actions, particularly channel bed aggradation, may be treating symptoms of other underlying problems with the geomorphic processes of the reach. When performing any restoration action, it is essential to consider the underlying drivers behind the current state of the reach in question, and address those as well. The restoration opportunities discussed here are identified simply as a measure of potential in the floodplain only. Section 7 explores additional restoration actions, measures, or considerations that may need to be taken to ensure the success of either of the above restoration actions.

Figure 10-2
Geomorphic Response to Removal of Encroaching Features and Bed Aggradation

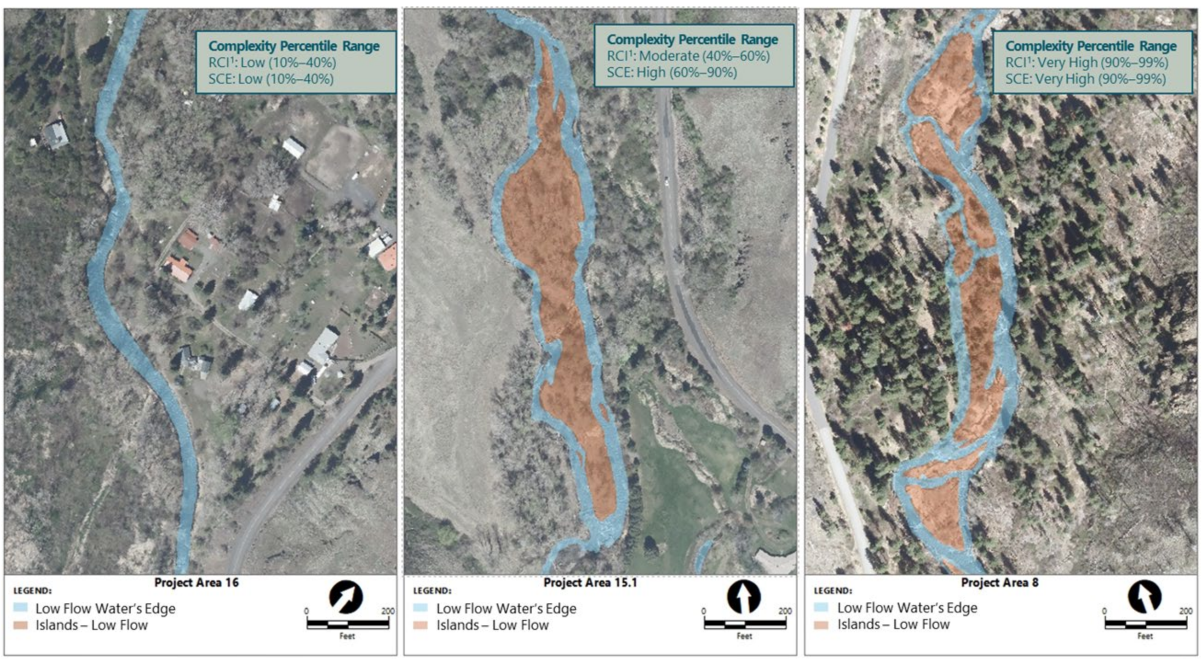


For this analysis, floodplain connectivity is a measure of the potential floodplain that could be gained with the restoration actions listed above. Each of the three above types of potential floodplain gain are weighted and combined for one connectivity score per project area. For more details on how this analysis calculates floodplain connectivity see Appendix F.

10.2 Complexity Analysis Summary

Complexity has taken on many meanings in the realm of fluvial sciences in multiple contexts, including ecologically and geomorphically. For this assessment, complexity primarily refers to the geomorphic concept of spatial heterogeneity of plan forms and channel types within the fluvial corridor. River reaches with multiple side channel, split flows or high sinuosity are thought of here as complex. Historically the Tucannon River was likely an anabranching river, which is defined as a multiple channel system characterized by forested and stable alluvial islands that divide flows up to bankfull, as shown in Figure 10-3. Much of the Tucannon River has diverged from the natural condition to a single planar bed, which is straighter, steeper, and wider than would be expected given valley characteristics.

Figure 10-3
Example of Complexity, From Uniform and Confined on the Left to Most Complex on the Right



Complexity is an important factor for both the geomorphic and ecological processes in a river corridor and the benefits of complexity have been discussed thoroughly in the literature of fluvial sciences (Amoros 2001; Carson 2007; Harrison 2009; Sheldon 2006; Wohl 2016). However, the geomorphic significance of complexity to river corridors has been well summarized into key points in Wohl 2016, of which four are directly relevant here:

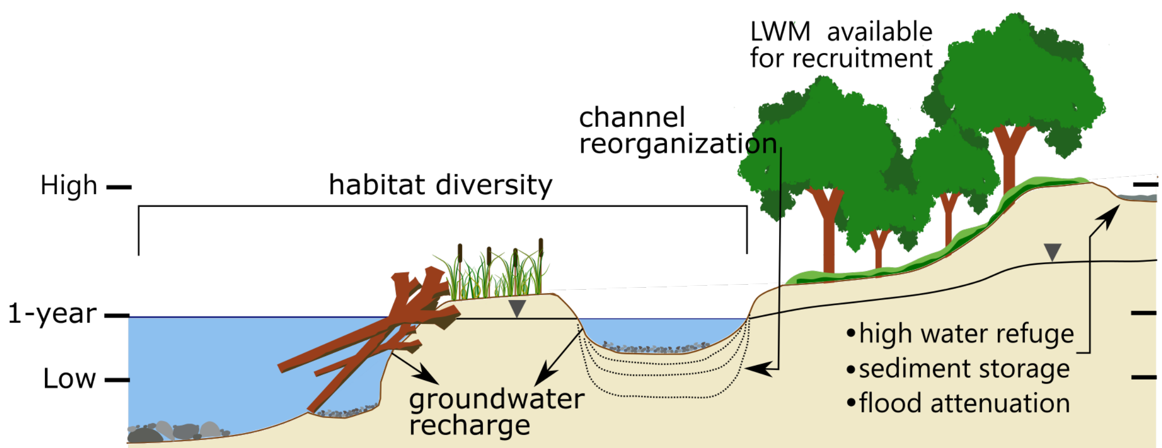
1. Provides habitat and biodiversity to the river system.
2. Attenuates downstream fluxes – of water (floods), sediment, and instream wood.
3. Provides resistance and resilience to catastrophic change.

4. Influences River Processes – sediment and wood transport, groundwater recharge, floodplain connectivity.

Note: Adapted from Wohl, 2016, Part II

Specific to the Tucannon Basin, channel and floodplain complexity have been identified as major objectives as complexity has increasingly been associated with juvenile salmonid rearing and over-wintering, as well as benefits for many other aquatic species of relevance based on local expertise and observations. In other basins throughout Washington and the Pacific Northwest, complexity is being recognized as an important factor for habitat and salmonid recovery at multiple life stages (Quinn and Peterson 1996; Collins and Montgomery 2002). Because of this multi-species and multi-lifestage benefit, it is important to examine a reach's complexity at several different flow levels—typically at lower, sustained flows (see Table 10-1).

Figure 10-4
Complexity at Multiple Flow Stages



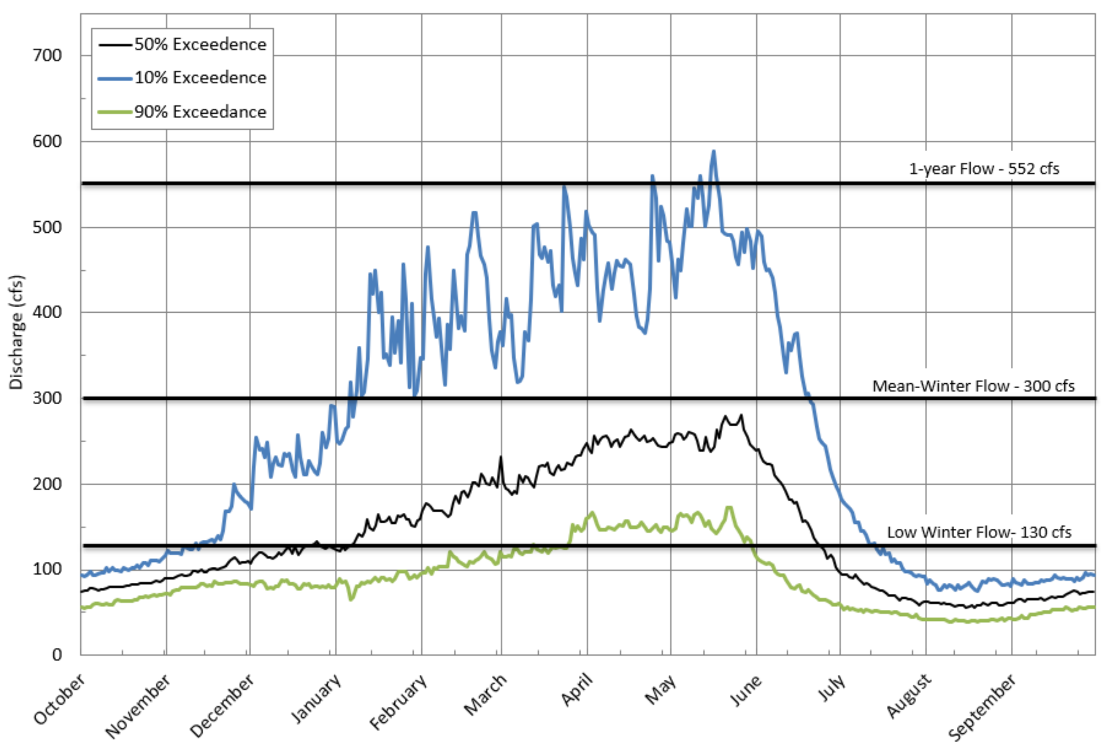
When complexity is maintained during summer low flows and winter flows, it indicates that side channels, backwaters, and other off-channel areas that are important for a variety of ecological process are sustained for longer periods of time and will therefore provide these ecological benefits including juvenile salmonid rearing for a large portion of the hydrograph. While the 1-year flow is episodic in nature, maintaining complexity at this flow level is important for both the geomorphic and ecological processes of the system. Channel systems that maintain and reoccupy alternative channels during high-flow events create geomorphically resilient systems that mobilize sediment stored in the floodplain and recruit wood material from riparian areas, both key aspects of the natural processes of a riverine system. Furthermore, the lower velocity channel alternatives, and backwaters indicated by complexity, provide essential hydraulic refugia for fish during these high-flow events. These three flows should represent the normal range of river conditions where habitat benefits from complexity are most relevant for juvenile salmonids. Figure 10-4 illustrates what complexity at these three flow stages might look like in the Tucannon River and highlights some of the geomorphological and ecological benefits described by Wohl (2016), and listed previously.

Table 10-1
Flow Used for Examining Complexity

Flow Description	Data Source	Flow Rate at Starbuck
Low-Winter Flow	Water Surface DEM	130 cfs
Mean-Winter Flow	2D Hydraulic Model	300 cfs
1-year Flood Event	2D Hydraulic Model	552 cfs

DEM: digital elevation model

Figure 10-5
Complexity Flows and Hydrograph at the Starbuck Gage, 10% 50% and 90% Flows from 1971 to 2019



This assessment uses three separate geomorphic indicators to determine the complexity of a reach:

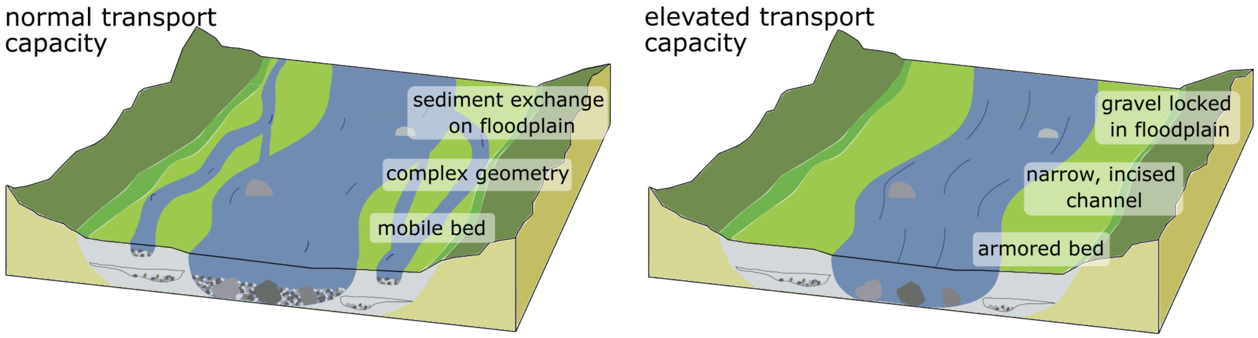
- Number of islands in the channel (and therefore number of side channels/split flows)
- Total size of the islands in the reach (perimeter length)
- Reach length sinuosity of the main channel

These three characteristics were chosen as they provide insight into how complex, and how close to the original anastomosing channel state the Tucannon River is in a given reach at a given flow. However, as discussed above, complexity is important for many different parts of the hydrograph such as habitat for salmonids at low flow, over-wintering and refugia during higher flows and attenuation of downstream fluxes at flood flows. For this reason, this analysis examines complexity at three flows shown in Table 10-1. These three flows are plotted on the mean hydrograph shown in Figure 10-5, and are a good representation of flows that would be experienced in a normal year. The complexity value used to assess reaches in this analysis is a combination of the previously listed geomorphic indicators (island count, island perimeter, and sinuosity) at the flows listed in Table 10-1. For more information about how complexity is calculated for this assessment see Appendix G.

10.3 Transport Capacity

The availability and abundance of gravel or small cobble-sized material in the plays a large role in the geomorphic processes that force bedforms, complexity, and connectivity. Figure 10-6 illustrates how these variables can vary in a reach based on the presence of gravel as determined by transport capacity. Through on-site assessment, it is clear that reaches with ample gravel to small cobble-sized material, available throughout the reach, form pools at instream wood locations more easily, access the floodplain more frequently, and develop complex side channels and split flows. The individual project area assessments show that many of these areas are associated with river avulsions or migrations shortly upstream, providing a potential source of these gravel-sized materials. However, for other reaches, as is often the case with confined and incised systems, the supply of material can become "locked" in the floodplain and is no longer accessed on a regular basis. The materials remaining in the channel bottom often represent lag deposits and collectively form an armor layer that resists pool formation and temporary sediment storage and facilitates high-energy flows through the reach. When this happens, a feedback loop of confinement and incision propagates and can extend downstream over time. Without human intervention or a large natural change, such as a large tree falling into the river and capturing additional wood and sediment, the dominant channel bed material becomes resistant to regularly occurring geomorphic change. With less frequent geomorphic change, the floodplain and the smaller material stored therein are accessed and mobilized less frequently, contributing to this feedback loop. The process of confinement often continues until a threshold and possibly catastrophic flow breaks the cycle.

Figure 10-6
Geomorphic Response to Elevated Transport Capacity



Note: both depictions have the same valley slope.

One solution to this cycle is to provide another source of material that is sized to be frequently mobilized. This material can quickly cause localized geomorphic change, which in turn will release material "locked" in the floodplain and jumpstart the process of sediment transport and minor avulsions or migrations. For this reason, gravel augmentation is one of the restoration opportunities identified in this assessment. However, to make decisions on the placement and amount of this restoration action, it is important to understand how the transport capacity of a reach might be different from other reaches in the basin.

The Excess Transport Capacity analysis described in Appendix H establishes a basin-wide trend in transport capacity based on the modeled shear stress and uses this trend to identify reaches of the basin where shear stress and transport capacity differ from the expectations for the basin. While this method does not determine what the transport capacity of a reach is, it can tell us something about how the reach is different from other similar reaches in this basin, and provide enough clues for better identification of opportunities for gravel augmentation and sediment transport continuity in general.

10.4 Riparian Vegetation Assessment

Riparian vegetation and geomorphic processes of the channel and floodplain are closely linked and exhibit multiple feedbacks. Vibrant floodplains provide immediate habitat for both aquatic and terrestrial species, but also influence geomorphic processes that lead to more beneficial habitat down the line. Channel complexity is important for providing rich and resilient habitat, and is largely influenced by patterns of vegetation. Vegetation amplifies complexity by diverting streamflow onto the floodplain when large pieces fall in the main channel and encouraging channel formation on the floodplain by routing streamflow and focusing stream power. Vegetation also increases roughness on the floodplain, which both reduces flood risk downstream, and increases deposition and temporary storage of sediment on the floodplain—the root benefits of floodplain connectivity.

Phreatophytes living adjacent to or in the active channel, such as reeds, sedges, or willows, can also trap sediment along the banks, building natural levees, and collecting nutrient-rich detritus, in even low-magnitude floods.

The Tucannon Basin has a long history of logging and land-clearing. The logging industry has removed much of the old-growth vegetation in the upper basin, drastically reducing the size and density of riparian trees. In the lower basin, land-clearing for agriculture and development has had similar effects and narrowed the riparian corridor. Further degradation of the riparian corridor was caused by the introduction of invasive species, which have outcompeted endemic vegetation. Historical accounts and photography indicate that before significant development in the basin, the riparian corridor of the Tucannon River was much denser than it is today.

Human development of the basin has also modified and halted geomorphic processes that have implications for riparian vegetation. Flood prevention and channel straightening measures reduce floodplain connectivity, which has a suite of implications for riparian vegetation, including lowering of the groundwater table and reduction of nutrient flux.

The riparian area has been further degraded by the halting of geomorphic processes like flooding and avulsion. Flood prevention and channel straightening measures have disconnected the river from its natural floodplain. This lowers the groundwater table and reduces nutrient flux, limiting plant growth. In addition, dams have reduced native migratory fish populations which bring nutrients from the ocean and lower basin into the upper basin.

The purpose of this analysis on the Tucannon River is to detect change in riparian vegetation since 2010 (the previous date of data collection) and to set a new baseline for comparison with detailed, repeatable steps (available in Appendix K). It allows for assessment of the current state of riparian vegetation and reveals trends in riparian conditions over time. Repeated scans of high resolution LiDAR data allow for the assessment of the overall coverage of riparian vegetation within the riparian corridor, and investigation in to the breakdown of vegetation heights, which can be used as a proxy for vegetation type and also show patterns in growth over time. Comparing the results to target values based on ideal conditions shows which project areas are lacking riparian vegetation and showing their trends over time reveals which project areas are in decline or moving towards a more robust riparian corridor.

The riparian vegetation analysis for this report uses a Canopy Height Model (CHM) to quantify the extent of riparian vegetation in each project area, and classifies the vegetation based on height as shown in Table 10-2. The CHMs were calculated as the difference between the first returns and the bare earth results from LiDAR datasets and sorted into vegetation size classes. Additionally, two CHMs were created using LiDAR data collected in 2010 and 2017 (QSI 2018). Comparing CHMs from different years allows for the quantification of change in the riparian vegetation. Interpretation of these results provides a way to assess the condition of riparian vegetation in each project area and to understand the trends of coverage and vegetation type over time. It also provides a baseline for future riparian vegetation analyses which will help inform restoration efforts.

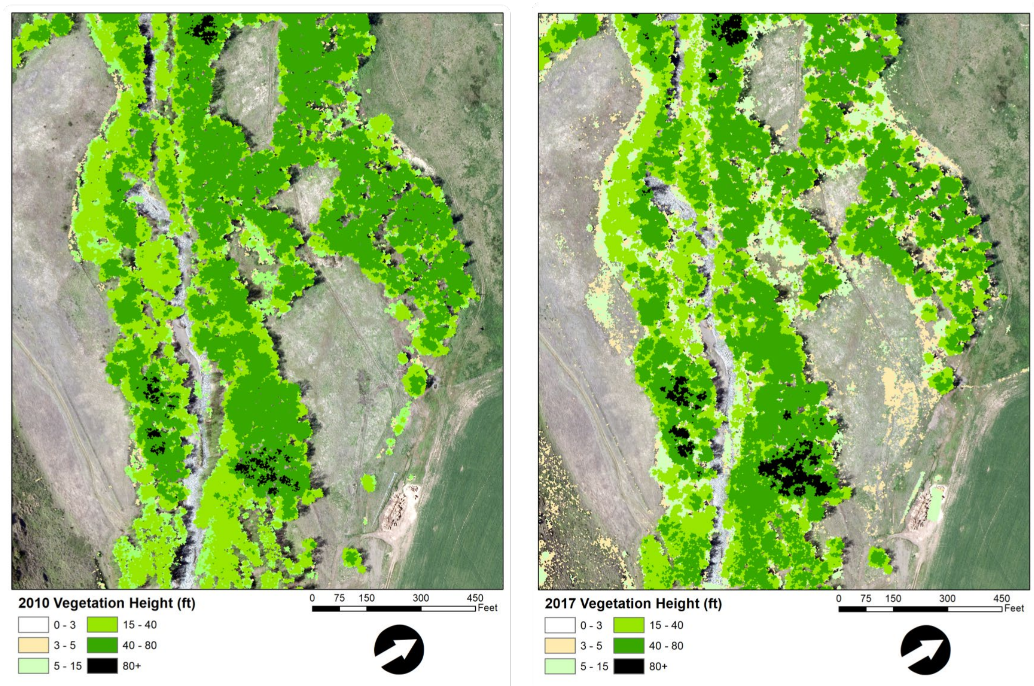
Table 10-2
Breakdown of Vegetation Classes

Size Range (ft)	Designed to Capture
0-3	Crops; grasses; wildflowers
3-5	Emergent or establishing woody vegetation like willows
5-15	Small deciduous trees like alders or elms
15-40	Intermediate range of large alders, or smaller cottonwoods
40-80	Large, deciduous trees like cottonwoods
80+	Very old cottonwoods and large conifers in upper basin

The canopy height models were only examined within the riparian area, which was determined based on a combination of a thalweg buffer, historical migration paths and the 5-year floodplain. This area is described in more detail in Appendix K. Further filtering of the data was deemed not necessary because of the lack of man-made structures within the boundaries of the study area. Once calculated, the vegetation heights were separated into classes (listed in Table 10-2) that are based on experiential knowledge of vegetation in the basin and isolate vegetation types that hold different roles in the riparian corridor. A portion of the results are displayed in Figure 10-7. The extent of coverage, the distributions of vegetation type, and the change in each vegetation type between the two years were investigated for each project area.

Having this information will benefit restoration efforts in the basin by highlighting project areas that are lacking robust riparian vegetation in the short term and revealing trends in vegetation growth in the long-term. Vegetation growth (both vertical and total area) over time can be used to track the efficacy of restoration efforts and also to identify any project areas that may have appeared in good condition at the time of initial assessment but are actually in gradual decline. Results of the vegetation analysis will be considered together with the results of connectivity analyses to quantify how connectivity is related to vegetative cover in the Tucannon Basin and used to inform future restoration strategies.

Figure 10-7
Results from Vegetation Analysis



Target values of 25% and 40% were set for the percentage of riparian area in each project area covered by the 15- to 40-foot and 40- to 80-foot vegetation classes, respectively, as summarized in Table 10-3. These two vegetation classes are especially important for health of the riparian corridor because they provide the most shade and shelter to the river and are the most commonly recruited as LWM. The target values were chosen based on experiential knowledge of healthy riparian corridors and the Tucannon Basin. Secondary, 5% lower, targets and a 7-year trend of riparian coverage were also evaluated to highlight project areas that are close to the target values or trending towards target value. These results are shown and discussed further for each project area in Appendix K.

Table 10-3
2017 Riparian Vegetation Targets

Size Class (feet)	Target	Near Target Level
15–40	25%	20%
40–80	40%	35%

11 Prioritization Summary

This section will give an overview of the evaluation and prioritization methods and describe how the goals and objectives of this report were used to develop the project area prioritization methods. Additionally, this section breaks down in detail the methods used for prioritization and how the analysis results were used to develop the prioritization metrics.

11.1 Prioritization Methods

The prioritization methods attempt to combine the raw assessment results from the Geomorphic Assessment in such a way that prioritized projects will be the most effective at reaching the objectives described in Section 8. A total of eight analysis results (shown in the first row of Figure 11-1) were produced directly from the methods described in the Geomorphic Assessment. The first step in the prioritization is to weight similar analysis results into the primary geomorphic metrics shown in the second row of Figure 11-1: Complexity, Connectivity, and Excess Transport Capacity. It should be noted that two analysis results were removed as factors in the prioritization. The Existing Connected Floodplain analysis was discounted because it is numerically the inverse of Total Floodplain Potential, and any factoring with both would be counterproductive. See Appendix F on Connectivity for a more detailed explanation of why these analysis results cancel each other out.

In order to combine similar analysis results into the three geomorphic metrics used in this prioritization, weights were assigned to each analysis result, which were then summed to produce the final metric value. Table 11-1 and Figure 11-1 show the weights for both complexity and connectivity. It should be noted that the analysis result for Excess Transport Capacity is the only result that factors into the Excess Transport Capacity metric and therefore does not need to be weighted at this step of the prioritization.

Figure 11-1
Prioritization Flow Chart From Analysis Result to Final Prioritization

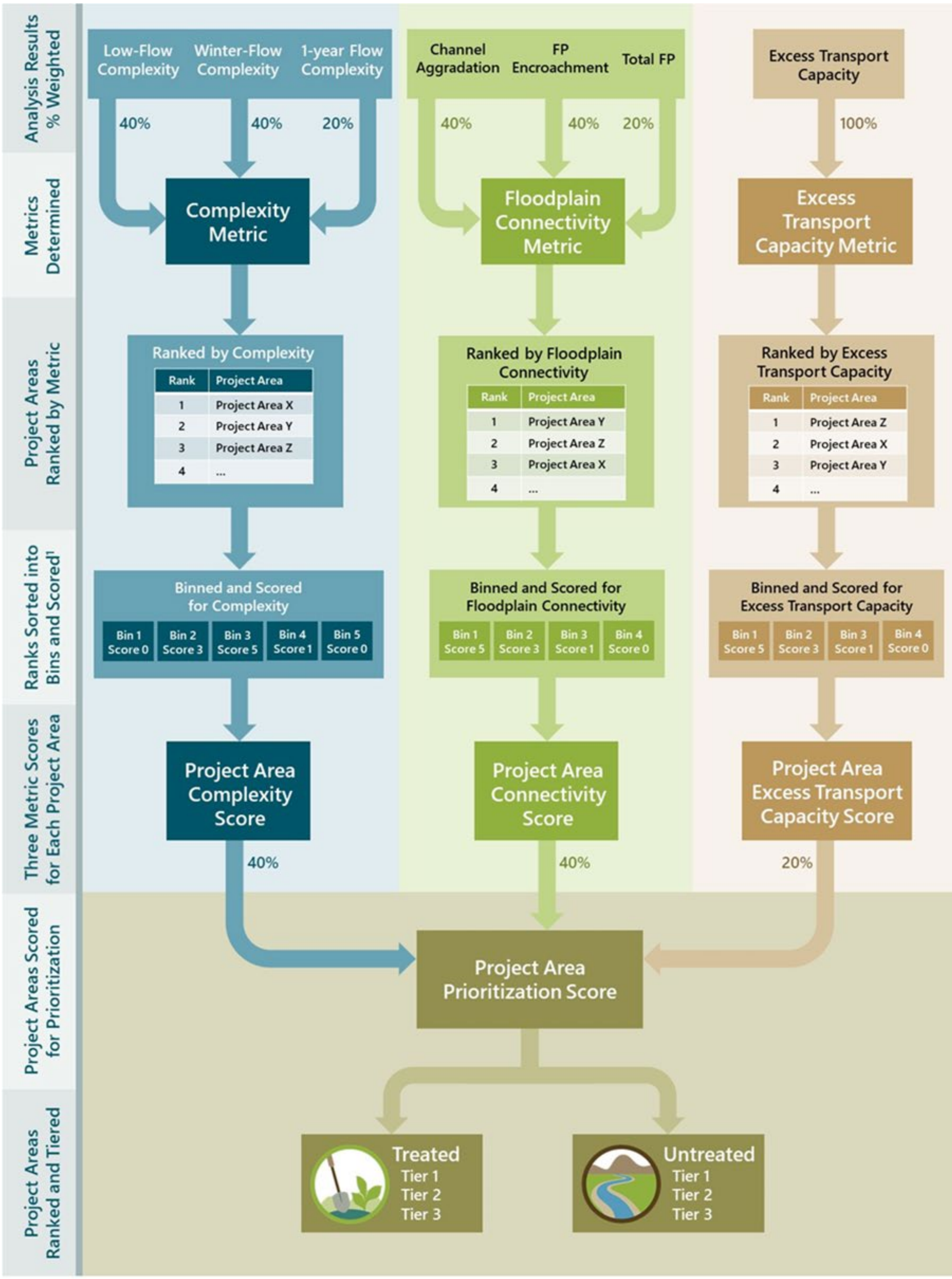


Table 11-1
Complexity and Connectivity Weighting

Complexity Weighting		Connectivity Weighting	
Analysis Result	**Percent Weight**	**Analysis Result**	**Percent Weight**
Low-Winter Flow Complexity	40%	Channel Aggradation Floodplain Potential	40%
Mean-Winter Flow Complexity	40%	Encroachment Removal Floodplain Potential	40%
1-year Flow Complexity	20%	Total Floodplain Potential	20%

The complexity weighting in Table 11-1 favors the Low-Winter Flow and Mean-Winter Flow Complexity values over the 1-year Flow Complexity results due primarily to the fact that the mean-winter and low-winter flows represent a significant portion of the hydrograph compared to the 1-year flow. While the high-flow refugia provided by the complexity at the 1-year flow is important, the mean-winter and low-winter flows better indicate habitat conditions as well as overall geomorphic processes. Similarly, for connectivity, the Channel Aggradation Floodplain Potential and Encroachment Removal Floodplain Potential are favored in the weighting over the Total Floodplain Potential. The Total Floodplain Potential represents the areas where benefit can be gained only by performing both floodplain connection restoration actions; while these areas still have value, they would require more restoration effort for similar benefits and therefore are weighted lower. For a complete explanation of why the Total Floodplain Potential is different than the simple sum of the other two metrics, see the Geomorphic Assessment (Anchor QEA 2019).

The next step in the prioritization process is to rank, classify, and score each project area in each of the three metrics (Complexity, Connectivity, and Excess Transport Capacity). Project areas are ranked from best to worst by the scores determined in the previous step. Each project area then has a rank for each metric and can be classified and scored according to the classification and scoring systems outlined in the individual appendices. Scoring is done differently for each metric as the three analyses measure different things. Floodplain connectivity measures the potential for restoration actions to improve the floodplain, and thus are score on a simple highest to lowest basis as shown in the in the fourth row of Figure 11-1. Similarly, the Excess Transport Capacity produces results where the highest scores need restoration the most and are also score on a simple high to low basis as shown in the in the fourth row of Figure 11-1. The complexity scores, however, rank Project Areas that are already very complex and may not need additional restoration work the highest and so Project Areas that rank near the middle are scored higher than those that rank very higher or very low as shown in the fourth row of Figure 11-1. A full explanation of these scores can be found in the respective appendices for these analyses.

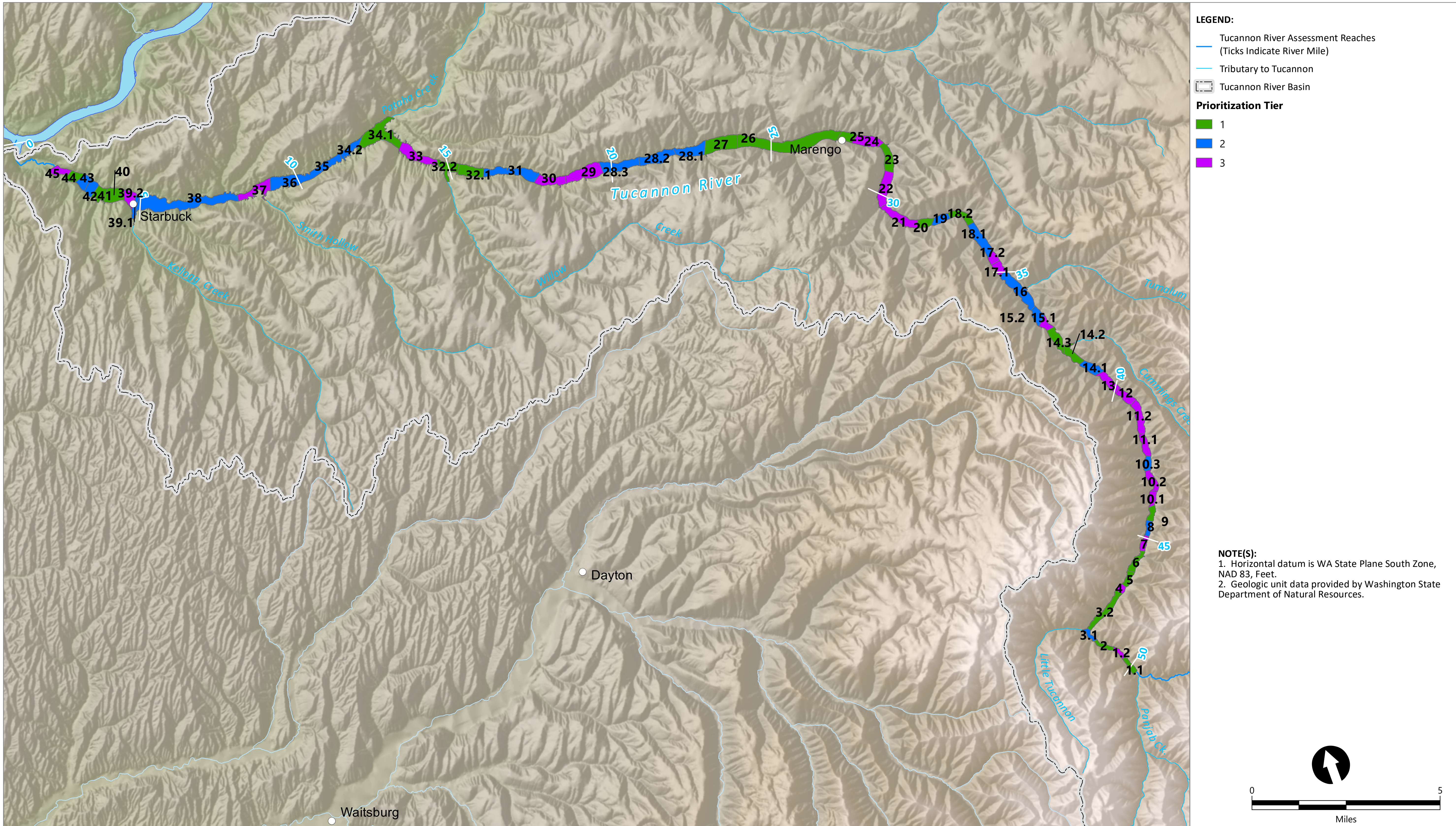
The final step in the prioritization method is to take the scores for each project area based on the above rankings and classifications and weight them towards total importance for restoration. As shown in Table 11-2, the Complexity and Floodplain Connectivity Potential metrics each provide 40% of the final score towards the prioritization ranking and Excess Transport Capacity was valued less at 20%. Over the period of restoration activities since the last assessment, complexity and connectivity have become recognized as the primary indicators of restored geomorphic processes in a reach. The specific restoration actions and strategies used to restore complexity and connectivity are all major influences on the larger geomorphic processes ongoing in the reach and will drive the achievement of the goals and objectives described in Sections 1 and 8 of this report. However, it has been increasingly recognized that some reaches simply do not have the easily transportable sediment supply within the active channel to induce the geomorphic processes that bring about both complexity and connectivity. For this reason, the Excess Transport Capacity metric is a valuable tool in identifying why geomorphic processes have not been restored in some areas where restoration actions targeted complexity and connectivity objectives.

Table 11-2
Prioritization Weighting of Classified Metrics

Metric	Percent Weight
Complexity	40%
Floodplain Connectivity Potential	40%
Excess Transport Capacity	20%

11.2 Prioritization Results

Once the final prioritization scores are calculated, projects areas are sorted into those that have had restoration work since the last assessment (called treated reaches) and those that have not had restoration work (called untreated reaches). These two categories were prioritized into three tiers for restoration, as shown in Figure 11-1. A full list of the treated and untreated tiers can be found in Appendix J. Figure 11-2 shows an overview map of the project areas color-coded by tier.



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ANCHOR QEA

Figure 11-2
Project Area Prioritization
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

12 Limitations

This report has been prepared for use by the CCD to evaluate project areas and suggest a priority system for implementing project areas, along with identified opportunities for restoration strategies. Within the limitations of scope, schedule, and budget, Anchor QEA's services have been executed in accordance with generally accepted scientific and engineering practices in this area at the time this report was prepared. The information presented in this report is based on available data and limited site reconnaissance at the time of report development. Conditions within the study reach will change both spatially and with time.

It is understood that this report is in part meant to provide a baseline for future evaluations and prioritization, and as a guide for processing data as they become available. No dataset is perfect, and a complex river system cannot be perfectly modeled. There are several gaps in the currently available data that, if addressed, could greatly increase the accuracy and usefulness of this prioritization and evaluation of project areas, including and perhaps most importantly the repeated collection of LiDAR data over time. The repetition of the analyses within the Geomorphic Assessment as they pertain to the available digital elevation model would provide a temporal picture of the geomorphic processes in each reach. This would allow for a prioritization that reflects not only the state of the basin at the time, but also the direction in which the basin and individual project areas are headed. With the increased availability and affordability of collecting LiDAR data, it may be possible to conduct basin-wide surveys on a regular basis. More data on fish use and survivability could also better direct habitat actions and increase survival across life stages and rivers. Specifically, more information on egg-to-fry survival would be useful for determining habitat benefits at this life stage.

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Appendix A
Project Areas Overview

Appendix A
Project Areas Overview

1.1 Project Area Summary

This assessment used the project areas from the previous assessments as basic geomorphic reaches and modified and split as necessary to match current conditions. No new reaches were added, but project area boundaries were modified, and some project areas were split into subsections as discussed in this appendix. Table A-1 summarizes the location and status of each reach, and the provided GIS data display the aerial imagery and boundary for each project area, as well as the most up-to-date information on restoration structures currently built. Analysis results for each individual reach are laid out and described in more detail in the respective appendices of this report. The project area cut sheets in Appendix J describe each project area and identified restoration opportunities in more detail. Appendix J also provides a table of recognizable landmarks in relation to project areas for reference.

Table A-1
Project Area Summary

Project Area	Valley Mile Start	Valley Length (mile)	River Mile Start	River Length (mile)	Treated or Untreated[1]
1.10	44.02	0.50	49.63	0.55	Treated
1.20	43.66	0.36	49.24	0.39	Untreated
2.00	43.10	0.56	48.60	0.64	Untreated
3.10	42.73	0.37	48.23	0.37	Untreated
3.20	41.44	1.29	46.79	1.44	Treated
4.00	41.23	0.21	46.55	0.24	Untreated
5.00	40.80	0.43	46.09	0.45	Untreated
6.00	40.16	0.64	45.35	0.74	Treated
7.00	39.74	0.42	44.90	0.45	Untreated
8.00	39.33	0.41	44.45	0.45	Treated
9.00	38.92	0.41	44.05	0.40	Treated
10.10	38.52	0.41	43.58	0.47	Treated
10.20	37.89	0.63	42.86	0.72	Treated
10.30	37.51	0.38	42.45	0.41	Treated
11.10	36.88	0.62	41.70	0.75	Treated
11.20	36.00	0.89	40.73	0.96	Treated
12.00	35.48	0.52	40.08	0.65	Untreated
13.00	34.81	0.67	39.32	0.77	Untreated
14.10	34.26	0.56	38.71	0.61	Treated

Project Area	Valley Mile Start	Valley Length (mile)	River Mile Start	River Length (mile)	Treated or Untreated[1]
14.20	33.64	0.61	37.88	0.82	Treated
14.30	33.00	0.64	37.16	0.72	Untreated
15.10	32.68	0.32	36.78	0.38	Treated
15.20	32.29	0.39	36.36	0.42	Treated
16.00	31.05	1.24	34.97	1.39	Untreated
17.10	30.71	0.34	34.62	0.34	Untreated
17.20	30.45	0.27	34.32	0.31	Untreated
18.10	29.48	0.96	33.24	1.08	Treated
18.20	28.78	0.70	32.46	0.78	Untreated
19.00	28.31	0.47	31.90	0.56	Untreated
20.00	27.91	0.40	31.46	0.44	Untreated
21.00	26.85	1.06	30.41	1.05	Untreated
22.00	25.87	0.98	29.33	1.08	Treated
23.00	25.06	0.81	28.28	1.05	Treated
24.00	24.35	0.71	27.52	0.76	Treated
25.00	23.90	0.45	26.98	0.54	Untreated
26.00	21.11	2.79	23.99	2.99	Treated
27.00	20.21	0.90	22.95	1.05	Untreated
28.10	19.42	0.79	22.08	0.87	Untreated
28.20	18.41	1.01	20.91	1.17	Treated
28.30	17.38	1.03	19.75	1.16	Treated
29.00	16.37	1.01	18.63	1.12	Treated
30.00	15.54	0.83	17.62	1.01	Untreated
31.00	14.11	1.44	16.13	1.49	Untreated
32.10	13.42	0.69	15.34	0.79	Untreated
32.20	12.84	0.58	14.65	0.69	Untreated
33.00	11.71	1.12	13.43	1.22	Untreated
34.10	10.55	1.17	12.28	1.14	Untreated
34.20	9.92	0.63	11.50	0.78	Untreated
35.00	9.27	0.65	10.81	0.69	Untreated
36.00	7.83	1.44	9.11	1.70	Untreated
37.00	6.86	0.97	8.01	1.10	Untreated
38.00	4.09	2.77	5.04	2.97	Untreated
39.10	4.00	0.09	4.94	0.10	Untreated
39.20	3.68	0.31	4.61	0.33	Untreated
40.00	3.16	0.52	4.03	0.57	Treated
41.00	2.85	0.31	3.68	0.35	Untreated

Project Area	Valley Mile Start	Valley Length (mile)	River Mile Start	River Length (mile)	Treated or Untreated[1]
42.00	2.60	0.26	3.35	0.33	Untreated
43.00	2.32	0.28	2.92	0.43	Untreated
44.00	2.01	0.31	2.49	0.43	Untreated
45.00	1.58	0.43	1.96	0.52	Untreated

Notes:

1. Designates project areas where restoration activities have occurred since the 2010 Assessment.

1.2 Delineation of Geomorphically Distinct Reaches for Project Areas

The study area of this assessment includes approximately 51 river miles from the mouth of the Tucannon River, a scale which requires the delineation of the river into discrete units for analysis. Several of the following analysis methods rely on properly scaled reaches with geomorphically similar characteristics. In order to capture the significance of each analysis parameter, the reaches cannot span lengths of river with widely varying geomorphic characteristics. For example, should a reach begin in an area with well-connected floodplain and end in an area with poorly connected floodplain, it may appear in the floodplain connectivity analysis to be a moderately connected reach, which would misrepresent the geomorphic characteristics of the area. For this reason, the concept of performing analyses by river mile or by valley mile was discarded because these boundaries would fall in geomorphically random locations. Instead, previously delineated reaches served as the basis for the reach selection in this report.

The original *Tucannon River Geomorphic Assessment and Habitat Restoration Study* completed in 2010 (Anchor QEA 2011a) scaled the river into 10 reaches, which were delineated based on the results of the basin-scale geomorphic analyses with particular emphasis on floodplain confinement and hydrologic inputs. In the subsequent conceptual restoration plans and prioritizations (Anchor QEA 2011b, 2012a, 2012b), these reaches were separated into 45 distinct project areas based on localized geomorphic features as well as restoration opportunities. These project areas were defined by river mile location and ranged in length from a quarter of a mile to more than 3 miles. The original project areas captured the scale and geomorphic homogeneity necessary for the analyses of this report; however, several changes were made based on evolving geomorphic conditions.

For purposes of these analyses, evaluation units were modified by either subdividing project areas or moving the upstream or downstream boundary of the project area. Project area subdivision occurred due to changes in geomorphic conditions within a portion of the existing project area, or restoration activities within a portion of the project area. Project area boundaries were moved upstream or downstream to better include similar geomorphic conditions. This resulted in both changing the extents of project areas and dividing project areas into subsections to better capture geomorphic differences within the project area. Additionally, the previous assessments (Anchor QEA 2011a, 2011b, 2012a, 2012b, 2012c) defined project areas by the beginning and ending river miles, which could make locating project area boundaries difficult should river avulsions or meanders occur. Project areas in this report are defined by valley mile, allowing the analyses to be repeatable over time and providing a consistent metric for measuring the temporal changes in geomorphic processes.

1.3 Changes to Project Areas

Changes to the project areas from the 2010 Tucannon Assessment were made based on shifting geomorphic features and reaches with restoration projects that only encompassed a portion of the reach. Additionally, a change was made in the theory behind assigning bridges to project areas. The previous assessments ended upstream or downstream of the bridge, with the idea that bridge removal or modification could be included as a restoration action in the project area. However, bridges often mark the beginning or end of distinct geomorphic reaches because they are major influences on the geomorphic processes themselves and, therefore, often represent the best place to split into a new reach to keep reaches with differing geomorphic characteristics separate. Furthermore, bridge modification projects are expensive and difficult, making them relatively uncommon. Therefore, this assessment often uses bridges as a break point for project areas. Table A-2 summarizes the project area changes from the original assessments to the current assessment.

Table A-2
Changes to Project Areas

Original Project Area	New Project Area	Change Type	Change Justification
PA 1	PA 1.1	Boundary Moved Upstream	The upstream boundary was moved upstream to coincide with the nearby bridge and encompass the restoration work done in the area.
PA 1	PA 1.1 – PA 1.2	Project Split	Separated into treated and untreated sections.
PA 1 – PA 2	PA 1.2 – PA 2	Boundary Moved Upstream	Moved to section of river that is less geomorphically active than the previous location, based on LiDAR change analysis.
PA 2 – PA 3	PA 2 – PA 3.1	Boundary Moved Downstream	Boundary moved to coincide with bridge.
PA 3	PA 3.1 – 3.2	Project Split	Separated into treated and untreated sections.
PA 3 – PA 4	PA 3.2 – PA 4	Boundary Moved Downstream	Moved to better coincide with floodplain levee and avoid splitting a high-flow side channel.
PA 4 – PA 5	PA 4 – PA 5	Boundary Moved Upstream	Moved to better coincide with levee and consolidate floodplain opportunities in one PA.
PA 5 – PA 6	PA 5 – PA 6	Boundary Moved Upstream	Moved to coincide with U.S. Forest Service campground bridge.

Original Project Area	New Project Area	Change Type	Change Justification
PA 10	PA 10.1 – PA 10.2	Project Split	Split based on differing geomorphic characteristics. 10.1 is complex and depositional, 10.2 has been treated but has not reached full potential.
PA 10	PA 10.2 – PA 10.3	Project Split	Split based on differing geomorphic characteristics. 10.2 has been treated but has not reached full potential, 10.3 is characterized by a long side channel.
PA 11	PA 11.1 – PA 11.2	Project Split	Both reaches have been treated but 11.2 is much more complex than 11.1.
PA 12 – PA 13	PA 12 – PA 13	Boundary Moved Upstream	Moved boundary to coincide with hatchery dam.
PA 13 – PA 14	PA 13 – PA 14.1	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 14	PA 14.1 – PA 14.2	Project Split	Both areas were treated but were split to isolate geomorphically similar reaches.
PA 14	PA 14.2 – PA 14.3	Project Split	Split to separate the untreated section (14.3) from the rest of the reach; split at bridge.
PA 15	PA 15.1 – PA 15.2	Project Split	Both reaches have been treated but were split based on differing geomorphic characteristics. PA 15.1 is characterized by a long side channel.
PA 16 – PA 17	PA 16 – PA 17.1	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 17	PA 17.1 – PA 17.2	Project Split	Split to isolate geomorphically similar reaches. PA 17.1 is highly leveed and confined.
PA 18	PA 18.1 – PA 18.2	Project Split	Split into treated and untreated; split at bridge.
PA 18 – PA 19	PA 18.2 – PA 19	Boundary Moved Upstream	Boundary moved to coincide with levee encroaching on floodplain.
PA 19 – PA 20	PA 19 – PA 20	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 20 – PA 21	PA 20 – PA 21	Boundary Moved Downstream	Boundary moved to consolidate floodplain opportunity.
PA 21 – PA 22	PA 21 – PA 22	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 25 – PA 26	PA 25 – PA 26	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 26 – PA 27	PA 26 – 27	Boundary Moved Upstream	Boundary moved to coincide with encroaching levee.
PA 27 – PA 28	PA 27 – PA 28.1	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 28	PA 28.1 – PA 28.2	Project Split	Split to separate untreated section (28.1) from the rest of the reach.
PA 28	PA 28.1 – PA 28.2	Project Split	Both sections were treated but were split to isolate geomorphically similar reaches.

Original Project Area	New Project Area	Change Type	Change Justification
PA 29 – PA 30	PA 29 – PA 30	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 32	PA 32.1 – PA 32.2	Project Split	Split at location of falls.
PA 33 – PA 34	PA 33 – PA 34.1	Boundary Moved Upstream	Boundary moved to coincide with bridge.
PA 34	PA 34.1 – PA 34.2	Project Split	Project area split at bridge.
PA 34 – PA 35	PA 34.2 – PA 35	Boundary Moved Upstream	Boundary moved to coincide with the start of the levee encroaching on the floodplain.
PA 43 – PA 44	PA 43 – PA 44	Boundary Moved Upstream	Moved to section of river that is less geomorphically active than the previous location, based on LiDAR change analysis.
PA 44 – PA 45	PA 44 – PA 45	Boundary Moved Downstream	Boundary moved to coincide with pinch point in floodplain.
PA 45	PA 45	Boundary Moved Downstream	Boundary moved to coincide with bridge.

Notes:
LiDAR: Light Detection and Ranging
PA: project area

1.4 References

Anchor QEA (Anchor QEA, LLC), 2011a. *Tucannon River Geomorphic Assessment and Habitat Restoration Study*. Prepared for Columbia Conservation District. April 2011.

Anchor QEA, 2011b. *Conceptual Restoration Plan Reaches 6 To 10*. Prepared for Columbia Conservation District. November 2011.

Anchor QEA, 2012a. *Conceptual Restoration Plan Reaches 3 and 4*. Prepared for Columbia Conservation District. October 2012.

Anchor QEA, 2012b. *Conceptual Restoration Plan Reaches 5*. Prepared for Columbia Conservation District. October 2012.

Anchor QEA, 2012c. *Integrated Species Restoration Prioritization.* Prepared for Columbia Conservation District. November 2012.

Appendix B
Viable Salmonid Population

Appendix B
Viable Salmonid Population

The restoration objective for the Tucannon River is to improve habitat conditions for Endangered Species Act (ESA)-listed species (spring/summer Chinook salmon, Snake River fall Chinook salmon, Snake River steelhead, and bull trout) for all life history stages within the river. Improving habitat conditions may lead to an increase in the abundance of listed species returning to the river. Increasing abundance could lead to delisting of the species, which is the overall recovery goal for the system.

Throughout this section, spring Chinook salmon are used as an example species to help clarify the discussion and to provide examples for the types of data collected and evaluated in the basin. Similar types of data (where available) are also being evaluated for the other ESA-listed species included in the prioritization framework.

Viable Salmonid Population

To inform habitat restoration actions, spring Chinook salmon in Reach 5 were identified as a species to focus on with the expectation that restoration actions targeted at improving habitat conditions for spring Chinook salmon life stages will also improve conditions for steelhead and other species important to the Tucannon River. Another approach to evaluate the health of Tucannon River spring Chinook salmon is to consider how the population is performing compared to the National Marine Fisheries Service (NMFS) standard of a Viable Salmon Population (VSP), a population biology concept. According to the NMFS, a VSP is an "independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame" (McElhany et al. 2000). McElhany et al. (2000) identified four key population characteristics or parameters for evaluating population viability status:

- Abundance
- Population growth rate or entire lifecycle productivity
- Population spatial structure
- Diversity

The following sections present a brief introduction to each of the VSP parameters and how these apply to the Tucannon River habitat conditions and future restoration planning.

It must be emphasized that any change in risk associated with these population parameters is affected by myriad factors (including in-basin factors; conditions in the Snake and Columbia rivers; predation from avian, mammal, and piscivorous species; and ocean conditions), and consequently is a long-term proposition. Many of these factors (e.g., ocean conditions and marine survival rates) are largely outside of human control. Moreover, changes expected from the types of actions considered in this report are most likely to occur on a generational scale; the likelihood is low that there would be detectable changes in the near future. Also, there is uncertainty associated with the Tucannon River supplemental hatchery program that may affect the spring Chinook salmon population in ways that may not be well understood.

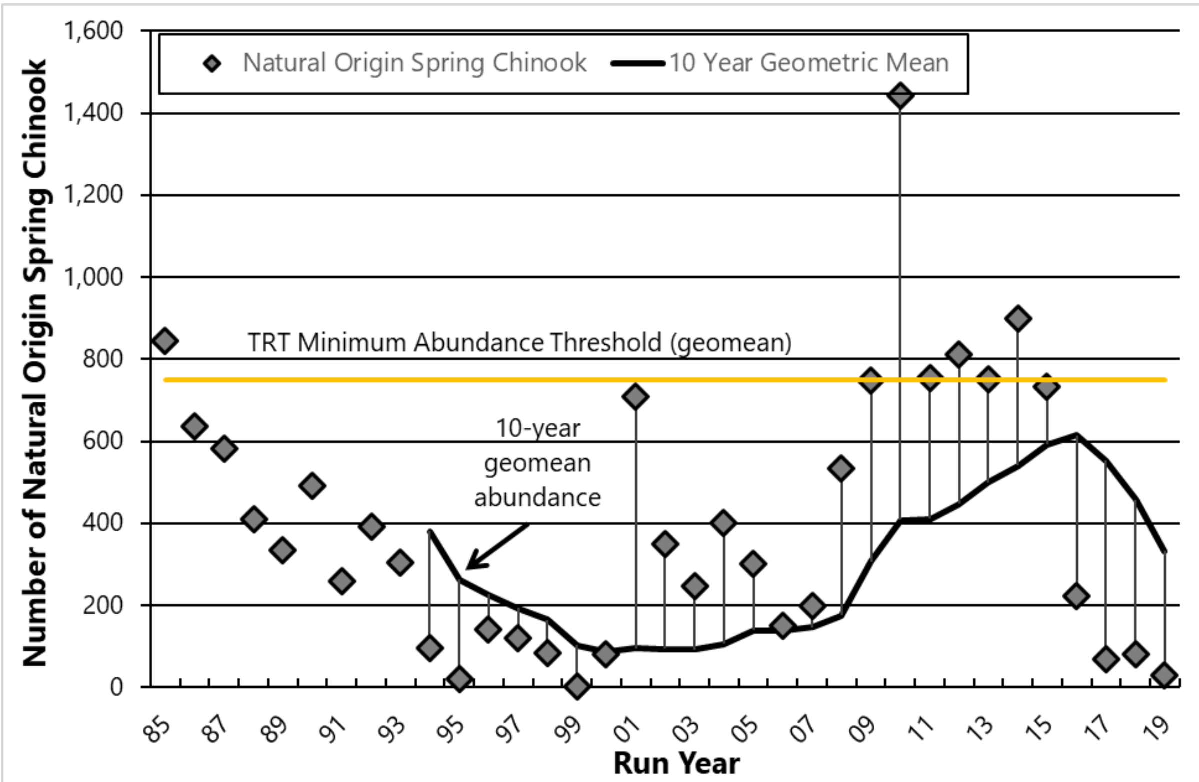
Abundance

Population size is perhaps the most straightforward measure of the VSP parameters and is an important consideration in estimating extinction risk. All other factors being equal, a population at low abundance is intrinsically at greater risk of extinction than is a larger one. The primary drivers of this increased risk are the many processes that regulate population dynamics, particularly those that operate differently on a relatively small population, such as Tucannon River spring Chinook salmon. Examples include environmental variation and catastrophes, demographic stochasticity (intrinsic random variability in population size), selected genetic processes (e.g., inbreeding depression), and deterministic density effects. Although the negative interaction between abundance and productivity may protect some small populations, there is obviously a point below which a population is unlikely to persist (McElhany et al. 2000).

Tucannon River spring Chinook populations spawn exclusively in the mainstem Tucannon River with the majority of spawning occurring from just above the mouth of Sheep Creek (RM 52) downstream to about King Grade (RM 21). Average annual spawning for the past 20 years (1998 to 2018) is 181 redds, with 55% of these being natural spawners and 45% hatchery-origin fish (Gallinat and Kiefel 2019). Average annual spawning for the past 10 years (2009 to 2018) is 211 redds, with 49% of these being natural spawners and 51% hatchery-origin fish (Gallinat and Kiefel 2019). Natural-origin returns have dropped off considerably in the last 4 years and are similar to those experienced in the mid to late 1990s (Figure B-1).

Between 1985 and 2019, the annual returns of natural-origin spring Chinook salmon to the Tucannon River ranged from near zero to approximately 1,450 adults; the high of 1,443 returning adults occurred in 2010 and the low of 3 returning natural-origin spawners occurred in 1999 (Figure B-1; Gallinat and Kiefel 2019; Bumgarner 2019, personal communication). The 10-year geometric mean abundance has varied between approximately 100 and 600 returning adults. The Interior Columbia Technical Recovery Team (ICTRT) estimated that the minimum abundance threshold of returning adults is 750, with the current average of 292 (Gallinat and Kiefel 2019; Bumgarner 2019, personal communication).

Figure B-1
Estimated Abundance of Natural-Origin Spring/Summer Chinook Salmon Adults and 10-year Geometric Mean from the Tucannon River (1986 to 2019 Run Years)

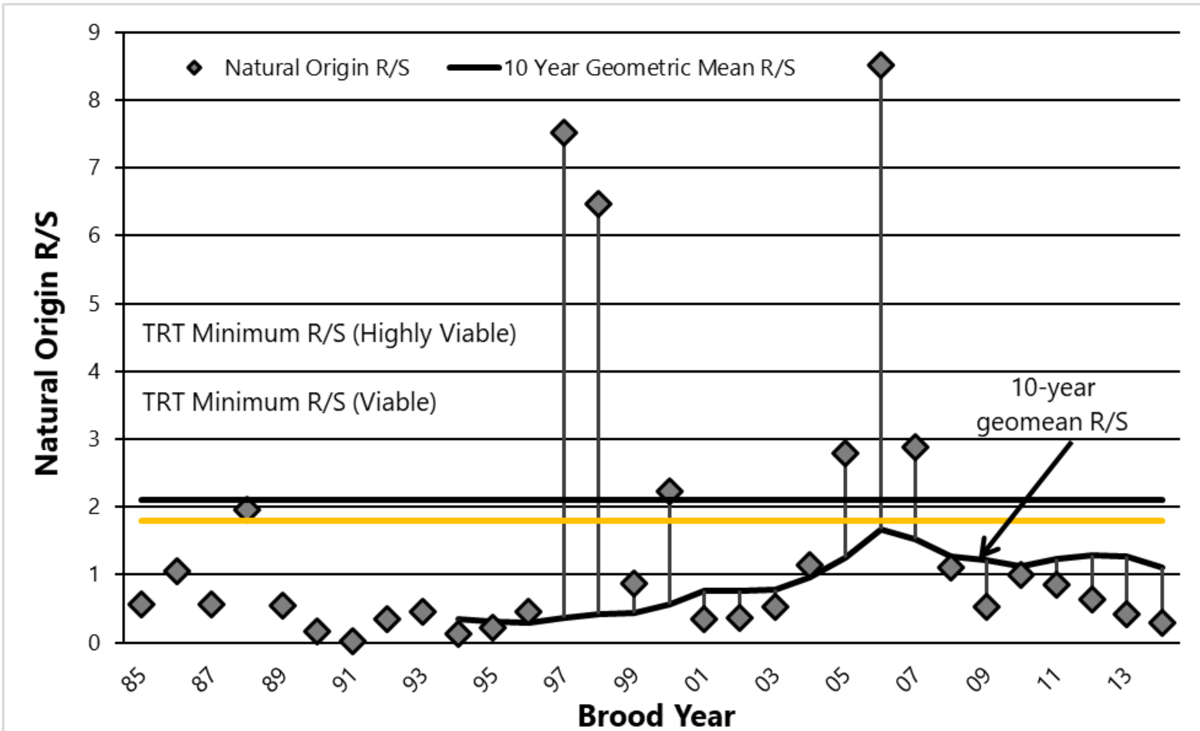


Sources: Gallinat and Kiefel 2019; Bumgarner 2019, personal communication

Lifecycle Productivity

Population growth rate (λ) or productivity over the entire lifecycle is a key measure of population performance in a species' habitat. In simple terms, it describes the degree to which a population is replacing itself. A population growth rate of 1 (λ = 1.0) means that a population is exactly replacing itself (one spawner produces one spawner in the next generation), whereas a λ = 0.71 (the λ value determined in the Tucannon River for spring Chinook salmon) means that the population is declining at a rate of 29% annually—a trend that is obviously not sustainable in the long term (Figure B-2). Recruits per spawner are often less than one, with 19 of 30 (63%) years below the replacement level (Gallinat and Kiefel 2019). The population has experienced brief periods of high productivity in the late 1990s and mid-2000s, but only 5 of the last 30 years (17%) have been above both TRT minimum threshold values. The Technical Review Team estimated that an R/S of 1.8 is needed for an extinction risk of less than 5% and an R/S of 2.1 is needed for an extinction risk of less than 1% (highly viable criteria) (SRSRB 2011).

Figure B-2
Estimated Productivity of Natural-Origin Spring/Summer Chinook Salmon Adults and 10-year Geometric Mean from the Tucannon River (1985 to 2014 Brood Years)



Source: Gallinat and Kiefel 2019

The causes for the low R/S are not precisely known and likely include multiple factors that are difficult to quantify, such as potential effects from habitat conditions and habitat capacity (WDFW 2011). Hatchery supplementation, the Columbia and Snake rivers, predation, harvest, and ocean conditions are also factors of the R/S value.

Spatial Structure

Spatial structure, as the term suggests, refers to the geographic distribution of individuals in a population unit and the processes that generate that distribution. Distributed populations that interact genetically are often referred to as a metapopulation. Although the spatial distribution of a population, and thus its metapopulation structure, is influenced by many factors, none are perhaps as important as the quantity, quality, and distribution of habitat. One way to think about the importance or value of a broad geospatial distribution is to consider that in the presence of such a distribution, a population is less likely to go extinct from a localized catastrophic event or localized environmental perturbations (McElhany et al. 2000).

Spatial distribution (of spawning and summer rearing) of spring Chinook salmon in the Tucannon River is primarily restricted to the area upstream of Marengo (RM 25) to the headwaters, yet historically it is presumed that spring Chinook salmon spawned and reared at least down to Pataha Creek, near RM 12.5 (Gallinat and Ross 2011).

Per Table B-1, it is noteworthy that approximately 97% of the spring Chinook salmon spawning documented over the past 30 years occurs between RM 26.9 (Marengo Bridge) and RM 58.3 (about 3 miles above Sheep Creek), recognizing that spawning near the headwaters may have occurred historically at a higher density than is currently occurring (WDFW 2011). This is like due to the implementation of the hatchery program in the mid-1980s, which removed wild-origin spawners to begin the program, and likely shifted the overall spawning distribution because of hatchery fish homing to either the Tucannon Fish Hatchery or Curl Lake acclimation pond where hatchery fish have been released.

Table B-1
Spring/Summer Chinook Redd Distribution in the Tucannon River (1985 to 2019)

Section	River km (Rkm)	River mile (RM)	Percent of Total Redds	Average Redds	Redds per Rkm	Redds per RM
Mouth to Marengo (Lower)	0–20.1	0–13.6	1.7	2.7	0.1	0.2
Marengo	20.1–39.9	13.6–26.9	1.0	1.6	0.1	0.1
Hartsock	39.9–55.5	26.9–37.5	19.2	31.0	2.0	2.9
HMA	55.5–74.5	37.5–50.3	64.0	103.2	5.4	8.1
Wilderness	74.5–86.3	50.3–58.3	14.1	22.7	1.9	2.7

Notes:
1. 1985 to 2018 data are from Gallinat and Kiefel (2019). Data from 2019 were added in by Joe Bumgarner (WDFW), personal communication.
2. Rkm and RM differ slightly; RM shown were developed for the current scope of work and have been compared to Rkm primarily based on landmarks (bridges, property boundaries) for consistency.
3. Local biologists believe that all or most of the redds found in the lowest section are likely strays from other Snake River spring/summer populations that come into the river late as spawning time is near its end, and do not necessarily represent “true” Tucannon River stock returns. However, few carcasses have ever been recovered to document this.

Life History Diversity

Biological diversity within and among populations of salmon is generally considered important for three reasons (McElhany et al. 2000):

- Diversity of life history patterns is associated with the use of a wider array of habitats.
- Diversity protects a species against short-term spatial and temporal changes in the environment.
- Genetic diversity is the so-called raw material for adapting to long-term environmental change.

The latter two reasons are often described as nature's way of hedging its bets—a mechanism for dealing with the inevitable fluctuations in environmental conditions—in the long and short terms. With respect to diversity, more is better to minimize the risk of extinction.

Current life history diversity of Tucannon River spring Chinook salmon is presumed to reflect historical life history diversity, with the majority of juveniles emerging from the gravel in spring, rearing for one summer and one winter, and then out-migrating as 1-year-old smolts in the spring. Of interest is the apparent lack of winter-rearing habitat and channel complexity (e.g., side channels, back water, and pools) that support juvenile fish. Existing data demonstrate that the largest mortality occurs between egg and smolt, with the majority of the mortality occurring between egg and parr; it is alarming that, from brood year 1983 to brood year 2003, on average less than 6% of spring Chinook salmon survived from egg to smolt (Gallinat and Ross 2010).

Restoration Expectations Related to Viable Salmonid Population Goals

Abundance

Population abundance is a key parameter used to assess the status of a stock and evaluate trends in stock improvement or decline. Abundance is also useful in identifying critical population dynamics that can be used to identify success in restoring a stock or levels at which extinction risk is high and the level of attention given to restoration be increased. Collectively proposed restoration actions in the Tucannon River are intended to improve abundance holistically; hence, no restoration action proposed in this report is targeting abundance specifically.

Lifecycle Productivity

As presented and referenced in this document, previous studies have identified degraded habitat conditions and juvenile carrying capacity as primary causes for the low R/S ratio currently observed in the Tucannon River. Therefore, proposed restoration actions are highly focused on addressing limitations to productivity. The largest mortality occurs between egg and smolt, with the majority of the mortality occurring between egg and parr (SRSRB 2006). In addition, WDFW data indicate that smolt production generally increases with an increase in adult returns in the basin, although a carrying capacity issue may exist above approximately 200 female spawners (Gallinat and Ross 2010). Spawning and incubation for spring Chinook salmon begins in late August and continues through March, with fry developing to parr through June. This timeline represents a large range in hydrologic conditions and habitats used by Chinook salmon; prioritizing specific time periods and associated habitats is necessary to target critical lifecycle periods affecting productivity (ISRP 2011a).

The life stage between egg and parr coincides with late summer low flow, winter storm flows, and the spring runoff period. Summer low flows are unpredictable, and other efforts in the basin are focused on improving water quality and quantity. Winter storm events are stochastic and vary greatly in the effect that they may have on growth and productivity. For example, several consecutive years of minor peak flows, where impacts to fish are also minor, may occur between larger, less frequent flood events that have the ability to scour redds, resulting in significant losses to the run. Spring runoff flows occur each year and are relatively predictable in their magnitude and their effect on the habitat types required by juvenile salmonids; these habitats are currently lacking in the system. Data from smolt trapping in the lower river indicate that parr are arriving in the lower basin throughout the spring runoff period, long before their genetic signal should be initiating movement downstream (WDFW 2011). It is speculated that this may be occurring either because they are being flushed downstream and are not able to find suitable refuge habitat or because juvenile fish are actively seeking out habitats in the lower river because of the lack of refuge areas (carrying capacity) in the preferred rearing areas upstream.

Based on high egg-to-parr mortality and uncertainty related to much of the hydrologic cycle during the egg-to-parr timeline, improving habitat conditions for juveniles during the spring runoff period was determined to be of high priority and to provide the greatest certainty of success with respect to improving growth and productivity for the ESA-listed species collectively. Therefore, restoration actions that will provide hydraulic complexity; will improve or create side channels, alcoves, or hydraulic refuge and cover; or will improve low-lying floodplain connectivity will be considered to have high biological benefit when developing conceptual projects.

Installing necessary instream structure to provide adequate cover and complexity, while designing within the basin and reach-scale geomorphic context, will be critical to achieving both an immediate biological benefit and long-term restoration success. Hydraulic complexity and off-channel habitat projects will provide hydraulic refuge and rearing habitat for juvenile salmonids during moderate to high flows and will also provide more desirable habitat during lower flow conditions. LWD placements will provide refuge and cover and will be used to initiate a geomorphic response in many locations where natural channel development and floodplain connectivity can be achieved. Levee and riprap removal will remove stressors in the system, allowing for more natural geomorphic processes and promoting habitat recovery. See Appendix A for more details on specific restoration actions proposed for the Tucannon River.

Collectively, these improvements can re-establish natural "processes of material and energy transfer across the watershed that enables the formation and maintenance of productive habitat," identified by the Independent Scientific Review Panel (ISRP) for the Tucannon River (ISRP 2011b). It is expected that these improvements will promote the re-establishment of natural processes, which will increase habitat diversity and total rearing area available for juveniles and will improve their survival and productivity. The habitat improvements should also increase spawning and emergence conditions over time through improved energy dissipation from increases in channel complexity, improved temperature conditions, and improved distribution of nutrients and fine sediment across the floodplain.

Spatial Structure

Improving the population spatial structure relates to improving habitat conditions throughout the river corridor such that habitat needs are met across the various life stages and hydrologic regimes, and the health of the population is not jeopardized by local environmental effects. The restoration approach for the Tucannon River does not focus exclusively on one reach or segment of the study area, but values both areas of the river currently experiencing high fish use, as well as areas with high restoration potential should a “full build out” of restoration opportunity be realized. This approach is further described below and in Section 4 of the main report.

In general terms, the restoration strategy for the Tucannon River is a holistic basin-scale approach that values both immediate and long-term biological benefits. Implementation of restoration projects will likely occur in high-use areas early to maximize growth and productivity in areas of current use. In addition, projects with high benefit and low cost will be highly recommended regardless of location to maximize the growth and productivity of the segment of the population currently using those areas. Projects implemented on the fringes of the current high-use areas will expand the linear extent of high-quality habitat throughout the river corridor, increasing the distribution and carrying capacity for fish using those areas. Projects removing stressors on habitat will allow for natural recovery of the system and better habitat continuity through the river in the long term.

This restoration strategy will improve the spatial distribution of the stock by improving existing high-use areas, implementing high-benefit/low-cost projects in non-high-use areas, expanding the size of high-use areas by implementing projects on the fringes of those areas, removing stressors affecting natural processes for long-term improvement of quality habitat throughout the river corridor production, and improving the spatial distribution of the stock.

Life History Diversity

None of the proposed restoration actions will specifically target improving life history diversity within the target species.

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SRSRB, 2011. *Snake River Salmon Recovery Plan, Draft. Appendix B. Current Status Assessment of Southeast Washington Management Unit Populations*. April 2011.

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Appendix C
Hydrologic Analysis Methods and Results

Appendix C
Hydrologic Analysis Methods and Results

The methods of hydrologic analysis described in the following sections closely mimic the processes used for the 2010 Geomorphic Assessments and Habitat Prioritizations hydrologic analyses. The last 8 years of flow data from the following described sources were updated in the existing analyses and, apart from the updated results, all other methodologies remained the same. Because hydrology analyses can be subjective depending on the methods used and data sources drawn from, it is recommended that this method be repeated for any future analyses unless new sources of information become available and allow for a more accurate approach.

It should be noted that the "Low-Winter Flow" seen in this assessment was not determined using a hydrologic analysis. Instead, this is the flow that occurred during periods of key data collection, the low-winter flow during the Light Detection and Ranging (LiDAR) collection in November 2017, and the mean-winter flow during the aerial collection in April 2018. While these flows do not correspond directly to a statistically recognized flow event, they are representative of typical lower flows that occur during that time of year.

Hydrologic Information

Information on hydrology in the Tucannon River basin was available from multiple stream gages (both on the Tucannon River and its tributaries) and spatially distributed rainfall data. Subbasin delineations were also available for use in estimating discharge contributions from tributaries that are not gaged.

Stream Discharge Data

Stream discharge data were available from three gages on the Tucannon River and its major tributaries. See Figure 2-5 of the main report for a basin map including stream gage locations. The following sections provide a brief description of the gages used to help evaluate basin hydrology.

U.S. Geological Survey Gage near Starbuck, Washington

Discharge data in the Tucannon River near Starbuck were available from the U.S. Geological Survey (USGS) gage No. 13344500 (USGS 2018a). The gage is located at approximately river mile (RM) 8.2, just downstream of the Smith Hollow Road crossing and the confluence of the Smith Hollow tributary. The drainage basin upstream of the gage is approximately 431 square miles. The available period of record for the gage is from October 1, 1914, through August 5, 2018. Three significant data gaps exist in the period of record: one from water years 1918 to 1928, a second from water years 1932 to 1958, and a third from water years 1991 to 1994. A total of 62 water years are available in the gage data. Approved peak streamflow data were available for 61 of the water years (water year 2018 peak streamflow was not approved for publication at the time of this analysis).

Department of Ecology Gage near Marengo, Washington

Discharge data in the Tucannon River near Marengo were available from the Washington State Department of Ecology (Ecology) gage 35B150. The gage is located at approximately RM 26.9, just downstream of Marengo and the Turner Road crossing. The drainage basin upstream of the gage is approximately 160 square miles. The available period of record for the gage is from June 2003 to the present. This location was also the site of a former USGS gage (No. 13344000). The available period of record for the former USGS gage is from water years 1913 to 1930. The data from the former USGS gage were not used in the analysis.

Department of Ecology Gage on Pataha Creek near the Mouth

Discharge data in Pataha Creek near the confluence with the Tucannon River were available from Ecology gage 35F050. The gage is located on Pataha Creek at approximately RM 1.2, just downstream of the State Route 261 crossing. Pataha Creek enters the Tucannon River at approximately RM 12.5. The drainage basin upstream of the gage is approximately 184 square miles.

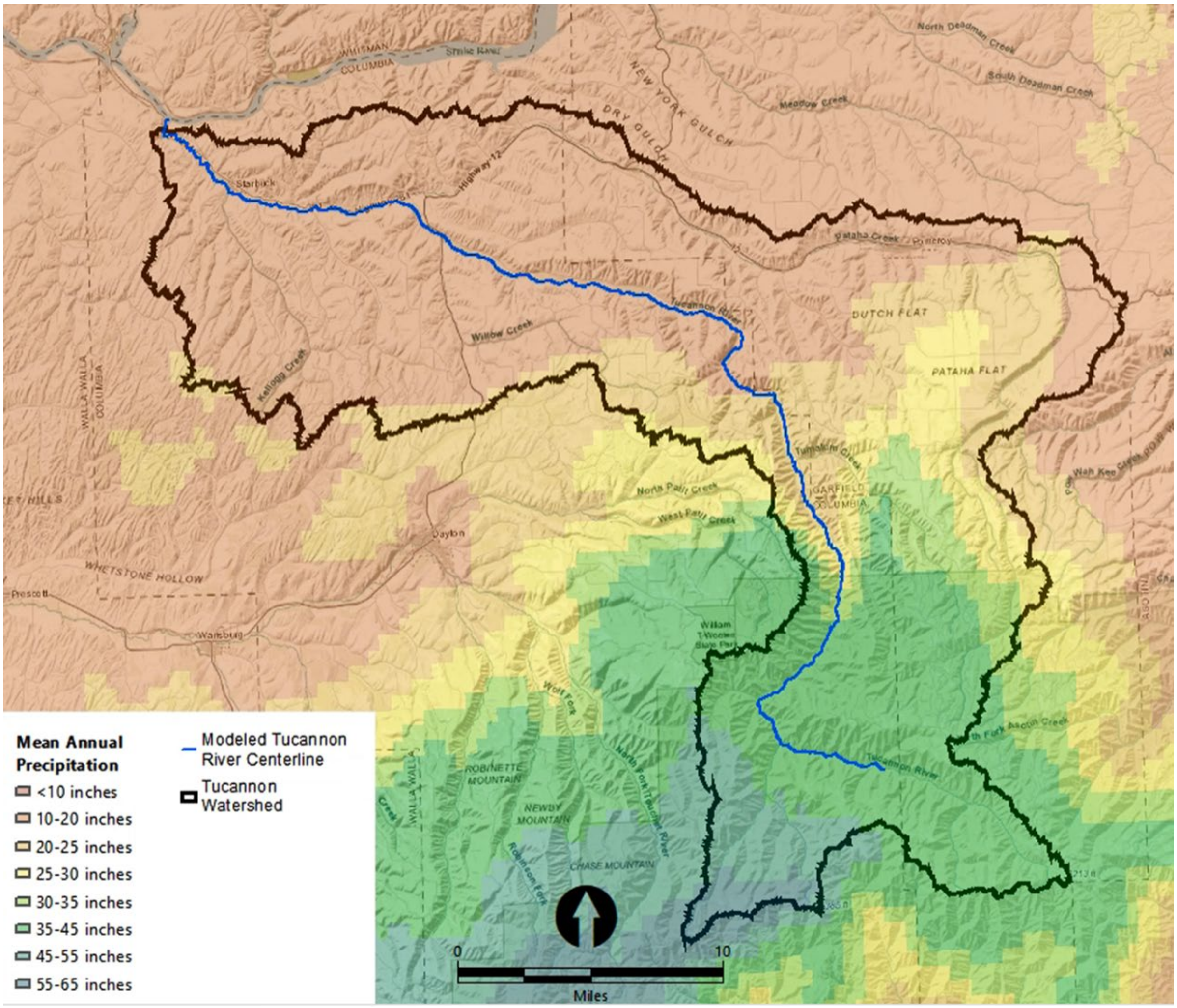
Precipitation Data

Precipitation data for the basin were summarized in the Tucannon Subbasin Plan and were available geospatially from Oregon State University through the PRISM climate model (OSU 2019). The distribution of precipitation in the basin is highly dependent on elevation. Mean annual precipitation ranges from 10 inches at lower elevations to more than 40 inches at higher elevations. Figure C-1 shows the distribution of mean annual precipitation over the Tucannon River basin (CCD 2004).

Basin Delineations

Basin and subbasin delineations are available as geospatial data through USGS stream stats (BLM 2009; USGS 2018b) for the Tucannon River. These delineations provided information on contributing area, basin shape, slope, and elevation. The major subbasins and gage locations in the Tucannon River basin are listed in Table C-1.

Figure C-1
Mean Annual Precipitation Distribution – Tucannon River Basin



Note: Precipitation data were drawn from the Oregon State University PRISM climate model (OSU 2019) and represent the 30-year (1981 to 2010) annual average.

Table C-1
Tucannon Tributaries and Basin Areas

Major Tributary/ Location on River	Location (RM)	Tributary Area (square miles)	Basin Area Above Confluence (square miles)	Basin Area Below Confluence (square miles)	Basin Area Increase (square miles)
Mouth	0	-	504	504.0	14.0
Kellogg Creek	4.9	34.5	455.5	490.0	58.5
Starbuck Gage	8.8	-	431.5	431.5	0.77
Smith Hollow	8.8	20.6	410.1	430.7	25.8
Pataha Creek *(Gaged)*	12.4	184.8	220.1	404.9	189
Willow Creek	14.9	29.9	186.4	216.3	56.3
Marengo Gage	27.2	-	160	160.0	22.2
Tumalum Creek	35.8	16.0	121.8	137.8	19.7
Cummings Creek	38.1	19.9	98.3	118.2	42.1
Little Tucannon River	48.3	8.4	67.7	76.1	12.4
Panjab Creek	50.4	25.4	38.3	63.7	25.4

Hydrologic Analysis

Flood Magnitude and Frequency Analysis

A flood magnitude and frequency analysis for the Tucannon River was conducted using peak discharge data from the gage at Starbuck. Two methods were used in the selection of the peak discharge event series for the flood magnitude and frequency analysis:

1. The series of annual peak discharges for the period of record.
2. All independent discharge peaks above a threshold of 720 cubic feet per second (cfs). This threshold provided a series of 63 independent flood events (equivalent to the number of years of record). This selection method is also known as a partial duration series (PDS) analysis (Madsen et al. 1997).

The two peak discharge series selection methods were justified given the nature of the basin hydrology (i.e., the occurrence of drought years with no appreciable flood event) and the goals of the analysis. The drought year peak discharges can be seen below the PDS threshold of 720 cfs. Each peak discharge series was used to develop a Log-Pearson Type III (LP3) exceedance probability curve. Overall, the PDS method typically provides larger peak discharges for the more frequent events (i.e., 1- and 2-year return periods) while only providing slightly smaller peak discharges for the less frequent flood events when compared to using the annual peak discharge series method. The results of the LP3 analysis using both data sets are shown in Table C-2.

Table C-2
Flood Magnitude and Frequency at the Starbuck Gage

Return Period (year)	Annual Exceedance Probability	Peak Discharge (cfs): LP3	Peak Discharge (cfs): LP3 over Threshold	Percent Difference
1	100%	164	552	237%
2	50%	1,108	1,436	30%
5	20%	2,420	2,530	5%
10	10%	3,713	3,589	-3%
25	4%	5,948	5,437	-9%

It is important to note the large difference in the peak discharge between the LP3 analysis using the annual peaks series and the PDS for the 1-year return period. Using the annual peak discharges series for the LP3 analysis yields a 1-year return period discharge less than the mean annual discharge. However, using the PDS method for the LP3 analysis yields a 1-year return period discharge roughly 3 times the magnitude of the mean annual discharge. This difference is the result of drought years in the annual peak discharge series and the absence of small peak discharges from drought years in the PDS method. As the exceedance probability decreases, the results of the two methods become more similar, with the PDS method providing a slightly smaller discharge for return periods longer than 5 years.

For the 1-year return period, the peak discharge from the LP3 analysis using the PDS was used for subsequent analysis. For the 2-, 5-, 10-, 25-, and 100-year return periods, the peak discharges from the LP3 analysis using the annual peak discharge series were used for subsequent analysis.

Basin Area Discharge Scaling

To calculate the discharge contributions for ungaged flow change locations on the Tucannon River, the basin area scaling method developed by Thomas et al. (1994) and referenced in the USGS Fact Sheet *Methods for Estimating Flood Magnitude and Frequency in Washington* (USGS 2001) was used. Thomas's basin area scaling method (Equation C-1) uses the basin area proportions and a regional exponent to scale discharges from a gaged location to an ungaged location. The method is suitable for ungaged basins with a basin area between 50% and 150% of the gaged location basin area.

The regional exponent (x) for the Tucannon River basin is 0.59 (Table 3, USGS 2001). The results of this method applied to the major tributary basin areas are shown in Table C-3 as flow proportion percentages. It should be noted that several ungaged flow change locations in the upper basin are less than 50% of the gage location's basin area. These estimates are beyond the recommended limitations of the method and should therefore be compared with other methods for determining basin contributions including stream gage data correlations.

Equation C-1[1]

$$Q_u = Q_g \left(\frac{A_u}{A_g}\right)^x$$

where:

Q_u	=	peak discharge, in cfs, at the ungaged site for a specific recurrence interval
Q_g	=	peak discharge, in cfs, at the gaged site for a specific recurrence interval
A_u	=	contributing drainage area, in square miles, at the ungaged site
A_g	=	contributing drainage area, in square miles, at the gaged site
x	=	exponent for the region in which both sites are located

Note:

1. USGS Fact Sheet Methods for Estimating Flood Magnitude and Frequency in Washington (USGS 2001) developed by Thomas et al. 1994.

Table C-3
Flow Change Locations and Discharge Contributions

Major Tributary/ Location on River	Thomas (1994) Flow Proportion as % of Starbuck	Flow as % of Marengo[5]	Flow as % of Starbuck, with Gage Corrections	Difference in Proportion
Kellogg Creek	109.6%	-	109.6%	0.0%
Starbuck Gage	107.8%	-	107.8%	0.0%
Smith Hollow[1,3]	100.0%	-	100.0%	0.0%
Pataha Creek[2]	99.9%	-	100.0%	0.1%
Willow Creek[3]	96.3%	-	97.0%	0.7%
Marengo Gage[4,5]	66.5%	100%	86.0%	19.5%
Tumalum Creek	55.7%	92%	82.0%	26.3%
Cummings Creek	51.0%	84%	75.1%	24.1%
Little Tucannon River	46.6%	64%	68.6%	22.0%
Panjab Creek	35.9%	58%	52.9%	17.0%
Above Panjab Creek	32.3%	43%	47.6%	15.3%

Notes:

1. For the purposes of modeling, the discharge downstream of Smith Hollow was assumed to be equivalent to the discharge at the Starbuck gage.
2. The gage correlation correction for Pataha Creek is 9% of the discharge at Starbuck.
3. The remainder of the discharge proportion for the gage correction method was split evenly between Smith Hollow and Willow Creek, with both tributaries accounting for 1% of the discharge at the Starbuck gage.
4. The gage correlation correction for the Marengo gage is 86% of the discharge at Starbuck.
5. Proportioning of the discharge at Marengo to tributaries used Thomas's basin area scaling method with Marengo as the gaged location.

Stream Gage Correlations

To improve the flow estimates provided by the basin area scaling method, correlations between discharge at the Starbuck gage and two other gages (Marengo and Pataha) were made. Although the period of record at these gages is not sufficiently long to conduct a flood frequency analysis using the LP3 method, the gage data were sufficient to develop reasonable discharge correlations to the gage at Starbuck. To develop the correlation, mean daily discharges at the Marengo and Pataha Creek gages were plotted against mean daily discharges greater than or equal to 400 cfs at the Starbuck gage and a linear trend line with an origin of (0,0) was fit to the data. These correlations showed the following:

- Discharge at the Marengo gage was typically 86% of the discharge at the Starbuck gage (Figure C-2).
- Discharge at the Pataha Creek gage was typically 9% of the discharge at the Starbuck gage (Figure C-3).

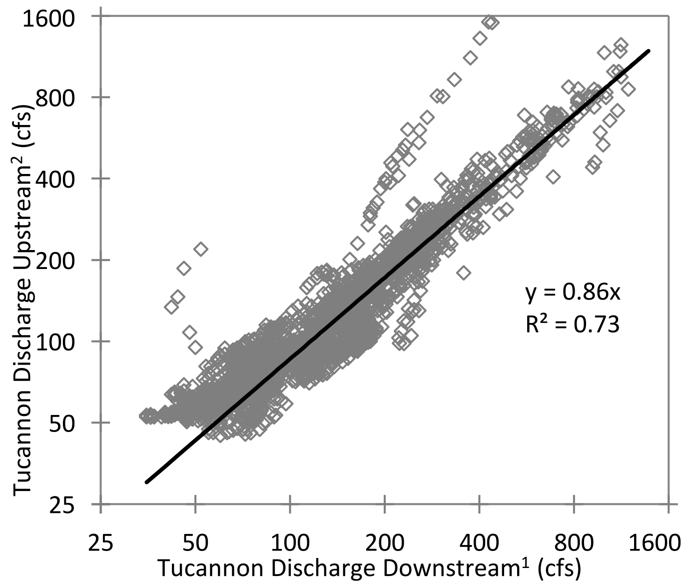
The results of applying these gage correlation corrections to the basin area scaling method are shown in the column titled "Flow as % of Starbuck, with Gage Corrections" in Table C-3 as flow proportion percentages. The table also shows the difference in flow proportions between the basin area scaling method and the gage correlation corrections to the basin area scaling method. The flow change locations and discharge contributions are also shown in Figures C-2 and C-3.

Table C-3 shows the basin area scaling method's underestimation of the discharge at Marengo and overestimation of discharge from Pataha Creek. The differences can be attributed to differences in the shape of the contributing areas and the distribution of mean annual precipitation in the basins. Although the Pataha Creek subbasin comprises approximately 43% of the contributing area to the Tucannon River at the Starbuck gage, it produces a significantly smaller percentage of the discharge as shown by the gage data correlation. Two primary factors reduce the relative discharge contribution of Pataha Creek:

- The long and narrow shape of the Pataha Creek basin is not conducive to producing large peak discharges.
- The Pataha Creek basin receives less precipitation per area compared to the upper portion of the Tucannon River. For example, only 8.8% of the Pataha Creek subbasin receives more than 30 inches of precipitation per year, compared to nearly 59% of the Tucannon River basin above Pataha Creek.

The stream gage correlation results are consistent with previously published hydrologic analysis results (Hecht et al. 1982). Hecht et al. focused on a single water year (1980) and found that, relative to total average annual flow at the Starbuck gage, Pataha Creek contributed approximately 11% of the average annual flow while the Tucannon basin upstream of Pataha Creek contributed approximately 85% of the flow.

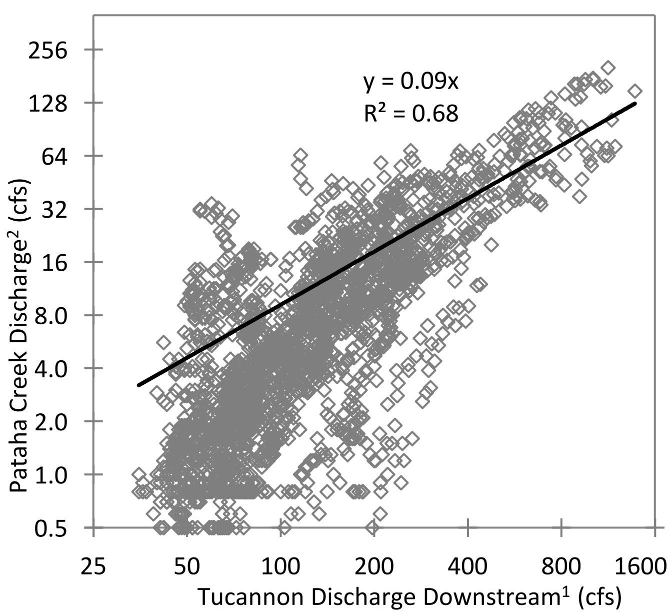
Figure C-2
Discharge Correlation Between Marengo and Starbuck Gages



Notes:

1. Discharge at the USGS Starbuck gage (13344500, RM 8.8, drainage area 431.5 square miles
2. Discharge at the Ecology Marengo gage (35B150), RM 27.2, drainage area 160 square miles

Figure C-3
Discharge Correlation Between Pataha Creek and Starbuck Gages



Notes:

1. Discharge at the USGS Starbuck gage (13344500, RM 8.8, drainage area 431.5 square miles
2. Discharge at the Pataha Creek gage, drainage area 184.8 square miles

Final Flows used for Modeling

Final reporting of the basin and tributary hydrology is provided in Table C-4. These flows were used in the final modeling effort, in addition to the standard return period statistics. The maximum monthly average flow for the months of January to May was used to represent higher winter flows. This metric is based on the average monthly statistics at the Starbuck gage, and scaled using the same final equation as the yearly return periods.

Table C-4
Model Hydrology

Flow Change (RM)	Tributary/ Location Name	Return Period (years)							Maximum Average Winter Flow[2] (cfs)
		1	2	5	10	25	50	100	
4.9	Kellogg Creek	595	1,548	2,728	3,869	5,861	7,850	10,379	323
8.8	Smith Hollow[1]	552	1,435	2,528	3,585	5,431	7,275	9,619	300
12.4	Pataha Creek	532	1,383	2,437	3,457	5,237	7,014	9,275	289
14.9	Willow Creek	367	956	1,683	2,388	3,617	4,845	6,406	200
35.8	Tumalum Creek	367	954	1,573	2,231	3,327	4,418	5,799	199
38.1	Cummings Creek	348	906	1,474	2,090	3,106	4,117	5,411	189
48.3	Little Tucannon River	284	738	1,192	1,691	2,512	3332	4,367	154
50.4	Panjab Creek	267	694	1,109	1,574	2,334	3,094	4,058	152
55.14	Above Panjab	168	436	723	1,026	1,545	2,072	2,745	145

Notes:

1. For the purposes of modeling, the discharge downstream of Smith Hollow was assumed to be equivalent to the discharge at the Starbuck gage.
2. The highest monthly average flow during the months of January to May at the Starbuck gage.

One additional flow was used in the analyses, termed the "Low-Winter Flow" as shown in Table C-5. This flow was not based on a statistical analysis but rather is the flow that occurred during the LiDAR flight. The topobathymetric LiDAR was able to produce a water surface elevation raster that made modeling this flow unnecessary. This flow does not have an exact statistical relevance but is approximately the average flow for the late summer and early fall months.

Table C-5
Low Flow Information

Flow Designation	Data Source	Data Dates	Average Flow During Dates at Starbuck Gage	Approximate Statistical Flow[1]
Low-Winter Flow	2017 LiDAR Water Surface Raster	November 17–19, 2017	120 cfs	20% Exceedance Flow for November

References

BLM (Oregon Bureau of Land Management), 2009. Watershed Boundaries Oregon and Washington. GIS Shapefile.

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Hecht, B., R. Enkelboll, C. Ivor, and P. Baldwin, 1982. *Sediment transport, water quality, and changing bed conditions, Tucannon River, southeastern Washington*. Report prepared for the USDA Soil Conservation Service, Spokane, Washington, April 1982.

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OSU (Oregon State University Climate Service), 2019. PRISM Climate Group. Available at: http://prism.oregonstate.edu. Map Created July 2019.

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USGS (U.S. Geological Survey), 2001. Fact Sheet on Methods for Estimating Flood Magnitude and Frequency in Washington.

USGS, 2018a. Monitoring Location 13344500, Tucannon River Near Starbuck, Washington. Accessed November 2018. Available at: https://waterdata.usgs.gov/monitoring-location/13344500/.

USGS (U.S. Geological Survey), 2018b. Streamstats in Washington. Available at: http://water.usgs.gov/osw/streamstats/Washington.html.

Appendix D
Topographic Data Summary

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Topographic Data Summary

Light Detection and Ranging (LiDAR) topographic data have been collected twice within the Tucannon River basin area since 2010. The comparison of these two datasets provides some insight into how geomorphic change has occurred during the time between flights. However, technological capabilities in LiDAR collection and processing techniques have changed significantly since 2010, and it is therefore necessary to determine what change is geomorphic process, what change is anthropogenic, and what change is simply due to differences in the LiDAR collection. This appendix explains how those determinations were made, how observations of actual geomorphic change were categorized, and the information used in the individual project area assessments in the main report.

LiDAR Comparison

The two datasets were analyzed to quantify physical change within the study area by comparing elevations at coincident locations to determine if topographic change (aggradation, incision, avulsion, or migration) has occurred.

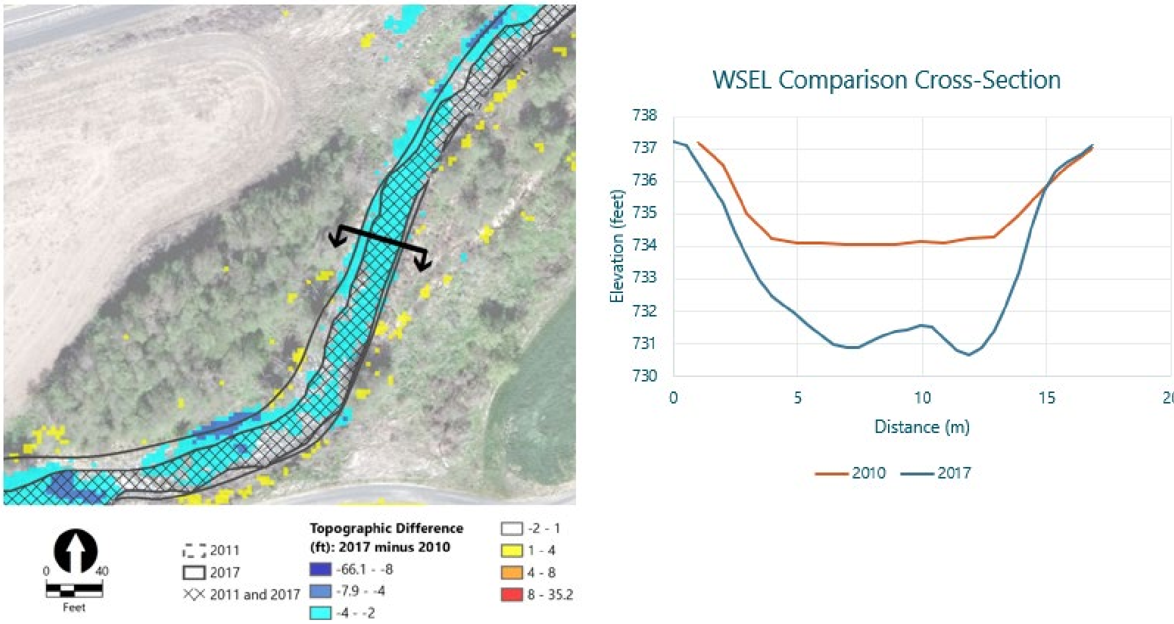
In the spring of 2010, Watershed Sciences, Inc. (WSI) was contracted to collect approximately 16,000 acres of elevation data within the basin. The WSI data measured topographic elevations only, although no bathymetric data were collected. Those data included digital elevation models (DEMs) of both the bare earth conditions and highest hit returns, which include vegetation, structures, etc. Resolution of the DEMs is 1.0 meter and the assessed vertical accuracy was approximately 3.70 centimeters (WSI 2010). Because these are topographic data only, channel bottoms show up at the water surface elevation at the time of the LiDAR flight. It can be assumed that the actual channel bed in 2010 was several feet lower in elevation than appears in the 2010 topographic data. In Figures D-1 to D-4, the range from -2 to 1 foot is shown as no change to better represent this fact. Additionally, it should be noted that change in the area where the 2010 main channel was may be underestimated for aggradation and overestimated for degradation.

A more recent LiDAR collection effort was conducted by Quantum Spatial, Inc. (QSI) in November 2017 and covered approximately 15,500 acres. QSI used airborne bathymetric sensors, which are capable of some penetration into the water column and depending on depths can resolve the riverbed topography. DEMs delivered by QSI are resolved to approximately 0.5 meter and have an assessed vertical accuracy of approximately 6 centimeters based on the LiDAR report published by QSI (QSI 2018).

While vertical accuracy of the QSI 2017 LiDAR data is slightly reduced from that of the WSI 2010 data, the half-meter resolution provides more channel definition, particularly in smaller off-channel and floodplain areas where channel widths are generally narrower, and the larger pixel size of the

2010 data is unable to represent the feature accurately shown in Figure D-1. This is useful in identifying areas of potential channel avulsion.

Figure D-1
LiDAR Bathymetry Comparison



WSEL: water surface elevation

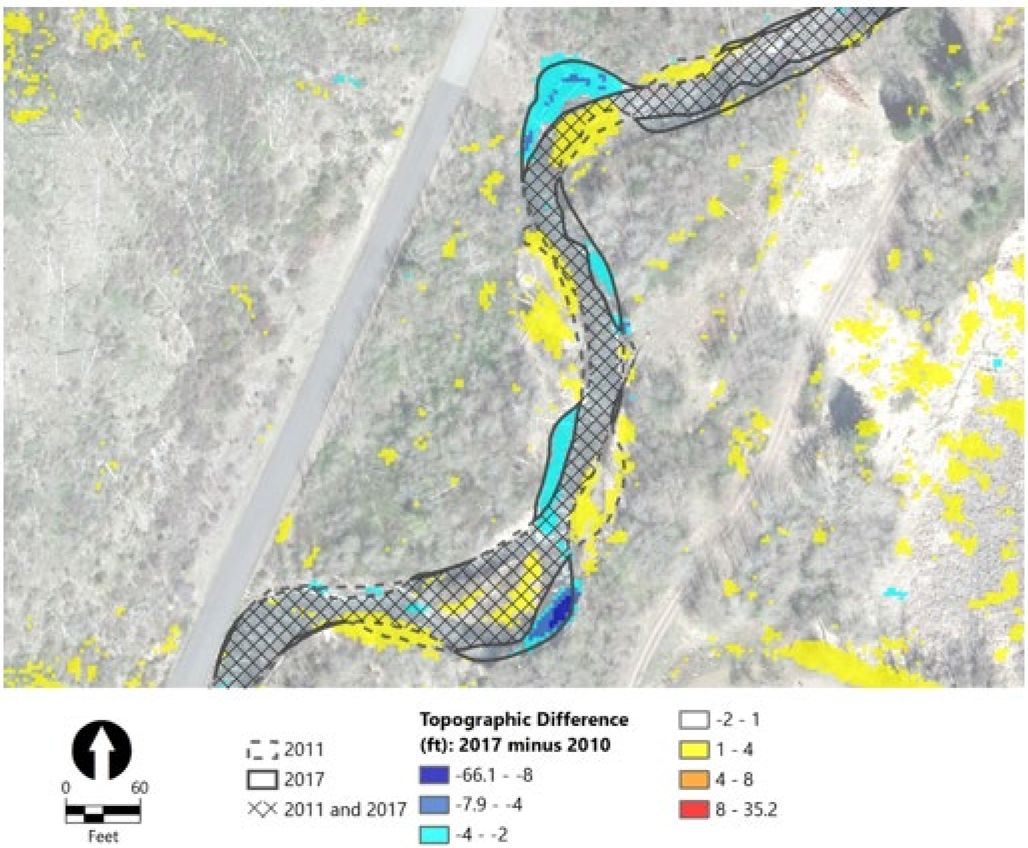
Characterization of Change

Overall change within the basin and subsequent project areas can be quantified by the elevation difference at a given pixel. This analysis is more appropriately applied to off-channel areas as the blue-green bathymetric LiDAR is able to penetrate the water while the topographic LiDAR is reflected from the water surface; thus, a comparison between the two sets of data within the channel is likely to show a lower elevation in the 2017 data relative to the 2010 data, which is an artifact of the two different sensor types rather than a physical change of the river planform. The difference in cell resolution may also result in artificial change when compared to the 2010 data due to being unresolved in the DEM.

Quantifying physical change on a small scale can be difficult when using only the topographic change DEM created from the LiDAR data due to the previously discussed limitations. However, when looked at discrete areas/reaches and with ancillary lines of evidence (e.g., aerial photographs, channel traces, field observations, local knowledge) the topographic change analysis can be useful in identifying and quantifying localized and reach-scale geomorphic processes (e.g., avulsions, head-cutting and associated downstream deposition, channel migration, and activation/deactivation).

Within the Tucannon River study area, the topographic change data resolves multiple geomorphic processes and features. These geomorphic processes include channel migration, avulsion, aggradation, incision, bar building, and bank erosion, among others. Channel migration is characterized by several alternating areas where the 2017 LiDAR elevation is deeper than the 2010 elevation was on either side of the channel. This effectively increases the number of meanders and sinuosity of a reach and is often seen in unconfined higher energy areas, as shown in Figure D-2.

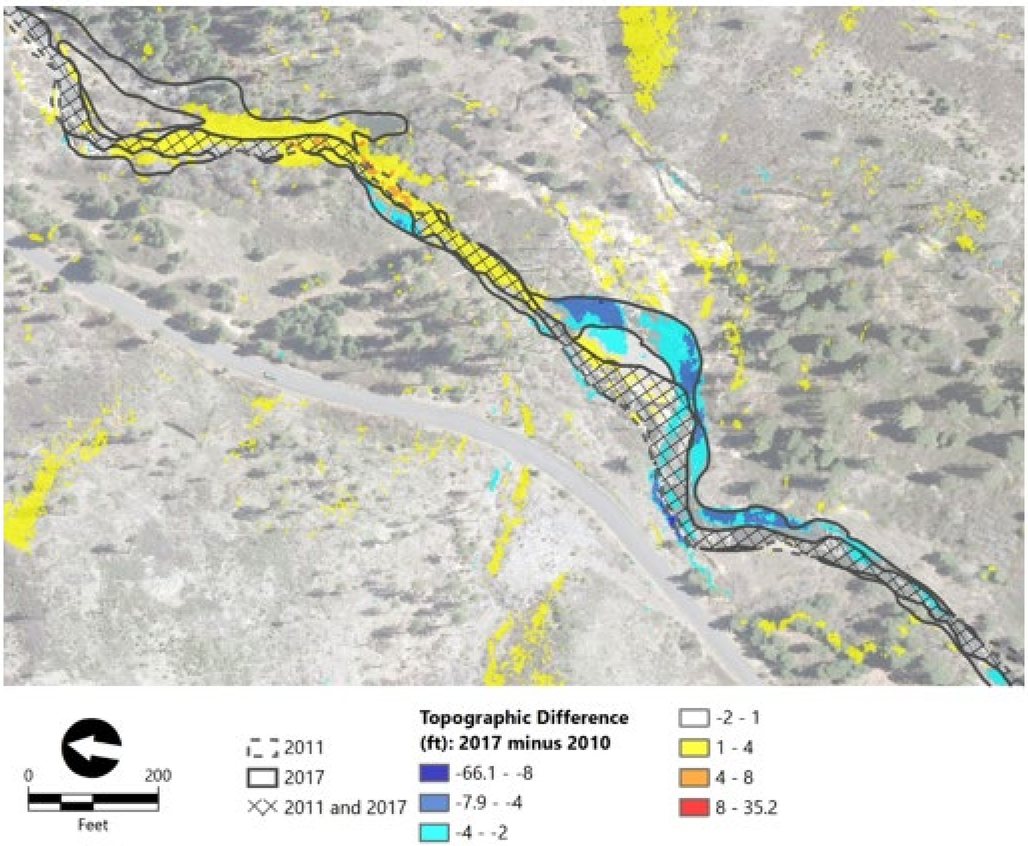
Figure D-2
Channel Migration



Project Area 11

Several large-scale avulsions were observed in this change analysis. Avulsions are characterized by whole reaches of river moving completely outside of the banks of the 2010 location. Figure D-3 shows where the river has migrated towards the right bank and eventually avulsed outside of the 2010 channel completely. Often, avulsions cause a large amount of floodplain material to be mobilized. Depending on how long ago these avulsions occurred, they are often associated with bed aggradation just downstream, as shown in Figure D-3. The area in the channel just downstream of the avulsion is 1 to 4 feet higher in 2017 than the water surface elevation was in 2010, indicating that much of the material from this avulsion has been deposited here at least temporarily. Areas of aggradation are not always associated with avulsions, and the source of the sediment for aggradation may be unclear. Unlike erosion within the channel, it is unlikely that areas of channel bed aggradation are false positives because the 2017 LiDAR should always register deeper channel elevation, as discussed previously. It can also be noted in Figure D-3 that aggradation downstream from the avulsion area resulted in split flow conditions and likely greatly improved floodplain connectivity. Thus, the process of avulsion and aggradation can improve habitat conditions and promote a reach-scale trend toward natural habitat creation and maintenance over time.

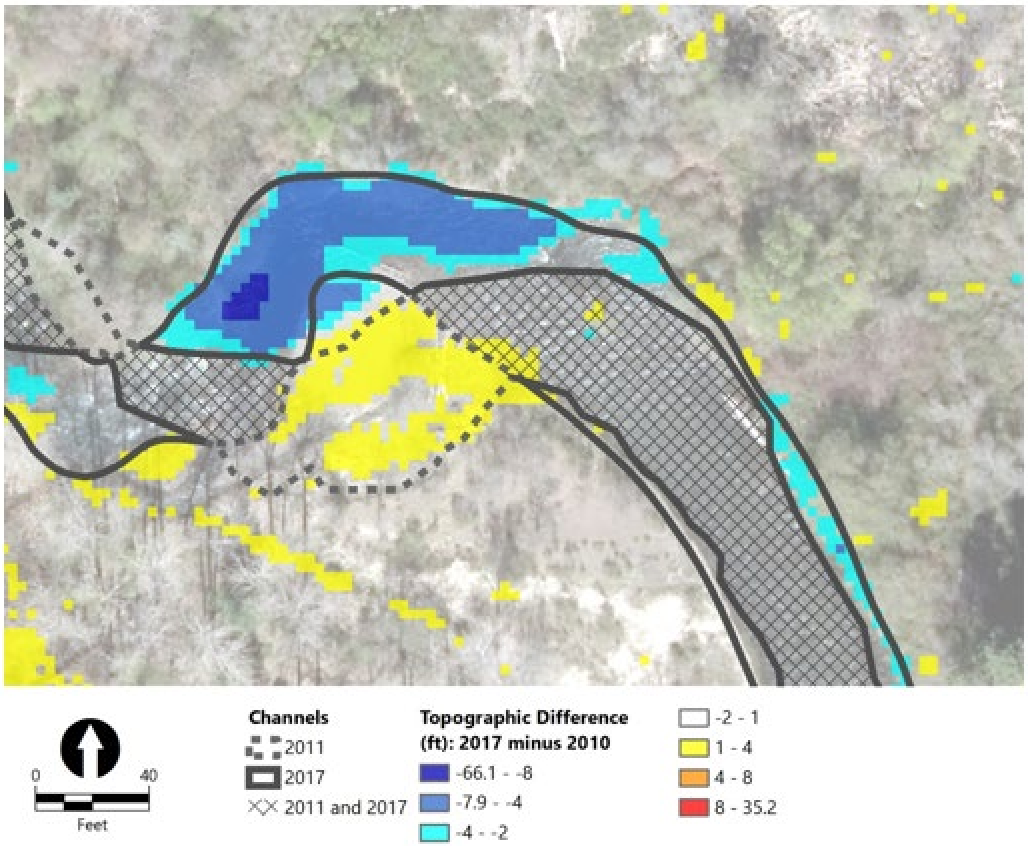
Figure D-3
Avulsion and Aggradation



Project Area 10

Finally, a commonly seen geomorphic change in the basin is the process of bar building and bank erosion. Figure D-4 shows an example of this geomorphic process. Bar building and bank erosion happen on a relatively small spatial scale compared to other geomorphic processes and can either be a localized event or part of a larger geomorphic process such as channel migration, as shown in Figure D-2. However, bar building and particularly bank erosion can often threaten critical infrastructure, possibly prompting actions such as emergency riprap placement, which could have negative effects on the natural processes of sediment transport and channel migration. Therefore, these areas were identified and special attention was paid to the surrounding landscape.

Figure D-4
Bar Building/Bank Erosion



Project Area 13

Uses of Topographic Data

The analyses described in this assessment use a combination of water surface information and DEMs to determine geomorphic conditions. Water surface elevations in turn were determined from a combination of 1-dimensional (1D) and 2-dimensional (2D) hydraulic models as well as directly from LiDAR results. Several relevant flow events were selected for the analyses and are described in Table D-1 along with one of three methods used to obtain them. The low-winter flow data raster was taken from the LiDAR output of water surface elevation and clipped to only include the main channel. The LiDAR was taken on November 11, 2017, when the flow at the Starbuck gage was approximately 130 cubic feet per second (cfs) and was used as the representative "low-winter flow" for this analysis. Lower flows may occur in the Tucannon River; however, these are likely to be episodic and only periodic.

Table D-1
Geomorphic Flows

Flow Significance	Flow at Starbuck	Method	Analyses Used In
Low-Winter Flow	130	2017 LiDAR Digital Elevation Model	River Complexity, Pool Frequency
Mean-Winter Flow	300	2D Hydraulic Model	River Complexity
1-Year Event (yearly high)	552	2D Hydraulic Model	River Complexity
2-Year Event	1,435	1D Hydraulic Model and Relative Elevation Map	Floodplain Connectivity, Stream Power
5-Year Event	2,528	1D Hydraulic Model and Relative Elevation Map	Floodplain Connectivity

The hydraulic model development is the largest data processes operation performed for this assessment. However, several smaller processes were used to obtain critical pieces of information as well. Both methods are based either on the LiDAR survey or the aerial photographs taken shortly afterwards.

Aerial photographs taken in April of 2018 (QSI 2018) were used to estimate roughness values for the HEC-RAS model as well as define rough channel extents. Channel extents were used to help characterize the change in LiDAR described previously. Additionally, major features such as roads, levees, floodplain lakes, and structures were digitized based on these aerial photographs.

It should be noted that the aerial photographs were taken at a different date than the LiDAR (April 2018 vs. November 2017) and therefore represent different flow conditions. The flow on the date of the aerial photographs is estimated at 320 cfs at the Starbuck gage, which corresponds to the flow analyzed for "mean-winter flow" in Table D-1. The flow rate during the LiDAR flight was 130 cfs at the Starbuck gage, which more closely represents the "low-winter flow" in Table D-1. Finally, the

Tucannon River basin experienced one of the highest flows since the previous geomorphic assessment on March 16, 2017, at 1,790 cfs (USGS 2018), just before the LiDAR imagery and aerial photographs were taken. There may be significant channel or floodplain changes shown in the aerial photographs that are not reflected in the LiDAR.

In addition to aerial photograph digitization, relative elevation maps (REMs) were developed for a variety of situations. REMs show the floodplain elevation relative to a point along the river channel. Typically, the thalweg elevation is used as the point of reference and the resulting REM displays floodplain elevations as they relate to the lowest point in the channel. However, for this assessment REMs were also created based on several different water surface elevations obtained from the modeling results. The effect is a REM that shows the floodplain as it relates to the water surface, quickly identifying areas that would be inundated at a given flow.

References

QSI (Quantum Spatial, Inc.), 2018. Topobathymetric LiDAR Technical Data Report: Tucannon River.

USGS (U.S. Geological Survey), 2018. Monitoring Location 13344500, Tucannon River Near Starbuck, Washington. Accessed November 2018. Available at: https://waterdata.usgs.gov/monitoring-location/13344500/.

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Appendix E

Hydraulic Modeling

Appendix E
Hydraulic Modeling

Two separate hydraulic models were developed for the analyses in this assessment, a 1D model and a 2D model, both developed using U.S. Army Corps of Engineers (USACE) HEC-RAS 5.0.7 (USACE 2016a, 2016b). Because a 2D model produces multi-dimensional velocity results, it provides more accurate results concerning split flows, side channels, and back waters at the lower flows. However, 2D models are much more time consuming to use as the area of inundation increases and can become unstable for very large watersheds. Additionally, the advantages a 2D model provides for isolated side channel and split flows is not as prevalent at the higher flow events when most of the low floodplain is inundated, and the 1D model may provide similar or even better results. Therefore, the 2D model was developed for lower flows and complexity analysis and the 1D model was used for higher flows and connectivity analysis.

1D Hydraulic Model

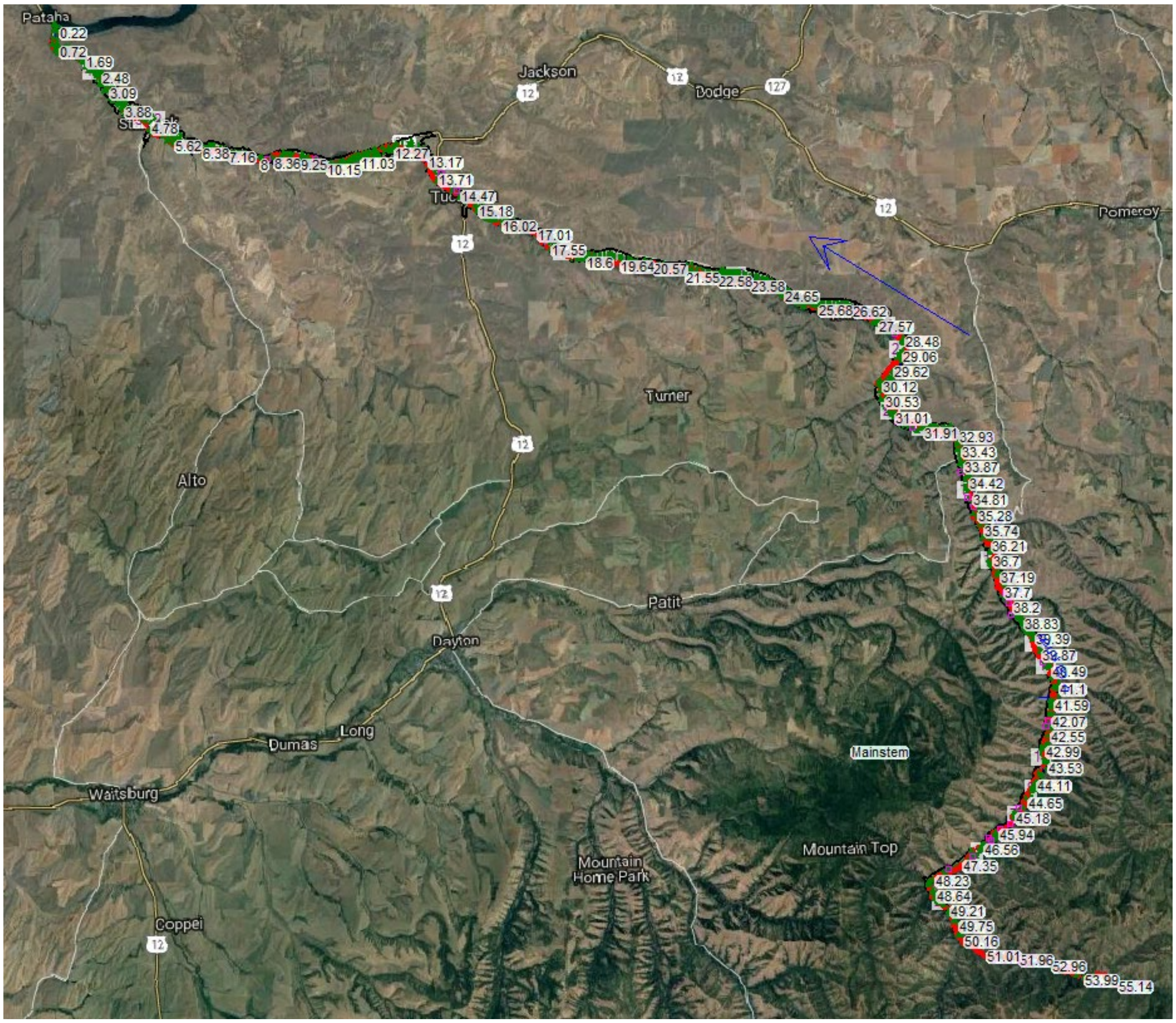
The basin-scale 1D hydraulic model (HEC-RAS 5.0.7; USACE 2016a, 2016b) was developed to provide estimates of main channel and floodplain hydraulic conditions for the discharges shown in Table E-1. The model was created for the mainstem Tucannon River only and does not model any of the tributaries, as shown in Figure E-1.

Table E-1
Standard Manning's n Values

Land Cover Type	Manning's n Value
River Channel	0.035–0.04
Agricultural Field	0.045
Developed: Low Intensity, Shrub/Scrub	0.06
Developed: Medium Intensity	0.08
Developed: High Intensity, Evergreen Forest, Deciduous Forest	0.1

The cross section locations in the 1D model developed for the 2010 assessment were projected onto the terrain from the 2017 Light Detection and Ranging (LiDAR) data where they were originally located to capture significant changes in channel and floodplain planform as well as changes in channel gradient, with the spacing of cross sections varying in proportion to planform complexity of the channel and floodplain. Adjustments to these cross sections were made based on changes in channel locations, changes in features, and land use changes affecting the roughness coefficients. Roughness values were chosen based on land use information and aerial imagery and corresponding to the land use categories described by the U.S. Geological Survey (USGS 2014). Manning's n values, shown in Table E-1, are based on those described in Janssen 2016. Additionally, approximately 50% more cross sections were added to better capture the channel features and utilize the higher resolution elevation data available with the 2017 LiDAR.

Figure E-1
HEC-RAS Model Extents



2D Hydraulic Model

2D hydraulic models are typically developed for short reaches, usually no more than a few miles in length and often as short as a quarter mile for complicated systems. This is due to the difficulty in stabilizing and obtaining accurate results from larger models. Therefore, the 2D hydraulic model for this assessment (HEC-RAS 5.0.7; USACE 2016a, 2016b) was developed using a simplified method. The 2D model for this assessment is actually a series of results of individual 2D models based on more manageable reach lengths of 1 to 3 miles. Developing the model in this manner was possible due to several simplifications and assumptions.

First, the 2D model was run for only the lower three steady state flows shown in Table E-2, and was not run with a dynamic realistic hydrograph, but rather an artificial hydrograph designed to ramp up slowly to the studied flows, stay at that flow for enough time to stabilize results, and then ramp up slowly to the next flow. Therefore, the results are only accurate for the three targeted flows described in Table E-2.

Table E-2
Flow Used for 2D Hydraulic Model

Flow Description	Data Source	Flow Rate at Starbuck
Low-Winter Flow	Water Surface DEM	130 cfs
Mean-Winter Flow	2D Hydraulic Model	300 cfs
1-year Flood Event	2D Hydraulic Model	552 cfs

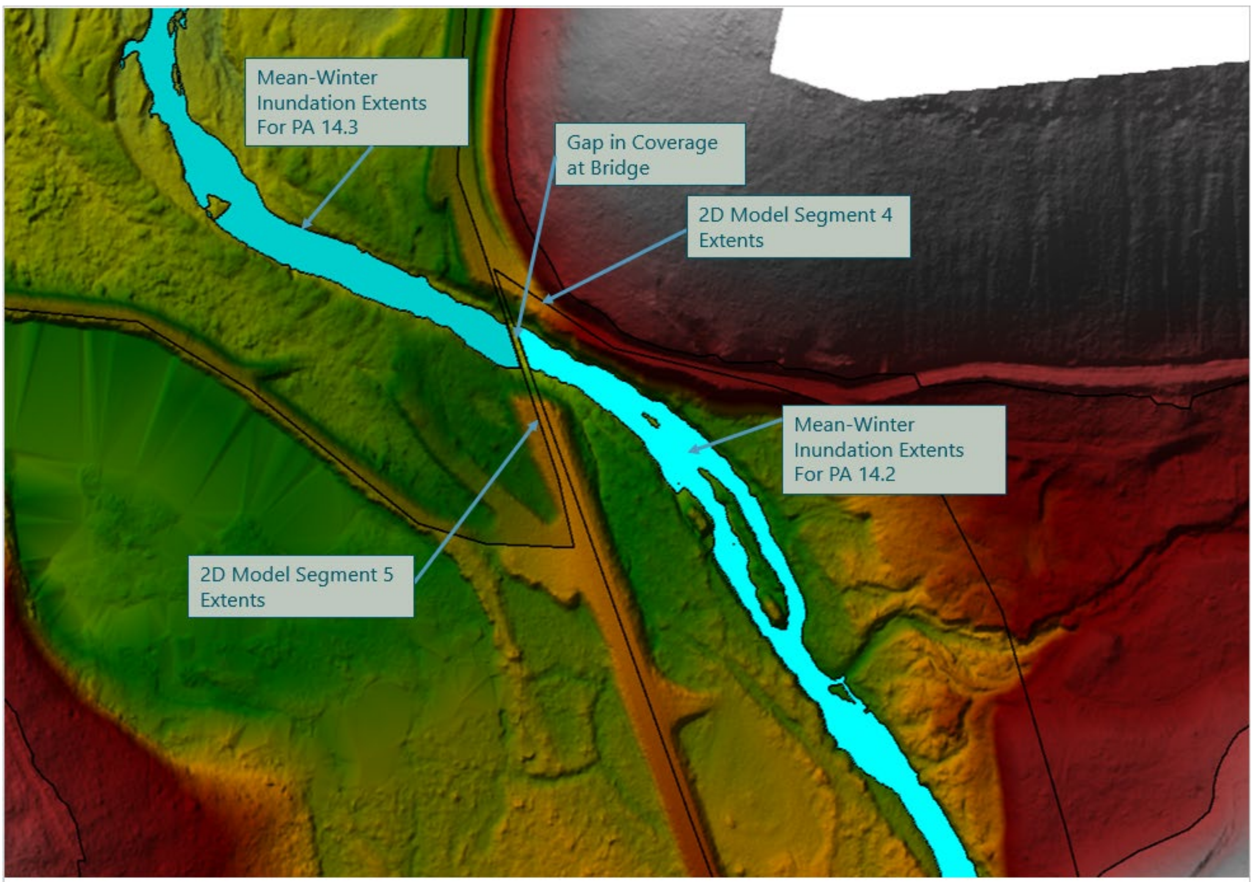
cfs: cubic foot per second
DEM: digital elevation model

Next, hydrologic inputs such as small tributaries were not modeled as 2D inputs, but rather the targeted flows for the low-winter flow, mean-winter flow, and 1-year flow for the individual model sections were adjusted based on the same adjustments made in the 1D model. These flow changes are described previously in the 1D Hydraulic Modeling section. This was made easier by ending individual model sections at each major flow input and beginning a new model section with the modified flows. This does create some minor inconsistencies at the intersection point of model sections with flow changes, but not enough to affect the results. Additionally, model section intersection points were chosen to occur in areas with very uniform flow. These areas include road crossing bridges, flow between levees, or in channel sections that were relatively straight and uniform in the 1D model. Figure E-2 shows an example of the intersection point between two model sections. Because the 2D model is only run at low flows, these change locations are uniform and predictable during all three events analyzed. The models begin and end slightly offset from each other to avoid conflicting results; this small gap in coverage was removed through interpolation after the results were determined.

Finally, the 2D model relies on an assumption of the simplification of roughness. A single roughness value was used for the model and does not vary across the floodplain, nor were any changes made to reaches that had been treated with restoration actions. The roughness for the whole model was set to the channel roughness value of n=0.04, a typical value for river channel. While not ideal because roughness effect does change with terrain, there are several strong justifications for this assumption. First, the model only deals with the lower flows of the 1-year level or less, and therefore the vast majority of flow will be in channel, not in the floodplain, and will by definition be within the bankfull flow. Additionally, any attempt at assigning more detailed roughness values to areas in channel would be assumptions in and of themselves and would not necessarily provide more accurate results. The simplification of roughness for lower flows makes the development of this 2D model feasible.

Once the 2D model sections were completed, the inundation results were then imported into GIS where they were modified slightly to fit together into a single inundation shapefile. The 2D model provides much more detailed results for side channels and split flows and is an essential piece of the complexity analysis.

Figure E-2
Gap in Coverage in 2D Model Results



Project Area 14.2 to 14.3

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Appendix F
Connectivity Analysis

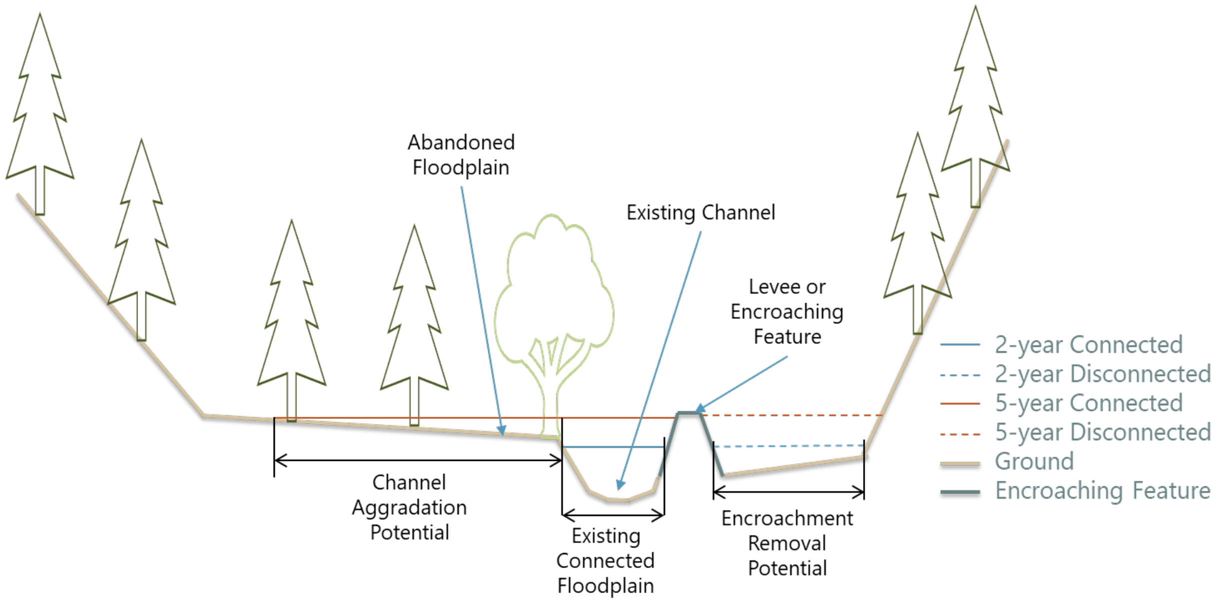
Appendix F
Connectivity Analysis

Floodplain connectivity is an important metric for gauging the state of a riparian area. Connected floodplains provide benefit for nearly all riverine aquatic species in the form of habitat, high-flow refugia, nutrient influx, and woody material. Hydraulically connected floodplains are key in developing riparian areas, which provide the material for instream wood, which in turn forces much of the geomorphic processes associated with the functioning river system. Confining features along the banks of the Tucannon River and within the floodplain influence hydraulic conditions during large floods, affecting local and reach-scale geomorphic processes such as sediment mobility and channel migration. Confining features may be both natural and influenced by anthropogenic activities. Inspections of aerial photography, Light Detection and Ranging (LiDAR), and field reconnaissance were used to identify confining features within the study area. These features include bedrock along the valley wall, alluvial fan deposits, bank armoring (e.g., riprap), levees and pond berms, and road prisms. Additionally, the Tucannon River can be disconnected from the floodplain through channel incision and downcutting. Channel incision is often associated with encroaching features such as levees or bedrock valley walls because straightened channels provide more stream power for sediment transport. Channel incision is often the beginning of a cycle of sediment starvation. The benefits and concept of floodplain connectivity are discussed in greater detail in the main report. The following section describes how floodplain connectivity was assessed for this assessment as well as a detailed review of the results of the assessment.

Analysis Overview

The purpose of this analysis is to describe the floodplain connectivity of a reach in a way that can be compared to the other reaches in the system and help inform potential restoration actions. The analysis focused on three characteristics of the floodplain: 1) the area of floodplain currently accessed and connected at a given flow event; 2) the area that could potentially be accessed given the removal of encroaching features; and 3) the area that could be accessed given sediment deposition and reversal of channel incision. Figure F-1 provides a conceptual valley cross section showing these three floodplain characteristics. The existing floodplain and potential floodplains are represented as lengths in this cross section but will be discussed as 2D (areas) for this assessment as the concept in Figure F-1 is applied along the length of the valley for each assessment reach.

Figure F-1
Conceptual Cross Section of Floodplain and Floodplain Potential



Removal of encroaching features and channel bed aggradation (or reversing channel incision) were chosen as potential restoration actions because they are common restoration techniques and are recommended in the main report. They are also two metrics that are directly related to floodplain connectivity, making representations of these actions easily computed using these data. It should be noted that these restoration actions, particularly channel bed aggradation, may be treating symptoms of other underlying problems with the geomorphic processes of the reach. When performing any restoration action, it is essential to consider the underlying drivers behind the current state of the reach in question, and address those as well. The restoration actions discussed here are recommended simply as a measure of potential in the floodplain. The main report explores additional restoration actions, measures, or considerations that may need to be taken to ensure the success of either of the above restoration actions.

Based simply on the frequency of occurrence, outcomes from restoration efforts in the Tucannon River basin are best evaluated on a flow recurrence interval of 2 years or less, and therefore this analysis focuses on that 2-year flow recurrence interval. To assess how much area could potentially be inundated at the 2-year flow event with minimal investment, the analysis examined the 5-year event as a representation of floodplain inundation potential at the 2-year event given positive outcomes from restoration activities. Figure F-1 shows how these flow events relate to the three conceptual floodplain characteristics discussed previously, and Table F-1 describes in more detail how these areas are used in this assessment.

The first step in evaluating the availability and potential for floodplain connectivity was to create relative elevation maps (REMs) based on the water surface elevations from the hydraulic 1D model. The REMs were then projected onto the terrain to determine estimated extents of inundation at the 2-year and 5-year flow events. This method allows all areas to be counted in the floodplain below the water surface elevation at a given point along the thalweg. This has the advantage of counting areas that are not hydraulically connected and that would not otherwise be counted using only the hydraulic model results. However, it should be noted that because these results are based only on the elevations and data from the LiDAR, they may not exactly match the conditions seen at this time in reality. For example, a side channel that is currently inundated because a large log jam has caused a backwater and forced flow down the channel has the possibility of appearing as not connected in these results if that side channel is actually higher in elevation than the water surface would be without the log jam. Therefore, this analysis should be seen as an assessment of how the elevations and channel geometries would be inundated without more temporary features such as log jams. Because these temporary features that could cause these minor inconsistencies may not exist after several high-flow events, this analysis represents a longer-term assessment of the topography and geomorphology of the basin and is appropriate for an analysis of events that occur less frequently.

These results were then trimmed slightly to discount areas that could never reasonably be inundated, such as behind highway prisms, in the Wooten Lakes, or in the town of Starbuck. Additional areas, which are unlikely to be inundated in the foreseeable future but are not impossible based on input from the basin stakeholders, have been labeled as "Unobtainable" and not included in the assessment. However, these areas are still shown on the GIS layers as part of this assessment, for reference, and mostly include agricultural fields with already installed setback levees and other low-lying areas behind levees that are unlikely to be removed.

The final resulting area, example shown in Figure F-2, represents the total amount of floodplain that could possibly be available at the given flow event, including areas that are currently disconnected via levees or other non-anthropogenic features. These floodplain areas were then separated into connected and disconnected areas so that the sum of both represents the total available low-lying floodplain (see Equation F-1). The disconnected areas are any part of the available floodplain that would be inundated during the flow event but are not hydraulically connected to the main channel. These areas can either be completely disconnected or hydraulically disconnected, meaning that, while the area does connect to the floodplain at the downstream end, there is no upstream flow path and the area is unlikely to be inundated through backwater alone. Removing these areas leaves the connected low-lying floodplain (the area that is currently available at a given flood event), as shown in Figure F-3. These areas were evaluated on a project area reach basis and divided by valley length to determine a standardized value.

Equation F-1

$$C_{yp} + D_{yp} = A_{yp}$$

where:

A_{yp}	=	available floodplain per valley length
D_{yp}	=	disconnected floodplain per valley length
C_{yp}	=	connected floodplain per valley length
Y	=	any given flow recurrence interval (2-year or 5-year)
P	=	any given project area

Figure F-2
Total Available Floodplain for 2-year and 5-year Flow Events

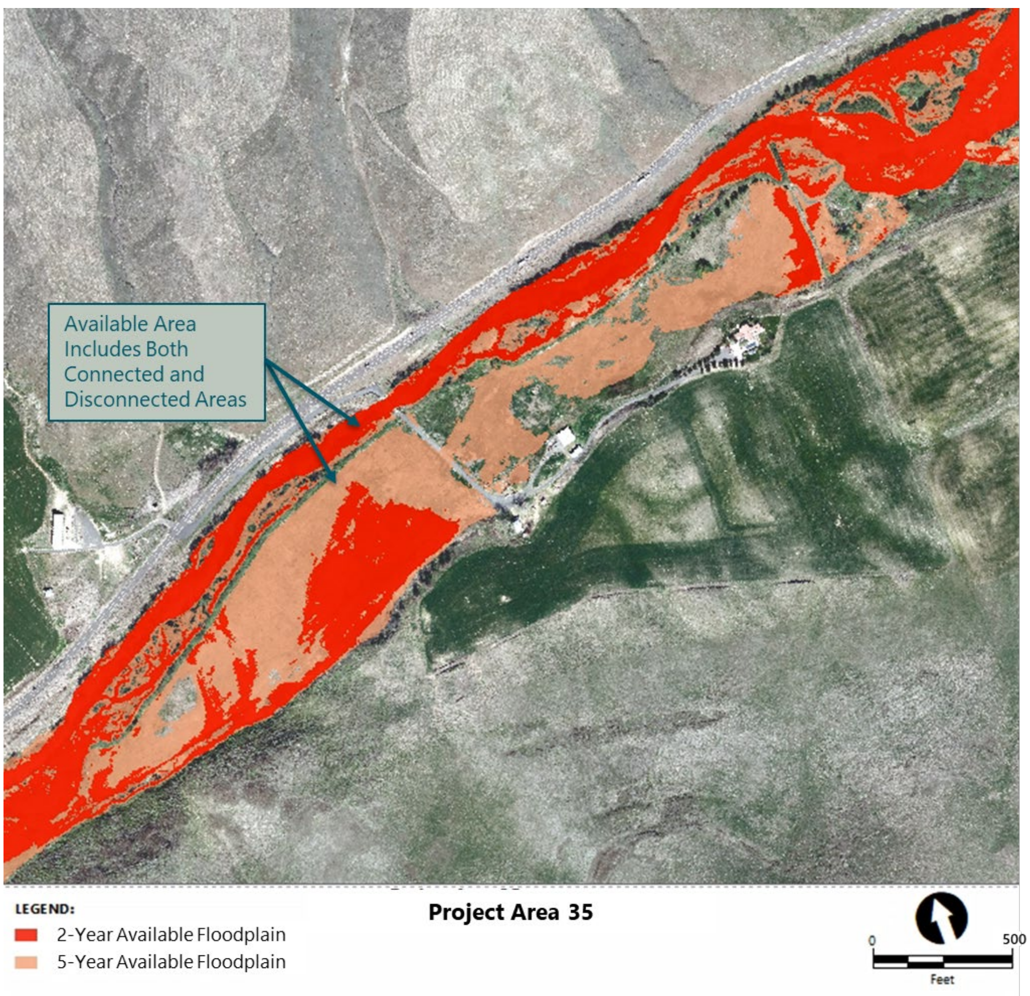
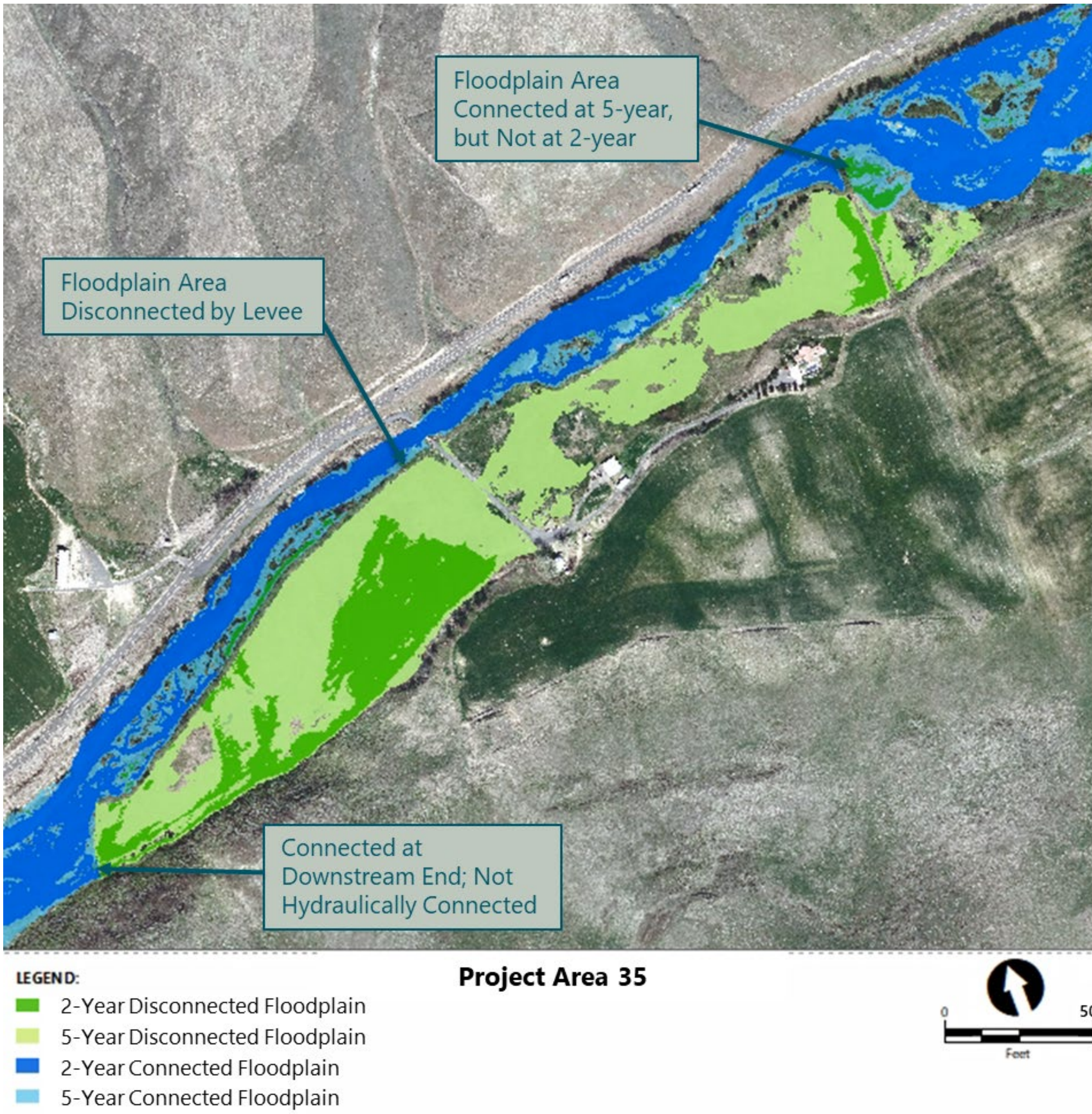


Figure F-3
Connected vs. Disconnected Floodplain for the 2-year and 5-year Events



Based on the assumption that the area inundated at the 5-year flow event represents the approximate maximum possible potential for the 2-year floodplain connection, the different areas of inundated floodplain can be assigned a conceptual significance greater than what they directly represent. These modeled inundated areas and the conceptual areas they represent are explained in

Table F-1. This analysis focuses on four of these areas in particular, examined as a percent of the total potential area that could be inundated (represented by the 5-year available floodplain):

- The area currently inundated at the 2-year flow, shown in Figure F-1 as the "Existing Floodplain"
- The additional area that could be inundated given channel bed aggradation, shown in Figure F-1 as the "Channel Aggradation Potential"
- The additional area that could be inundated given removal of encroaching features, shown in Figure F-1 as the "Encroachment Removal Potential"
- The additional area that could be inundated given both channel bed aggradation and removal of encroaching features, shown in Figure F-1 as both the "Encroachment Removal Potential" and Channel Aggradation Potential" combined

Table F-1
Modeled Floodplain Areas and Conceptual Significance

Floodplain Area	Description	Conceptual Significance	Use in Final Analysis
2C	2-year connected floodplain	The currently connected floodplain at the 2-year event.	None
2D	2-year disconnected floodplain	The floodplain disconnected by levee or other encroaching feature at the 2-year event.	None
2A	2-year available floodplain	The total floodplain area with elevation low enough to be accessed by the 2-year event, connected or not.	None
5C	5-year connected floodplain	The area of floodplain that could potentially be connected at the 2-year event with sufficient channel bed aggradation or other rise in water surface elevation.	None
5D	5-year disconnected floodplain	Not used. [1.]	None
5A	5-year available floodplain	The total area potentially connected at the 2-year event given channel bed aggradation and removal of encroaching features.	None
$\frac{2C}{5A}$	2-year connected divided by 5-year available floodplain	The percent of the potentially available area that is <u>currently inundated at the 2-year flow.</u> Used as an analysis result for connectivity (Figures F-4 and F-5).	Existing Connected Floodplain
$\frac{(5C-2C)}{5A}$	5-year connected minus 2-year connected divided by 5-year available floodplain	The percent of the potentially available area <u>gained via channel bed aggradation.</u> Used as an analysis result for connectivity (Figure F-6).	Channel Aggradation Potential

Floodplain Area	Description	Conceptual Significance	Use in Final Analysis
$\frac{2D}{5A}$	2-year disconnected divided by 5-year available floodplain	The percent of the potentially available area gained via removal of encroaching features. Used as an analysis result for connectivity (Figure F-7).	Encroachment Removal Potential
$\frac{(5A-2C)}{5A}$	5-year available minus 2-year connected divided by 5-year available floodplain	The percent of the potentially available area gained via simultaneous removal of encroaching features and channel bed aggradation.[2] Used as an analysis result for connectivity (Figure F-8).	Total Floodplain Potential

Notes:

1. The 5-year disconnected area cannot be conceptually accessed without both channel bed aggradation and removal of encroaching features; therefore, modeling just the removal of encroaching features at the 5-year event is not useful for this analysis.
2. This includes removing features that encroach on both the 2-year and 5-year inundation area.

This analysis therefore produces four distinct results: Existing Connected Floodplain, Channel Aggradation Potential, Encroachment Removal Potential, and Total Floodplain Potential. The concepts behind these results are shown in Table F-2. How an individual project area scores in each one of these analysis results can provide insight into what restoration actions will be most effective for that project area. Because all of the analysis results are measured as a percent of the total available floodplain, if a project area scores highly in the Existing Connected analysis result it can be due to two different scenarios.

In the ideal scenario represented in Figure F-4, the existing connected floodplain (2C), is similar to the potential connected floodplain (5C) in that both are already well-connected floodplains and therefore do not have a large amount of potential for restoration. However, the scenario represented in Figure F-5 would also score very similarly to Figure F-4, but in this case the channel is so incised or confined that the potentially available floodplain, as defined for this assessment, is not much larger than the existing connected floodplain. Even though both score highly in the Existing Connected Floodplain analysis result, the two are at the opposite ends of the spectrum for floodplain connection. While this may seem like a drawback to this method, it is actually very useful for prioritization and conceptual restoration. For prioritizing restoration work, reaches with a high amount of potential area available to be reconnected via restoration actions are desirable for restoration work and should be prioritized highly, and conversely project areas with a small amount of potential area are not desirable for restoration work and should not be prioritized. The scenarios in Figures F-4 and F-5 are opposite ends of the connected floodplain spectrum, but both represent scenarios where there is little potential floodplain area to be gained from restoration work. Therefore, project areas similar to these scenarios with high scores in the Existing Connected analysis result can be sorted to the bottom of a prioritization.

Figure F-4
High Existing Connected Floodplain – Ideal Scenario

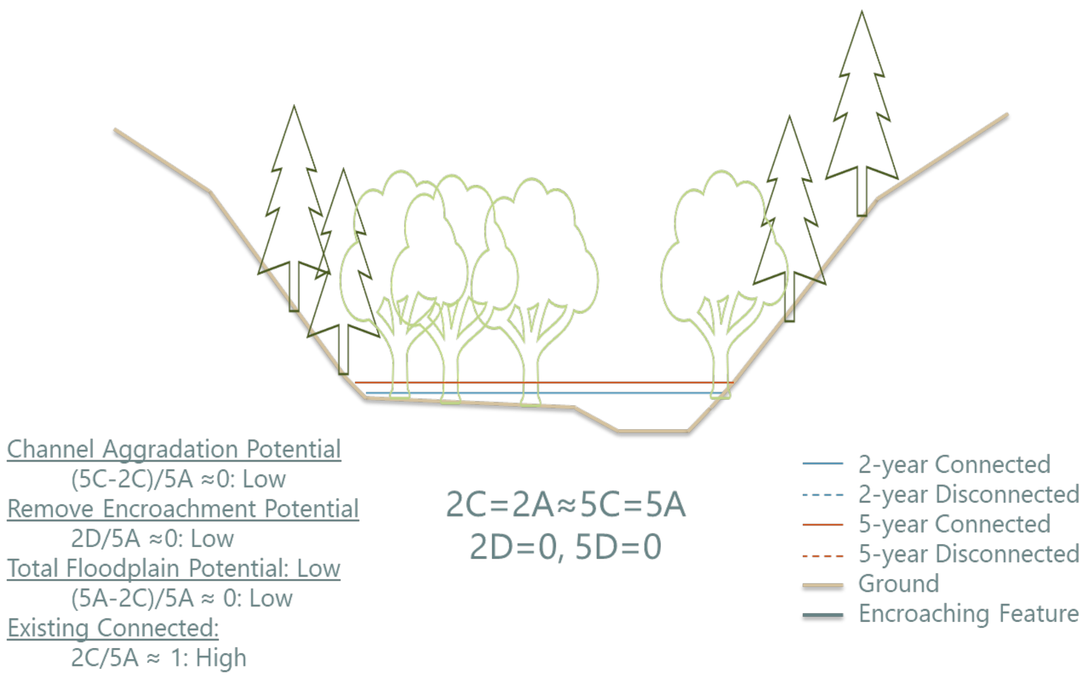
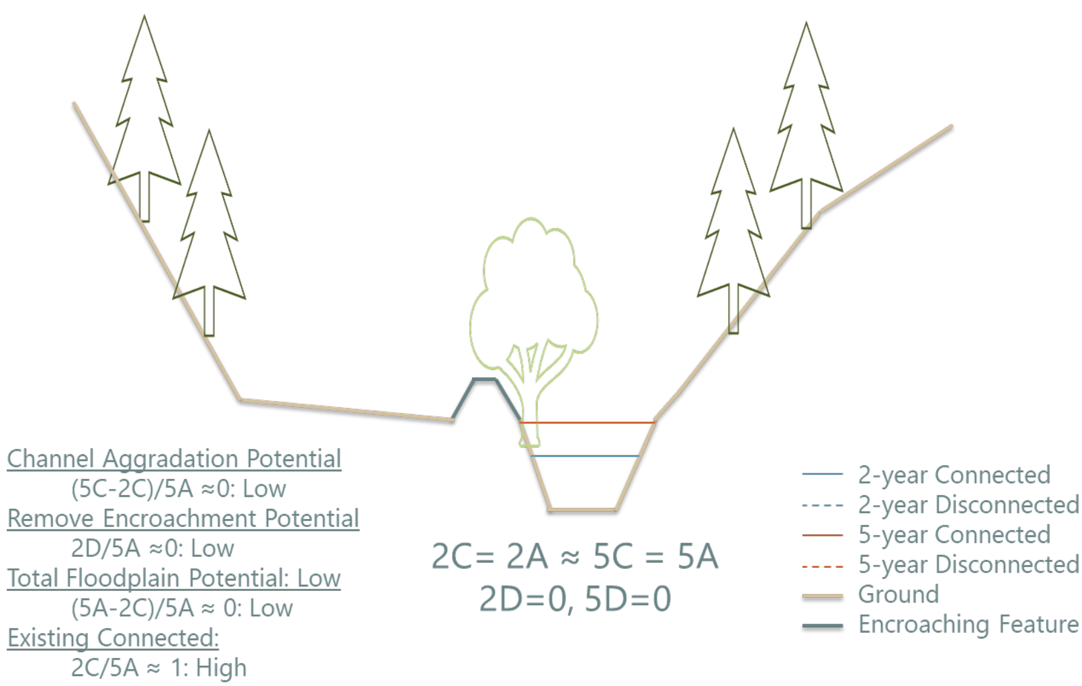


Figure F-5
High Existing Connected Floodplain – Highly Confined Scenario



Several scenarios related to the analysis results indicate that these reaches have floodplain area that is not currently connected but could potentially be connected with restoration work. Figure F-6 shows a scenario where the 2-year connected floodplain connection area is low, but if the channel bed were to aggrade and the water surface elevation raise to a level similar to the current 5-year connected floodplain, a significantly larger area would be connected. This scenario represents a reach that would score highly in the Channel Aggradation potential analysis result. Project areas that score highly in this analysis result will be ranked highly in the prioritization and will have restoration strategies recommended that can help to aggrade the channel bed and reconnect some of this potential area.

Figure F-7 shows a scenario where the 2-year connected floodplain connection area is low, but if an encroachment such as a levee, high bank, or structure were removed a significantly larger area would be connected. This scenario represents a reach that would score highly in the Encroachment Removal potential analysis result. Project areas that score highly in this analysis result will be ranked highly in the prioritization and will have restoration strategies recommended that can reconnect disconnected floodplain.

Finally, a scenario exists where there is some area that could potentially be connected at a 2-year event but is not currently, and neither Encroachment Removal nor Channel Aggradation on their own would be enough to connect these areas. Figure F-8 shows a scenario where, should the encroachment be removed, not much area would be gained, and if the channel bed elevation were raised and the water surface elevation rise to the 5-year level still not much area would be gained. However, if both actions were to occur, a large amount of floodplain area could be connected at the 2-year event. This scenario is represented by the Total Floodplain Potential analysis result and these project areas will be ranked more moderately in the prioritization because they have potential, but more effort is required to connect it.

All of these scenarios represent an idealized condition; in reality, most, if not all, project areas will have some combination of the above scenarios and will be more similar to the scenario shown in Figure F-1.

Figure F-6
High Channel Aggradation Potential

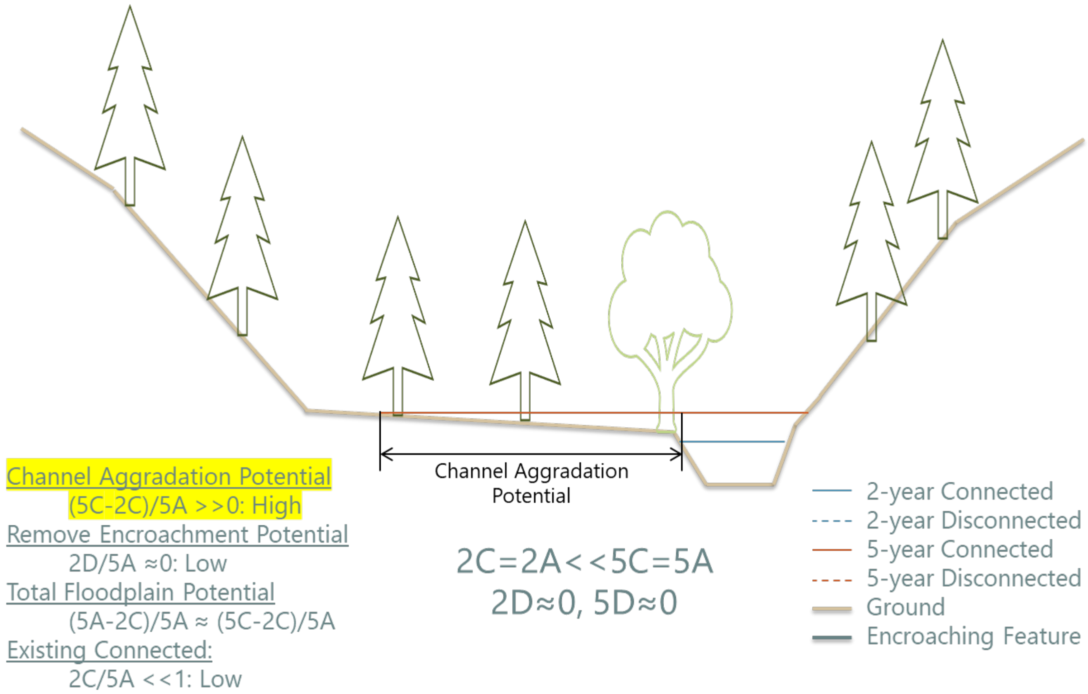


Figure F-7
High Encroachment Removal Potential

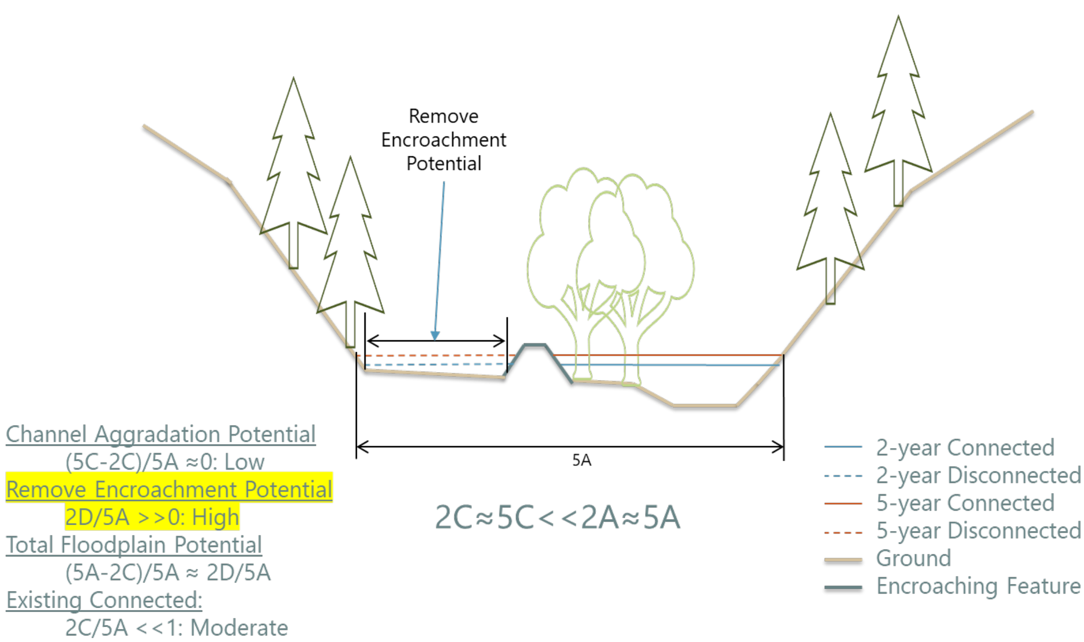
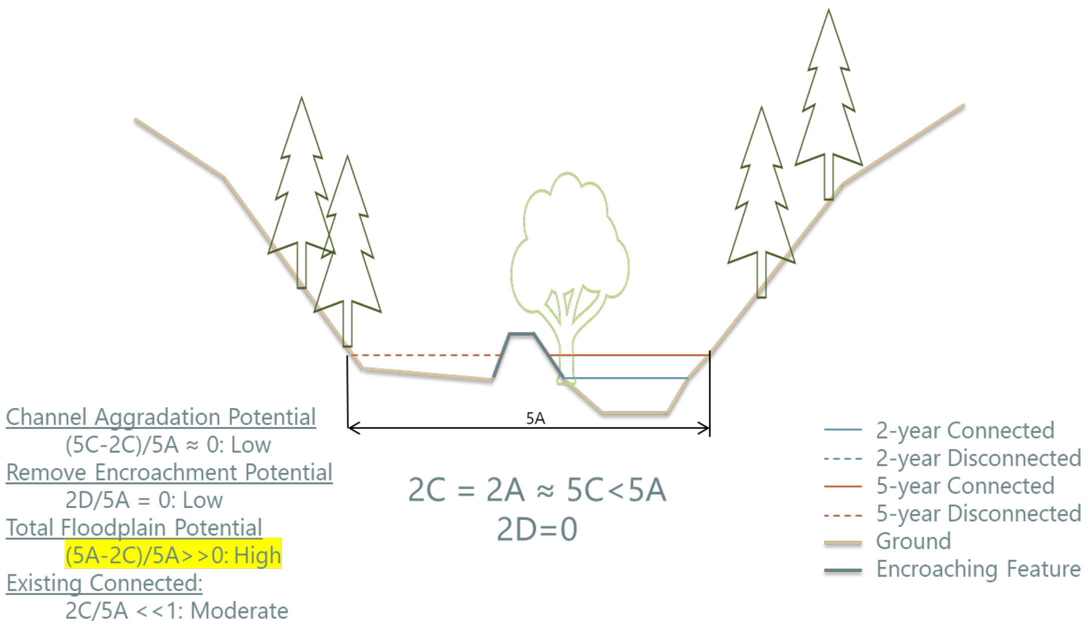


Figure F-8
Total Floodplain Potential – Both Channel Aggradation and Encroachment Removal are Necessary



Connectivity Trends and Patterns

This section briefly describes some of the basin-wide trends that result from the Connectivity analysis. A more detailed breakdown of how this analysis applies to individual project areas is discussed in the Project Area Cut sheets in Appendix J. This section references figures and tables that are provided at the end of this appendix and also heavily references terms defined and explain in the previous section.

The 2-year connected area per valley mile shown in Figure F-12 is the most direct measurement of the current connection of the floodplain. As shown in Figure F-11, the 2-year connected area is expressed as a percentage the total 5-year floodplain area. Similarly, Figures F-13, F-14, F-15, and F-16 show the same information but for potential floodplain area per the two potential restoration actions: channel bed aggradation (i.e., reversing channel incision) and removal of encroaching features (i.e., levees).

Figure F-9 combines the existing floodplain area and "potential floodplain area through restoration actions" expressed as a percentage of the total potential floodplain area. In an ideal situation, these three percentages would total 100%. However, there are several situations where this is not the case, and understanding those situations provides insight into how this analysis and metric is useful.

The difference between the totals and 100% is the same as the difference in the "5-year disconnected area percentage" and the "2-year disconnected area percentage." For most of the project areas, the "currently connected area percentage" and both individual "restoration action area percentages" total less than 100%. This is because the two restoration actions are viewed as if they were done individually, either channel bed aggradation or removing encroaching features but not both, so they will discount the additional area from the "5-year disconnected area percentage" over the "2-year disconnected area percentage" shown in Equation F-2.

Equation F-2

$$100\% = C_2 + P_{RL} + P_{RB} + (D_5 - D_2)$$

and

$$P_B = P_{RL} + P_{RB} + (D_5 - D_2)$$

where:

C_2	=	currently connected area at 2-year, as a percentage of the total available
P_{RL}	=	potential area by removal of encroaching features restoration action, as a percent
P_{RB}	=	potential area by channel bed aggradation restoration action, as a percent
D_5	=	disconnected area at 5-year, as a percentage of the total available
D_2	=	disconnected area at 2-year, as a percentage of the total available
P_B	=	potential area by doing both restoration actions together

Figure F-10 shows the third potential restoration metric ("Total Floodplain Potential"), which considers both channel bed aggradation and removal of encroaching features. The "Total Floodplain Potential" metric counts the difference in 5-year and 2-year disconnected percentage, which explains the difference between the "Total Floodplain Potential" restoration action and the sum of the two individual restoration actions alone.

When the total is greater than 100%, as shown in Figure F-9, this indicates that the difference in 5-year to 2-year disconnected area is negative. Physically, this means the 2-year disconnected area is reconnected as water surface elevation increases to the 5-year level, thus making the 5-year disconnected area smaller than the 2-year disconnected area. This is shown in Figure F-10 where the "Total Floodplain Potential" restoration action is smaller than the sum of the two individual restoration actions. This simply indicates that the individual actions are "double counting" the difference between the 2-year and 5-year disconnected area, because either removing encroaching features or raising the water surface elevation would reconnect that area.

There are several interesting trends that should be noted to understand how connectivity is occurring across the basin. The connected area per valley mile (Figure F-11) shows a clear trend towards the lower end of the basin. However, when looking at connected area per valley mile per available area (as a percentage), no relevant trend is discernable. This indicates that, while there is technically more connected floodplain in the downstream reaches, this is likely due to natural river processes of increased deposition and spreading out while moving downstream into these lower energy reaches. So, the connected area as a factor of its potential remains similar throughout the basin.

The two potential areas obtained via restoration actions in Figures F-14 and F-16 show only a slight trend towards the lower reaches of the basin and show no correlation when expressed as a percentage of the total potential in Figures F-13 and F-15.

It is also interesting that channel bed aggradation shows at least some benefit for all of the project areas except Project Area 43 (see Figure F-13). All other project areas show a benefit of more than 5% and most more than 15%. By comparison, removing encroaching features (see Figure F-15) shows a large benefit for some project areas but also many others that show almost no benefit (less than 5%). The restoration option for removing encroaching features has a few outliers that make physical sense as well: Project Areas 5 and 6 include the large Camp Wooten levee, and Project Areas 13 and 14.1 include the Rainbow Lake and Hatchery levees.

Finally, it should be noted that in Figure F-11, which shows the percentage of currently connected area, the majority (49/60) of project areas are already above 50%. While this is a good indication for the basin, it does not necessarily mean most reaches are connected to at least 50% of their optimal level. The metric used as 100% in this analysis is the 5-year available floodplain; it is very likely that much of the basin has been incised or confined beyond this point, making the "100%" level less than the potentially optimal level. This assessment chose to use the 5-year available as the "100%" level because it seemed like a reasonable goal for floodplain connection. With future iterations of assessment, this may be adjusted to expand as opportunities arise or decrease as others are deemed impossible based on anthropomorphic demands on the river and basin and balanced with the benefit to fish and aquatic species.

Scoring for Prioritization

In order to combine the Connectivity analysis results of Channel Aggradation, Encroachment Removal, and Total Floodplain Potential into one Connectivity value to be used as a metric in the prioritization, weights were assigned to each Connectivity analysis result, which were then summed to produce the final metric value. Table F-2 provides the weights chosen to combine these results. The Channel Aggradation Floodplain Potential and Encroachment Removal Floodplain Potential are favored in the weighting over the Total Floodplain Potential. The Total Floodplain Potential represents the areas where benefit can be gained only by performing both floodplain connection restoration actions; while these areas still have value, they would require more restoration effort for similar benefits and therefore are weighted lower.

Table F-2
Complexity and Connectivity Weighting

Connectivity Weighting	
Analysis Result	**Percent Weight**
Channel Aggradation Floodplain Potential	40%
Encroachment Removal Floodplain Potential	40%
Total Floodplain Potential	20%

The next step in the prioritization process is to rank, classify, and score each project area in each of the three metrics (Complexity, Connectivity, and Excess Transport Capacity). Project areas are ranked in the Connectivity metric from best to worst by the scores determined using the weightings described in Table F-2. Each project area is then ranked for the Connectivity prioritization metric and can be classified and scored according to the system outlined in Table F-3.

The Connectivity analysis results, and therefore the Connectivity prioritization metric, already inherently measures the potential of the project areas to reconnect the floodplain at the 2-year event. Therefore, the project areas that would gain the most benefits from reconnecting floodplain with the least amount of effort will already be ranked at the top, and as such receive the highest scores. It should be noted that the floodplain connectivity metric reflects the potential for each project area as they currently stand. Should events occur, such as channel bed aggradation that opens more floodplain potential, or land ownership change that makes floodplain area designated “unobtainable” become available, the potential of a project area could change drastically. Table F-3 describes the concepts behind the classifications and scoring for connectivity.

Table F-3
Floodplain Connectivity Potential Classification and Scoring

Percentile Rank	Class	Class Score	Metric Score Threshold[1]	Class Conceptualization
75th to Top	1	5	0.235	Project areas in this class have the most floodplain potential, indicating that restoration efforts have the potential to raise the percentage of connected area to the highest potential based on current conditions. These should be the primary target of floodplain reconnection restoration actions.
50th to 75th	2	3	0.204	Project areas in this class score above average for floodplain connection potential and should be a secondary target for floodplain reconnection restoration actions.
25th to 50th	3	1	0.155	Project areas in this class have below average floodplain connection potential and should be the last group of project areas targeted for floodplain reconnection restoration.
Bottom to 25th	4	0	0	Project areas in this class have the least floodplain connection potential. This can either indicate that the project area is not well connected and has little room for improvement, or it is very well connected and there is little else to be connected via restoration efforts. In either case, these should not be targeted for floodplain reconnection actions, based on their current conditions.

Notes:

1. This is the score that defines the lower limit for the corresponding classification for this metric. These data can be used to track progression of project areas and compare to how they would rank according to the levels of this assessment, as new restoration projects are completed and new data become available.

Detailed Instructions for Performing This Analysis

Part of the purpose of this assessment is to define repeatable and data driven methods for assessing project areas and how they have progressed in relation to their goals. This section provides the detailed steps taken to perform the Connectivity analysis of the Tucannon River so that these analyses can be repeated in the future for additional analyses and evaluation of progress. Table F-4 provides the data that will need to be collected to reassess the project areas for complexity.

Table F-4
Raw Data Needed to Perform Connectivity Analysis

Data Needed	Used For	Source
Topography Digital Elevation Model	1D hydraulic modeling	LiDAR, preferably blue-green and 0.5-meter horizontal accuracy or greater
Hydrology	Flows used in hydraulic modeling	Hydrologic gage data[2]
Water surface inundation boundaries[1]	Calculation of island count and island perimeters	1D hydraulic modeling results
Levees and encroachments	Delineation of disconnected area	Aerial photographs or field data
Relative elevation map	Calculation of inundated area	LiDAR, preferably blue-green and 0.5-meter horizontal accuracy or greater
Project area delineations	Calculation of all metrics per project area	Project area shapefiles from this assessment

Notes:
1. Water surface boundaries should be for the flows desired for the analysis: in this assessment, the 2-year (1,436 cfs), and 5-year (2,530 cfs).
2. See Appendix C for a description of gage locations on the Tucannon River and methods used to interpret those data.

The following steps will assume the user has adequate GIS knowledge and access to the same data sources as those produced in this report.

1. This analysis uses HEC-RAS 1D model results for the 2-year and 5-year flow events as a base layer. See the main report and Appendix C for details on how the modeling was done, and how the hydrologic flow events were determined.
2. Water surface elevation raster's (produced in HEC-RAS) were imported into GIS.
3. A REM was created based on the steps outlined in Ecology 2014 using the water surface elevation rasters as the base digital elevation model (DEM) (as opposed to the terrain raster described in Ecology 2014). The REM was created relative to the river centerline, which was manually digitized.
4. All results from the resulting relative elevation raster with a value of 0 or less will be under the water surface at that flow event. These areas were isolated from the REM and the bounding areas were exported as simple polygons.
5. These polygon shapefiles were then manually edited to delete areas not relevant to this analysis. These areas include areas within lakes or standing bodies of water, areas behind well-established levees or roads, such as in the town of Starbuck, and areas on the opposite side of the Tucannon River valley that are not realistically reconnectable. The resulting polygon shapefiles form the total available floodplain area for the 2-year and 5-year event described in Table F-5.

6. The water surface break line shapefile, obtained as a data file from the LiDAR survey, was imported into GIS. Any areas of the total available polygons not directly connected to the low-winter flow were labeled as "disconnected areas." Additionally, areas that were only connected on the downstream side or were behind known levees were manually separated and counted as disconnected areas as shown in Figure F-3. This produces four distinct floodplain shapefiles: 2-year Available, 2-year Disconnected, 5-year Available, and 5-year Disconnected.
7. These four shapefiles were broken up by project area and summed for each project area to produce the disconnected areas and available areas described in Table F-5.
8. The disconnected area was subtracted from the total area to produce the connected area described in Table F-5. Each of these metrics was also differenced between the 2-year and 5-year areas to obtain the available difference, disconnected difference, and connected difference.
9. All nine of these areas shown in Table F-5 were divided by the valley length, which was manually digitized, to obtain the area per valley mile of each of the floodplain areas shown in Table F-6.
10. These values of area per valley mile were used to calculate the restoration actions in Table F-6:
    a. Raise bed: 5-year connected minus 2-year connected divided by the 5-year available (5C-2C)/5A
    b. Remove levee: 2-year disconnected divided by 5-year available (2D/5A)
    c. Doing both: 5-year available minus 2-year connected divided by 5-year available (5A-2C)/5A
    d. Existing: 2-year connected divided by 5-year available 2C/5A

References

Ecology (Washington State Department of Ecology), 2014. "A Methodology for Delineating Planning-Level Channel Migration Zones." Pub. No. 14-06-025. Shorelands and Environmental Assistance. Olympia, Washington. July 2014. Available at: https://fortress.wa.gov/ecy/publications/SummaryPages/1406025.html.

Tables

Table F-5
Connectivity Analysis Floodplain Area Results

Project Area	Restoration Status	River Mile Start	Valley Mile Start	Floodplain Area (acres)								
				Available 2-year	Available 5-year	Available Difference	Disconnected 2-year	Disconnected 5-year	Disconnected Difference	Connected 2-year	Connected 5-year	Connected Difference
1.1	Treated	49.6	44.0	6.10	9.21	3.11	0.60	1.42	0.82	5.50	7.80	2.30
1.2	Untreated	49.2	43.7	2.66	3.52	0.85	0.39	0.84	0.45	2.27	2.68	0.41
2	Untreated	48.6	43.1	6.82	8.86	2.04	1.25	1.68	0.43	5.57	7.18	1.61
3.1	Untreated	48.2	42.7	3.04	4.25	1.21	0.63	1.02	0.39	2.40	3.23	0.82
3.2	Treated	46.8	41.4	17.44	23.60	6.16	0.39	0.34	-0.05	17.05	23.27	6.21
4	Untreated	46.5	41.2	2.56	3.02	0.46	0.20	0.29	0.09	2.36	2.73	0.37
5	Untreated	46.1	40.8	10.71	13.83	3.12	6.18	8.30	2.11	4.53	5.53	1.00
6	Treated	45.4	40.2	11.61	15.02	3.42	4.12	5.76	1.64	7.48	9.26	1.78
7	Untreated	44.9	39.7	4.28	5.28	1.00	0.47	1.01	0.53	3.80	4.27	0.47
8	Treated	44.4	39.3	5.68	7.82	2.14	0.22	0.71	0.49	5.46	7.11	1.65
9	Treated	44.0	38.9	8.47	11.64	3.17	3.08	5.02	1.94	5.38	6.62	1.24
10.1	Treated	43.6	38.5	9.20	11.44	2.24	0.50	0.78	0.28	8.70	10.66	1.96
10.2	Treated	42.9	37.9	9.36	11.55	2.20	0.17	0.40	0.23	9.19	11.16	1.97
10.3	Treated	42.4	37.5	6.43	8.67	2.23	0.10	0.34	0.24	6.33	8.32	1.99
11.1	Treated	41.7	36.9	8.67	11.06	2.38	0.41	0.25	-0.16	8.26	10.81	2.55
11.2	Treated	40.7	36.0	20.53	25.71	5.18	1.94	1.90	-0.04	18.59	23.81	5.22
12	Untreated	40.1	35.5	10.01	13.03	3.03	0.52	0.65	0.13	9.48	12.38	2.90
13	Untreated	39.3	34.8	5.08	5.73	0.65	0.11	0.24	0.13	4.97	5.50	0.52
14.1	Treated	38.7	34.3	7.36	9.97	2.61	0.26	1.02	0.77	7.10	8.94	1.84
14.2	Treated	37.9	33.6	5.71	7.47	1.76	0.31	0.54	0.23	5.40	6.93	1.53
14.3	Untreated	37.2	33.0	10.59	15.35	4.77	1.84	2.04	0.20	8.74	13.31	4.57
15.1	Treated	36.8	32.7	4.63	6.13	1.51	0.17	0.40	0.23	4.45	5.73	1.28
15.2	Treated	36.4	32.3	4.31	6.09	1.78	0.46	0.29	-0.16	3.86	5.80	1.94
16	Untreated	35.0	31.1	16.92	24.42	7.51	5.40	6.52	1.12	11.51	17.90	6.39
17.1	Untreated	34.6	30.7	5.30	7.94	2.65	0.40	0.62	0.22	4.90	7.32	2.42
17.2	Untreated	34.3	30.4	7.38	10.35	2.97	0.81	1.13	0.31	6.57	9.22	2.65
18.1	Treated	33.2	29.5	20.22	28.94	8.73	0.48	0.74	0.26	19.73	28.21	8.47
18.2	Untreated	32.5	28.8	10.74	15.47	4.73	1.41	2.46	1.04	9.33	13.02	3.69
19	Untreated	31.9	28.3	7.77	9.89	2.12	0.25	0.04	-0.20	7.52	9.85	2.33
20	Untreated	31.5	27.9	7.13	10.04	2.91	0.47	0.94	0.47	6.66	9.10	2.45
21	Untreated	30.4	26.9	9.75	12.28	2.54	0.47	0.89	0.41	9.27	11.39	2.12
22	Treated	29.3	25.9	8.46	10.02	1.56	0.04	0.31	0.27	8.42	9.71	1.29
23	Treated	28.3	25.1	9.37	16.31	6.95	1.00	3.39	2.39	8.37	12.92	4.56
24	Treated	27.5	24.3	7.70	8.73	1.03	0.17	0.48	0.32	7.53	8.24	0.71
25	Untreated	27.0	23.9	5.66	9.66	4.00	1.05	3.51	2.45	4.61	6.15	1.55
26	Treated	24.0	21.1	54.67	68.76	14.09	2.83	2.42	-0.41	51.84	66.34	14.50
27	Untreated	22.9	20.2	19.33	31.27	11.94	7.48	11.25	3.76	11.85	20.02	8.18
28.1	Untreated	22.1	19.4	23.93	31.88	7.95	4.20	6.25	2.05	19.72	25.63	5.90
28.2	Treated	20.9	18.4	28.82	48.09	19.27	5.07	8.52	3.46	23.75	39.57	15.81
28.3	Treated	19.7	17.4	19.94	31.20	11.25	0.41	0.44	0.02	19.53	30.76	11.23
29	Treated	18.6	16.4	11.70	20.79	9.09	1.44	8.32	6.89	10.26	12.47	2.20
30	Untreated	17.6	15.5	17.18	22.98	5.80	1.70	0.82	-0.88	15.49	22.16	6.68
31	Untreated	16.1	14.1	23.57	32.84	9.27	3.79	7.98	4.19	19.78	24.86	5.08
32.1	Untreated	15.3	13.4	18.04	25.29	7.26	9.48	7.28	-2.20	8.56	18.02	9.46
32.2	Untreated	14.6	12.8	9.74	14.82	5.09	1.23	0.41	-0.83	8.50	14.42	5.92

Table F-5
Connectivity Analysis Floodplain Area Results

Project Area	Restoration Status	River Mile Start	Valley Mile Start	Floodplain Area (acres)								
				Available 2-year	Available 5-year	Available Difference	Disconnected 2-year	Disconnected 5-year	Disconnected Difference	Connected 2-year	Connected 5-year	Connected Difference
33	Untreated	13.4	11.7	8.83	10.80	1.97	0.12	0.18	0.05	8.71	10.62	1.92
34.1	Untreated	12.3	10.5	35.75	49.64	13.89	8.39	14.99	6.61	27.36	34.65	7.29
34.2	Untreated	11.5	9.9	21.14	28.26	7.12	3.66	5.67	2.01	17.48	22.58	5.10
35	Untreated	10.8	9.3	15.37	35.00	19.62	6.67	22.47	15.80	8.70	12.52	3.83
36	Untreated	9.1	7.8	51.72	76.84	25.12	3.08	0.65	-2.43	48.63	76.19	27.56
37	Untreated	8.0	6.9	10.68	13.52	2.84	0.17	0.54	0.37	10.51	12.98	2.47
38	Untreated	5.0	4.1	41.21	61.27	20.06	4.40	6.30	1.90	36.81	54.97	18.16
39.1	Untreated	4.9	4.0	1.88	2.22	0.34	0.00	0.00	0.00	1.87	2.22	0.34
39.2	Untreated	4.6	3.7	3.22	4.01	0.79	0.00	0.01	0.01	3.22	3.99	0.78
40	Treated	4.0	3.2	18.42	27.47	9.05	2.48	3.17	0.69	15.94	24.30	8.36
41	Untreated	3.7	2.9	13.72	22.95	9.23	2.18	5.11	2.93	11.53	17.84	6.30
42	Untreated	3.3	2.6	7.85	12.16	4.31	0.78	3.67	2.89	7.08	8.49	1.42
43	Untreated	2.9	2.3	16.04	27.58	11.54	6.31	8.54	2.24	9.73	19.04	9.31
44	Untreated	2.5	2.0	6.90	20.42	13.52	0.34	5.01	4.68	6.56	15.40	8.84
45	Untreated	2.0	1.6	12.43	16.43	4.00	1.75	4.08	2.34	10.68	12.35	1.67

Table F-6
Connectivity Analysis Restoration Action Results

Project Area	River Length (miles)	Valley Length (miles)	Area Per Valley Length (acres per mile)									Restoration Actions			
			Available 2-year	Available 5-year	Available Difference	Disconnected 2-year	Disconnected 5-year	Disconnected Difference	Connected 2-year	Connected 5-year	Connected Difference	Raise Bed (5C-2C)/5A	Remove Levee 2D/5A	Do Both (5A-2C)/5A	Existing 2C/5A
1.1	0.55	0.50	12.21	18.44	6.23	1.20	2.83	1.63	11.01	15.61	4.60	25%	7%	40%	60%
1.2	0.39	0.36	7.38	9.75	2.37	1.09	2.33	1.24	6.29	7.42	1.13	12%	11%	35%	65%
2.0	0.64	0.56	12.09	15.71	3.62	2.22	2.98	0.77	9.87	12.72	2.85	18%	14%	37%	63%
3.1	0.37	0.37	8.27	11.56	3.30	1.73	2.79	1.06	6.54	8.78	2.24	19%	15%	43%	57%
3.2	1.44	1.29	13.51	18.29	4.77	0.30	0.26	-0.04	13.21	18.03	4.81	26%	2%	28%	72%
4.0	0.24	0.21	11.92	14.06	2.14	0.92	1.36	0.44	11.00	12.70	1.70	12%	7%	22%	78%
5.0	0.45	0.43	25.10	32.40	7.30	14.49	19.44	4.95	10.61	12.96	2.35	7%	45%	67%	33%
6.0	0.74	0.64	18.24	23.61	5.37	6.48	9.06	2.58	11.76	14.55	2.80	12%	27%	50%	50%
7.0	0.45	0.42	10.16	12.53	2.37	1.12	2.39	1.26	9.03	10.14	1.11	9%	9%	28%	72%
8.0	0.45	0.41	13.76	18.94	5.19	0.53	1.71	1.18	13.23	17.24	4.01	21%	3%	30%	70%
9.0	0.40	0.41	20.76	28.54	7.78	7.56	12.31	4.75	13.20	16.23	3.03	11%	26%	54%	46%
10.1	0.47	0.41	22.63	28.13	5.50	1.24	1.92	0.68	21.40	26.21	4.82	17%	4%	24%	76%
10.2	0.72	0.63	14.87	18.36	3.49	0.26	0.63	0.37	14.61	17.73	3.13	17%	1%	20%	80%
10.3	0.41	0.38	16.89	22.76	5.87	0.27	0.90	0.63	16.62	21.85	5.23	23%	1%	27%	73%
11.1	0.75	0.62	13.96	17.80	3.84	0.66	0.40	-0.26	13.30	17.40	4.10	23%	4%	25%	75%
11.2	0.96	0.89	23.16	29.01	5.85	2.19	2.15	-0.04	20.98	26.86	5.89	20%	8%	28%	72%
12.0	0.65	0.52	19.25	25.07	5.82	1.01	1.25	0.24	18.24	23.82	5.58	22%	4%	27%	73%
13.0	0.77	0.67	7.62	8.59	0.98	0.16	0.35	0.19	7.45	8.24	0.79	9%	2%	13%	87%
14.1	0.61	0.56	13.23	17.92	4.69	0.46	1.84	1.38	12.77	16.08	3.31	18%	3%	29%	71%
14.2	0.82	0.61	9.31	12.18	2.86	0.51	0.88	0.37	8.81	11.30	2.49	20%	4%	28%	72%
14.3	0.72	0.64	16.57	24.04	7.46	2.89	3.19	0.31	13.69	20.84	7.16	30%	12%	43%	57%
15.1	0.38	0.32	14.44	19.14	4.71	0.54	1.26	0.72	13.90	17.89	3.99	21%	3%	27%	73%
15.2	0.42	0.39	10.99	15.52	4.53	1.17	0.75	-0.42	9.83	14.77	4.94	32%	8%	37%	63%
16.0	1.39	1.24	13.66	19.73	6.06	4.36	5.27	0.90	9.30	14.46	5.16	26%	22%	53%	47%
17.1	0.34	0.34	15.61	23.42	7.81	1.17	1.83	0.66	14.44	21.58	7.14	31%	5%	38%	62%
17.2	0.31	0.27	27.78	38.95	11.17	3.06	4.24	1.18	24.72	34.71	9.99	26%	8%	37%	63%
18.1	1.08	0.96	20.95	30.00	9.04	0.50	0.77	0.27	20.45	29.23	8.78	29%	2%	32%	68%
18.2	0.78	0.70	15.39	22.17	6.78	2.02	3.52	1.50	13.36	18.64	5.28	24%	9%	40%	60%
19.0	0.56	0.47	16.56	21.08	4.52	0.53	0.09	-0.44	16.03	20.98	4.96	24%	3%	24%	76%
20.0	0.44	0.40	17.72	24.97	7.25	1.17	2.34	1.17	16.55	22.63	6.08	24%	5%	34%	66%
21.0	1.05	1.06	9.18	11.57	2.39	0.45	0.84	0.39	8.73	10.73	2.00	17%	4%	25%	75%
22.0	1.08	0.98	8.65	10.24	1.59	0.04	0.32	0.28	8.61	9.92	1.31	13%	0%	16%	84%
23.0	1.05	0.81	11.51	20.04	8.53	1.23	4.16	2.93	10.28	15.88	5.60	28%	6%	49%	51%
24.0	0.76	0.71	10.83	12.28	1.45	0.23	0.68	0.45	10.60	11.59	1.00	8%	2%	14%	86%
25.0	0.54	0.45	12.54	21.42	8.87	2.33	7.77	5.44	10.21	13.64	3.43	16%	11%	52%	48%
26.0	2.99	2.79	19.62	24.68	5.06	1.02	0.87	-0.15	18.61	23.81	5.20	21%	4%	25%	75%
27.0	1.05	0.90	21.52	34.81	13.29	8.33	12.52	4.19	13.19	22.29	9.10	26%	24%	62%	38%
28.1	0.87	0.79	30.16	40.19	10.02	5.30	7.88	2.58	24.87	32.31	7.44	19%	13%	38%	62%
28.2	1.17	1.01	28.55	47.64	19.09	5.02	8.44	3.43	23.53	39.20	15.67	33%	11%	51%	49%
28.3	1.16	1.03	19.32	30.23	10.90	0.40	0.42	0.02	18.92	29.80	10.88	36%	1%	37%	63%
29.0	1.12	1.01	11.63	20.68	9.04	1.43	8.28	6.85	10.21	12.40	2.19	11%	7%	51%	49%
30.0	1.01	0.83	20.75	27.76	7.01	2.05	0.99	-1.06	18.70	26.77	8.06	29%	7%	33%	67%
31.0	1.49	1.44	16.42	22.87	6.46	2.64	5.56	2.92	13.78	17.32	3.54	15%	12%	40%	60%
32.1	0.79	0.69	26.14	36.66	10.52	13.74	10.55	-3.19	12.40	26.12	13.72	37%	37%	66%	34%
32.2	0.69	0.58	16.72	25.46	8.74	2.12	0.70	-1.42	14.60	24.76	10.16	40%	8%	43%	57%
33.0	1.22	1.12	7.87	9.63	1.76	0.11	0.16	0.05	7.76	9.47	1.71	18%	1%	19%	81%
34.1	1.14	1.17	30.62	42.52	11.90	7.18	12.84	5.66	23.44	29.68	6.24	15%	17%	45%	55%
34.2	0.78	0.63	33.77	45.13	11.36	5.85	9.06	3.21	27.92	36.07	8.15	18%	13%	38%	62%
35.0	0.69	0.65	23.50	53.51	30.00	10.20	34.36	24.15	13.30	19.15	5.85	11%	19%	75%	25%

Table F-6

Connectivity Analysis Restoration Action Results

Project Area	River Length (miles)	Valley Length (miles)	Area Per Valley Length (acres per mile)									Restoration Actions			
			Available 2-year	Available 5-year	Available Difference	Disconnected 2-year	Disconnected 5-year	Disconnected Difference	Connected 2-year	Connected 5-year	Connected Difference	Raise Bed (5C-2C)/5A	Remove Levee 2D/5A	Do Both (5A-2C)/5A	Existing 2C/5A
36.0	1.70	1.44	35.93	53.38	17.45	2.14	0.45	-1.69	33.79	52.93	19.14	36%	4%	37%	63%
37.0	1.10	0.97	11.03	13.96	2.93	0.18	0.56	0.38	10.85	13.40	2.55	18%	1%	22%	78%
38.0	2.97	2.77	14.88	22.12	7.24	1.59	2.28	0.69	13.29	19.85	6.56	30%	7%	40%	60%
39.1	0.10	0.09	20.82	24.63	3.81	0.03	0.03	0.01	20.80	24.60	3.80	15%	0%	16%	84%
39.2	0.33	0.31	10.22	12.74	2.52	0.00	0.04	0.04	10.22	12.70	2.48	19%	0%	20%	80%
40.0	0.57	0.52	35.38	52.75	17.38	4.76	6.08	1.32	30.61	46.67	16.06	30%	9%	42%	58%
41.0	0.35	0.31	44.48	74.40	29.93	7.08	16.57	9.49	37.40	57.84	20.44	27%	10%	50%	50%
42.0	0.33	0.26	30.45	47.14	16.70	3.01	14.21	11.20	27.44	32.93	5.50	12%	6%	42%	58%
43.0	0.43	0.28	56.98	97.98	41.00	22.40	30.34	7.94	34.58	67.64	33.06	34%	23%	65%	35%
44.0	0.43	0.31	22.23	65.80	43.57	1.08	16.16	15.08	21.15	49.64	28.50	43%	2%	68%	32%
45.0	0.52	0.43	29.14	38.53	9.38	4.10	9.57	5.48	25.05	28.96	3.91	10%	11%	35%	65%

Figures

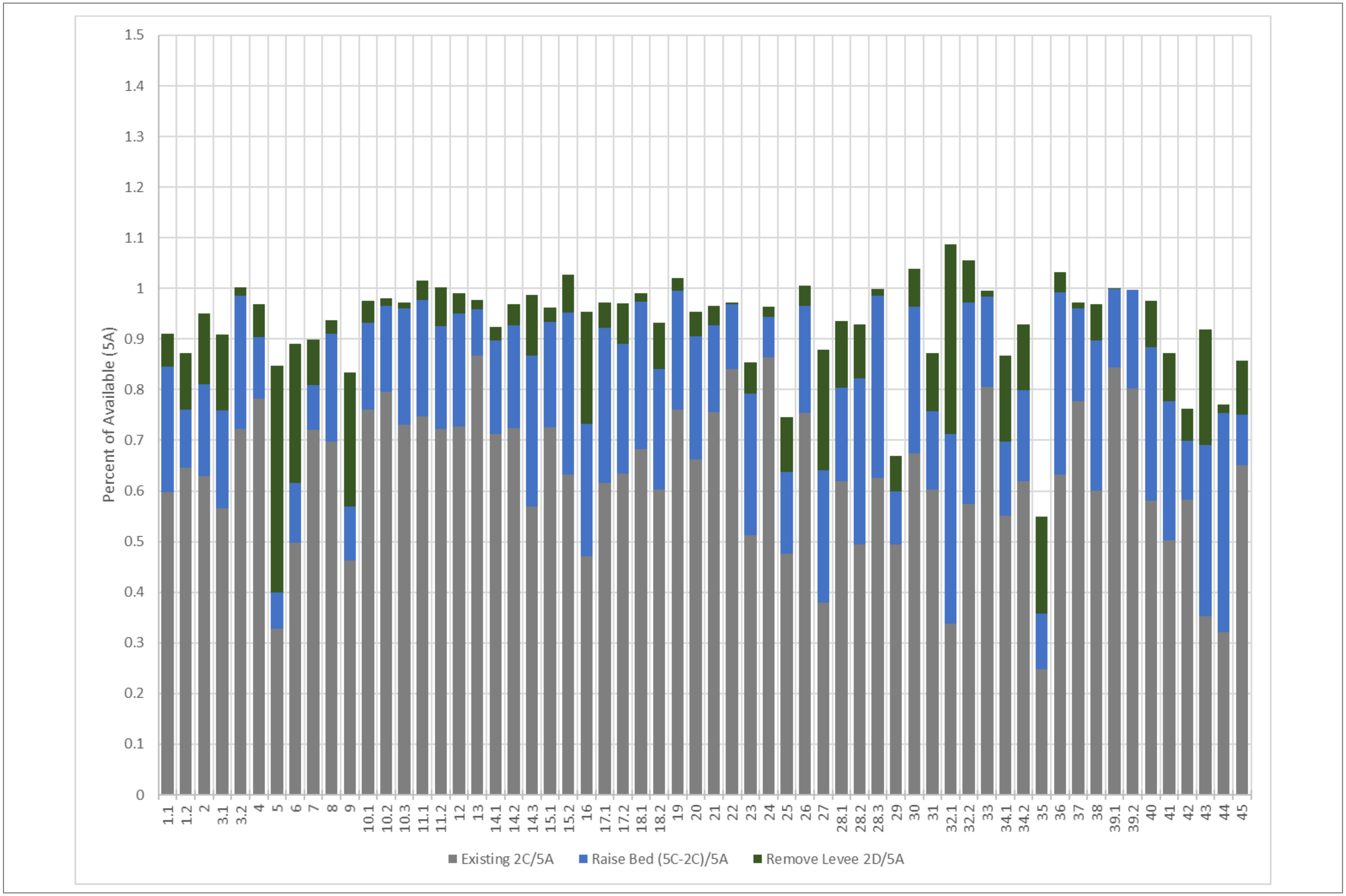


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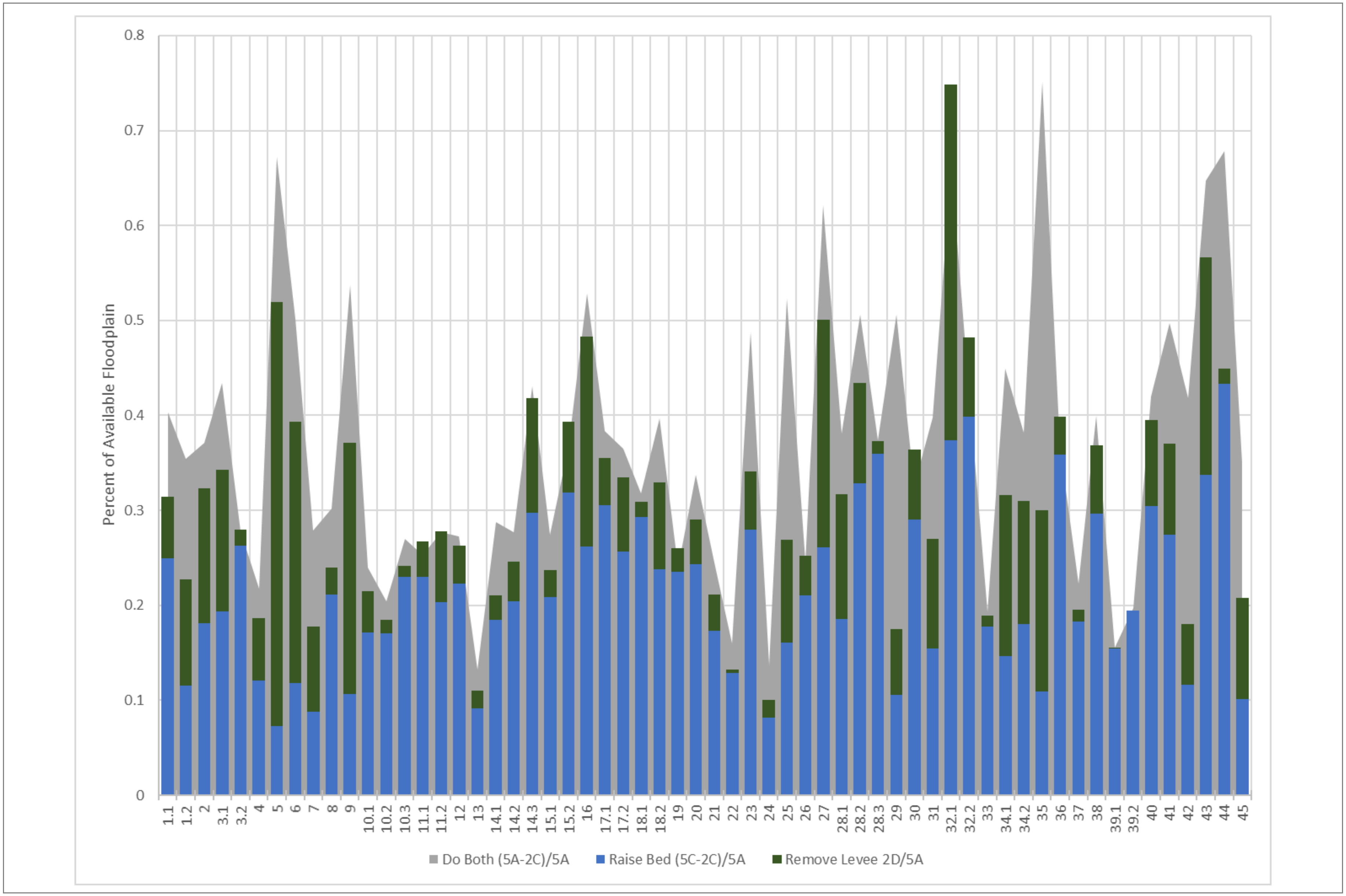
Figure F-9
Existing and Potential Floodplain as Percent of Available Floodplain
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



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ANCHOR QEA

Figure F-10
Select Restoration Action Benefits as Percent of Available Floodplain
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

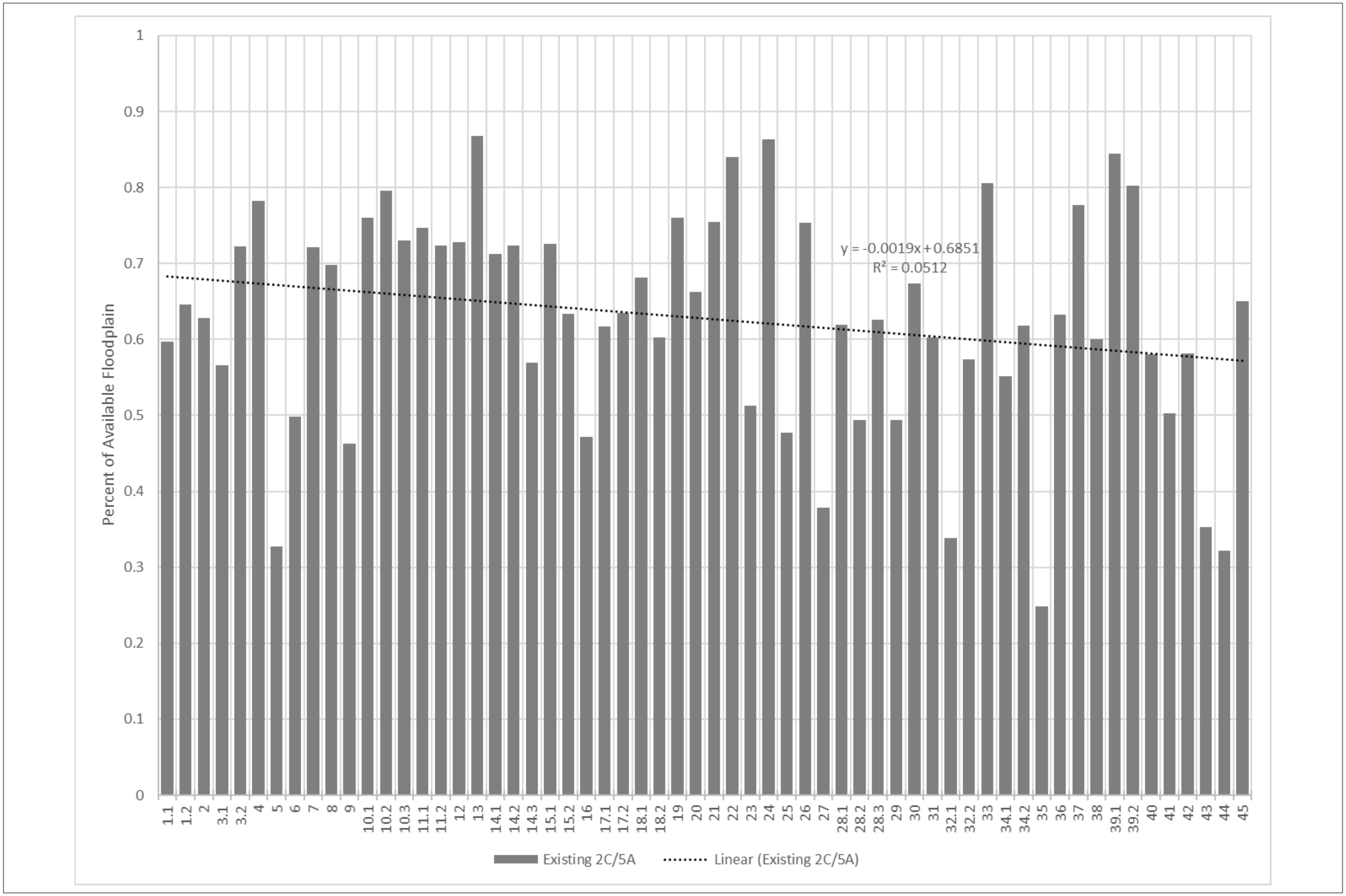

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Figure F-11
Existing Connected 2-Year Floodplain as a Percentage of Total Available Floodplain (2C/5A)

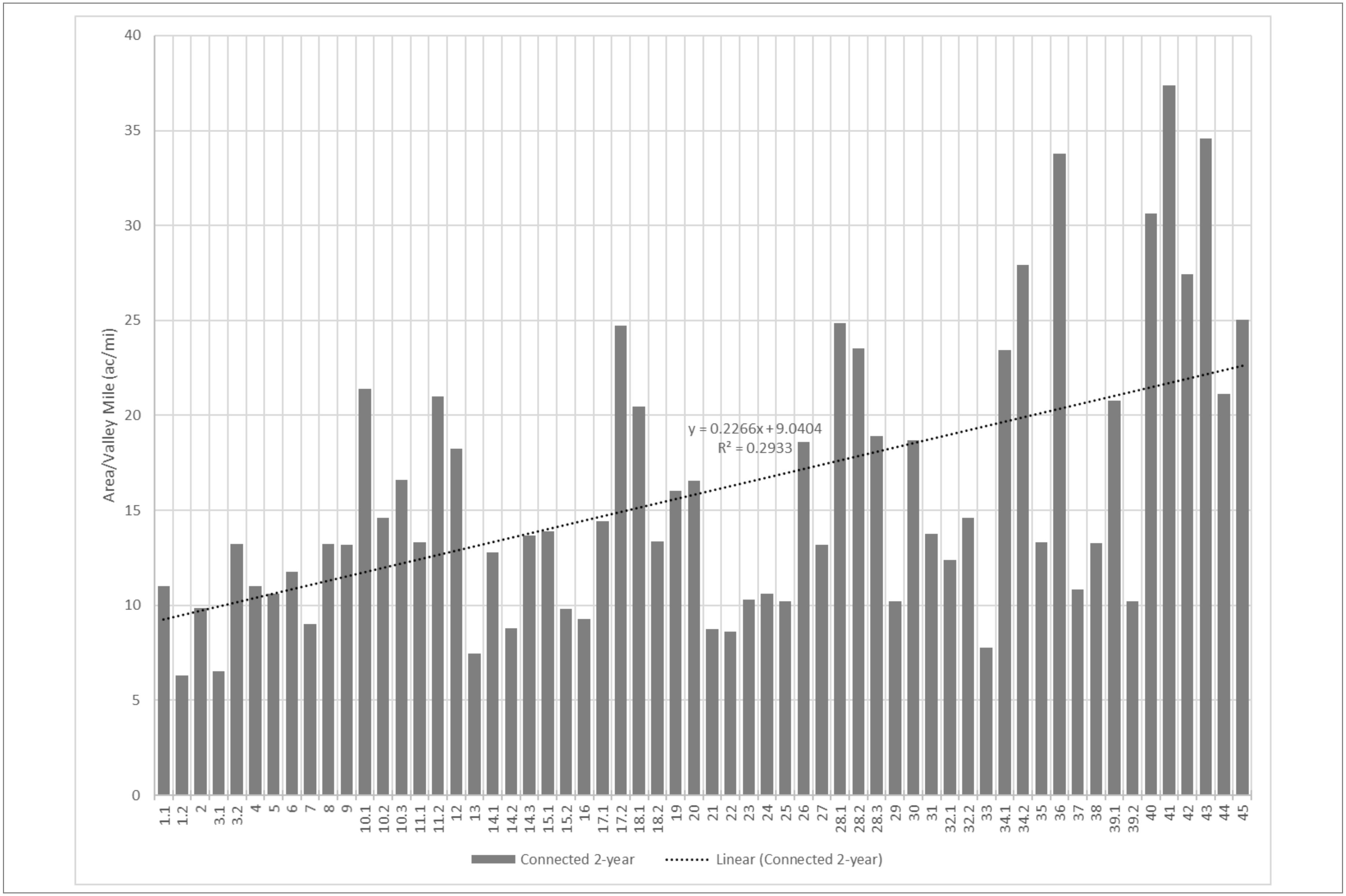

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Figure F-12
Existing Connected 2-Year Floodplain Area per Valley Mile

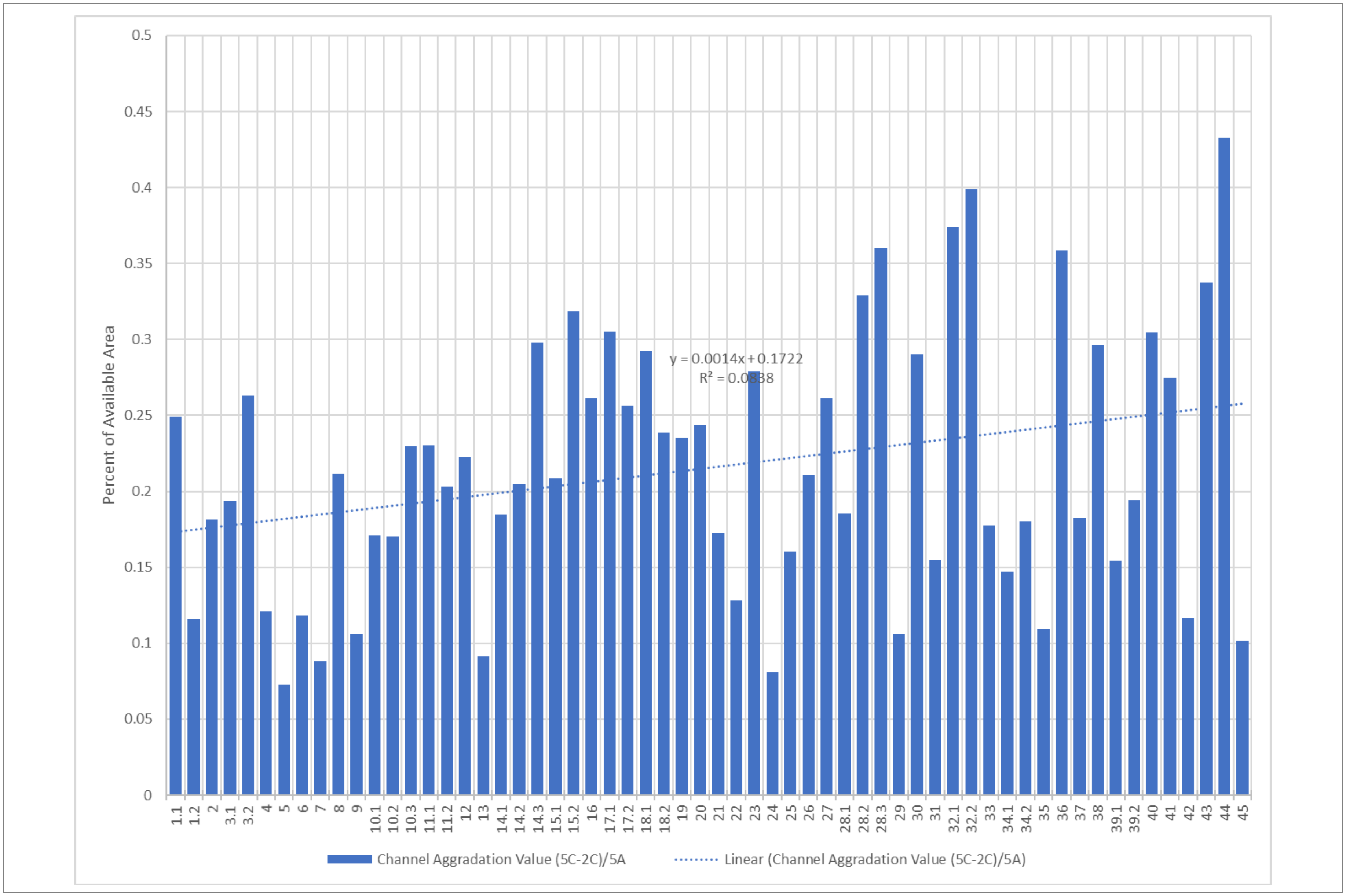

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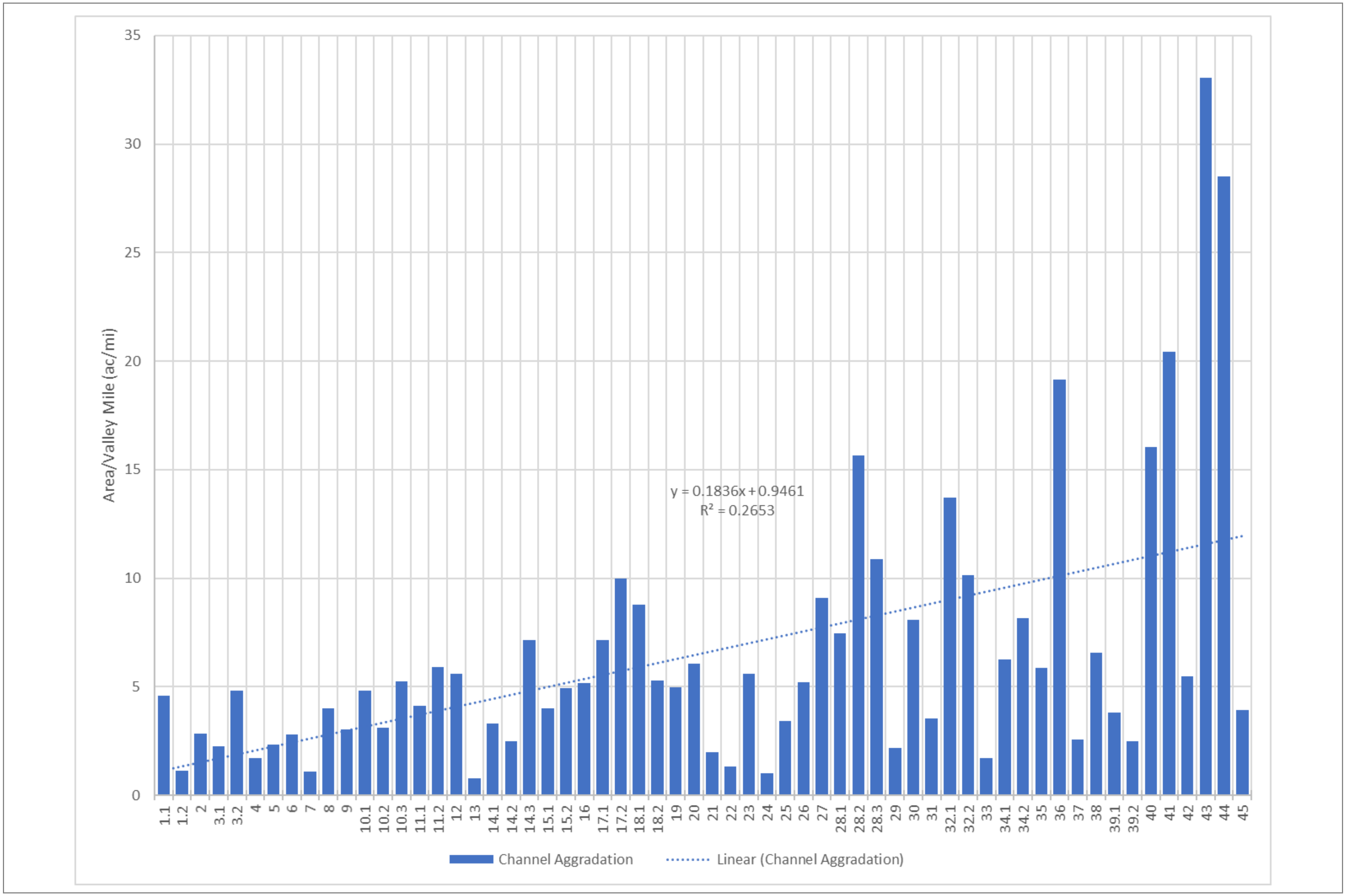
Figure F-13
Potential Benefit of Channel Aggradation as Percent of Available Area (5C-2C)/5A

Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration



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ANCHOR QEA

Figure F-14
Benefit of Channel Aggradation Area per Valley Mile (5C-2C)
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

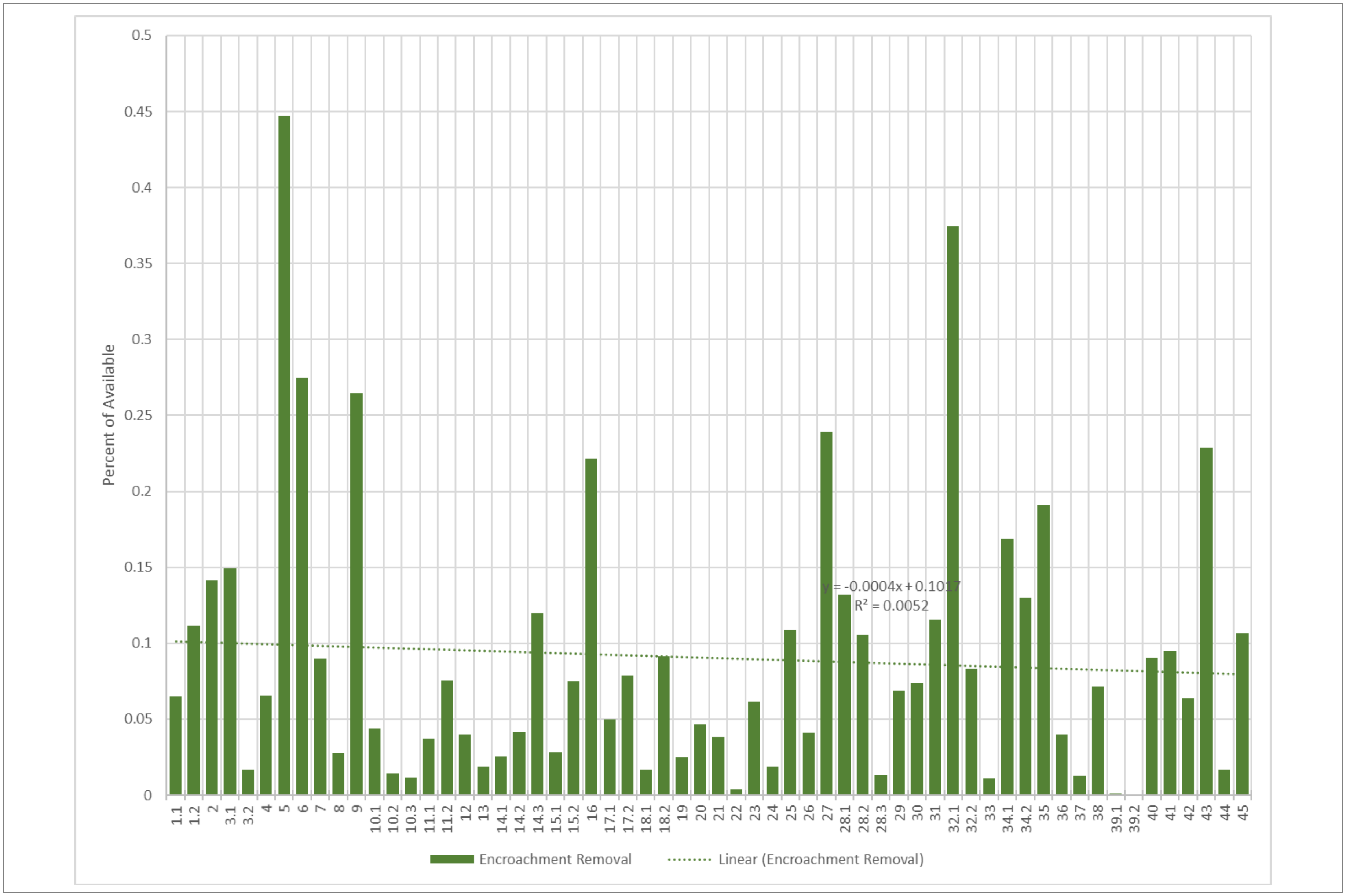

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Figure F-15

Potential Benefit of Encroachment Removal as a Percent of Available Area 2D/5A

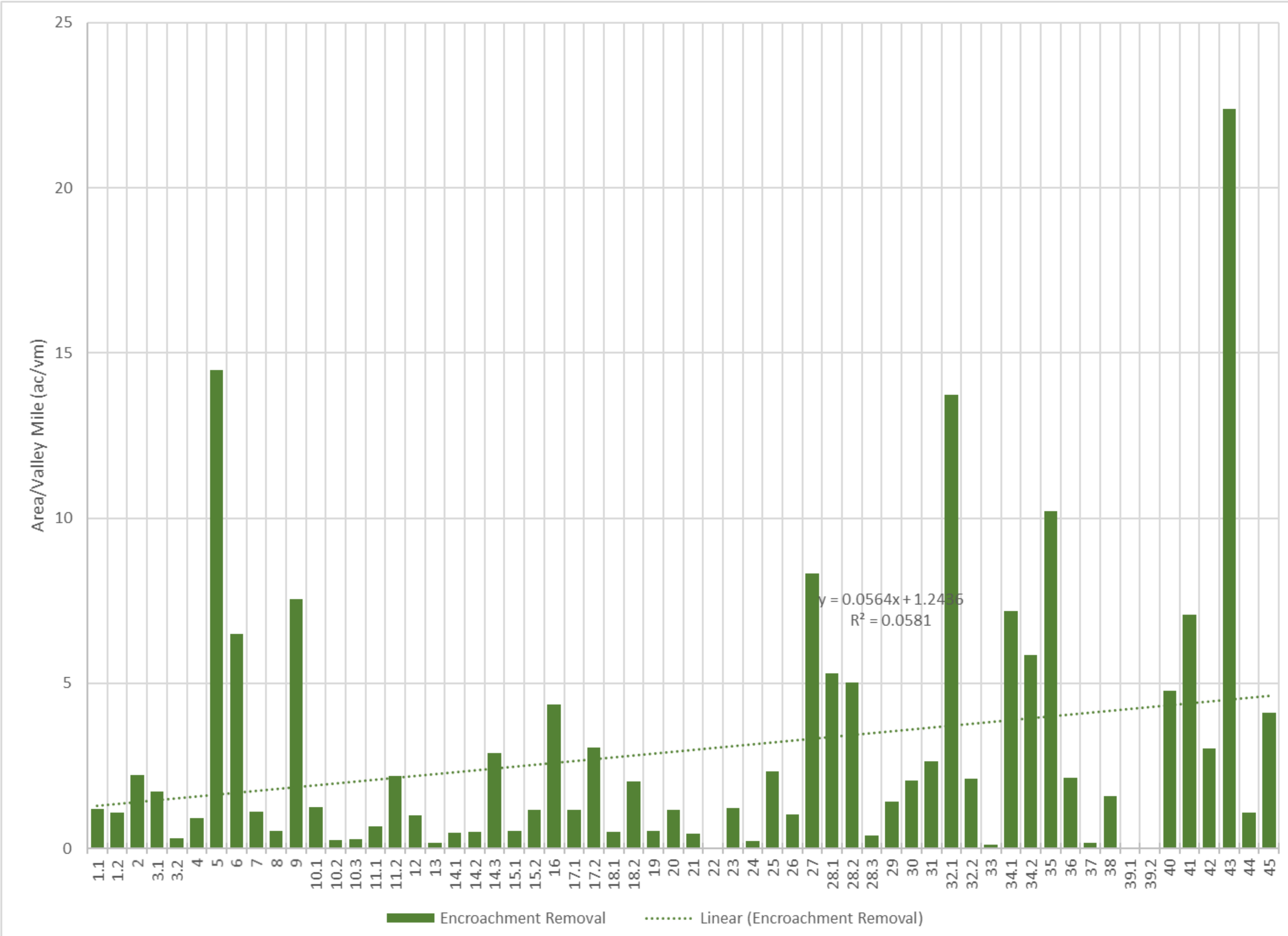

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Figure F-16
Benefit of Encroachment Removal Area per Valley Mile (2D)

Appendix G
Channel Complexity Analysis

Appendix G
Channel Complexity Analysis

Channel and floodplain complexity have been identified as major objectives for the Tucannon River, and complexity has increasingly been associated with juvenile salmonid rearing and overwintering, as well as benefits for many other aquatic species in the main report. Because of this multi-species and multi-lifestage benefit, it is important to examine a reach's complexity at several different flow levels—typically at lower, sustained flows (see Table G-1). For this assessment, river complexity refers to the geomorphic condition of multi-threaded or anastomosing channels, side channels, and split flow. Floodplain complexity is often characterized by small, dynamic channels that interact freely with the surrounding floodplain. While greater floodplain complexity typically results in a larger total water surface area, it is distinct from floodplain connectivity in that it examines individual flow paths separated by floodplain.

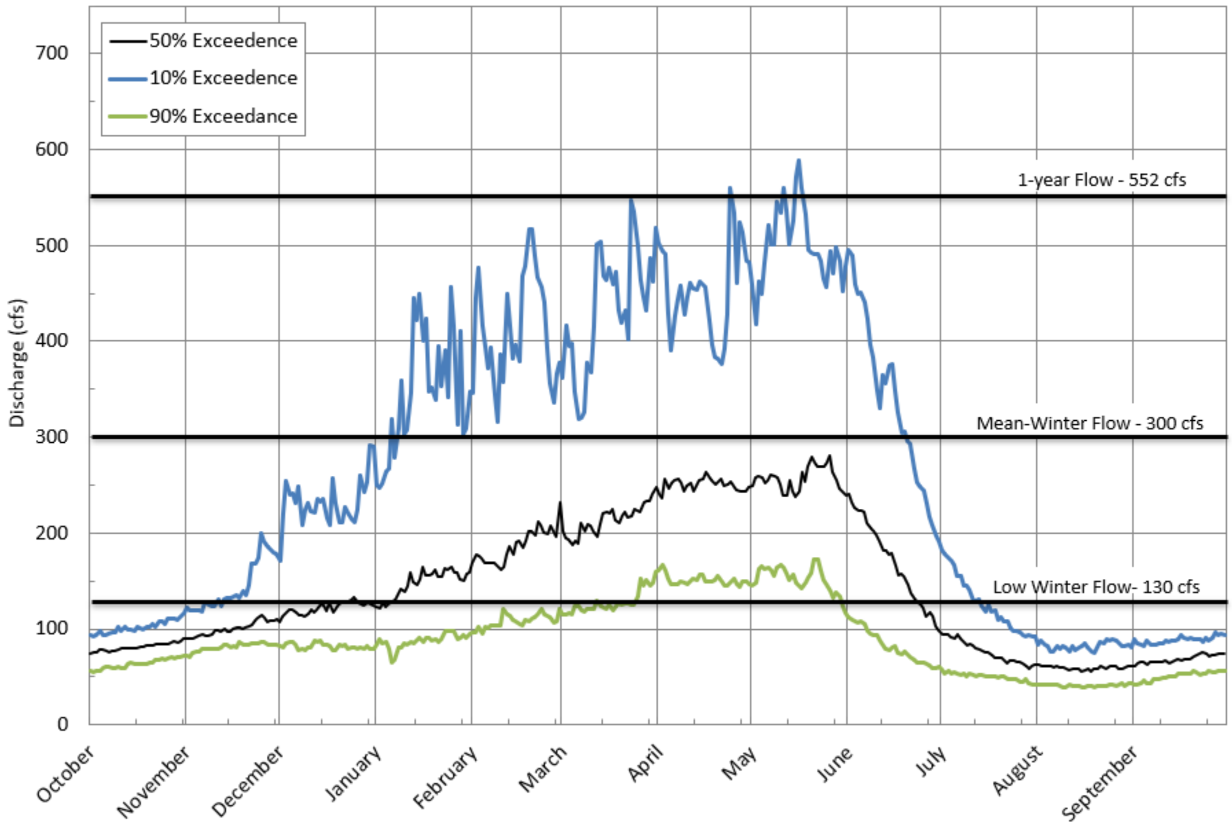
Table G-1
Flow Used for Examining Complexity

Flow Description	Data Source	Flow Rate at Starbuck
Low-Winter Flow	Water Surface DEM	130 cfs
Mean-Winter Flow	2D Hydraulic Model	300 cfs
1-year Flood Event	2D Hydraulic Model	552 cfs

cfs: cubic foot per second
DEM: Digital Elevation Model

Low-winter and mean-winter flows are sustained for longer periods of time and will therefore provide benefits to juvenile salmonid rearing habitat. The 1-year flow is episodic in nature, and complexity will most likely provide benefit in the form of high-velocity refugia. These three flows should represent a broad range of river conditions where habitat benefits from complexity are most relevant for juvenile salmonids as shown in Figure G-1.

Figure G-1
Complexity Flows and Hydrograph at the Starbuck Gage: 10%, 50%, and 90% Flows from 1971 to 2019



Analysis Overview

The concept for the Standardized Complexity Evaluation (SCE) discussed in this section was largely influenced by the River Complexity Index (RCI) shown in Equation G-1. RCI is a method of measuring complexity at bankfull flow proposed by (Brown 2002; Beechie et al. 2017; USFS 2012). The method takes the product of reach sinuosity and node density, a measure of channel connections in a reach. A more complete explanation of the RCI method can be found in "River Complexity Index (RCI): A Standard Method" (Buelow et al. 2017).

Equation G-1

$$RCI = S * (1 + D) = \left(\frac{Main\ Channel\ Length}{Valley\ Centerline\ Length}\right) * \left(1 + \frac{Number\ of\ Stream\ Nodes}{Valley\ Centerline\ Length}\right)$$

where:

RCI	=	River Complexity Index for a reach
S	=	sinuosity of the reach
D	=	node density of the reach

Note: RCI equation from "River Complexity Index (RCI): A Standard Method" (Buelow et al. 2017). Originally developed by Brown 2002.

The SCE developed in this analysis draws from the basic parameters of RCI by using the sinuosity of the reach and the number of islands in the reach, as shown in Figure G-2. For this assessment, RCI presents three problems that led to the development and use of the new method, SCE. First, the nodes described in the RCI method are difficult to capture and define using Light Detection and Ranging (LiDAR)-produced Digital Elevation Model (DEM) and Geographic Information Systems (GIS) data processing techniques. Second, RCI does not sufficiently capture the complexity gained through a single long side channel, as explained in more detail below. Finally, the RCI method presents no way to weight different complexity factors (sinuosity and node density).

In order to address the first problem, islands were counted instead of nodes. Because every pair of nodes represents an island, counting the number of islands per reach can be used as a scalable representation for node density, as shown in Figure G-2. Islands can be easily recognizable as distinct polygons in GIS applications, and statistics can be quickly generated on where and how big these islands are. Water surface polygons for the low-winter flow, mean-winter flow, and 1-year flow were generated using a two-dimensional (2D) HEC-RAS model and the direct outputs from the LiDAR water surface data. For a complete discussion on the modeling, see Appendix D of this report.

For this assessment, only islands that were greater than 12 meters in length were counted towards this metric to remove any short side channels or areas that form small mid-channel bars. The RCI method recommends choosing the bankfull width as the threshold for island length, and the SCE method used in this analysis follows that recommendation. The island length threshold of 12 meters was chosen based on an average wetted flow width at the 1-year flow event. It should be noted that, because islands were used instead of nodes, the complexity values produced by this analysis are not directly comparable to the RCI method. For more details on how island data are extracted from the dataset, see the Detailed Instructions for Performing this Analysis section below.

In order to more accurately represent a single long side channel in the SCE method, a third parameter was used to characterize complexity in addition to sinuosity and island density: island perimeter length. Through the analysis, it was observed that several reaches with long side channels were scoring more poorly in the Complexity analysis than expected from field observations when using only sinuosity and island density. While a single long side channel may not represent as much complexity as many smaller side channels and split flows, it does represent significantly more complexity than a confined single thread channel, as shown in Figure G-3. Therefore, the island perimeter length parameter was added into the calculation of complexity to account for these situations, as well as to provide a more complete and accurate view of complexity within the project area.

Figure G-2
Islands (using Standardized Complexity Evaluation) vs. Nodes (using River Complexity Index)

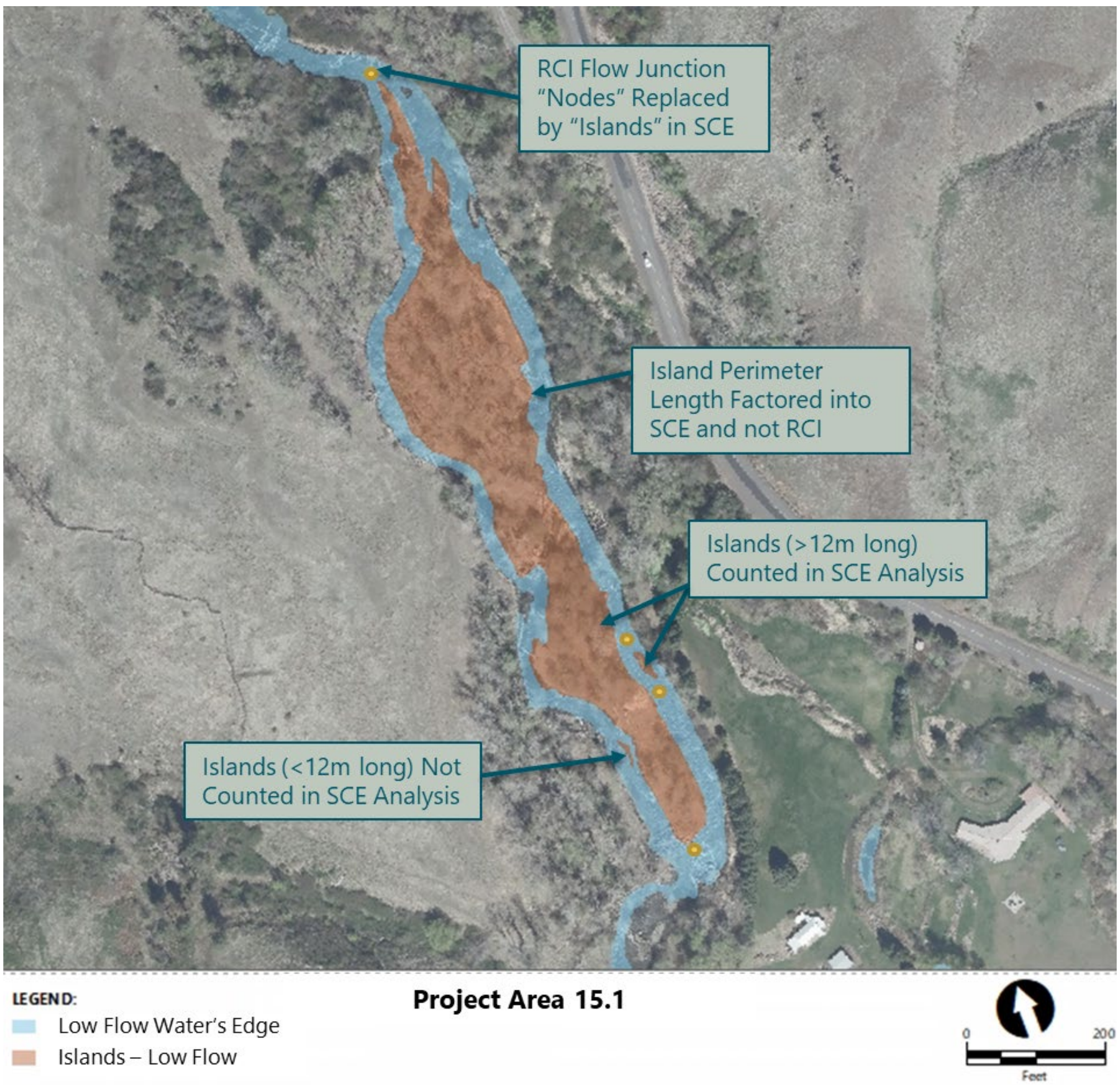
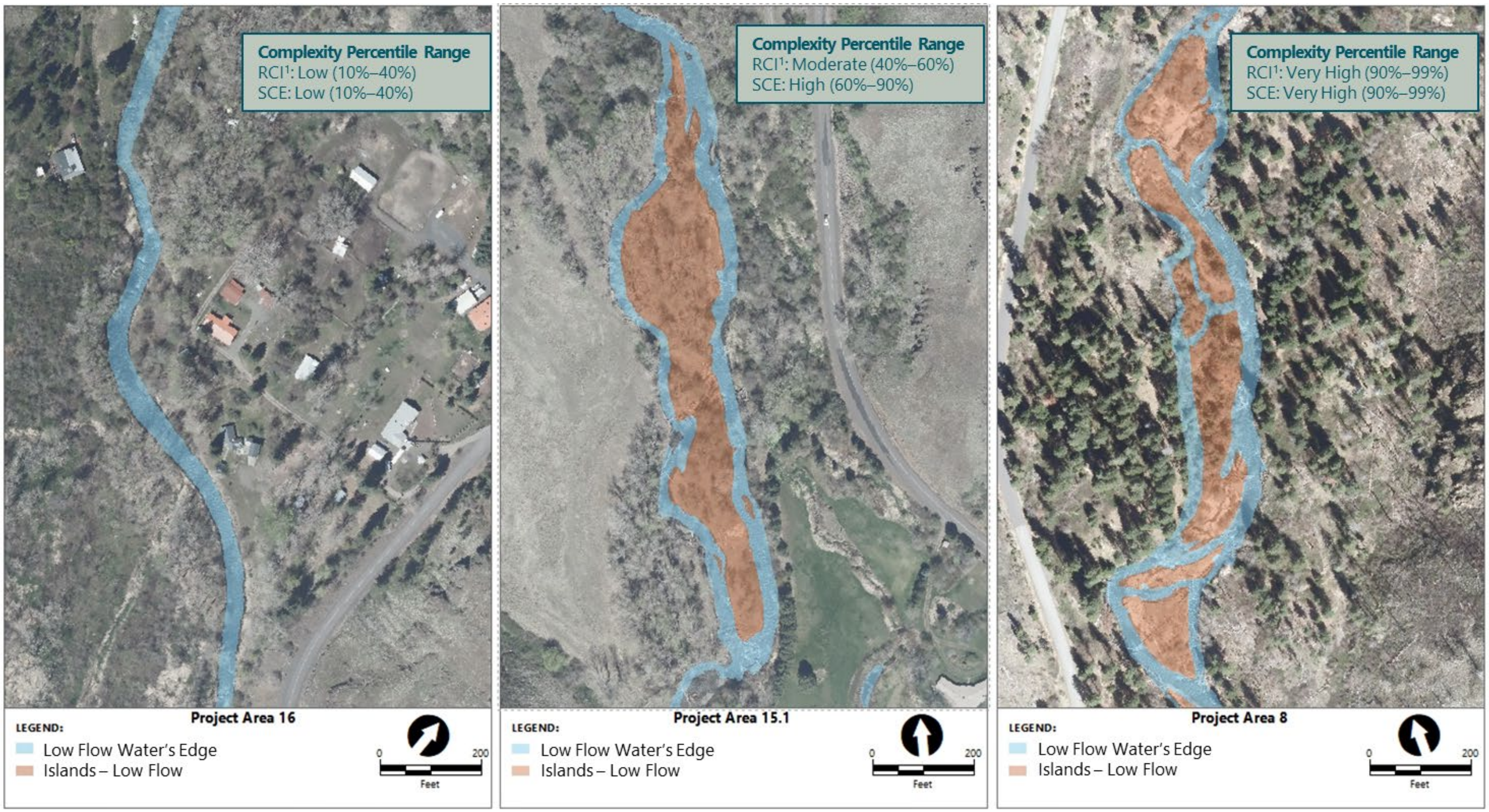


Figure G-3
Complexity Comparison



Note:

1. RCI values were standardized based on the same standardization techniques in SCE to obtain comparable values.

The complexity evaluation used in this analysis sums these three parameters, as shown in Equation G-2. In order to account for differing reach lengths, each parameter was divided by the length of the valley (already included in the calculation of sinuosity) and standardized such that the maximum value across all three flows examined was 1. The benefit of standardizing all three parameters allows for each parameter to be examined initially on an equal footing, without weighting any parameter without purpose. After the standardization, with the SCE it is then possible to choose weighting factors based on the perceived importance towards complexity.

Equation G-2

$$W_s(\mathrm{S}) + W_i(\mathrm{I}) + W_p(\mathrm{P}) = \text{Standardized Complexity Evaluation (SCE)}$$

where:

W_x	=	weighting factor for the given parameter
S	=	standardized sinuosity per project area
I	=	island count per valley length per project area, standardized across all three flows
P	=	island perimeter per valley length per project area, standardized across all three flows

The utility of this tool is that these factors can be weighted differently, and the amount of influence a specific factor has on the complexity evaluation can be changed based on a specific need. As shown in Equation G-2, each of these parameters was weighted based on perceived importance to the Tucannon River: 0.5 for island count, 0.4 for island perimeter, and 0.1 for sinuosity. Sinuosity in the Tucannon River basin has very little variation; even the river's most complex sections do not form large meander bends due to its tendency to quickly form side channels and cut off the meander bends. For this reason, the complexity in the Tucannon River basin is much more dependent on the number of flow paths and the size of side channels than the overall sinuosity, as demonstrated in Figure G-3.

It should be noted that, because of the way the complexity index is calculated, the resulting values are comparable only to other reaches in this analysis. Should this method be applied to other river systems, the resulting values would only be relative to that system. This method is not meant to compare complexity between river systems but rather to examine the complexity of a reach compared to other reaches within the system. Furthermore, the selection of these specific parameters and weighting factors is tailored to the Tucannon River system, its geomorphic processes, and unique history, and may need modification before applying to other systems.

Complexity Trends and Patterns

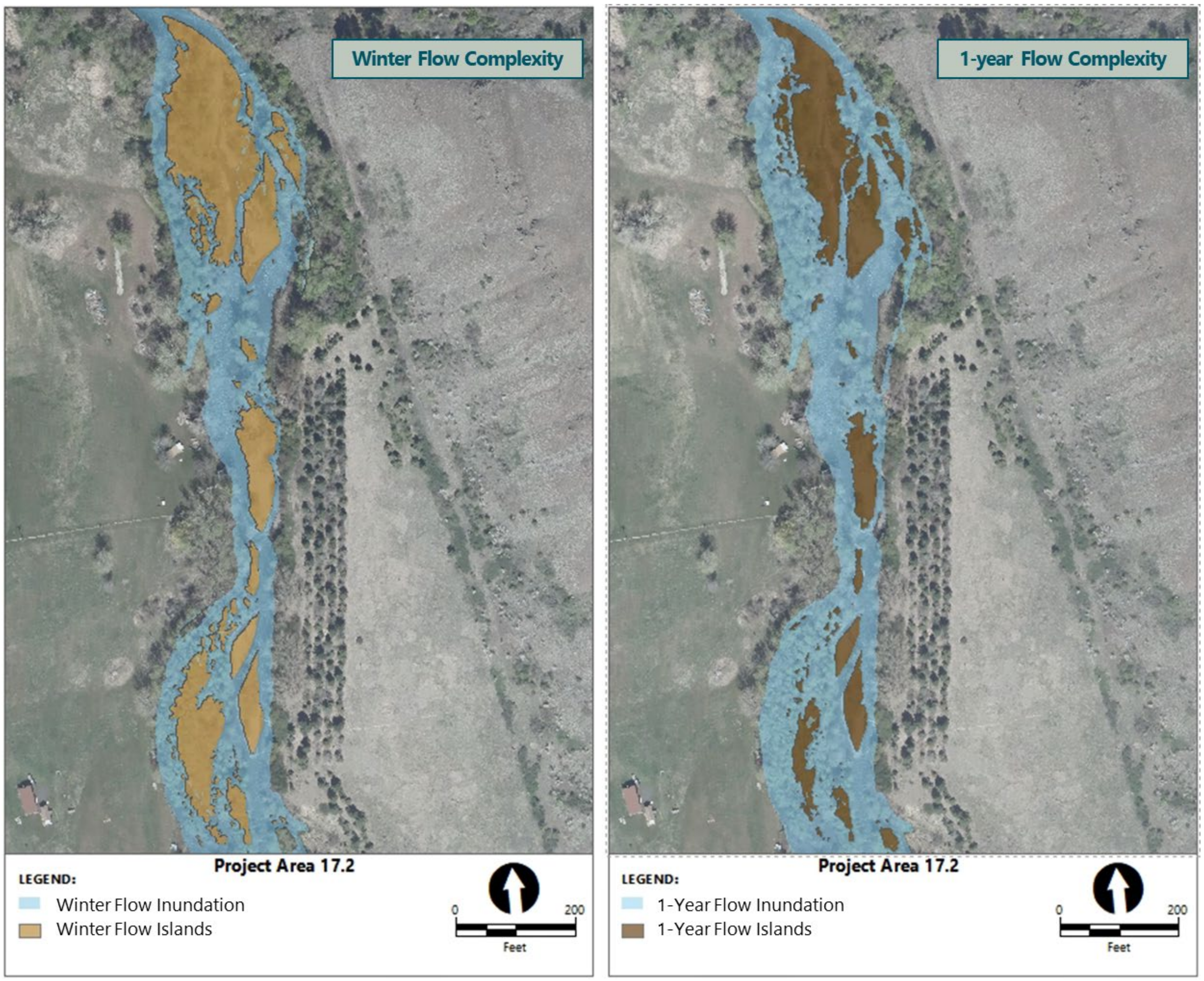
This section briefly describes some of the basin-wide trends and findings from the Complexity analysis. A more detailed breakdown of how this analysis applies to individual project areas is discussed in the Project Area Cut Sheets in Appendix J. This section references figures that are provided at the end of this appendix.

Unlike the floodplain connectivity analysis, river complexity shows few basin-wide trends and is more useful when examined on an individual basis in the assessment. Complexity at any of the three flows (low-winter flow, mean-winter flow, and 1-year flow), shown in Figure G-5, shows very little correlation with valley position, which is likely due to the fact that complexity is more dependent on localized geomorphic features such as instream wood and sediment size and availability.

As expected, most project areas show an increase in complexity as flows increase, likely due to more of the floodplain, and therefore higher flow side channels, becoming activated. However, there are a few exceptions that show a decreasing trend of complexity across flows. These exceptions are likely due to island size decreasing as flows rise, which decreases the total island perimeter length and possibly puts the island below the size class as shown in Figure G-4. The individual characteristics that make up the complexity score for each project area are shown in Figures G-6, G-7, and G-8.

Complexity does not show any strong correlations to the other metrics, although the low-winter flow complexity shows the most correlation (although a low r^2 of 0.2 to 0.3) with the 2-year connected area per valley mile (positive) and channel stream power and total stream power (negative). As described in Appendix H, stream power plays a large role in sediment transport dynamics, suggesting that complexity may be tied to the availability of sediments transported at the 2-year flow.

Figure G-4
Decreasing Complexity at Higher Flows



Scoring for Prioritization

In order to combine the SCE analysis results for the three flow levels into one complexity value to be used as a metric in the prioritization, weights were assigned to each SCE analysis result, which were then summed to produce the final metric value. Table G-2 provides the weights chosen to combine these results. The complexity weighting in Table G-2 favors the low-winter flow and mean-winter flow complexity values over the 1-year flow complexity results due primarily to the fact that the mean-winter and low-winter flows represent a significant portion of the hydrograph compared to the 1-year flow. While the high-flow refugia provided by the complexity at the 1-year flow is important, the mean-winter and low-winter flows better indicate habitat conditions as well as overall geomorphic processes.

Table G-2
Weighting SCE Analysis Results for Prioritization Metric

Complexity Metric Weighting	
SCE Analysis Result	**Percent Weight**
Low-Winter Flow Complexity	40%
Mean-Winter Flow Complexity	40%
1-year Flow Complexity	20%

The next step in the prioritization process is to rank, classify, and score each project area in each of the three metrics (Complexity, Connectivity, and Excess Transport Capacity). Project areas are ranked in the Complexity metric from best to worst by the scores determined using the weightings described in Table G-2. Each project area then has a rank for the Complexity metric and can be classified and scored according to the classification and scoring systems outlined in Table G-3.

This step is needed because the most benefit from restoration actions does not necessarily come from the projects that rank the highest. Because restoration work has been performed in this watershed for several years, some areas already have excellent complexity and rank the highest in that metric. But performing additional complexity-targeted restoration work on these areas would provide very little benefit. Therefore, through discussion with the basin stakeholders, it was decided that the classification and scoring system for complexity would not target the best or the worst ranked project areas in complexity but rather those with moderate complexity scores, as shown in Table G-3. This approach takes into account that the moderately complex reaches still have the opportunity to improve in complexity, but they are also not so homogenous that a great deal of restoration work would be required to raise the complexity. Table G-3 describes the concepts behind the classifications and scoring for complexity.

Table G-3
Complexity Classifications and Scoring

Percentile Rank	Class	Class Score	Metric Score Threshold[1]	Class Conceptualization
90th to Top	1	0	0.471	Project areas in this class are the most complex in the assessment area and therefore have very little additional complexity potential to be gained. Restoration efforts targeting complexity should focus instead on raising other project areas towards this level.
60th to 90th	2	3	0.206	Project areas in this class have moderately high complexity scores, such that restoration efforts should quickly achieve gains in the complexity of the reach pushing it towards the upper 10% of project areas. These project areas should be a secondary target for complexity-focused restoration efforts.
40th to 60th	3	5	0.177	Project areas in this class have the most potential for complexity gains and may currently be subpar for geomorphic processes and habitat conditions. The high potential in these areas means any effort will provide excellent benefit. These areas should be the primary target of complexity-focused restoration efforts in order to maximize benefit for effort.
10th to 40th	4	1	0.095	Complexity in project areas of this class falls below average for the assessment area, and complexity-focused restoration in these reaches should only be targeted after areas where it will be easier to maximize the benefit gained for the effort. These areas should be the last targeted for restoration focused on complexity.
Bottom to 10th	5	0	0	Project areas in this class are the least complex in the assessment area and would likely require a large amount of restoration effort to make only marginal gains in complexity. Restoration efforts for complexity should focus on areas with more easily achievable complexity.

Notes:

1. This is the score that defines the lower limit for the corresponding classification for this metric. These data can be used to track progression of project areas and compare to how they would rank according to the levels of this assessment, as new restoration projects are complete and new data become available.

Detailed Instructions for Performing this Analysis

Part of the purpose of this assessment is to define repeatable and data driven methods for assessing project areas and how they have progressed in relation to their goals. This section provides the detailed steps taken to perform the Complexity analysis of the Tucannon River so that these analyses can be repeated in the future for additional analyses and evaluation of progress. Table G-4 provides the data that will need to be collected to reassess the project areas for complexity.

Table G-4
Raw Data Needed to Perform SCE Analysis

Data Needed	Used For	Source
Topography Digital Elevation Model	2D hydraulic modeling	LiDAR, preferably blue-green and 0.5-meter horizontal accuracy or greater
Hydrology	Flows used in hydraulic modeling	Hydrologic gage data[3]
Water surface inundation boundaries[1]	Calculation of island count and island perimeters	2D hydraulic modeling results, or as a product of LiDAR flown at the desired flow[4]
River centerline	Calculation of sinuosity	Aerials or LiDAR
Valley centerline	Calculation of sinuosity, ICPVL[2], and PPVL[2]	Aerials or LiDAR
Project area delineations	Calculation of all metrics per project area	Project area shapefiles from this assessment

Notes:
1. Water surface boundaries should be for the flows desired for the analysis: in this assessment, 130 cfs, 300 cfs, and 552 cfs.
2. Island count per project area valley length (ICPVL) and perimeter per project area valley length (PPVL), as described below.
3. See Appendix C for a description of gage locations on the Tucannon River and methods used to interpret those data.
4. With blue-green LiDAR now commonly available, water surface shapefiles are easily produced with LiDAR flights. This has the effect of providing the necessary inundation information for whatever flow the LiDAR is collected. Ideally, in the future, LiDAR flights would be timed to approximately match one of the low-flow conditions described for complexity in this assessment (low-winter 130 cfs).

The following steps will assume the user has adequate GIS knowledge and access to the same data sources as those produced in this report.

1. This analysis uses three flow water surface inundation boundaries: the low-winter flow (130 cubic feet per second [cfs]), mean-winter flow (300 cfs), and 1-year flow (552 cfs). The low-winter flow water surface elevation raster was obtained directly from LiDAR survey information. The mean-winter flow and 1-year flows were obtained as a HEC-RAS 2D model output. See the main report and Appendices C and E for details on the hydrologic analysis and hydraulic modeling methods.
2. The water surface elevation rasters were imported into GIS as simple polygon shapefiles. These were manually reviewed and corrected for inconsistencies and differences from the conditions noted during field observations.

3. GIS was used to separate the void spaces of each flow polygon into their own polygon shapefile. These areas represent the islands for analysis.
4. The minimum bounding geometry was then calculated for each island. The island shapefiles were then filtered to include only islands with a minimum dimension of the minimum bounding geometry greater than 12 meters.
5. GIS was used to calculate the perimeter of each island as well as which project area each island occurs in. These figures are summed together for each project area, and from this the "island count per project area" and "perimeter sum per project area" seen in Table G-5 were calculated. Islands that span two project areas were counted as 0.5 island in each for the island count, and only the length of the perimeter that occurred in each project area was counted in the perimeter sum.
6. Both the river centerline and the valley center line were manually digitized from the aerial photographs and relative elevation maps. These were used to calculate the valley length and river length for each project area shown in Tables G-5 and G-6. Sinuosity was also calculated by dividing the river length by the valley length.
7. These three statistics form the basis for this analysis: island count per project area, island perimeter per project area, and sinuosity.
8. As shown in Tables G-5 and G-6, island count per project area and island perimeter per project area were divided by the valley length to standardize and obtain the island count per project area valley length (ICPVL) and perimeter per project area valley length (PPVL).
9. The ICPVL and PPVL were each standardized across all three flows by dividing by the largest value of the respective statistic (see Equation G-3). Sinuosity was also standardized to the largest value but is the same across all three flows. These three standardized statistics are shown for each project area in Tables G-5 and G-6.

Equation G-3

$$\text{Standarized CS } = \frac{CS_i}{CS_{\max all\ flows}}$$

where:

CS = complexity statistic (either ICPVL or PPVL)

10. Finally, these three statistics were summed with weighting factors shown in Equation G-4. These provide the final SCE values shown in Tables G-5 and G-6. These SCE values are used in the final prioritization.

Equation G-4

$$W_s(\mathrm{S}) + W_i(\mathrm{I}) + W_p(\mathrm{P}) = \text{Standardized Complexity Evaluation (SCE)}$$

where:

W_s	=	0.1: weighting factor chosen for the standardized sinuosity
W_i	=	0.5: weighting factor for standardized ICPVL
W_p	=	0.4: weighting factor for standardized PPVL
S	=	standardized sinuosity per project area
I	=	island count per valley length per project area, standardized across all three flows
P	=	island perimeter per valley length per project area, standardized across all three flows

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Tables

Table G-5
Complexity Analysis Results

Project Area	River Length (mile)	Valley Length (mile)	Island Count			Island Count Per Valley Length			Sinuosity	Island Perimeter (feet)			Perimeter Per Valley Length (feet/foot)			Flow Standardized PPVL		
			Low-Winter Flow	Mean-Winter Flow	1 Year	Low-Winter Flow	Mean-Winter Flow	1 Year		Low-Winter Flow	Mean-Winter Flow	1 Year	Low-Winter Flow	Mean-Winter Flow	1 Year	Low-Winter Flow	Mean-Winter Flow	1 Year
1.10	0.55	0.50	4.00	11.00	15.00	8.01	22.02	30.03	1.10	4488.06	7829.44	8333.06	1.70	2.97	3.16	0.70	0.57	0.53
1.20	0.39	0.36	0.00	2.00	0.00	0.00	5.54	0.00	1.09	0.00	470.58	0.00	0.00	0.25	0.00	0.00	0.05	0.00
2.00	0.64	0.56	6.00	6.00	11.00	10.64	10.64	19.50	1.14	2500.82	3406.13	5117.09	0.84	1.14	1.72	0.35	0.22	0.29
3.10	0.37	0.37	1.00	4.00	4.50	2.72	10.89	12.25	1.01	206.88	1155.99	1739.45	0.11	0.60	0.90	0.04	0.11	0.15
3.20	1.44	1.29	10.00	25.00	31.50	7.75	19.37	24.40	1.12	3770.91	8710.37	12927.46	0.55	1.28	1.90	0.23	0.24	0.32
4.00	0.24	0.21	1.00	1.00	3.00	4.66	4.66	13.98	1.11	316.45	152.34	520.45	0.28	0.13	0.46	0.12	0.03	0.08
5.00	0.45	0.43	9.00	10.00	15.00	21.09	23.43	35.14	1.06	3527.67	3659.03	5330.29	1.57	1.62	2.37	0.65	0.31	0.39
6.00	0.74	0.64	9.00	11.00	17.00	14.15	17.29	26.72	1.17	3549.56	4770.94	6315.43	1.06	1.42	1.88	0.44	0.27	0.31
7.00	0.45	0.42	1.00	2.00	1.00	2.37	4.75	2.37	1.07	277.86	517.75	269.13	0.12	0.23	0.12	0.05	0.04	0.02
8.00	0.45	0.41	8.50	10.50	12.00	20.59	25.44	29.07	1.09	5264.56	6030.90	7456.04	2.42	2.77	3.42	1.00	0.53	0.57
9.00	0.40	0.41	5.50	7.50	10.50	13.49	18.39	25.75	0.98	3311.21	3960.76	5114.85	1.54	1.84	2.38	0.64	0.35	0.40
10.10	0.47	0.41	6.00	11.00	15.50	14.76	27.06	38.13	1.15	3074.07	4716.30	6117.13	1.43	2.20	2.85	0.59	0.42	0.48
10.20	0.72	0.63	5.00	17.50	25.50	7.95	27.81	40.53	1.14	2819.20	10732.64	12746.55	0.85	3.23	3.84	0.35	0.62	0.64
10.30	0.41	0.38	4.00	10.50	21.50	10.50	27.57	56.46	1.09	1654.29	7686.78	12054.24	0.82	3.82	6.00	0.34	0.73	1.00
11.10	0.75	0.62	2.00	3.00	7.50	3.22	4.83	12.07	1.21	574.22	809.48	2449.33	0.18	0.25	0.75	0.07	0.05	0.12
11.20	0.96	0.89	11.00	32.00	34.50	12.41	36.11	38.93	1.09	9266.34	17475.40	17851.78	1.98	3.73	3.82	0.82	0.71	0.64
12.00	0.65	0.52	6.00	17.00	22.00	11.54	32.70	42.32	1.25	5873.21	10419.91	12718.10	2.14	3.80	4.63	0.89	0.72	0.77
13.00	0.77	0.67	1.00	2.00	0.00	1.50	3.00	0.00	1.15	107.39	306.64	0.00	0.03	0.09	0.00	0.01	0.02	0.00
14.10	0.61	0.56	8.00	11.00	14.00	14.39	19.78	25.17	1.10	2073.43	2756.32	3016.55	0.71	0.94	1.03	0.29	0.18	0.17
14.20	0.82	0.61	7.00	12.00	11.00	11.41	19.56	17.93	1.34	1714.18	3420.04	3301.10	0.53	1.06	1.02	0.22	0.20	0.17
14.30	0.72	0.64	1.00	7.00	29.00	1.57	10.96	45.40	1.13	441.57	7759.31	17658.30	0.13	2.30	5.24	0.05	0.44	0.87
15.10	0.38	0.32	3.00	6.00	5.00	9.36	18.73	15.61	1.19	3093.54	3839.03	3610.16	1.83	2.27	2.13	0.76	0.43	0.36
15.20	0.42	0.39	2.00	3.00	4.00	5.10	7.65	10.19	1.08	649.96	944.34	939.92	0.31	0.46	0.45	0.13	0.09	0.08
16.00	1.39	1.24	3.00	2.00	2.00	2.42	1.62	1.62	1.12	578.32	842.86	639.59	0.09	0.13	0.10	0.04	0.02	0.02
17.10	0.34	0.34	0.00	1.50	0.00	0.00	4.42	0.00	1.01	0.00	470.08	0.00	0.00	0.26	0.00	0.00	0.05	0.00
17.20	0.31	0.27	4.00	17.50	15.50	15.06	65.88	58.35	1.15	2698.73	7358.17	6070.22	1.92	5.25	4.33	0.80	1.00	0.72
18.10	1.08	0.96	12.00	23.00	32.50	12.44	23.84	33.68	1.12	6404.07	12883.71	14166.38	1.26	2.53	2.78	0.52	0.48	0.46
18.20	0.78	0.70	2.00	11.00	18.00	2.87	15.76	25.79	1.11	1493.15	3460.26	7106.62	0.41	0.94	1.93	0.17	0.18	0.32
19.00	0.56	0.47	3.00	8.00	11.00	6.39	17.04	23.43	1.20	767.86	2586.01	2718.67	0.31	1.04	1.10	0.13	0.20	0.18
20.00	0.44	0.40	2.00	4.00	6.00	4.97	9.94	14.91	1.08	727.07	1585.45	4528.60	0.34	0.75	2.13	0.14	0.14	0.36
21.00	1.05	1.06	2.00	1.00	6.00	1.88	0.94	5.65	0.99	896.81	303.28	3038.45	0.16	0.05	0.54	0.07	0.01	0.09
22.00	1.08	0.98	1.00	2.00	6.00	1.02	2.04	6.13	1.11	157.94	577.11	1614.69	0.03	0.11	0.31	0.01	0.02	0.05
23.00	1.05	0.81	6.00	3.50	3.50	7.37	4.30	4.30	1.29	1608.18	1295.87	867.16	0.37	0.30	0.20	0.15	0.06	0.03
24.00	0.76	0.71	2.00	7.50	9.00	2.81	10.55	12.66	1.07	367.89	1764.66	4373.91	0.10	0.47	1.17	0.04	0.09	0.19
25.00	0.54	0.45	3.00	3.00	7.50	6.65	6.65	16.62	1.20	719.92	1804.42	2636.60	0.30	0.76	1.11	0.13	0.14	0.18
26.00	2.99	2.79	16.50	32.50	32.50	5.92	11.66	11.66	1.07	5960.96	11660.55	14015.20	0.41	0.79	0.95	0.17	0.15	0.16
27.00	1.05	0.90	16.50	17.50	21.50	18.37	19.48	23.94	1.17	5027.11	5389.67	8228.59	1.06	1.14	1.74	0.44	0.22	0.29
28.10	0.87	0.79	13.00	20.00	36.00	16.39	25.21	45.39	1.09	4817.51	6177.92	15890.05	1.15	1.48	3.79	0.48	0.28	0.63
28.20	1.17	1.01	14.50	26.00	41.00	14.36	25.76	40.61	1.16	12594.41	19648.60	22202.01	2.36	3.69	4.17	0.98	0.70	0.69
28.30	1.16	1.03	3.50	6.00	9.00	3.39	5.81	8.72	1.13	961.38	1838.43	3442.29	0.18	0.34	0.63	0.07	0.06	0.11
29.00	1.12	1.01	1.00	5.00	12.50	0.99	4.97	12.43	1.11	640.09	2387.90	4386.67	0.12	0.45	0.83	0.05	0.09	0.14
30.00	1.01	0.83	18.00	36.00	38.50	21.74	43.48	46.50	1.22	9046.29	11654.62	15922.83	2.07	2.67	3.64	0.86	0.51	0.61
31.00	1.49	1.44	8.50	12.00	18.00	5.92	8.36	12.54	1.04	4169.38	5722.14	7168.46	0.55	0.75	0.95	0.23	0.14	0.16
32.10	0.79	0.69	5.50	8.00	17.00	7.97	11.59	24.64	1.14	1666.97	2119.18	5611.54	0.46	0.58	1.54	0.19	0.11	0.26
32.20	0.69	0.58	3.00	4.50	3.50	5.15	7.73	6.01	1.19	520.28	873.01	843.03	0.17	0.28	0.27	0.07	0.05	0.05
33.00	1.22	1.12	3.00	0.50	1.50	2.67	0.45	1.34	1.09	314.21	32.05	380.95	0.05	0.01	0.06	0.02	0.00	0.01
34.10	1.14	1.17	3.00	23.00	31.00	2.57	19.70	26.55	0.98	1455.95	10093.16	10270.63	0.24	1.64	1.67	0.10	0.31	0.28
34.20	0.78	0.63	9.00	17.00	16.00	14.37	27.15	25.55	1.25	4196.59	6845.42	7375.63	1.27	2.07	2.23	0.53	0.39	0.37
35.00	0.69	0.65	2.00	2.00	2.50	3.06	3.06	3.82	1.05	370.71	386.63	799.56	0.11	0.11	0.23	0.04	0.02	0.04
36.00	1.70	1.44	19.00	25.00	40.50	13.20	17.37	28.14	1.18	6822.21	6625.88	16870.87	0.90	0.87	2.22	0.37	0.17	0.37
37.00	1.10	0.97	2.00	3.00	9.00	2.06	3.10	9.29	1.13	1243.24	1288.14	2534.38	0.24	0.25	0.50	0.10	0.05	0.08
38.00	2.97	2.77	4.00	15.00	17.00	1.44	5.42	6.14	1.07	853.90	3917.19	5459.86	0.06	0.27	0.37	0.02	0.05	0.06
39.10	0.10	0.09	1.00	2.00	6.50	11.10	22.19	72.13	1.15	97.17	786.97	2255.39	0.20	1.65	4.74	0.08	0.32	0.79
39.20	0.33	0.31	2.00	1.00	0.50	6.36	3.18	1.59	1.05	372.69	247.73	93.19	0.22	0.15	0.06	0.09	0.03	0.01
40.00	0.57	0.52	1.00	2.50	3.00	1.92	4.80	5.76	1.10	222.19	3110.60	3409.50	0.08	1.13	1.24	0.03	0.22	0.21
41.00	0.35	0.31	9.00	11.00	8.50	29.18	35.67	27.56	1.14	3365.41	3221.72	2707.48	2.07	1.98	1.66	0.86	0.38	0.28
42.00	0.33	0.26	5.00	5.50	7.00	19.39	21.33	27.14	1.29	2048.06	1224.93	1383.76	1.50	0.90	1.02	0.62	0.17	0.17
43.00	0.43	0.28	9.00	9.00	9.50	31.97	31.97	33.75	1.52	2829.72	3364.49	3594.67	1.90	2.26	2.42	0.79	0.43	0.40
44.00	0.43	0.31	3.00	2.00	2.00	9.67	6.45	6.45	1.39	578.29	565.63	625.95	0.35	0.35	0.38	0.15	0.07	0.06
45.00	0.52	0.43	1.00	3.00	6.00	2.34	7.03	14.07	1.23	107.32	602.30	3945.13	0.05	0.27	1.75	0.02	0.05	0.29

Table G-6
Standard Complexity Evaluation Results

Project Area	Pop. Standardized ICPVL			Standardized Sinuosity	Pop. Standardized PPVL			Original RCI[1]			Stand. Complexity Eval. (SCE)		
	Low-Winter Flow	Mean-Winter Flow	1 Year		Low-Winter Flow	Mean-Winter Flow	1 Year	Low-Winter Flow	Mean-Winter Flow	1 Year	Low-Winter Flow	Mean-Winter Flow	1 Year
1.10	0.11	0.31	0.42	0.72	0.28	0.50	0.53	9.92	25.35	34.16	0.24	0.42	0.49
1.20	0.00	0.08	0.00	0.71	0.00	0.04	0.00	1.09	7.11	1.09	0.07	0.13	0.07
2.00	0.15	0.15	0.27	0.75	0.14	0.19	0.29	13.26	13.26	23.37	0.20	0.22	0.32
3.10	0.04	0.15	0.17	0.67	0.02	0.10	0.15	3.77	12.05	13.43	0.09	0.18	0.21
3.20	0.11	0.27	0.34	0.73	0.09	0.21	0.32	9.76	22.73	28.34	0.16	0.29	0.37
4.00	0.06	0.06	0.19	0.73	0.05	0.02	0.08	6.29	6.29	16.65	0.12	0.11	0.20
5.00	0.29	0.32	0.49	0.70	0.26	0.27	0.39	23.48	25.97	38.42	0.32	0.34	0.47
6.00	0.20	0.24	0.37	0.77	0.18	0.24	0.31	17.69	21.36	32.38	0.25	0.29	0.39
7.00	0.03	0.07	0.03	0.70	0.02	0.04	0.02	3.61	6.15	3.61	0.10	0.12	0.09
8.00	0.29	0.35	0.40	0.72	0.40	0.46	0.57	23.57	28.85	32.82	0.38	0.43	0.50
9.00	0.19	0.25	0.36	0.64	0.26	0.31	0.40	14.23	19.05	26.27	0.26	0.31	0.40
10.10	0.20	0.38	0.53	0.76	0.24	0.37	0.48	18.13	32.29	45.03	0.27	0.41	0.53
10.20	0.11	0.39	0.56	0.75	0.14	0.54	0.64	10.24	32.99	47.54	0.19	0.48	0.61
10.30	0.15	0.38	0.78	0.72	0.14	0.64	1.00	12.53	31.13	62.60	0.20	0.52	0.86
11.10	0.04	0.07	0.17	0.79	0.03	0.04	0.12	5.10	7.04	15.79	0.11	0.13	0.21
11.20	0.17	0.50	0.54	0.71	0.33	0.62	0.64	14.56	40.28	43.34	0.29	0.57	0.60
12.00	0.16	0.45	0.59	0.82	0.36	0.63	0.77	15.72	42.23	54.29	0.31	0.56	0.68
13.00	0.02	0.04	0.00	0.75	0.01	0.01	0.00	2.87	4.59	1.15	0.09	0.10	0.08
14.10	0.20	0.27	0.35	0.72	0.12	0.16	0.17	16.89	22.81	28.73	0.22	0.27	0.32
14.20	0.16	0.27	0.25	0.88	0.09	0.18	0.17	16.64	27.57	25.38	0.20	0.29	0.28
14.30	0.02	0.15	0.63	0.74	0.02	0.38	0.87	2.89	13.48	52.30	0.09	0.30	0.74
15.10	0.13	0.26	0.22	0.78	0.31	0.38	0.36	12.32	23.46	19.75	0.26	0.36	0.33
15.20	0.07	0.11	0.14	0.71	0.05	0.08	0.08	6.58	9.33	12.07	0.13	0.15	0.17
16.00	0.03	0.02	0.02	0.74	0.01	0.02	0.02	3.85	2.94	2.94	0.10	0.09	0.09
17.10	0.00	0.06	0.00	0.67	0.00	0.04	0.00	1.01	5.50	1.01	0.07	0.11	0.07
17.20	0.21	0.91	0.81	0.76	0.32	0.88	0.72	18.53	77.17	68.49	0.31	0.88	0.77
18.10	0.17	0.33	0.47	0.74	0.21	0.42	0.46	15.05	27.82	38.85	0.24	0.41	0.49
18.20	0.04	0.22	0.36	0.73	0.07	0.16	0.32	4.29	18.61	29.74	0.12	0.24	0.38
19.00	0.09	0.24	0.32	0.78	0.05	0.17	0.18	8.83	21.57	29.21	0.14	0.27	0.31
20.00	0.07	0.14	0.21	0.71	0.06	0.12	0.36	6.47	11.86	17.25	0.13	0.19	0.32
21.00	0.03	0.01	0.08	0.65	0.03	0.01	0.09	2.86	1.93	6.60	0.09	0.08	0.14
22.00	0.01	0.03	0.09	0.73	0.01	0.02	0.05	2.24	3.37	7.89	0.08	0.09	0.14
23.00	0.10	0.06	0.06	0.85	0.06	0.05	0.03	10.82	6.85	6.85	0.16	0.13	0.13
24.00	0.04	0.15	0.18	0.70	0.02	0.08	0.19	4.06	12.31	14.55	0.10	0.17	0.24
25.00	0.09	0.09	0.23	0.79	0.05	0.13	0.18	9.15	9.15	21.08	0.14	0.18	0.27
26.00	0.08	0.16	0.16	0.70	0.07	0.13	0.16	7.42	13.57	13.57	0.14	0.20	0.21
27.00	0.25	0.27	0.33	0.77	0.18	0.19	0.29	22.59	23.89	29.08	0.27	0.29	0.36
28.10	0.23	0.35	0.63	0.72	0.19	0.25	0.63	19.03	28.69	50.76	0.26	0.35	0.64
28.20	0.20	0.36	0.56	0.76	0.39	0.61	0.69	17.77	30.95	48.13	0.33	0.50	0.64
28.30	0.05	0.08	0.12	0.74	0.03	0.06	0.11	4.95	7.69	10.97	0.11	0.14	0.18
29.00	0.01	0.07	0.17	0.73	0.02	0.08	0.14	2.22	6.64	14.93	0.09	0.14	0.21
30.00	0.30	0.60	0.64	0.80	0.35	0.44	0.61	27.68	54.13	57.81	0.37	0.56	0.65
31.00	0.08	0.12	0.17	0.68	0.09	0.13	0.16	7.20	9.73	14.08	0.15	0.18	0.22
32.10	0.11	0.16	0.34	0.75	0.08	0.10	0.26	10.21	14.34	29.18	0.16	0.19	0.35

Table G-6
Standard Complexity Evaluation Results

Project Area	Pop. Standardized ICPVL			Standardized Sinuosity	Pop. Standardized PPVL			Original RCI[1]			Stand. Complexity Eval. (SCE)		
	Low-Winter Flow	Mean-Winter Flow	1 Year		Low-Winter Flow	Mean-Winter Flow	1 Year	Low-Winter Flow	Mean-Winter Flow	1 Year	Low-Winter Flow	Mean-Winter Flow	1 Year
32.20	0.07	0.11	0.08	0.78	0.03	0.05	0.05	7.34	10.41	8.36	0.13	0.15	0.14
33.00	0.04	0.01	0.02	0.71	0.01	0.00	0.01	4.00	1.57	2.55	0.09	0.07	0.09
34.10	0.04	0.27	0.37	0.64	0.04	0.27	0.28	3.50	20.28	26.99	0.10	0.31	0.36
34.20	0.20	0.38	0.35	0.82	0.21	0.35	0.37	19.19	35.13	33.14	0.27	0.41	0.41
35.00	0.04	0.04	0.05	0.69	0.02	0.02	0.04	4.28	4.28	5.09	0.10	0.10	0.11
36.00	0.18	0.24	0.39	0.78	0.15	0.15	0.37	16.77	21.70	34.42	0.23	0.26	0.42
37.00	0.03	0.04	0.13	0.74	0.04	0.04	0.08	3.47	4.65	11.67	0.10	0.11	0.17
38.00	0.02	0.08	0.09	0.70	0.01	0.04	0.06	2.62	6.89	7.66	0.08	0.13	0.14
39.10	0.15	0.31	1.00	0.76	0.03	0.28	0.79	13.94	26.73	84.28	0.17	0.34	0.89
39.20	0.09	0.04	0.02	0.69	0.04	0.02	0.01	7.71	4.38	2.71	0.13	0.10	0.08
40.00	0.03	0.07	0.08	0.72	0.01	0.19	0.21	3.22	6.40	7.46	0.09	0.18	0.20
41.00	0.40	0.49	0.38	0.75	0.34	0.33	0.28	34.49	41.91	32.64	0.42	0.45	0.38
42.00	0.27	0.30	0.38	0.85	0.25	0.15	0.17	26.39	28.90	36.42	0.32	0.29	0.34
43.00	0.44	0.44	0.47	1.00	0.32	0.38	0.40	50.23	50.23	52.94	0.45	0.47	0.50
44.00	0.13	0.09	0.09	0.91	0.06	0.06	0.06	14.84	10.36	10.36	0.18	0.16	0.16
45.00	0.03	0.10	0.20	0.81	0.01	0.04	0.29	4.11	9.87	18.50	0.10	0.15	0.30

Notes:
1. Refers to the River Complexity Index, orignally described by Brown (2002).

Figures

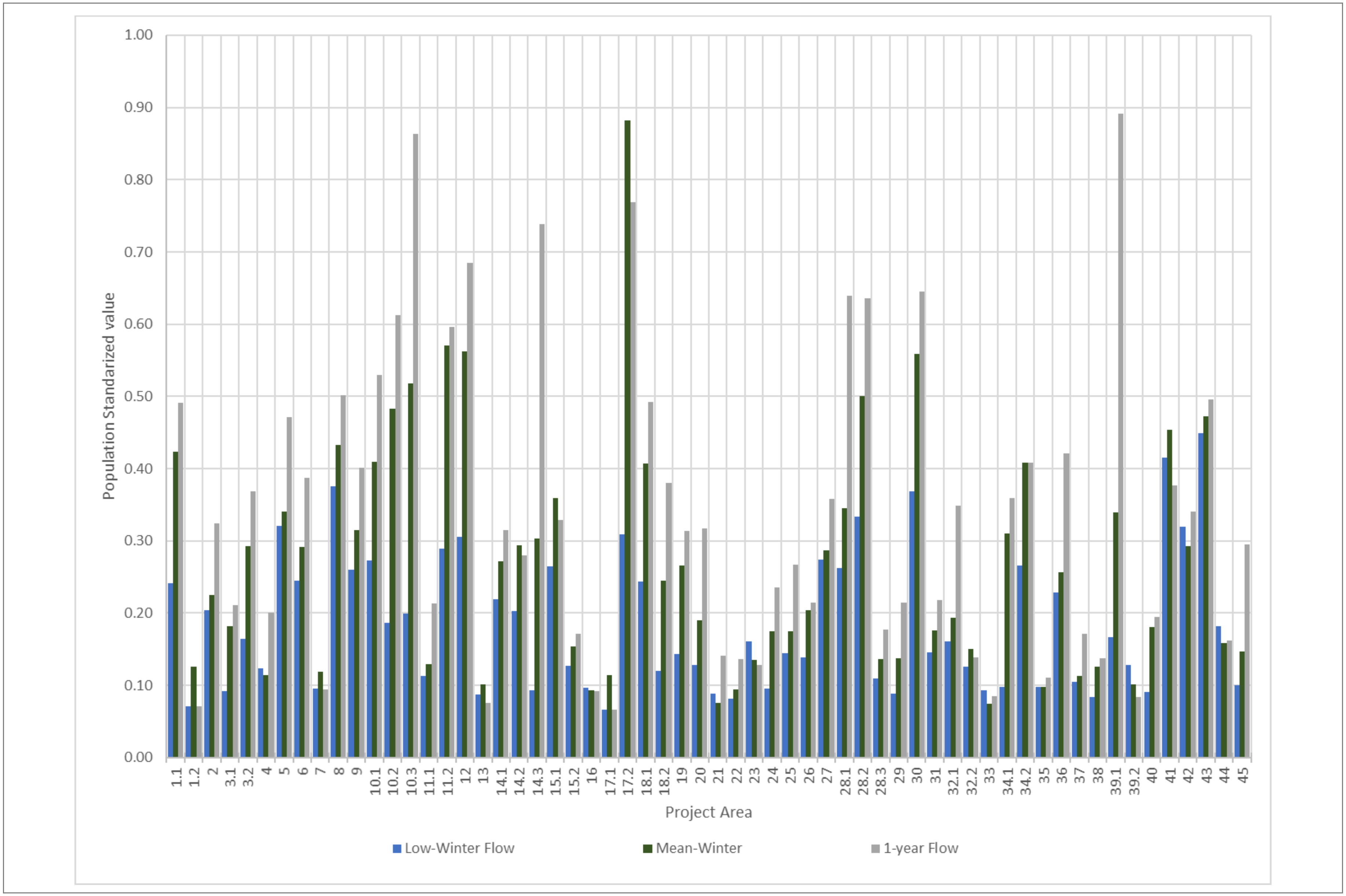

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Figure G-5
Standardized Complexity Evaluation Results
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

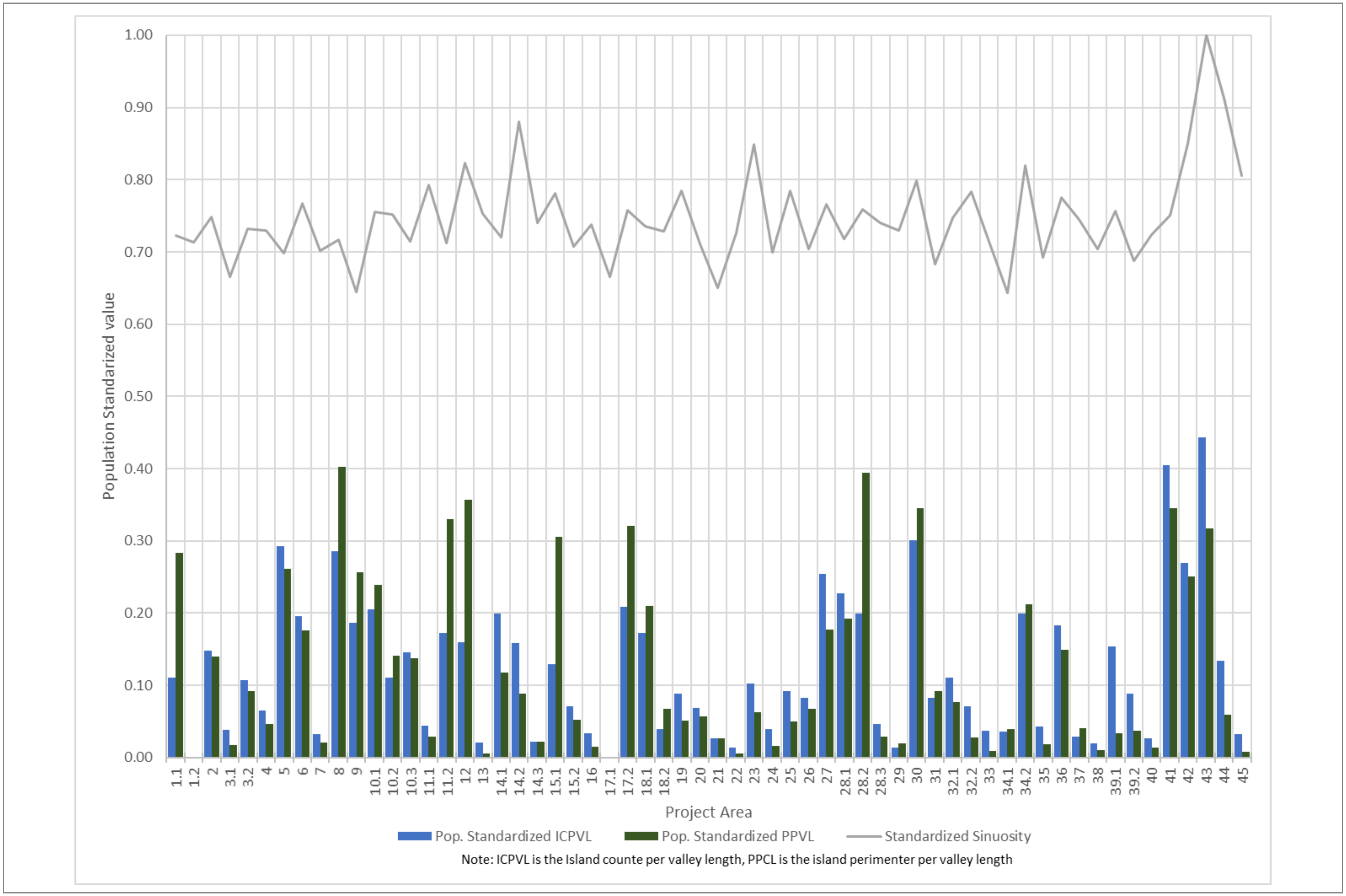

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Figure G-6
Low-Winter Flow Standardized Complexity Metrics

Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

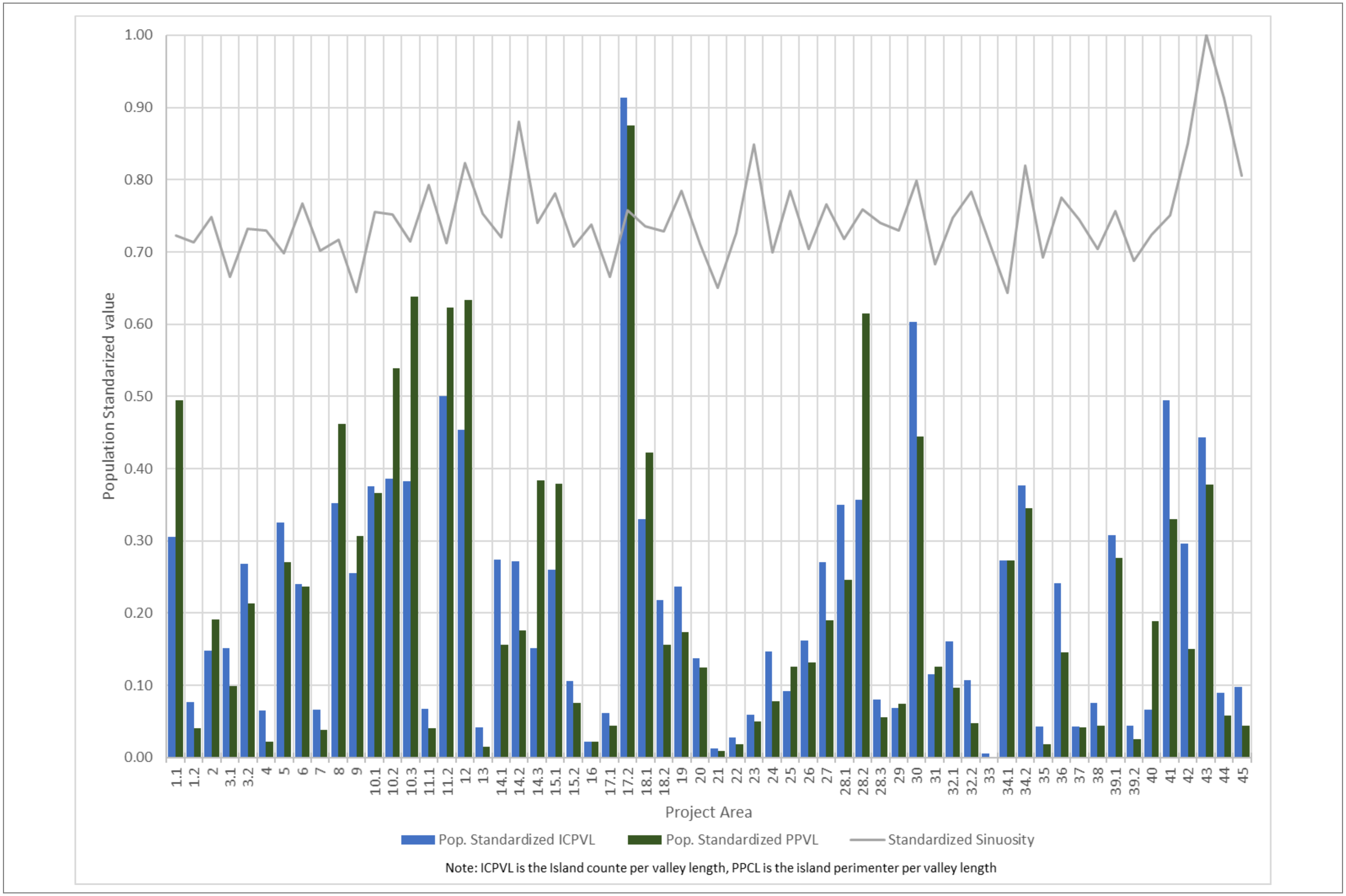

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Figure G-7
Mean-Winter Flow Standardized Complexity Metrics
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

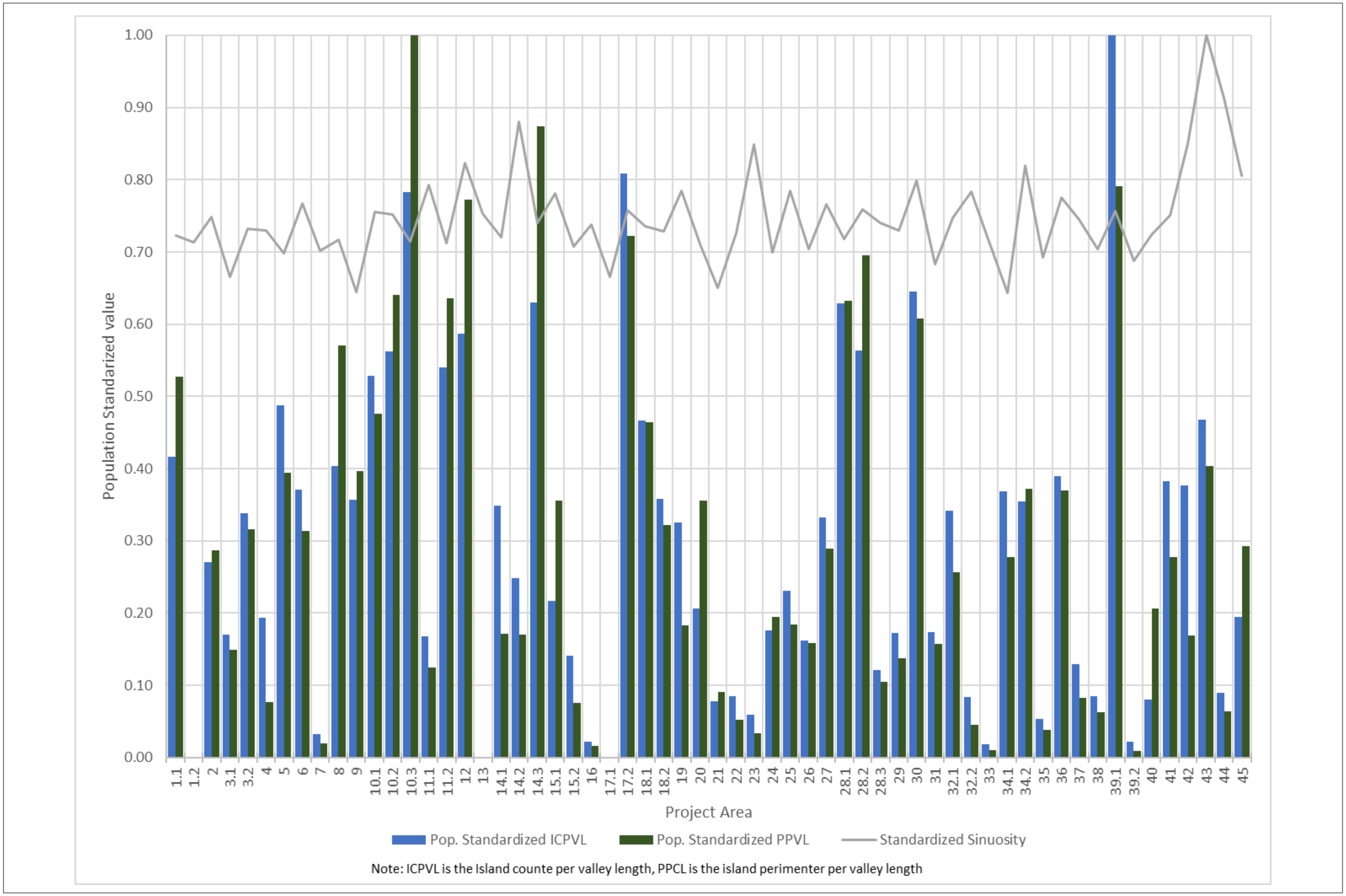

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Figure G-8
1-Year Flow Standardized Complexity Metrics
Geomorphic Assessment and Restoration Prioritization
Tucannon Basin Habitat Restoration

Appendix H
Excess Transport Capacity Analysis

Appendix H
Excess Transport Capacity Analysis

The availability and abundance of gravel or small cobble-sized material in the Tucannon River plays a large role in the geomorphic processes that force bedforms, complexity, and connectivity. Through on-site assessment, it is clear that the reaches with ample gravel to small cobble-sized material, available throughout the reach, form pools at instream wood locations more easily, access the floodplain more frequently, and develop complex side channels and split flows. The individual project area assessments in the assessment show that many of these areas are associated with river avulsions or migrations shortly upstream, providing a potential source of these gravel-sized materials. However, for other reaches, as is often the case with confined and incised systems, the supply of material can become "locked" in the floodplain and is no longer accessed on a regular basis. The materials remaining in the channel bottom often represent lag deposits and collectively form an armor layer that resists pool formation and temporary sediment storage and facilitates high energy flows through the reach. When this happens, a feedback loop of confinement and incision propagates and can extend downstream over time. Without human intervention or a large natural change, such as a large tree falling into the river and capturing additional wood and sediment, the dominant channel bed material becomes resistant to regularly occurring geomorphic change. With less frequent geomorphic change, the floodplain and the smaller material stored therein are accessed and mobilized less frequently, contributing to this feedback loop. The process of confinement often continues until a threshold and possibly catastrophic flow breaks the cycle.

One solution to this cycle is to provide another source of material that is sized to be frequently mobilized. This material can quickly cause localized geomorphic change, which in turn will release material "locked" in the floodplain and jumpstart the process of sediment transport and minor avulsions or migrations. For this reason, gravel augmentation is one of the restoration actions recommended in this assessment. However, to make decisions on the placement and amount of this restoration action, it is important to understand how the transport capacity of a reach might be different from other reaches in the basin. The following Excess Transport Capacity analysis establishes a basin-wide trend in transport capacity based on the modeled shear stress and uses this trend to identify reaches of the basin where shear stress and transport capacity differ from the expectations for the basin. While this method does not determine what the transport capacity of a reach is, it can tell us something about how the reach is different from other similar reaches in this basin, and provide enough clues for better recommendations for gravel augmentation and sediment transport continuity in general.

Analysis Overview

Shear stress has historically been used as a metric for gauging the bedload sediment transport capacity and potential for geomorphic change in a reach. Many commonly used transport models either use shear stress as a direct input or are indirectly related to shear stress (Wilcock 2001). For a full sediment transport model and detailed transport capacity information, the material size for each reach is usually required. Due to the large scale and scope of assessing the entire Tucannon River basin, this analysis does not include sediment size information. However, using shear stress information collected with a HEC-RAS one-dimensional (1D) model, trends and patterns for the basin can be determined and, taken over the whole basin, some information about the trends and patterns of the transport capacity in the basin can be inferred.

Shear stress (measured in pounds per foot*second [lb/ft^2]), is calculated in HEC-RAS as a product of shear stress and velocity and is used as a primary factor in many bedload transport equations (USACE 2016) and was chosen for this assessment as a representation of the bedload transport capacity of a reach. The 2-year event was chosen as the flow used for this analysis because it is the return flow in which geomorphic changes due to restoration efforts in this basin are expected to occur. Based on experience in the Tucannon River basin, this flow is known to mobilize the gravel and small cobbles most relevant to geomorphic change in the basin. Additionally, particular focus was placed on the 2-year flow event because it occurs more frequently than the 5-year flow event, and in reaches with process-based restoration efforts, immediate geomorphic response is desirable. Due to the selection of this flow for this model, it was necessary to use the results of the 1D HEC-RAS model for this analysis.

For this method, shear stress is defined as a product of friction slope and hydraulic radius and the unit weight of water. HEC-RAS directly outputs the variable shear stress in the form of two variables: total shear stress and channel shear stress. This analysis and the associated prioritization focus on channel shear stress, which gives a better indication of the bedload transport capacity than total shear stress because vegetation and largely ineffective flow prevent most bedload transport on the floodplain.

Examining shear stress at a single cross section can display some statistical noise because the exact location of the cross sections may not fully capture the slope and confinement of the channel. Additionally, the shear stress at a single cross section represents only the channel configuration at that exact location and may vary quite a bit over the length of a project area. Because the distances between cross sections is not constant, a length-weighted averaging method was required to determine a single shear stress value for each project area. This shear stress value will be referred to as the modeled shear stress for the purposes of this analysis.

These modeled shear stress values are only rough indicators of sediment transport, and these values only become useful when used to examine how they compare to large basin-wide trends. One of the primary factors that contributes to a reach naturally having higher transport capacity is the average energy slope. Reaches that are steeper, such as those generally seen in the upper portions of the basin, will naturally have more capacity for sediment transport regardless of external factors. Energy grade elevation is a HEC-RAS output that can be calculated for every cross section. The average grade slope was calculated for each project area, accounting for each cross section in a similar averaging method used for the modeled shear stress. The detailed mechanisms of the shear stress averaging calculation are discussed in more detail in the Detailed Instructions for Performing this Analysis section below.

The regression equation shown in Equation H-1 was developed to describe the relationship of the energy grade slope on the average shear stress for each project area. The power regression curve has a moderately good correlation, with an R^2 value of 0.538.

Equation H-1

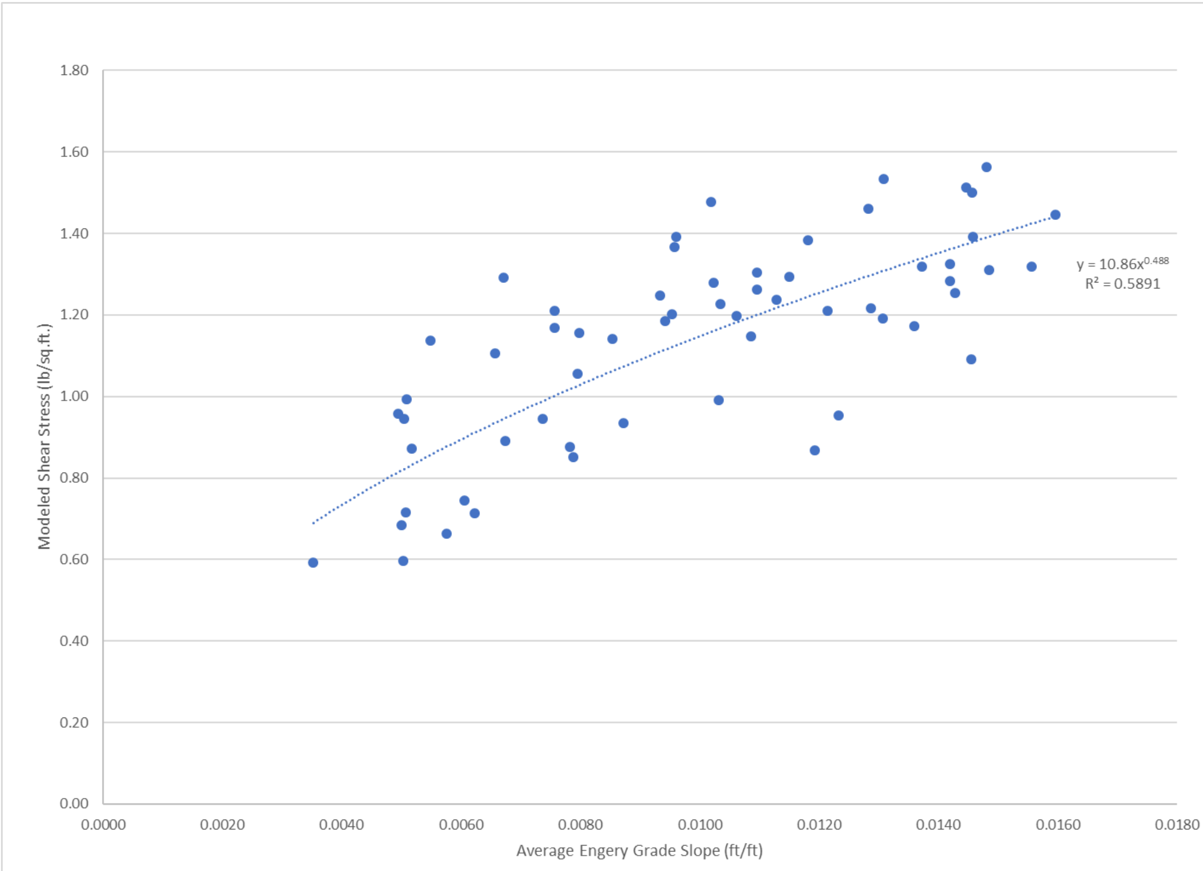
$$\tau_p = 10.86\, {S_{EG}}^{0.488}$$

where:

τ_p	=	predicted shear stress
S_{EG}	=	slope of the energy grade line

Figure H-1 shows the regression curve and how it relates the average energy grade slope and shear stress for each project area. There are several plain outliers to this trend, as well as many other project areas that are significantly higher than the regression average. These outliers and high values are the project areas that have much more transport capacity than would be expected of a project area in the Tucannon River basin with similar slopes. With this information, restoration actions that will account for this high transport capacity can be recommended for individual project areas, and basin-wide trends can be established for basin-wide actions such as gravel augmentation. These recommendations and how they affect individual project areas can be found in the Project Area Cut Sheets in Appendix J.

Figure H-1
Modeled Shear Stress vs. Energy Grade Slope



Aside from graphically seeing how the outliers occur to this trend, numerical values for excess transport capacity were determined that describe the variance from this trend. Equation H-1 is used to determine a shear stress value for each project area, predicted by the energy grade slopes and the relationship described in this regression equation. This value is referred to as the predicted shear stress for this assessment. By differencing the modeled shear stress and the predicted shear stress, the variance from the regression equation can be determined as shown in Equation H-2. This is the value referred to as the Excess Transport Capacity metric for this analysis and will be the value used in the assessment to indicate projects where restoration actions targeting sediment transport might be implemented. For a full list of the values of the modeled shear stress, predicted shear stress, energy grade slopes, and excess transport capacity, see Table H-3 at the end of this appendix.

Equation H-2

$$\text{ETC} = \tau_m - \tau_p$$

where:

ETC	=	excess transport capacity
τ_m	=	modeled shear stress
τ_p	=	predicted shear stress

Bedload Transport Trends and Patterns

This section briefly describes some of the basin-wide trends and findings from the Excess Transport Capacity analysis. A more detailed breakdown of how this analysis applies to individual project areas is discussed in the Project Area Cut Sheets in Appendix J. This section references figures that are provided at the end of this appendix.

Because the Excess Transport Capacity metric factors out slope though the regression equation in Equation H-1, the correlation with position in the basin seen in most of the other analysis results is not seen in the plot of excess transport capacity across the basin in Figure H-3. A basin-wide trend would be expected in a measure of just the transport capacity of individual project areas, but because this analysis result measures excess transport capacity, a basin-wide trend is not expected. However, small-scale trends are apparent and identifying these smaller trends is the strength of this analysis.

First, it should be noted that almost all project areas known to be highly confined will show high excess transport capacity. Examples include: Project Area 4, located behind the Camp Wooten levee; Project Area 13, which is currently confined by Rainbow Lake; Project Areas 21 and 22, which are both leveed and confined; Project Areas 37 and 38, which are both incised and confined; and many others. Table H-1 shows typical ranges of excess transport capacity and how those ranges have been incorporated into the prioritization. Channel confinement is a classic way of increasing the transport capacity in a reach. Straightening meanders, removing overbank flows and storage area, and decreasing roughness and complexity are all effects of channel confinement and causes of increased sediment transport. The reaches that will likely have a larger bed sediment size and be resistant to geomorphic change are exactly the type of reaches that need to be addressed with restoration strategies that are catered to reducing excess transport capacity.

Additionally, there are two distinct groupings evident in Figure H-3. Project Areas 8 to 12 all show less transport capacity than would be expected of their slopes. It is highly likely this is directly tied to the Tucannon Hatchery Dam, located at the downstream end of Project Area 12, which acts as a grade control structure and barrier for sediment transport, forcing a depositional area in Project Area 12 and upstream. Many of these reaches have also been noted as having high complexity and larger than normal floodplain areas.

The second grouping of project areas with similar excess transport capacity values is Project Areas 20 to 27, which all have high excess transport capacity values. Many of these project areas are highly leveed and confined, likely contributing to the high excess transport capacity. This is a long stretch of the river to have higher than usual transport capacities, which likely has a negative effect on the complexity and connectivity of these reaches.

Finally, when compared to the other metrics of this assessment, Excess Transport Capacity shows a moderate correlation to many of the complexity metrics. In particular, Excess Transport Capacity seems to be negatively correlated with low-flow complexity with a variance of 0.351, which is one of the highest correlations between any of the metrics. As discussed previously, complexity and transport capacity are closely tied fluvial processes. Without adequate available sediment, as is often the case in places with high excess transport capacities, the geomorphic changes that force complexity cannot form, causing more confinement and incision. It is also interesting that the Excess Transport Capacity metric shows no correlation at all with the Connectivity metric with r2 values of 0 for all three analysis results of Channel Aggradation, Encroachment Removal, and Total Floodplain Potential. Because these connectivity values are indicators of potential for additional connection, this lack of correlation indicates that project areas with abnormally high transport capacity might not have a lot of potential floodplain area to be connected.

Scoring for Prioritization

In order to fit analysis results into the prioritization process, each project area is ranked, classified, and scored in each of the three prioritization metrics (Complexity, Connectivity, and Excess Transport Capacity). Project areas are ranked in the Connectivity metric from best to worst based on the Excess Transport Capacity scores. Each project area then has a rank for the Excess Transport Capacity prioritization metric and can be classified and scored according to the classification and scoring systems outlined in Table H-1.

Similar to the Connectivity metric classifications, projects that rank highly in Excess Transport Capacity indicate that these are the project areas where the balance of sediment transport to slope is out of the ordinary. Therefore, project areas that rank high in the Excess Transport Capacity metric are those where efforts to balance sediment transport and allow more in-channel sediment deposition should be focused. The percentile rank where the classes change for the Excess Transport Capacity metric were chosen based on distinctive threshold values where the actual transport capacity score is much different from those ranked directly around it. Additionally, below 50%

already indicates that the project area is at or below the transport capacity for the reach and will not require any restoration focused on restoring sediment transport balance.

Table H-1
Excess Transport Capacity

Percentile Rank	Class	Class Score	Metric Score Threshold[1]	Class Conceptualization
90th to Top	1	5	0.247	These project areas have extremely high transport capacity for their slopes compared to what is typical in the basin, and restoration efforts. These project areas should be a primary target for restoration actions focused on sediment transport balance.
70th to 90th	2	3	0.126	Project areas in this class have significantly higher transport capacity than other project areas in this assessment. These project areas should be a secondary target for restoration actions focused on sediment transport balance.
50th to 70th	3	1	0.00	Project areas in this class have only slightly higher transport capacity than would be expected, and sediment transport balance restoration actions should only be targeted when other restoration actions are already considered for the project area.
Bottom to 50th	4	0	N/A	Projects areas in this class have a normal or less amount of transport capacity based on their slopes.

Notes:

1. This is the score that defines the lower limit for the corresponding classification for this metric. These data can be used to track progression of project areas and compare to how they would rank according to the levels of this assessment, as new restoration projects are completed and new data become available.

Detailed Instructions for Performing this Analysis

Part of the purpose of this assessment is to define repeatable and data-driven methods for assessing project areas and how they have progressed in relation to their goals. This section provides the detailed steps taken to perform the Excess Transport Capacity analysis of the Tucannon River so that these analyses can be repeated in the future for additional analyses and evaluation of progress. Table H-2 provides the data that will need to be collected to reassess the project areas for excess transport capacity.

Table H-2
Raw Data Needed to Perform Excess Transport Capacity Analysis

Data Needed	Used For	Source
Topography Digital Elevation Model	1D hydraulic modeling	LiDAR, preferably blue-green and 0.5-meter horizontal accuracy or greater
Hydrology	Flows used in hydraulic modeling	Hydrologic gage data[1]
Cross sectional shear stress and energy grade elevation	Modeled shear stress	1D hydraulic modeling results
Project area delineations	Calculation of the average model results per project area	Project area shapefiles from this assessment

Notes:
1. See Appendix C for a description of gage locations on the Tucannon River and methods used to interpret those data.

The following instructions will assume the user has adequate GIS and HEC-RAS modeling knowledge and access to the same data sources as those produced in this report.

Examining shear stress at a single cross section can display some statistical noise because the exact location of the cross sections may not fully capture the slope and confinement of the channel. Additionally, the shear stress at a single cross section represents only the channel configuration at that exact location and may vary quite a bit over the length of a project area. The simple solution to this is to take the average of the shear stresses at all cross sections in the project area. However, because the cross sections represent the shear stress at a given point, an averaging technique shown in Equation H-3 has been applied to each project area. Every pair of cross sections represents a length of channel between these two cross sections, so the shear stress over this length can be more accurately represented as the average of the upstream cross section and the downstream cross section, referred to here as the Reach Average Shear Stress. To find the average for a project area, each reach between a pair of cross sections in the project area were then averaged, and because not all cross sections are spaced evenly, these were weighted by length of each cross-sectional reach.

Equation H-3

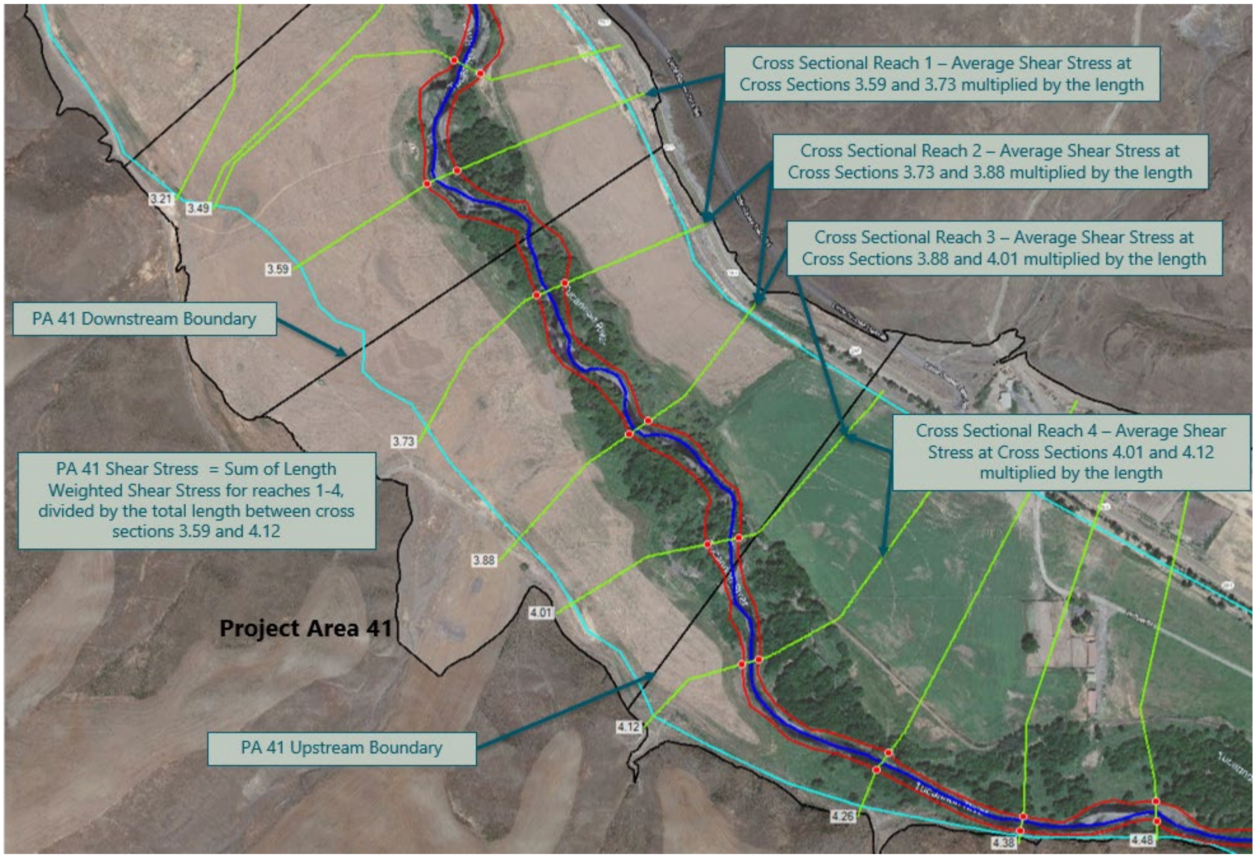
$$\tau_{a,b} = \sum_{a-1}^{b} (\tau_i + \tau_{i+1})\, L_{i,i+1} \Big/ \sum_{a-1}^{b} L_{i,i+1}$$

where:

$\tau_{a,b}$	=	length weighted, reach average, shear stress of the project area *a,b*
i	=	cross sections of the basin, where i=0 is the most downstream cross section in the basin and i=n is the most upstream cross section in the basin
τ_i	=	shear stress at cross section i
$L_{i,i+1}$	=	river length of the reach between cross sections i and $i+1$
a	=	most downstream cross section of the project area
b	=	most upstream cross section of the project area

Finally, each project area takes the average from the first cross section downstream of the downstream project boundary to the cross section that exists just upstream of the upstream project boundary. This is necessary to account for all area in a project area because cross sections and project boundaries do not often coincide exactly and some portion of the first and cross-sectional reach would be excluded from the analysis. This has the effect of slightly more of the river length being factored into each project area average. However, since the upstream and downstream conditions do have some effect on the transport capacity of the reach, this possibly serves to make this reach estimate of shear stress more accurate. The final result is a model result-based shear stress value for each project area, which will be referred to as the modeled shear stress. This process of calculation is visually described in Figure H-2 for Project Area 41.

Figure H-2
Project Area 41: Calculation of Length Weighted Reach Average Shear Stress



The average energy grade slope was calculated using the same array of cross sections, all of those that fall within the project area, as well as the cross sections immediately upstream and downstream. The energy grade elevation at each cross section at the upstream and downstream ends of the project area was differenced and divided by the total length to determine the energy grade slope for the project area.

Using the regression equation in Equation H-4, predicted shear stresses were found for each cross section. For an explanation of the source of the regression equation, see the Analysis Overview section and Figure H-1. Finally, predicted shear was subtracted from modeled shear to find the excess transport capacity shown in Equation H-5. Table H-3 lists the energy grade slope, modeled shear stress, predicted shear stress, and excess transport capacity for each project area.

Equation H-4

$$\tau_p = 10.86\, {S_{EG}}^{0.488}$$

where:

τ_p	=	predicted shear stress
S_{EG}	=	slope of the energy grade line

Equation H-5

$$\mathrm{ETC} = \tau_m - \tau_p$$

where:

ETC	=	excess transport capacity
τ_m	=	modeled shear stress
τ_p	=	predicted shear stress

References

USACE, 2016. *HEC-RAS River Analysis System Hydraulic Reference Manual*. Version 5.0. CPD-69. February 2016. Available at: https://www.hec.usace.army.mil/software/hec-ras/documentation/HEC-RAS%205.0%20Reference%20Manual.pdf.

Wilcock, P.R., 2001. Toward a practical method for estimating sediment-transport rates in gravel-bed rivers. *Earth Surface Processes and Landforms* 26(13): 1395-1408.

Tables

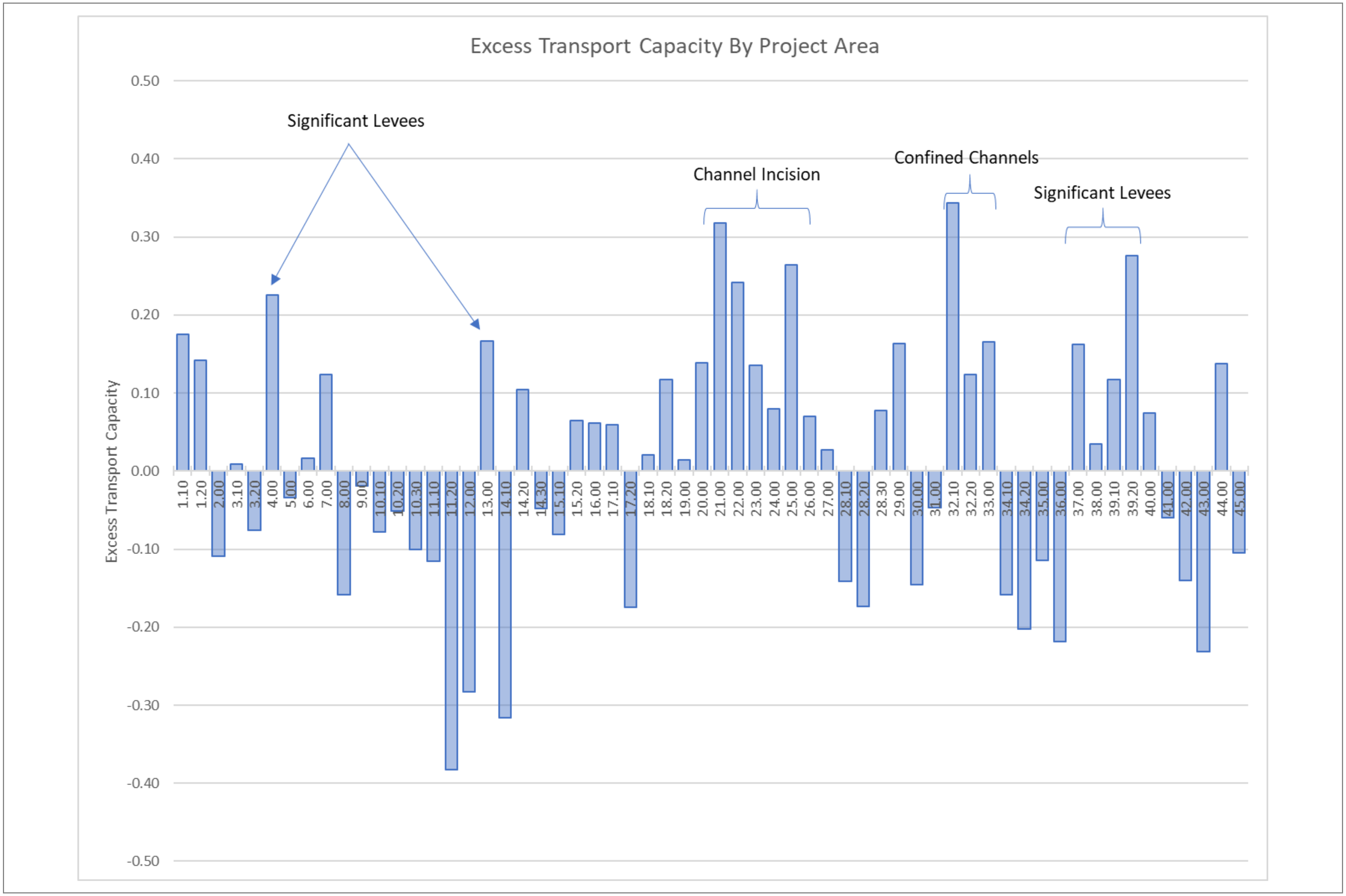
Table H-3
Excess Transport Capacity Analysis Results

Project Area	River Length (mile)	Cross-Sectional Reach Count	Average EGL Slope	Modeled Shear Stress (lb/ft s)	Predicted Shear Stress	Excess Transport Capacity
1.10	0.55	15.00	0.0148	1.56	1.387	0.176
1.20	0.39	11.00	0.0145	1.51	1.371	0.142
2.00	0.64	19.00	0.0143	1.25	1.362	-0.109
3.10	0.37	12.00	0.0160	1.45	1.437	0.009
3.20	1.44	26.00	0.0142	1.28	1.359	-0.075
4.00	0.24	4.00	0.0131	1.53	1.307	0.226
5.00	0.45	7.00	0.0142	1.33	1.359	-0.034
6.00	0.74	13.00	0.0146	1.39	1.376	0.016
7.00	0.45	5.00	0.0146	1.50	1.376	0.124
8.00	0.45	9.00	0.0136	1.17	1.331	-0.159
9.00	0.40	6.00	0.0137	1.32	1.337	-0.019
10.10	0.47	7.00	0.0148	1.31	1.388	-0.078
10.20	0.72	12.00	0.0121	1.21	1.261	-0.051
10.30	0.41	13.00	0.0156	1.32	1.420	-0.101
11.10	0.75	13.00	0.0131	1.19	1.306	-0.115
11.20	0.96	15.00	0.0119	0.87	1.250	-0.382
12.00	0.65	10.00	0.0146	1.09	1.375	-0.283
13.00	0.77	13.00	0.0128	1.46	1.294	0.166
14.10	0.61	10.00	0.0123	0.95	1.270	-0.316
14.20	0.82	11.00	0.0110	1.30	1.200	0.104
14.30	0.72	11.00	0.0109	1.15	1.195	-0.048
15.10	0.38	7.00	0.0129	1.22	1.296	-0.081
15.20	0.42	5.00	0.0115	1.29	1.228	0.065
16.00	1.39	15.00	0.0110	1.26	1.201	0.062
17.10	0.34	4.00	0.0103	1.23	1.167	0.059
17.20	0.31	6.00	0.0103	0.99	1.166	-0.174
18.10	1.08	15.00	0.0113	1.24	1.217	0.021
18.20	0.78	10.00	0.0102	1.28	1.162	0.117
19.00	0.56	9.00	0.0106	1.20	1.182	0.015
20.00	0.44	6.00	0.0118	1.38	1.244	0.139
21.00	1.05	13.00	0.0102	1.48	1.159	0.317
22.00	1.08	15.00	0.0096	1.37	1.125	0.241
23.00	1.05	11.00	0.0093	1.25	1.112	0.136
24.00	0.76	10.00	0.0095	1.20	1.123	0.080
25.00	0.54	6.00	0.0096	1.39	1.127	0.265
26.00	2.99	43.00	0.0094	1.19	1.116	0.070
27.00	1.05	13.00	0.0080	1.06	1.030	0.027
28.10	0.87	12.00	0.0087	0.93	1.076	-0.141
28.20	1.17	16.00	0.0079	0.85	1.025	-0.173
28.30	1.16	15.00	0.0085	1.14	1.065	0.077
29.00	1.12	15.00	0.0076	1.17	1.005	0.164
30.00	1.01	12.00	0.0078	0.88	1.021	-0.145
31.00	1.49	18.00	0.0074	0.95	0.993	-0.047
32.10	0.79	8.00	0.0067	1.29	0.949	0.343

Table H-3
Excess Transport Capacity Analysis Results

Project Area	River Length (mile)	Cross-Sectional Reach Count	Average EGL Slope	Modeled Shear Stress (lb/ft s)	Predicted Shear Stress	Excess Transport Capacity
32.20	0.69	8.00	0.0080	1.16	1.031	0.124
33.00	1.22	14.00	0.0066	1.11	0.940	0.166
34.10	1.14	13.00	0.0061	0.74	0.904	-0.159
34.20	0.78	10.00	0.0062	0.71	0.916	-0.202
35.00	0.66	12.00	0.0051	0.72	0.830	-0.114
36.00	1.73	22.00	0.0058	0.66	0.882	-0.218
37.00	1.10	14.00	0.0051	0.99	0.831	0.163
38.00	2.97	32.00	0.0052	0.87	0.838	0.034
39.10	0.10	1.00	0.0050	0.95	0.827	0.118
39.20	0.63	4.00	0.0055	1.14	0.862	0.276
40.00	0.28	6.00	0.0076	1.21	1.006	0.074
41.00	0.35	4.00	0.0067	0.89	0.951	-0.060
42.00	0.33	4.00	0.0050	0.68	0.824	-0.140
43.00	0.43	4.00	0.0050	0.60	0.827	-0.231
44.00	0.43	4.00	0.0049	0.96	0.819	0.138
45.00	0.52	6.00	0.0035	0.59	0.697	-0.105

Figures



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Appendix I
Webmap Overview

Appendix I
Webmap Overview

The Webmap produced as part of this assessment contains all the vital GIS information to accompany the reports. During the plan's development, the Webmap was hosted by Anchor QEA and this appendix describes the functionality of that Webmap format. It is the intention that the Webmap will be available publicly after the final report development and can be found at the Snake River Salmon Recovery Board website: https://snakeriverboard.org/reports/tucannon-river-documents/

Layer Overview

Each project area cut sheet refers extensively to the data displayed on the GIS layers provided as part of this assessment. In general, the GIS layers display all the data used to determine the analysis results and prioritization metrics. Table I-1 provides an inventory of the GIS layer, its significance to the project area evaluations, and whether the data on the layer are used for prioritization. Some layers, such as valley miles and valley centerline, are not directly used for prioritization but play an integral part in the calculations of other metrics. It should be noted that layers that are self-explanatory, such as the 2017 aerial imagery and 2017 river miles, are not listed below but are provided as part of the GIS layer package for this assessment.

Table I-1
Inventory of GIS Data used in Project Area Cut Sheets

GIS Layer	Description of Layer	Contributes to Prioritization?
Pools > Pools	These areas were the final areas counted towards the pool frequency analysis.	No
Pools > Depth Range	These areas show whether the pool classification was generated based on void data or meeting the depth threshold.	No
Islands > 1-year Islands and Water Surface	These layers show the islands that drive the 1-year complexity and the water inundation shape they are derived from.	Yes
Islands > Mean-Winter Flow Islands and Water Surface	These layers show the islands that drive the mean-winter flow complexity and the water inundation shape they are derived from.	Yes
Islands > Low-Winter Flow Islands and Water Surface	These layers show the islands that drive the low-winter flow complexity and the water inundation shape they are derived from.	Yes
Floodplain Connectivity > Unobtainable 2-year and 5-year	The unobtainable floodplain layer shows areas that would have been available or disconnected, but were deemed "unobtainable," mostly due to the presence of pivot irrigation infrastructure.	Not Directly
Floodplain Connectivity > Available at 2-year	This area minus the disconnected at 2-year represents the floodplain currently connect at the 2-year event.	Yes

GIS Layer	Description of Layer	Contributes to Prioritization?
Floodplain Connectivity >Available at 5-year	This layer shows all areas connected or disconnected at the 5-year event. It represents the total potential for the floodplain. All of the analysis results are shown as a percentage of this area. This area minus the available at 2-year and both disconnected areas represents the Channel Aggradation Potential analysis result.	Yes
Floodplain Connectivity >Disconnected at 2-year	This layer shows the areas that contribute to the Encroachment Removal Floodplain Potential analysis result.	Yes
Floodplain Connectivity > Disconnected at 5-year	The area in this layer, minus the disconnected at 2-year, represents the portion of the Total Floodplain Potential that is in addition to the Channel Aggradation Potential and Encroachment Removal Potential.	Yes
Change Analysis > Channel Trace Comparison	This layer shows the channel trace from the previous assessment based on the 2011 aerial imagery, as well as the channel trace from the 2017 aerial imagery. Areas where these overlap are hatched so channel avulsions and migrations are easy to see. It should be noted that the 2017 aerial imagery was flow at a higher flow event than the 2011 aerial imagery and accounts for some of the non-overlapping channels.	No
Change Analysis > Topographic Difference	This layer shows the areas of positive or negative differences in the 2017 and 2010 LiDAR data sets.	No
Change Analysis > Narrative Highlights	This layer puts boxes around areas of geomorphic change seen with the Topographic difference and highlighted for discussion in the Geomorphic Change Analysis narrative for each project area.	No
Relative Elevation > All	These layers show the elevation of the floodplain relative to the nearest point on the river thalweg.	No
Prior Phase>All	These layers were produced as part of the 2011 Tucannon Geomorphic Assessment and Conceptual restoration plan. Includes levees and low-lying floodplain area.	No
Aerial Imagery>All	Aerial imagery from 2017 and 2010.	No
Conceptual Restoration Opportunities>All	Conceptual Restoration opportunities as discussed in the Project Area Cuts sheets (Appendix J).	No
Other Flood Events	Inundation extents from the 1D HEC-RAS model for the 10-year, 25-year, 50-year, and 100-year events. The 1D hydraulic model was intended for the habitat assessment at the 2- and 5-year events and was not calibrated specifically for the 10+ year events. The higher flow event results from this hydraulic model are provided for reference only.	No

Notes:
Other GIS layers are provided as part of this assessment but are either self-explanatory or do not affect either the evaluation or prioritization.

Functionality

Once logged into the Webmap there are several functions available for viewing the data. Figure I-1 shows the four main areas where functionality is available:

- Box A: Zoom in and out with the +/- buttons. This can also be done with the mouse scroll wheel. The Home button will bring you to the extents of the Tucannon assessment area. The location button will zoom to your current location if using mobile.
- Box B: The first button provides a legend showing the symbology for all currently active data. The second button brings up the list of available data layers to add to the Webmap. Figure I-2 shows more details on available layers.
- Box C: The first button gives a variety of base maps that will be displayed under the selected data. The second button provides bookmarks to zoom to project areas. The third button brings up a measurement tool for length, path, or area. Finally, the last button is used for editing the Webmap and has been temporarily disabled.
- Box D: This box brings up a panel that provides in-depth information on the layers currently active on the screen. Figure I-3 shows more details on this functionality.

When the layer button in the top right of the screen is selected, as shown in Figure I-2, all the layer groups available will be displayed. By checking or unchecking the box next to the layer group, all layers in that group can be turned on or off. By selecting the arrow next to the layer group, the list of layers in that group is displayed, and individual layers can be turned on or off by checking the box next to the layer. Selecting the arrow next to any layer will show the symbology used for that layer on the Webmap. Table I-1 describes all of the layers available.

Using the arrow at the bottom of the screen (box D in Figure I-1), more detailed data about the layers currently on the screen can be found. Figure I-3 shows the detailed data for the "Reach Groups" layer. This will only show information for the layers on the screen, so in Figure I-3 only project areas 38 to 43 are shown. Using the "zoom to" button and selecting a data layer will bring that data layer to the center of the Webmap.

Figure I-1
Webmap Functionality Options

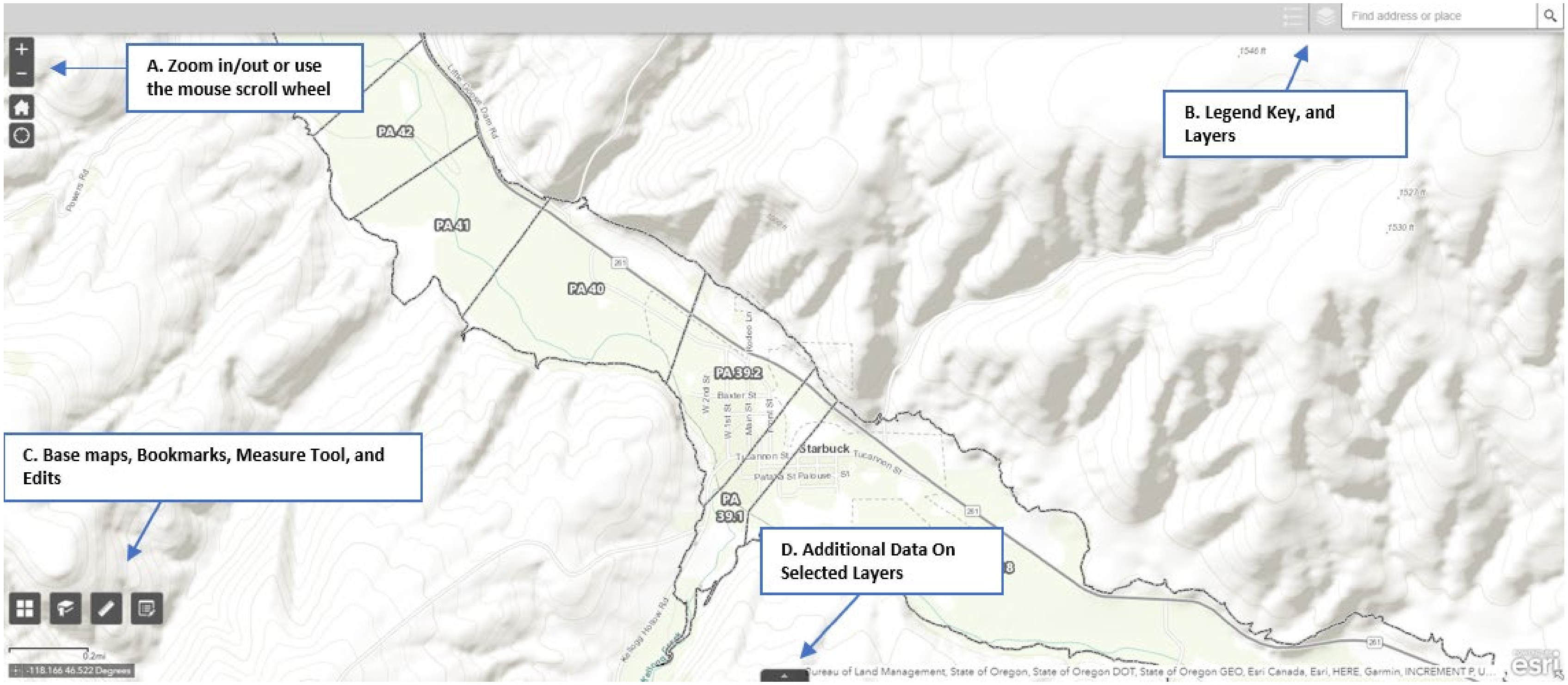


Figure I-2
Webmap Layer Options

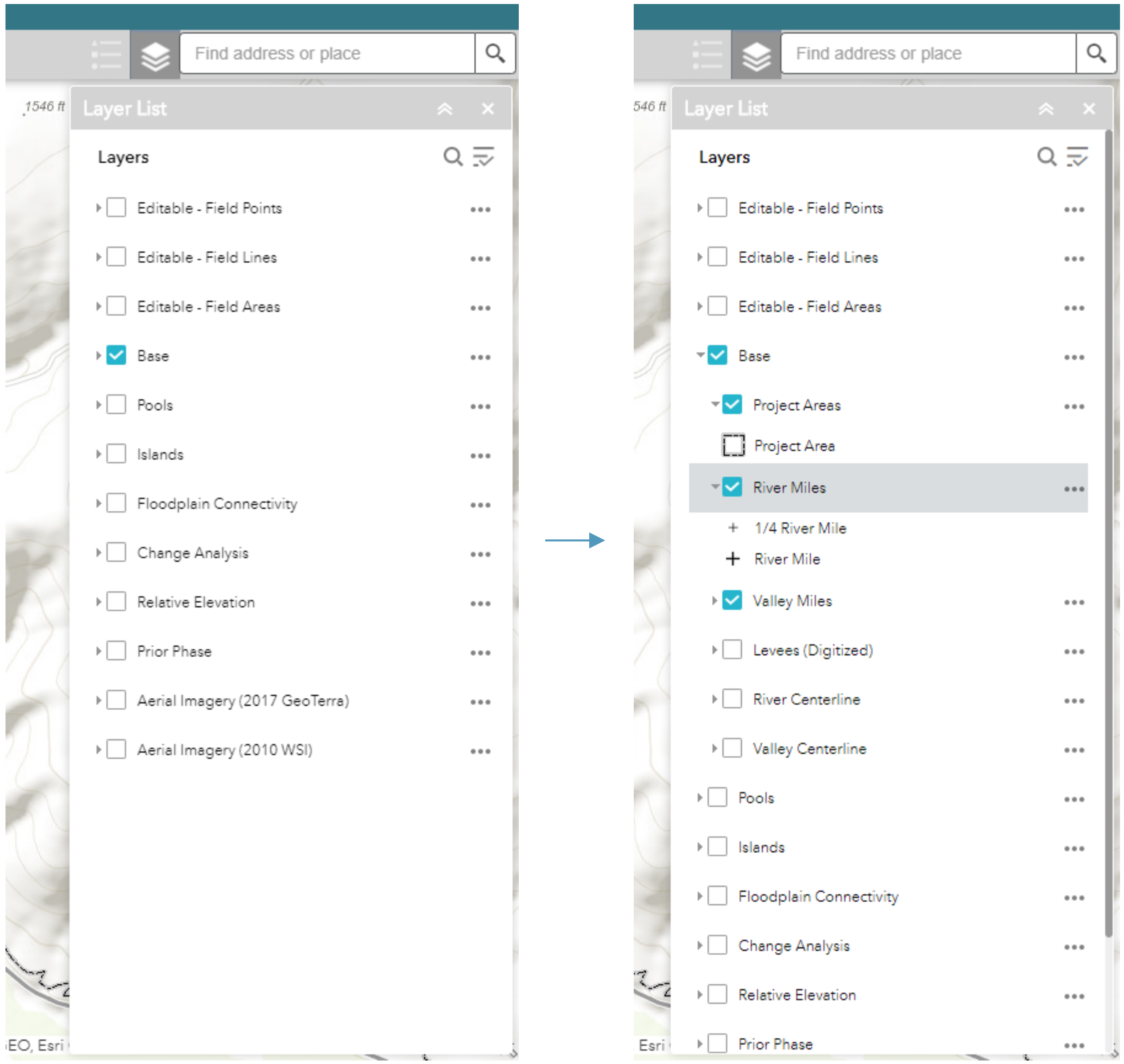
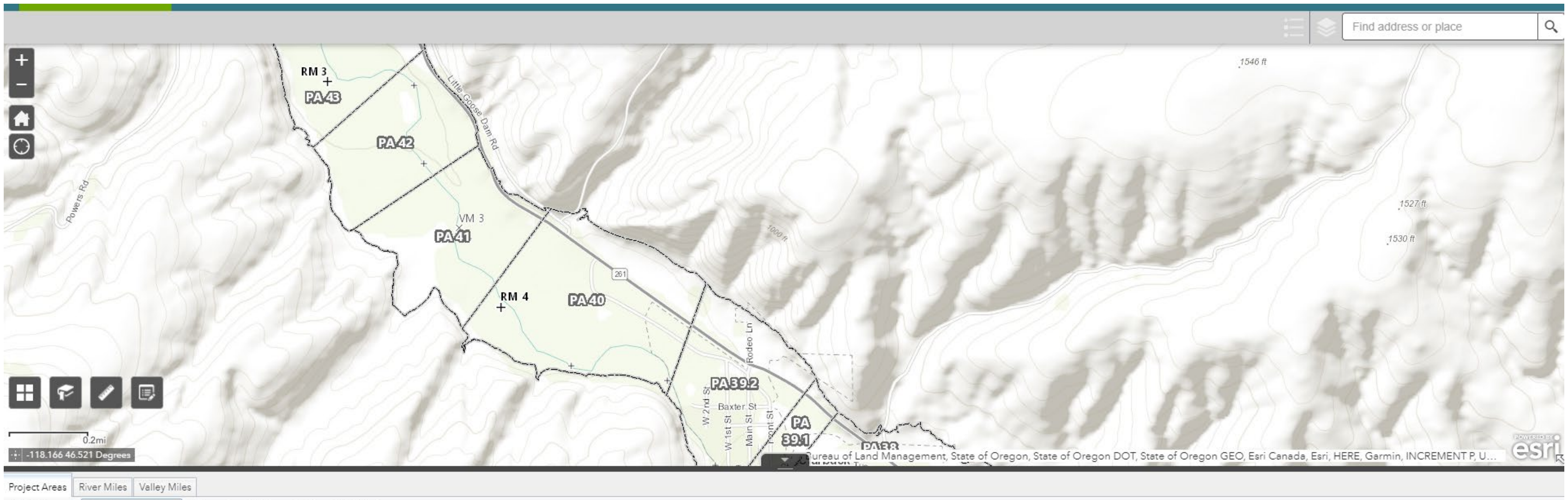


Figure I-3
Webmap Detailed Layer Data



OBJECTID	Shape	Id	gridcode	Project_Area	DDP_SORT	DDP_TITLE	DDP_TITLE2	DDP_TITLE3	DDP_NAME	DDP_NUM	DDP_ALPHA	DDP_SCALE	DDP_ANGLE	Use	Shape_Length	Shape_Area
173		128	1	38.00	38	Project Area 38			Project Area						42,281.06	19,951,040.29
182		128	1	41.00	41	Project Area 41			Project Area				55		8,412.46	3,052,582.14
183		128	1	42.00	42	Project Area 42			Project Area				55		6,970.99	2,713,838.94
184		128	1	43.00	43	Project Area 43			Project Area				44		6,908.87	2,635,467.16
185		128	1	44.00	44	Project Area 44			Project Area				43		7,379.30	2,610,192.27
186		128	1	39.20	39	Project Area 39			Project Area						7,918.08	3,114,976.64

8 features 0 selected

Appendix J
Project Area Cut Sheets

Appendix J
Project Area Cut Sheets

The restoration opportunities identified in these cut sheets represent the most effective restoration actions, based on current scientific data, to restore the geomorphic and ecological processes to the Tucannon River and floodplain to the highest extent possible. There are other interests and needs in the basin that represent constraints on the opportunities identified, but documents, such as the Wooten Wildlife Floodplain Management Plan (WDFW 2014), exist to express additional goals and interests. Therefore, this assessment does not make a specific attempt to identify those outside interests or the constraints they may have on restoration actions. Any restoration project that is pursued further will need to consider the constraints of individual interests in the basin and factor them in through collaboration and discussion with stakeholders. When projects move from the conceptual ideas of this assessment to project implementation in the future, the general public, in addition to those stakeholders and landowners directly involved, can also participate in the decision-making discussions. Interested parties should contact the Conservation District or one of the other restoration partners.

Individual evaluation cut sheets for each project area are separated into treated and untreated categories, which are further categorized into three tiers for prioritization, and listed from upstream to downstream within each tier. Appendix J.1 contains all the treated project areas and Appendix J.2 contains all the untreated project areas. Table J-1 provides the project area, river mile, and valley mile of several well-known landmarks throughout the valley for reference. Each of the categories and tiers provides slightly different information, but all follow the same general format. The first section of each cut sheet provides a general description of the project area and field observations noted during the Anchor QEA field staff site visit for those sites that were walked for this assessment. If the site was not visited as part of this assessment, the description was drawn from the 2011 assessment and modified to fit the updated project area boundaries. Photographs follow the same guideline with an updated photograph if the site was walked in 2018 and a photograph drawn from the 2011 assessment if the site was not visited as part of this assessment.

Table J-1
Reference Landmarks

Landmark	Project Area	River Mile	Valley Mile
Powers Road Bridge	45/44	2.0	2.5
Kellogg Hollow Bridge	39.2	4.9	4.0
Smith Hollow Bridge	37	8.3	7.2
Pataha Creek	34.1	12.5	10.8
Highway 12 Bridge	32.2/33	14.6	12.8
Enrich Road	29/30	18.6	16.4
King Grade	27/28.1	23	20.2
Turner Road (Marengo)	25/26	27	23.9
Hartstock Grade	18.1	33.7	29.9
Tumalum Creek	16	35.75	31.7
Spring Lake	14.3	37.8	33.5
Tucannon Hatchery	13/14.1	39.3	34.8
Beaver-Watson Lakes	11.1	42.2	37.3
Curl Lake	8	44.8	39.7
Camp Wooten Entrance	5/6	46.1	40.8
Little Tucannon Confluence	3.1/3.2	48.2	42.7

The second section provides the geomorphic change evaluation, which is based on the analysis of the difference between the 2010 and 2017 LiDAR data sets, highlighting locations of material aggradation and erosion. As discussed in further detail in Appendix D, the 2010 LiDAR does not register bathymetry and instead shows the water surface elevation as the channel bottom, which may cause some over or under-estimation of aggradation and erosion. Geomorphic change trends are discussed in general in the Appendix D, and these trends are identified in the geomorphic change evaluation for each project area cut sheet. These narratives refer often to the GIS layers in the "Change Analysis" layer group and locations are highlighted for discussion in the "Narrative Highlights" layer. For the treated project areas, this section also includes a brief description of the restoration project performed on the reach, and further evaluates whether the geomorphic changes seen in the project area are the result of those restoration actions.

The final section included on the cut sheets provides a discussion of the individual geomorphic analysis results, the resulting prioritization metrics, and an interpretation of what these metrics indicate about the geomorphic processes occurring in the project area. Based on these interpretations, as well as the GIS data, restoration strategies and basic methods for implementing them are recommended. These restoration strategies are described in Section 7 of this report.

Several graphics aid in the interpretation and display of the geomorphic analysis results and metrics, as well as how the final tiers were decided for each project area.

Figure J-1 shows an example of the Analysis Results Summary figure provided for each project area. The information in this figure is referenced within the narrative and provides an easy way to view all the analysis results that play into the prioritization metrics, as well as Total Floodplain Potential, Existing Floodplain Potential, and Pool Frequency. Complexity analysis results are all located in the upper left of the figure and Floodplain Connectivity metrics are all located at the bottom of the figure. It should be noted that this figure displays the project area's rank among all the other project areas for each analysis result, and not the actual value of the analysis result. As such, the lower the ranking for an individual analysis result, the closer the line will be to the center of the chart, which is the 60th and last ranked project area. The higher the ranking for an individual analysis result, the closer the line will be to the outside of the chart. For example, if the pool frequency value is at the 10 line, this indicates that the project area ranks 10th among project areas for pool frequency and not that the project area has 10 pools per valley mile. Additionally, the median rank is highlighted on the chart; a rank outside of this line indicates that the project area is better than the median in that analysis result, and a rank inside of this line indicates that the project area is worse than the median in that analysis result.

Figure J-1
Example of Analysis Results Summary Figure for Project Area 1.1

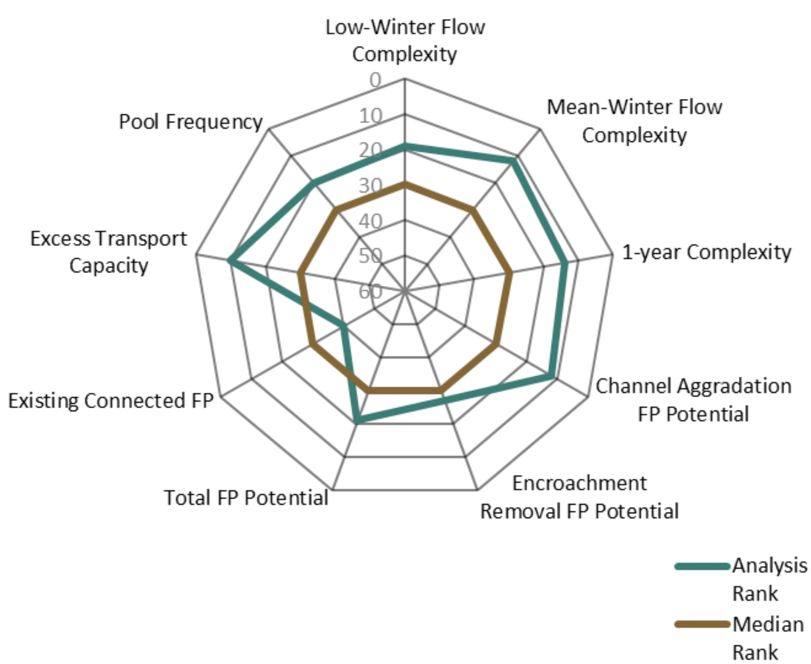
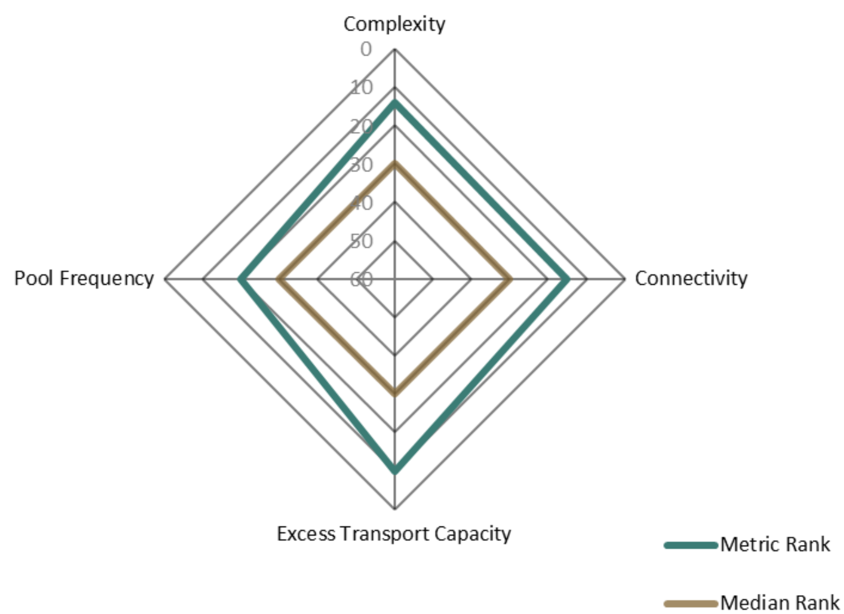


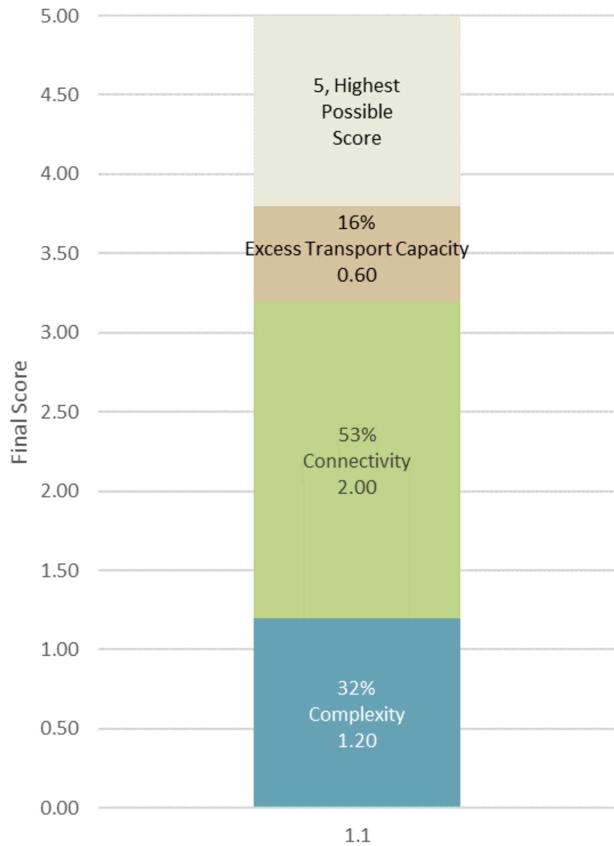
Figure J-2 shows an example of the Prioritization Scoring Summary figure provided for each project area. This figure shows the relative rank of the project area in the prioritization metrics as they have been calculated from the analysis results using the method described in Section 11.1 In addition to the three prioritization metrics, this figure includes pool frequency because it is uniquely integral to the goals and objectives for the basin. Just as in the Analysis Results Summary figure, the median rank is highlighted to show whether a project performs above or below the median for a given metric.

Figure J-2
Example of Prioritization Scoring Summary Figure for Project Area 1.1



Finally, Figure J-3 shows an example of the Score Breakdown figure provided for each project area. This figure shows how each of the three prioritization metrics is contributing to the project area's final score, with 5 being the highest score. The percentages listed described how much of an influence an individual metric has on the total score for the project area. The number listed is the score of the project area, weighted by the metric weighting coefficients described in Section 11.1 (40% for Complexity and Connectivity, 20% for Excess Transport Capacity). This chart can be used to quickly identify which prioritization metrics play the largest role in prioritizing restoration on a project area.

Figure J-3
Example of Score Breakdown Figure for Project Area 1.1



Reference

WDFW (Washington Department of Fish and Wildlife), 2014. *W.T. Wooten Floodplain Management Plan*. Authored by the Wooten Floodplain Management Plan Team. November 8, 2012; Update December 2014.

LIST OF PROJECT AREAS

Tier 1

Tier 2

Tier 3

ABBREVIATIONS

ac/VM	acres per valley mile
AEM	airborne electromagnetics
cfs	cubic feet per second
CHaMP	Columbia Habitat Monitoring Program
FP	floodplain
GIS	Geographical Information Systems
LiDAR	Light Detection and Ranging
LWD	large woody debris
mi	mile
NF	National Forest (road)
PA	Project Area
RM	river mile
USFS	U.S. Forest Service
VM	valley mile
WDFW	Washington Department of Fish and Wildlife

APPENDIX J.1
TIER 1: TREATED PROJECT AREAS

Project Area 1.1 Description

Project Area 1.1 begins at VM 44.02 and extends upstream to the bridge crossing at Tucannon Road at VM 44.52. The 2017 RM length is 0.55 mile. Field observations for PA 1.1 were conducted on September 27, 2018, when flow at the Starbuck gage was approximately 82 cfs.

For this assessment update, PA 1 as defined in the 2011 prioritization was separated into two project areas (PA 1.1 and PA 1.2) for distinct analysis. In 2014, PA 1.1 was the subject of a restoration project, while PA 1.2 has remained untreated.

PA 1.1 is characterized by several long side channels with flow even at some of the lowest flows during the year. At the upstream end of the project area, and just downstream of the bridge, a side channel into the right bank floodplain runs for approximately 650 feet. At the time of the site visit, the side channel had relatively low flow but a high amount of gravel material allowed instream wood to form multiple pools. In the main channel opposite this first channel, flow was relatively uniform. It was noted that this reach could use more instream wood to promote some in-channel complexity, although several structures were noted to be just disengaged at this low-flow level.

At approximately VM 44.41, there is a large side channel opportunity that is disconnected at the upstream end on the left bank floodplain. At VM 44.34, a side channel splits off into

Project Area 1.1
Engineered log jam with large wood recruits at the upstream end of PA 1.

Project Area 1.1 Reach Characteristics

VM Start (mi)	44.02
VM Length (mi)	0.50
Valley Slope	1.69%
RM Start (mi)	49.63
RM Length (mi)	0.55
Average Channel Slope	1.52%
Sinuosity	1.10
Connected FP (ac/VM)	11.01
Encroachment Removal (ac/VM)	1.20
Channel Aggradation (ac/VM)	4.60
Total FP Potential (ac/VM)	7.43
Encroaching Feature Length (ft)	213.18
Connected FP Rank	41

the right bank floodplain where it runs through young alders and ponderosa and may possibly drown them in the near future. This flow continues right along the road embankment on the right bank, which has been stabilized with large log poles. This side channel runs for approximately a quarter of a mile through well-established riparian vegetation. In the main channel in this section, a large channel-spanning log jam has created a backwater effect that is likely contributing to the amount of water in the right bank side channel. This reach of the mainstem has better instream wood than the upstream portion of this project area but could still benefit from more as it runs along the left bank valley wall.

At the downstream end of the project area, just past where the side channel rejoins the main channel, an old weir is providing grade control to the reach and a very large log jam on the right bank was mostly disengaged from flow at the time of the site visit. This structure was intended to backwater flow over the weir. Based on the site observations, it should be evaluated whether or not this structure is still functioning as intended.

Vegetation in the immediate riparian area of the channel is relatively good with large ponderosas and even some larger cottonwoods on some of the islands. Younger willows are being established on gravel bars and very few invasive species were noted. However, both of the large islands created by the side channels are very high compared to the water surface and are disconnected from the floodplain. The vegetation on these islands mostly consists of upland species such as ponderosa pines, often without any large woody vegetation at all. Both islands also seem to be composed of fine gravel alluvium that is easily transportable on a regular basis in the Tucannon River.

Restoration Actions and Geomorphic Changes

In 2014, restoration work in PA 1.1 included placing 38 log jams using 231 key logs within the channel and side channels, as well as excavating two side channel pilot cuts to activate about 0.3 mile of side channel habitat and reducing a WDFW campsite located on river right floodplain from 3.3 acres to 1.2 acres. Restoration in this project area had the objective of floodplain connectivity and channel complexity, including increasing perennial side channels and increasing pool frequency. A detailed as-built map of the project in pre/post conditions can be viewed in the Webmap.

Analysis of the difference between the 2010 and 2017 LiDAR data shows very little geomorphic change in PA 1.1, with five minor areas highlighted in this assessment. At the upstream end of the project area, a log jam on the left bank shows up as aggradation, and the pilot channel shows up as erosion in the right bank side channel (box 1). Where the side channel returns to the main channel, there is some minor erosion on the left bank and aggradation on the right bank that may result from a downstream log jam (box 2).

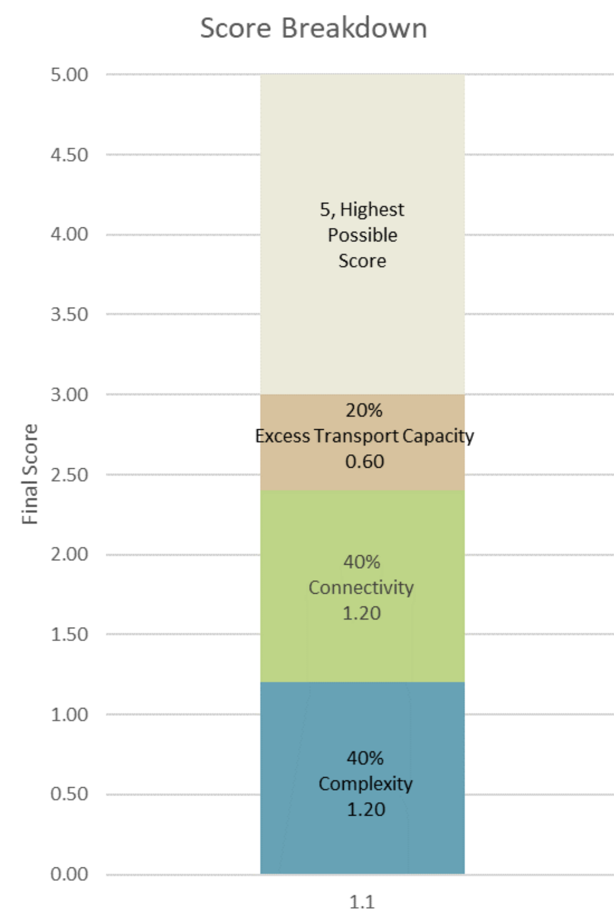
Where the second side channel splits off from the main channel, the log jam and pilot channel are again evident with some minor aggradation on the right bank (box 3). Further down on the main channel, a large bank barb shows a small scour pool off the front (box 4). Finally, a log jam in the downstream side channel has caused some erosion on the right bank (box 5).

Overall, this reach has experienced almost no geomorphic change compared to other treated reaches in this assessment. This is at least partially to be expected because this project area is the furthest upstream in the watershed, where the valley width is generally smaller and sediment sizes are generally larger and less easily transported. However, with large structures like those installed in this project area, more geomorphic change would be expected and more transportable material may be necessary to precipitate this change. A small pilot channel was cut as part of the restoration efforts in this project area, but it was likely too small to register on the LiDAR.

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 1.1 received the highest score possible in the Connectivity metric and moderate scores for both Complexity and Excess Transport Capacity metrics. PA 1.1 falls in the 60th to 90th percentile for complexity, a range that still shows moderate complexity but does not place it in the top 10% of project areas; this project area may need some additional restoration work to reach that

PA 1.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

mark. The moderate Excess Transport Capacity score indicates that this reach has a higher transport capacity than would be expected for a reach with this average slope.

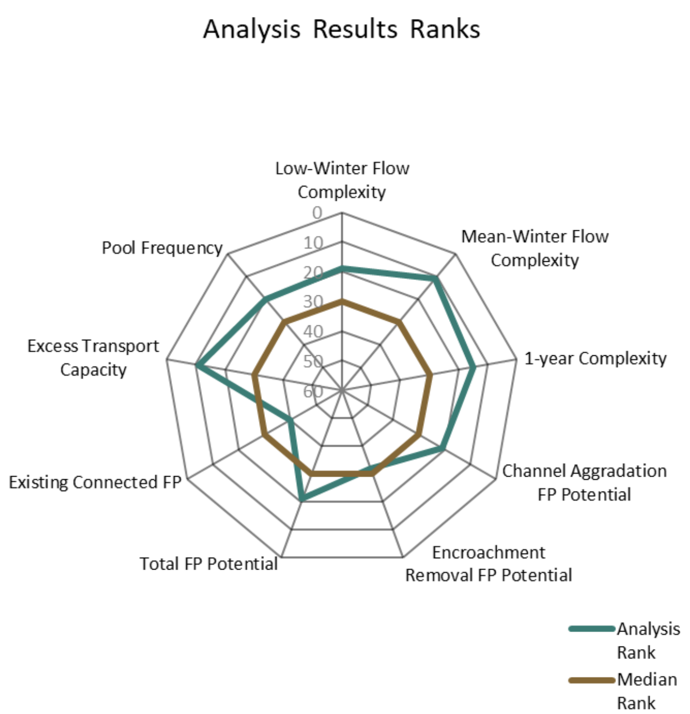
Side channel connection in PA 1.1 has been achieved moderately well; both side channels that were targeted in the restoration work were flowing during field observations. However, the main channel lacks significant mid-channel bars or split flow and is generally plane-bed with little instream complexity. There are also several additional side channel opportunities, visible on the relative elevation map, which have not been connected during low-winter, mean-winter, or 1-year flows. The primary enhancement strategy for this reach should be to develop instream structure through wood placement. The relative lack of geomorphic change in this reach is likely due in part to the lack of easily transportable gravel and cobble material in this reach. Augmenting the enhancement strategy of wood placement with gravel augmentation could help to develop instream complexity and habitat features on a more advanced timetable. It should be noted that PA 1.1 appears to have excess transport capacity relative to its average slope, and any gravel augmentation in this reach will be significantly more effective after more instream structure has been added to the channel. Field observations also noted that many of the abandoned floodplain terraces, particularly on the island formed by the side channels, appeared to be composed of the easily transportable material that would be ideal for gravel augmentation. A combined effort of floodplain benching and gravel augmentation may be an efficient use of resources in this area.

Much of the connectivity potential in this reach appears to be in the areas surrounding the existing 2-year floodplain, which could be activated through gravel augmentation and hopefully channel aggradation. The rest of the floodplain connectivity potential area is located in and around side channel opportunities, and reconnecting these side channels through pilot cuts and adding wood structure should be a secondary enhancement strategy for this reach. It is important to note that the downstream side channel, which was flowing during low-flow field observations, appears to be disconnected at the 2-year event. This side channel was initiated by an upstream structure and pilot channel. With consistent flows, and as long as the side channel forcing log jam does not wash out, enough geomorphic change in this channel should occur over time to lower it below the 2-year event elevation.

Summary of Restoration Opportunities Identified

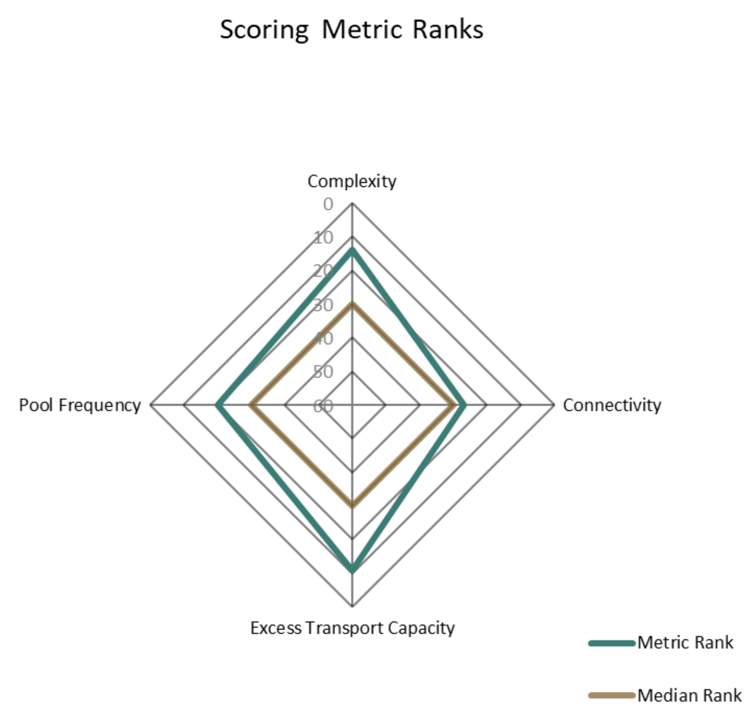
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure and wood loading (LWD)

PA 1.1 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

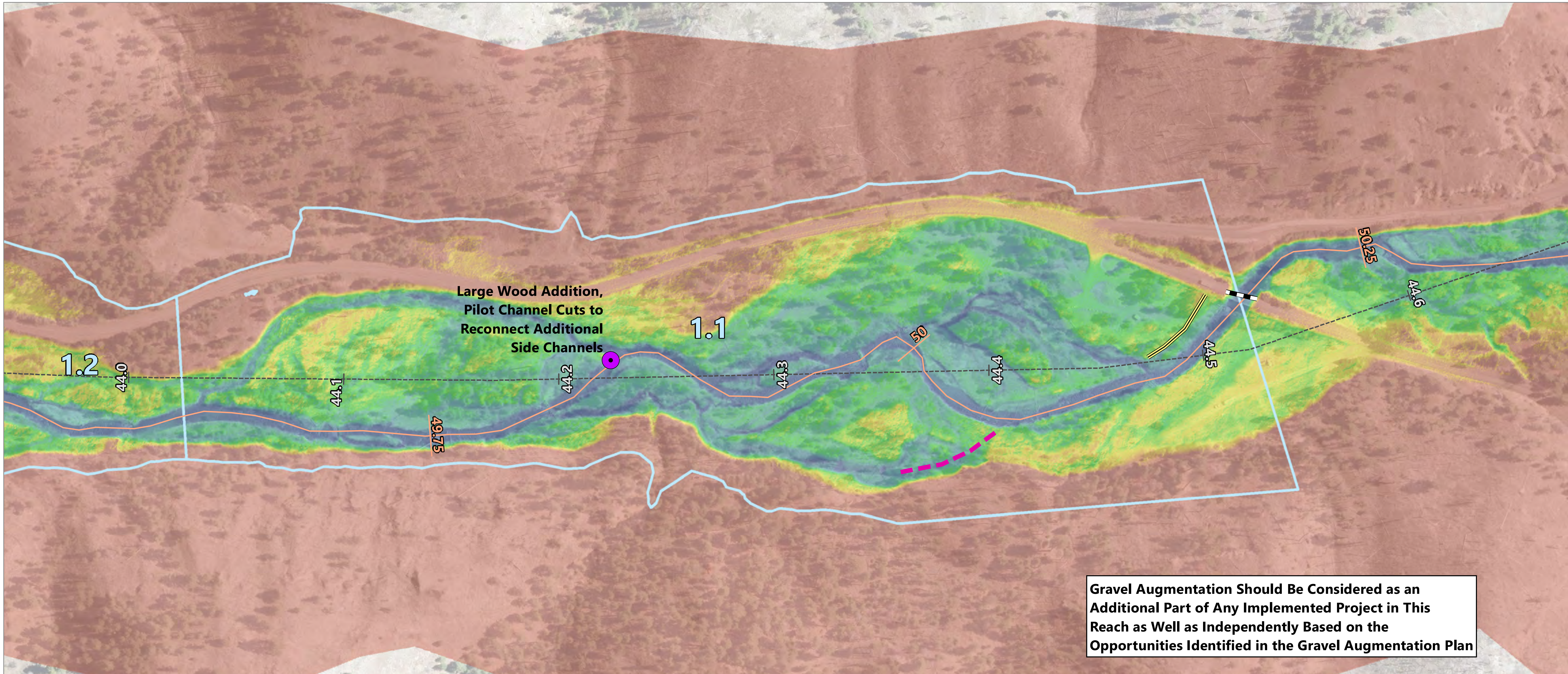
PA 1.1 Prioritization Scoring Summary

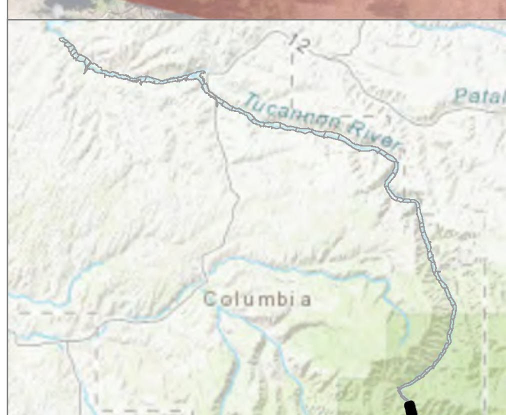


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 1.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.241	19	40%	**Complexity**	0.364	14	10% to 40%	2 of 5	3	40%	3.0	13	1	Treated	4	1
Mean-Winter Flow Complexity	0.423	11	40%													
1-year Complexity	0.491	15	20%													
Channel Aggradation FP Potential	0.249	21	40%	**Connectivity**	0.206	27	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.065	32	40%													
Total FP Potential	0.403	21	20%													
Existing Connected FP	0.597	40	0%													
Excess Transport Capacity	0.16	11	100%	**Excess Transport Capacity**	3.000	11	10% to 30%	2 of 4	3	20%						
Pool Frequency	14.55	20	100%	**Pool Frequency**	0.373	20	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 49.63
RIVER MILE END: 50.18
VALLEY MILE START: 44.02
VALLEY MILE END: 44.52

0 500
Feet

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Filepath: \\orcas\gis\Jobs\TucannonRiver_1006\Maps\Conceptual Maps\Tucannon Treated Project Areas_mg.mxd

ANCHOR QEA

Project Area 1.1
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 3.2 Description

Project Area 3.2 begins at VM 41.44 and extends upstream to VM 42.73. The 2017 RM length is 1.44 miles. Field observations for PA 3.2 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

For this assessment update, PA 3 as defined in the 2011 prioritization was separated into two project areas (PA 3.1 and PA 3.2) for distinct analysis because only PA 3.2 was treated. Since the 2011 assessment, this reach has undergone a restoration project in 2014 with additional wood loading in 2018, based in part on the opportunities identified in the 2011 prioritization. However, restoration actions in this project area were very recent and occurred after the raw data for this report were collected in 2017, and this project description may be out of date.

The channel through PA 3 is characterized as a single-thread channel containing both plane-bed and forced pool-riffle sections. Local steep rapids are present; in these sections, the thalweg is typically deep with high velocities. In the 2011 assessment, one rock weir and multiple rock and rootwad restoration features were identified in the project area. Only a few side channels were observed that appeared to provide minimal habitat benefit.

The availability and quality of instream habitat was limited by lack of complexity and hydraulic conditions that prevented the

Project Area 3.2
Post-project photograph taken May 7, 2019, post high flow. The log jams placed in 2018 captured disconnected floodplain channels.

Project Area 3.2 Reach Characteristics

VM Start (mi)	41.44
VM Length (mi)	1.29
Valley Slope	1.61%
RM Start (mi)	46.79
RM Length (mi)	1.44
Average Channel Slope	1.44%
Sinuosity	1.12
Connected FP (ac/VM)	13.21
Encroachment Removal (ac/VM)	0.30
Channel Aggradation (ac/VM)	4.81
Total FP Potential (ac/VM)	5.07
Encroaching Feature Length (ft)	1,344.17
Connected FP Rank	35

retention of sufficient volumes of LWD and sediment. The spatial distribution of existing LWD was limited. Large log jams and sediment deposits were present but sporadic; the log jams that were observed were typically associated with local areas of high temporary sediment storage, split flow, and side channels. However, the majority of the project area is made up of long, straight, plane-bed stretches that lack any adequate cover or hydraulic complexity.

Throughout a majority of the project area, the channel is moderately entrenched between the bedrock valley wall and remnant alluvial fan and hillslope deposits, resulting in a relatively high floodplain surface. Thus, much of the valley floor is not within the low floodplain.

The 2011 assessment noted that the riparian zone was in a moderately healthy condition, with local areas that had been degraded by infrastructure, fire, and development. Riparian trees were mixed deciduous and conifer, dominated by ponderosa pine, alder, and dogwood.

Restoration Actions and Geomorphic Changes

Restoration in PA 3.2 was conducted in both 2014 and 2018. In 2014, the goal was to return a roughly 1.3-mile reach of the river located within the Washington Department of Fish and Wildlife WT Wooten Wildlife Area property closer to its historical, naturally functioning state, and increase river complexity and floodplain connectivity. The 2014 restoration had the following specific short-term objectives: 1) conduct wood loading within the bankfull channel and on the floodplain to increase channel complexity, channel migration, and floodplain connectivity; 2) add 271 LWD key log pieces to increase reach LWD densities to be greater than two pieces per bankfull width; 3) place LWD in 42 strategic locations to increase channel habitat and river channel complexity; and 4) place two structures with the dual purpose of providing habitat cover and acting as a "catcher's mitt" to help prevent LWD from mobilizing from the project reach.

In 2018, the goal was to return a roughly 1.58-mile reach of the river located within the Washington Department of Fish and Wildlife WT Wooten Wildlife Area property closer to its historical, naturally functioning state, and increase river complexity and floodplain connectivity. The 2018 restoration had the following specific short-term objectives: 1) conduct wood loading within the bankfull channel and on the floodplain to increase channel complexity, channel migration, and floodplain connectivity; 2) place log jams in 58 predetermined locations (using 633 key LWD pieces greater than 6 meters long and 0.3 meter in diameter) to increase channel complexity and habitat cover; and 3) place 10 floodplain structures in currently disconnected flow paths in anticipation of flood flows.

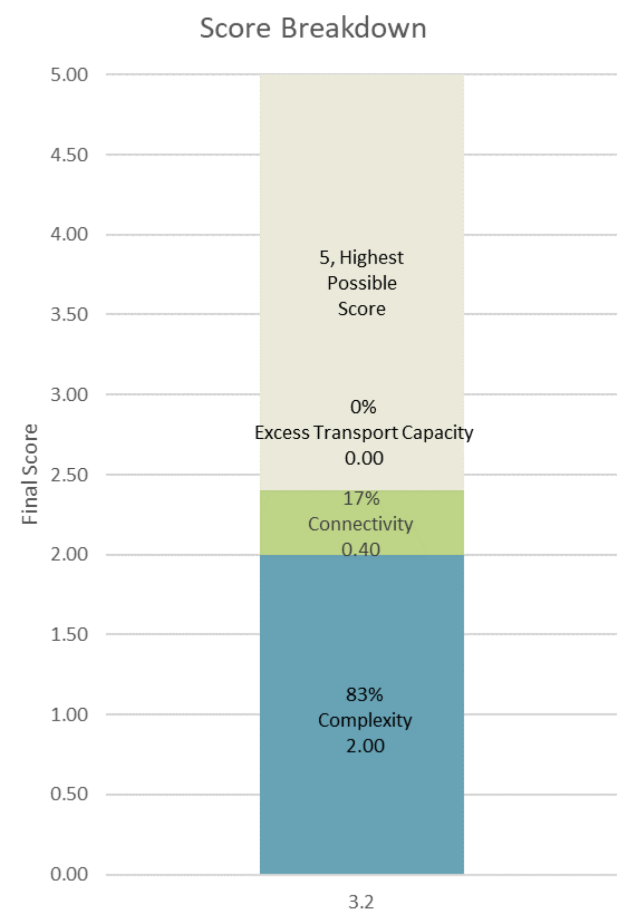
In addition, the 2018 restoration effort had the following specific long-term objectives: 1) strategically place LWD log jams to reconnect floodplain and disconnected side channel and off-channel habitats; 2) connect between 1,175 and 4,460 feet of additional side channel habitat; 3) increase the River Complexity Index value from the 2017 value of 35.09 to potentially 46.16 to 68.91; and 4) capture approximately 12 acres of disconnected floodplain.

Analysis of the difference between the 2010 and 2017 LiDAR data shows relatively minor and localized geomorphic change in PA 3.2; however, any changes resulting from the 2018 restoration efforts will not be reflected in this analysis. All of the highlighted change locations in this project area are relatively similar geomorphic reactions to instream wood. Aggregation and deposition is seen behind the large woody material and some small amount of erosion is seen on the outside of the bed adjacent to the wood. In boxes 3, 5, and 7, there is an associated new split flow with the minor geomorphic change, along with some deposition on the resulting island. These changes are all possibly due to the instream wood restoration efforts in 2014. The fact that changes have been relatively minor could indicate that bedload material in this reach is too large for geomorphic changes to occur after only 4 years.

Geomorphic Characteristics and Management and Enhancement Strategies

The management and enhancement opportunities identified here are based on the 2018 LiDAR and aerial imagery data. However, it should be noted that the restoration actions in this

PA 3.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

reach occurred shortly after the data were collected and geomorphic response may not have occurred yet and is not yet reflected in the prioritization score.

As shown in the following graphs and table, PA 3.2 scores almost all of its points in complexity, ranking near average in the 40th to 60th percentile, which is the range in which reaches have the most potential for improving complexity. A small amount of points were received for floodplain connectivity potential, mostly from the channel aggradation potential portion, and no points were received for excess transport capacity because PA 3.2 falls below the average transport capacity that would be expected for a project area with similar slope, and may be more depositional in nature then surrounding reaches.

Interestingly, the complexity score is driven by pockets of side channels that exist throughout the project area. At the low flow, only a few of these side channels are currently being activated and are mostly being driven by the split flows and minor geomorphic changes promoted by instream wood. Both the mean-winter and 1-year flows show significant increases to complexity as several longer and more significant side channels are activated. The primary restoration strategy for this reach, which was already implemented in 2018 but not reflected by the data in this assessment, is to improve the connection frequency of these mean-winter or 1-year flow side channels so that they flow perennially. This was accomplished by adding instream structure and LWD and cutting pilot channels when possible. This was the described goal and primary actions taken in the 2018 restoration efforts, which are not reflected in these data, so more time should be given to allow those efforts to cause geomorphic change. However, it should be noted this reach shows only very minor geomorphic change from the 2014 restoration actions of adding instream wood. Contributing factors could include that no significant flows were seen between this restoration and 2017 when the data were collected. It may also indicate that this reach is starved of easily transportable material that allows geomorphic changes to occur on a regular basis. If this is the case, gravel augmentation upstream of this project area may be necessary to jumpstart geomorphic processes in this project area.

Finally, the pool frequency in this reach appears to be slightly below average for the basin. More pools are likely to form as a result of the recent restoration actions. However, similar to complexity, should these changes not occur, gravel augmentation will allow for more frequent pool formation around any instream structure.

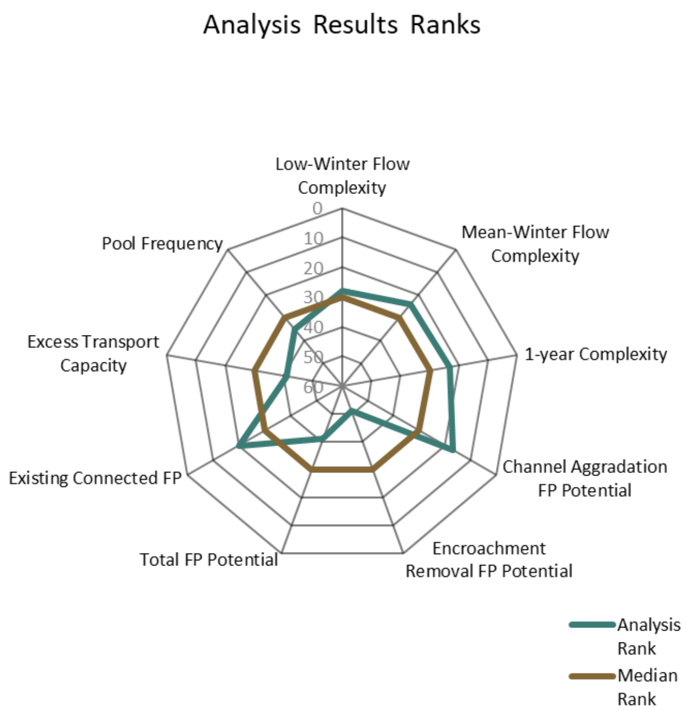
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats

Long-Term Opportunities in this Project Area

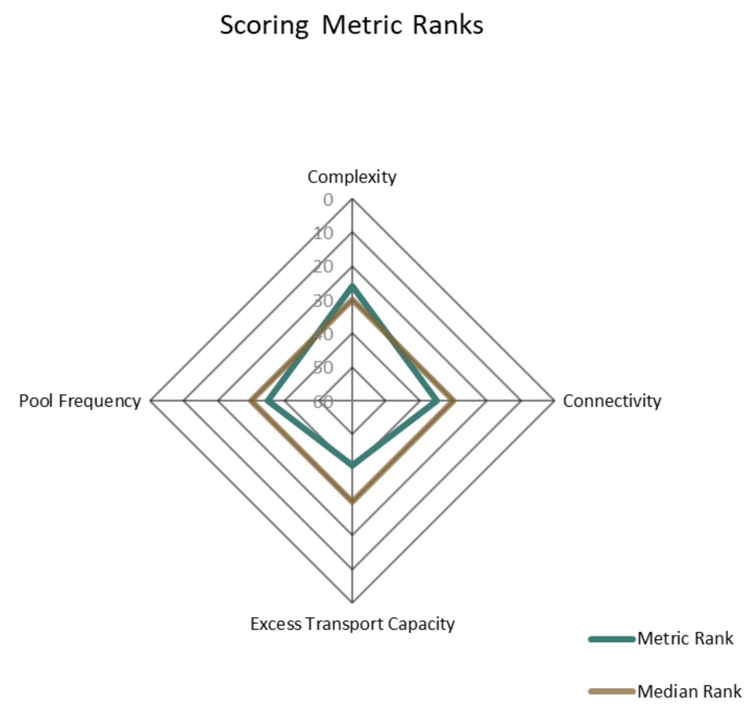
Reconfigure lake at Camp Wooten to reconnect floodplain and consider decommissioning and removing if ever feasible.

PA 3.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

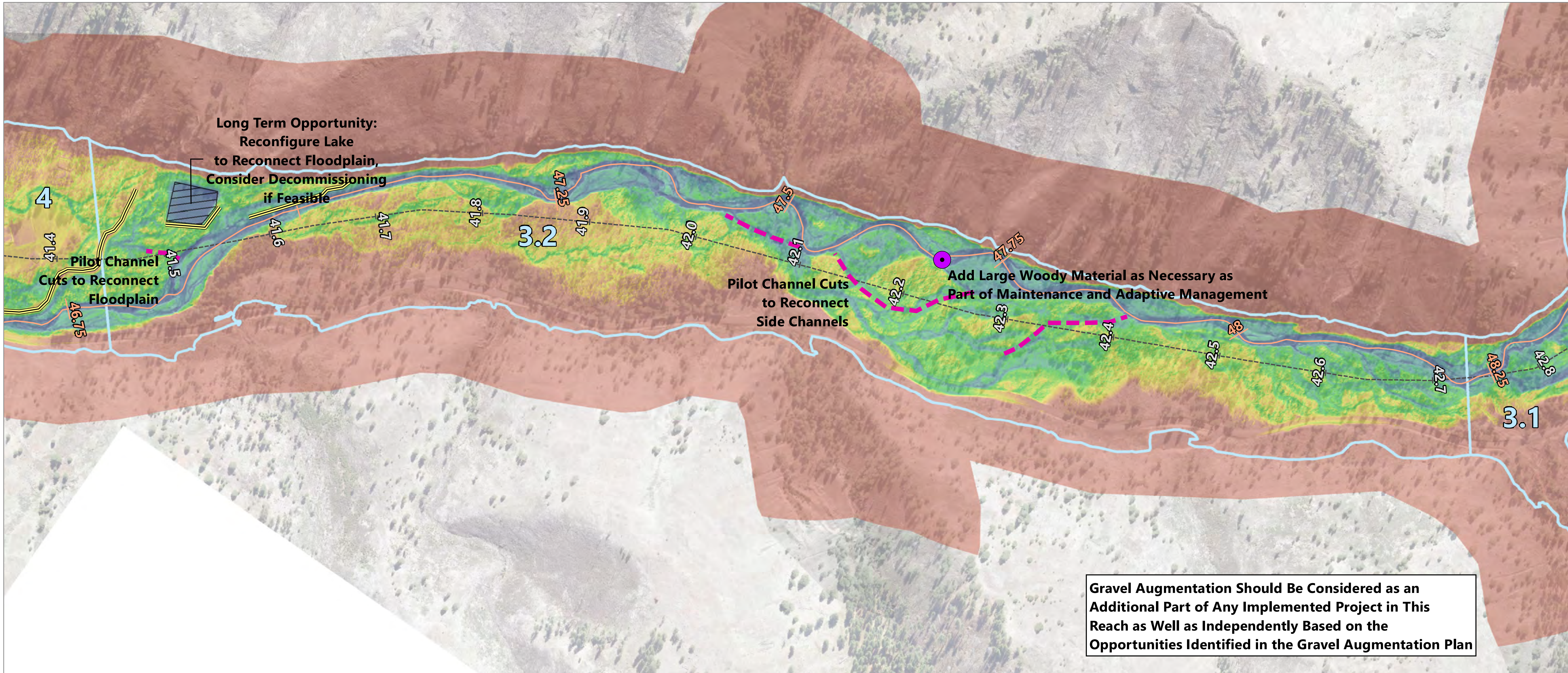
PA 3.2 Scoring Metric Ranks



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 3.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.164	28	40%	**Complexity**	0.256	26	40% to 60%	3 of 5	5	40%	2.4	20	1	Treated	7	1
Mean-Winter Flow Complexity	0.293	24	40%													
1-year Complexity	0.369	23	20%													
Channel Aggradation FP Potential	0.263	17	40%	**Connectivity**	0.167	35	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.017	51	40%													
Total FP Potential	0.277	41	20%													
Existing Connected FP	0.723	20	0%													
Excess Transport Capacity	-0.08	41	100%	**Excess Transport Capacity**	0.000	41	52% to 100%	4 of 4	0	20%						
Pool Frequency	10.42	35	100%	**Pool Frequency**	0.267	35	40% to 60%	3 of 5	5	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Side Channel
- Reconnect Floodplain

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 46.79
RIVER MILE END: 48.23
VALLEY MILE START: 41.44
VALLEY MILE END: 42.73

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Feet

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ANCHOR QEA

Project Area 3.2
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 6 Description

Project Area 6 begins at VM 40.16 and extends upstream to the NF-160 bridge crossing at VM 40.80. The 2017 RM length is 0.74 mile. Field observations for PA 6 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization. However, restoration actions in this Project Area were implemented very recently (July 2017) and occurred just before the raw data for this report were collected in 2017.

In the upper portion of the project area, the channel is a single-thread, plane-bed channel with little complexity. Two vortex weirs mid-reach were placed by the USFS to maintain and hold the channel grade for the Camp Wooten and USFS Tucannon Camp Ground. The 2011 assessment noted that this portion of the channel contained very little LWD or other hydraulic complexity, other than the pools at the weirs, which was also the observation in 2019 habitat survey conducted by the Programmatic. There continued to be very little suitable habitat for juvenile fish except near the channel margins. Habitat conditions are also affected in the summer months by recreational use related to the adjacent campground.

Project Area 6
Engineered log jam placed by helicopter 2 years following construction in 2017.

Project Area 6 Reach Characteristics

VM Start (mi)	40.16
VM Length (mi)	0.64
Valley Slope	1.69%
RM Start (mi)	45.35
RM Length (mi)	0.74
Average Channel Slope	1.44%
Sinuosity	1.17
Connected FP (ac/VM)	11.76
Encroachment Removal (ac/VM)	6.48
Channel Aggradation (ac/VM)	2.80
Total FP Potential (ac/VM)	11.86
Encroaching Feature Length (ft)	476.89
Connected FP Rank	40

About 0.25 river mile downstream, the channel was more complex in 2011, with a multi-channel configuration with forced pools and riffles at LWD and along the bedrock valley wall. Instream habitat conditions in the main channel were generally good, due to the presence of large LWD that retained additional mobile wood and forced deep pools. Two large side channels met the main river near the middle and downstream end of the reach, providing good off-channel rearing habitat with ample cover, depth, and low velocities. The large natural log jam that had existed in 2011 at this site had become undercut by the summer of 2017, reducing the number of side channels and complexity within the reach. In July 2017, a new channel-spanning jam was constructed to aid in reforming the initial natural jam's function (Webmap VM 40.5).

Floodplain connectivity in this project area was adversely affected by the presence of the NF-140 bridge and campground, which cut off approximately half of the low floodplain area. A major former channel position along the southeast valley wall was separated from the river by the campground area. Floodplain connectivity was less impacted for the last tenth of a mile at the downstream end of the project area, where no infrastructure was present. A short portion of the floodplain was somewhat naturally confined by remnant alluvial fan and hillslope deposits from the northwest side of the valley.

Hixon Creek joins with the mainstem at VM 40.48, about midway through the reach. However, Hixon Creek enters the Tucannon River valley at VM 41 in Project Area 5, and runs parallel to the mainstem for just over half a mile through the bottom half of PA 5 and the upper half of PA 6. For this distance, Hixon Creek is separated from the mainstem by Camp Wooten, the USFS Tucannon campground, and associated infrastructure. Hixon Creek has fish access from the mainstem up into the Tucannon Campground where it is disconnected by two undersized culverts in the campground access road.

At the upper end of the project area, riparian vegetation is reported as some of the older growth following the fires of 2006. Larger deciduous trees were present, including red alder, flowering dogwood, and vine maple. The understory was in moderate health but provided little overhanging vegetation.

Towards the downstream end of the project area, the riparian zone was in moderately healthy condition. Riparian trees were mixed coniferous and deciduous. Understory vegetation included groundcover, shrubs, and small trees that provided overhanging vegetation along the banks.

Restoration Actions and Geomorphic Changes

Restoration actions in 2017 began approximately 800 feet downstream of the upper project boundary and ended about 700 feet upstream of the downstream boundary, with a measured treatment length of 0.55 mile. Treatment actions involved placing 40 log jams using 255 key log pieces. The number of key LWD pieces increased from 0.52 key pieces per bankfull width to 3.79 key pieces per bankfull. Additionally, a small side channel pilot channel was excavated to reconnect about 0.22 mile of high-flow channels and floodplain at the lower end of Hixon Creek. Goals for restoration work on PA 6 included increasing pool frequency to greater than 50% increase in pools, which equates to about 10 to 20 pools; increasing channel complexity by increasing secondary channels from 0.24 mile total length to greater than 0.51 mile; and increasing floodplain connectivity.

This assessment assumes that restoration work and geomorphic changes are, for the most part, unrelated due to the timing of the restoration work, which occurred in 2017 shortly before the LiDAR data were collected for this assessment. With so little elapsed time, it is not expected that any geomorphic changes resulting from the restoration project would be apparent in the LiDAR or aerial imagery data. Additionally, a flow event in spring 2018 occurred shortly before the aerial imagery was captured.

The first change occurs at approximately VM 40.65 where significant erosion shows up on the left bank. There are several large channel-spanning log jams just downstream of here apparent in the 2018 aerial imagery and these, along with the upstream erosion, are associated with aggradation behind the log jam and on several bars, along with split flow that did not appear to exist in 2011 (box 1).

Just downstream of this location, there has been aggradation in the main channel and a mid-channel bar is apparent in the 2018 aerial imagery. This aggradation is associated with several large pieces of instream wood and several side channel erosional areas are apparent as a result (box 2). This area represents a good example of how channel aggradation can promote complexity with the addition of instream wood even in the upper reaches of this assessment area.

Several hundred feet downstream, a large channel-spanning log jam has triggered aggradation on the left bank as a bar is built on the inside of a bend. Just downstream of here, another bar is being built on the inside of a bend and minor erosion exists on the outside of the bend (box 3). Immediately downstream of this area, the final area shows a split flow with aggradation on the mid-channel bar forming from the nearby LWD. A significant erosional area is apparent on the bank side of the LWD and it appears that high flows may be cutting behind the log jam.

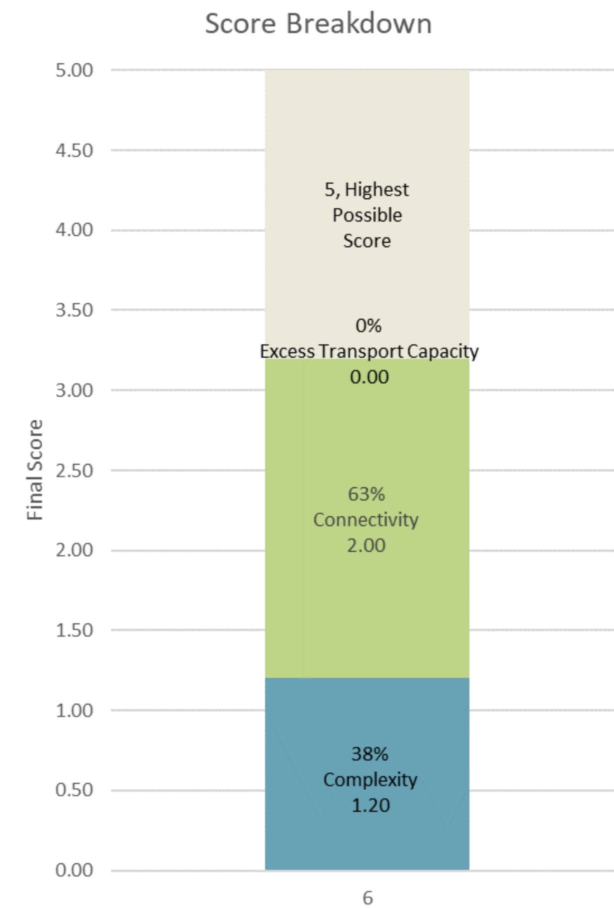
Geomorphic Characteristics and Management and Enhancement Strategies

The management and enhancement opportunities identified here are based on the 2018 LiDAR and aerial imagery data. However, it should be noted that the restoration actions in this reach occurred shortly before the data were collected and geomorphic response had not yet occurred and may not yet be reflected in the prioritization score.

PA 6 receives moderate scores in both Complexity and Connectivity metrics, with a small score for the Excess Transport Capacity metric. The Complexity for this reach is ranked above average in the 60th to 90th percentile, a range that still shows moderate complexity but does not place it in the top 10% of project areas; this project area likely only needs a little restoration work to reach that mark.

The Connectivity score is defined primarily by a high rank in the Encroachment Removal analysis result and is driven by a large low-lying area on the right bank floodplain at the downstream end of the Hixon Creek tributary. Hixon Creek and its associated floodplain runs parallel to the Tucannon River for nearly 0.5 mile, but is separated first by the road for Camp Wooten, and then by the USFS Tucannon campground for about 0.4 mile of this distance. The last 0.1 mile of this tributary and its low-lying floodplain though is what drives the connectivity metric in this project area. This area is disconnected by significant high banks, and the pilot channel cut as part of the restoration action appears to allow 2-year and a small amount of 1-year flow into this area. A primary enhancement strategy for this reach should be to cut pilot channels to reconnect this area at a more frequent rate and add wood structure to promote geomorphic change near where the pilot channels have been cut.

PA 6 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

The complexity score is moderate but shows that only a little work is necessary to reach the highest level of complexity for the assessment. As noted in the sections above, restoration actions were completed in 2017, just before these data were collected, and there seems to already have been significant geomorphic response. If the entire tributary was deemed unobtainable, the identified management strategy would be to let the restoration actions in this reach develop. Should geomorphic processes stop, and side channels begin to deactivate at perennial flow, a gravel augmentation plan to jumpstart the geomorphic processes should be considered.

Finally, the pool frequency in this reach appears to be slightly below average for the basin. More pools are likely to form as a result of the recent restoration actions. However, similar to complexity, should these changes not occur, gravel augmentation will allow for more frequent pool formation around any instream structure.

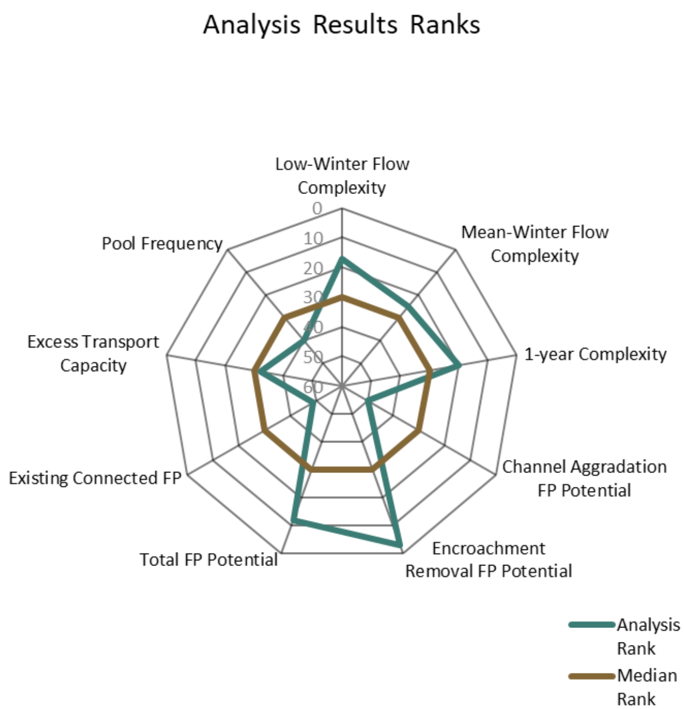
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

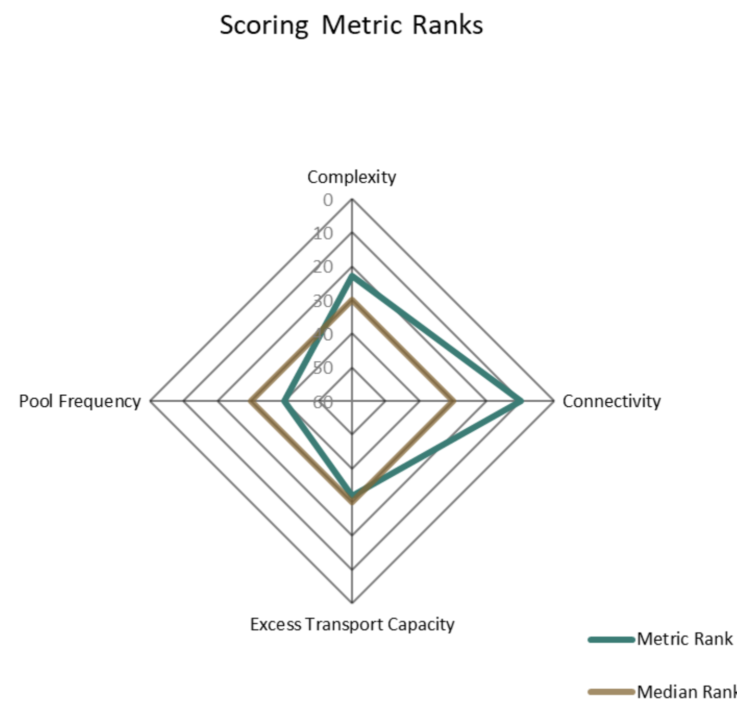
- Set back road against left valley wall for more floodplain connection and channel migration area.
- Relocate or reconfigure access bridge to Camp Wooten upstream, and enlarge the culvert.

PA 6 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

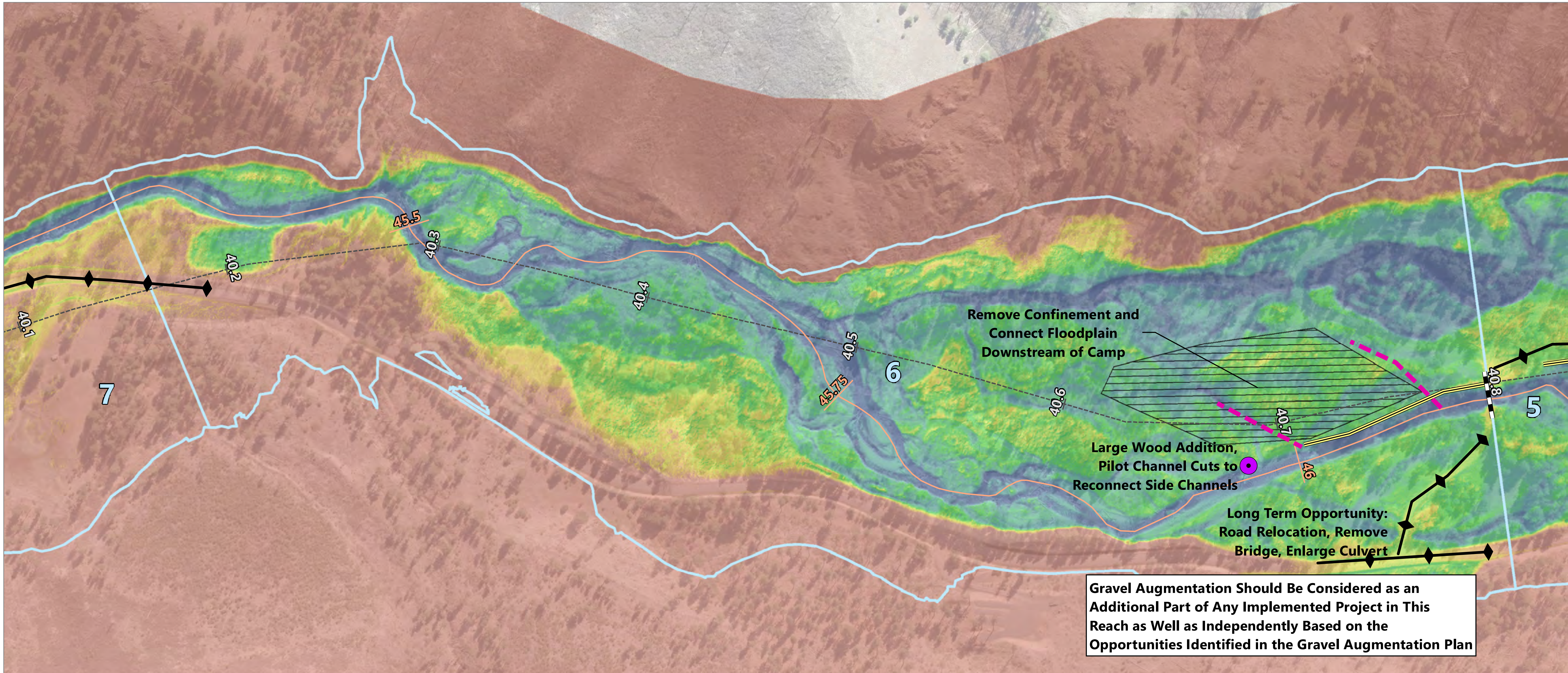
PA 6 Prioritization Scoring Summary



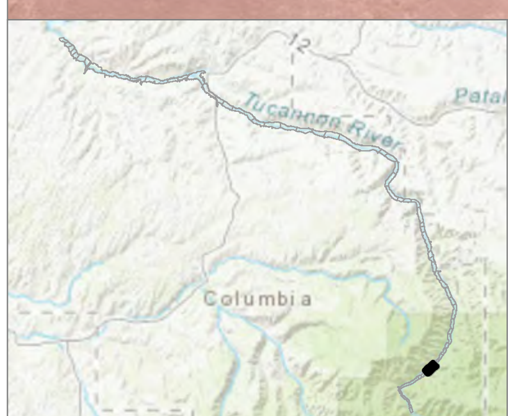
This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 6 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.245	17	40%	**Complexity**	0.292	23	10% to 40%	2 of 5	3	40%	3.2	8	1	Treated	2	1
Mean-Winter Flow Complexity	0.291	25	40%													
1-year Complexity	0.387	20	20%													
Channel Aggradation FP Potential	0.118	50	40%	**Connectivity**	0.258	10	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.275	3	40%													
Total FP Potential	0.502	12	20%													
Existing Connected FP	0.498	49	0%													
Excess Transport Capacity	0.01	32	100%	**Excess Transport Capacity**	0.000	32	52% to 100%	4 of 4	0	20%						
Pool Frequency	8.07	40	100%	**Pool Frequency**	0.207	40	60% to 90%	4 of 5	1	0%						



Gravel Augmentation Should Be Considered as an Additional Part of Any Implemented Project in This Reach as Well as Independently Based on the Opportunities Identified in the Gravel Augmentation Plan



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Side Channel
- Reconnect Floodplain
- Long Term: Relocate Road

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 45.35
RIVER MILE END: 46.09
VALLEY MILE START: 40.16
VALLEY MILE END: 40.8

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Feet

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ANCHOR QEA

Project Area 6
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 9 Description

Project Area 9 begins at VM 38.92 and extends upstream to VM 39.33. The 2017 RM length is 0.4 mile. Field observations for PA 9 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization or observations based on habitat surveys made in 2019 by the Programmatic partners. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

Throughout PA 9, the river is characterized by multiple-channel pathways containing a variety of hydraulic conditions caused by the presence of LWD, including several pools and secondary flow paths. The 2011 assessment noted that local channel expansion was occurring in the project area from just upstream, as evidenced by bank erosion and multiple-flow path development, recently recruited trees in the channel and side channels, and high amounts of temporary sediment storage. A levee is located along the right bank in PA 8 for a short distance at the diversion structure to Big Four Lake. The structure is composed of rock armoring and some rootwads along the toe. The channel adjacent to the levee was wide, shallow, and relatively well-armored due to locally high velocities. A straight, plane-bed stretch of channel adjacent to Big Four Lake had a well-armored bed lined with large cobbles. In general, the project area has good side channel connectivity

Project Area 9
Channel-spanning ELJ placed using a helicopter in July 2017; photograph taken in September 2017.

Project Area 9 Reach Characteristics

VM Start (mi)	38.92
VM Length (mi)	0.41
Valley Slope	1.39%
RM Start (mi)	44.05
RM Length (mi)	0.40
Average Channel Slope	1.38%
Sinuosity	0.98
Connected FP (ac/VM)	13.20
Encroachment Removal (ac/VM)	7.56
Channel Aggradation (ac/VM)	3.03
Total FP Potential (ac/VM)	15.34
Encroaching Feature Length (ft)	1,586.02
Connected FP Rank	36

and contains a variety of side channel types from perennial to high-flow pathways.

The complex sections of channel within this project area provide a variety of hydraulic conditions, including a relatively high amount of off-channel habitat, that provide preferred habitat throughout different life stages over the water year. In 2010, instream habitat conditions in the main channel were generally good in these complex sections due to the presence of large LWD that retained additional mobile wood, forced deep pools, formed side channels, and provided cover and hydraulic refuge. These areas had several well-connected side channels and a wide, active channel and floodplain, which has allowed the channel to migrate. However, the plane-bed sections of the project area lack sufficient volume and size of LWD necessary for instream complexity, which has led to wide, shallow conditions during low flows and high velocities during seasonal high flows. The LWD observed in these reaches did not appear substantial enough to persist and retain additional LWD over time, and by 2016 detreating conditions prompted WDFW to design a wood loading project funded through the Programmatic and implemented in July 2017 five months prior to the collection of LiDAR data in December 2017.

This project area is characterized by a large, active channel area but infrastructure disconnects and prevents connection or channel development in this reach. The floodplain surface is relatively high above the channel bed with a small amount of low floodplain area throughout the valley. The right bank Big Four Lake levee and infrastructure has likely prevented channel migration, but it did not cut the channel off from any significant low areas of the floodplain (within the 5-year water surface elevation). Big Four Lake is approximately two-thirds of the width of the valley, confining the potential width of the floodplain corridor. A large amount of low floodplain exists on the downstream side of the lake, which contained flowing water at the time of field observations that was likely sourced from lake seepage or tributary flow. The current position of the lake prevents an upstream surface water connection to this area. The lake itself accounts for more than 5 acres of floodplain, and its conversion to connected floodplain could be the target of an aggressive restoration project.

The riparian zone was generally in moderate health, with some local areas that had been highly disturbed by fire. Riparian trees were predominantly mature ponderosa pines and young dogwoods and alders. The understory was in moderate health dominated by emergent vegetation that provided little overhang. There were few mature trees and intermediate-sized plants and poor vegetation diversity in several areas. The upstream end of the severe burn zone from the 2005 School Fire begins at the downstream end of the project area.

Restoration Actions and Geomorphic Changes

In 2017, restoration work in PA 9 included placing 50 LWD log jams using 252 key LWD pieces to increase the number per bankfull width from 0.85 to 6.14. (Seven of the LWD log jams placed during this restoration work were downstream of the PA 9 boundary, covering approximately 800 feet of the upper PA 10.) The LWD was placed to promote channel avulsion and inundation during modest mean-winter flows to reconnect 0.44 mile and enhance flow into 0.18 mile of side channel.

This updated assessment assumes that restoration work and geomorphic changes are unrelated due to the timing of the restoration work, which occurred in 2017 shortly before the LiDAR data were collected for this assessment. With so little elapsed time, it is not expected that any geomorphic changes resulting from the restoration project would be apparent in the LiDAR or aerial imagery data.

At the upstream end of PA 9, a large split flow has formed from a mid-channel log jam located in PA 8, and the resulting mid-channel bar in PA 9 is apparent as aggradation in the change analysis. This has caused some minor bank erosion as well on the left bank in this area (box 1). 400 feet downstream of this split flow, additional deposition is apparent in the floodplain that appears to be associated with a channel split flow, indicating that this side channel receives higher flows during flood events to allow sediment to deposit (box 2).

Immediately downstream is the most significant change in the reach in the form of a large amount of aggradation in the main channel. This depositional reach extends for several hundred feet and appears to be associated with a large amount of instream wood seen in the 2018 aerial imagery. Based on local knowledge, the channel began to carve a meander into the gravel bar on river right until the flow undercut a large pine on the left bank, which recruited as a spanner. The plunge pool can be seen in the 2018 aerial imagery near the bottom of box 3. The spanner began to be cut around by 2017 and was augmented with additional materials as part of the PA 9 treatment (box 3).

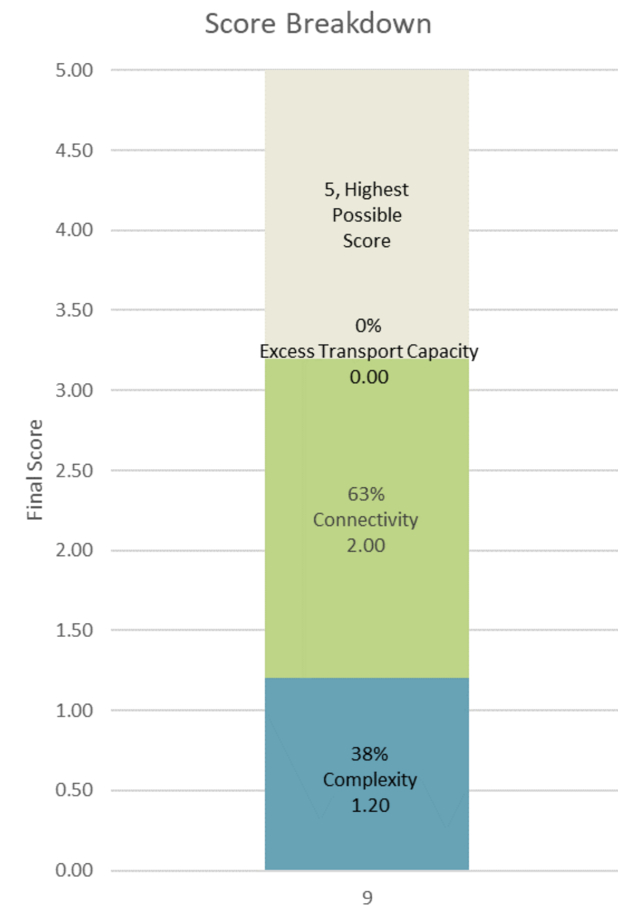
Because the restoration occurred in 2017, less than a year before these data were collected, it is difficult to attribute any of the geomorphic changes to the restoration efforts. However, the 2018 aerial imagery shows the restored project area after at least one major flow event (in the winter of 2017/2018), and there does appear to be some additional split flow and complexity resulting from the added instream wood.

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 9 receives a high score in the Connectivity metric and a moderate score in the Complexity metric. The high Complexity score indicates that this project area already ranks above average in the 60th to 90th percentile of project areas, a range that still shows moderate complexity but does not place it in the top 10% of project areas; this project area likely only needs a little restoration work to reach that mark. The high Connectivity score indicates this project area ranks near the top in the 75th to 99th percentile of all project areas. This high score is almost entirely driven by the Encroachment Removal analysis result, which ranks near the top, while the Channel Aggradation analysis result ranks near the bottom. The potential area to be reconnected exists almost entirely on the right bank, downstream of the Big Four Lake located in the floodplain of this project area. This area is a series of low-lying channels that could be relatively easily reconnected at the 2-year event. However, the largest benefit to the floodplain would be the decommission and reconnection of the lake itself, which would provide more than 5 acres of reconnected floodplain itself. The removal of this lake and associated levees would be a very large restoration project and would require additional restoration strategies such as riparian planting and addition of LWD. The levees from the lake present a possible opportunity for gravel augmentation, and the nearby fishing access parking lot presents a possible location for gravel augmentation. This project area has already been treated with a large amount of instream wood, so the primary enhancement strategy should be to reconnect this right bank area via pilot channel cuts or larger removal of the high right bank separating this area.

Additionally, if this area can be connected at the mean-winter flow or lower, this would also be a significant boost to the complexity in this reach by adding a long and potentially complex side channel. It should be noted that, while the main channel was heavily treated with instream wood, none of this additional potential area was treated on the floodplain, and adding wood to

PA 9 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

this area should be a primary enhancement strategy should this area be targeted for reconnection.

This project area was only treated shortly before the LiDAR data were collected and likely needs more time to respond to the large amount of instream wood added. However, should significant geomorphic changes not occur, gravel augmentation may be necessary to provide more easily transportable material to the reach and should be considered a management strategy for the restoration actions already implemented.

The pool frequency in this reach appears to be slightly below average for the basin. More pools are likely to form as a result of the recent restoration actions. However, should these changes not occur, gravel augmentation will allow for more frequent pool formation around any instream structure.

Finally, it should be noted that the Big Four Lake occupies a large portion of the floodplain in this project area. Reconfiguration of this lake, as discussed in the Wooten Floodplain Management Plan, should be considered to increase the floodplain connectivity in this area. Additionally, while decommissioning and removing this lake would require a specific set of circumstances to be possible, as well as a large effort, it would provide the largest benefit to both the floodplain connectivity and complexity of this project area.

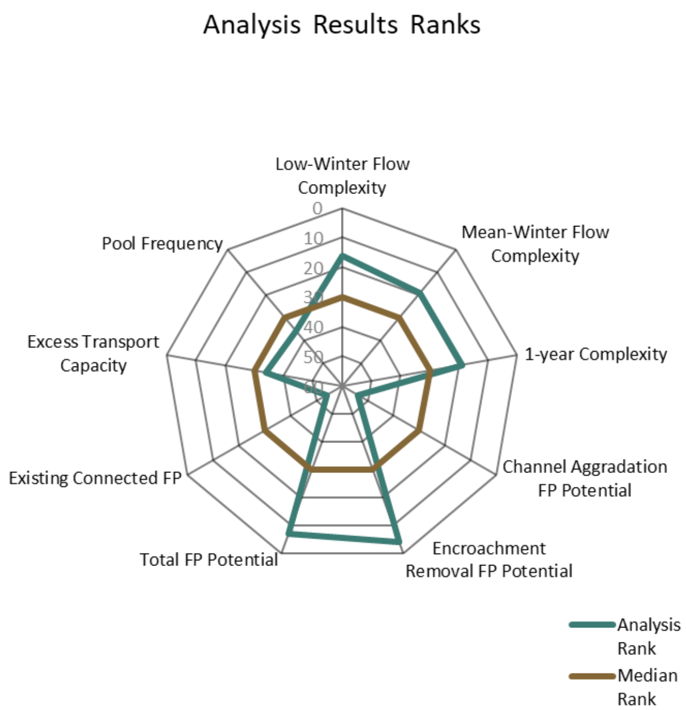
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

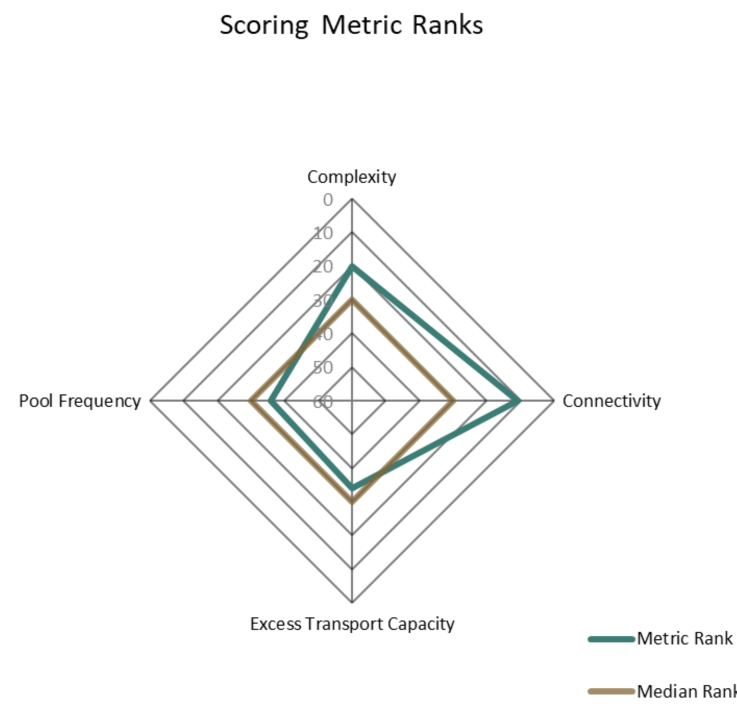
- Reconfigure Big Four Lake to reconnect floodplain and consider decommissioning and removing if ever feasible.

PA 9 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

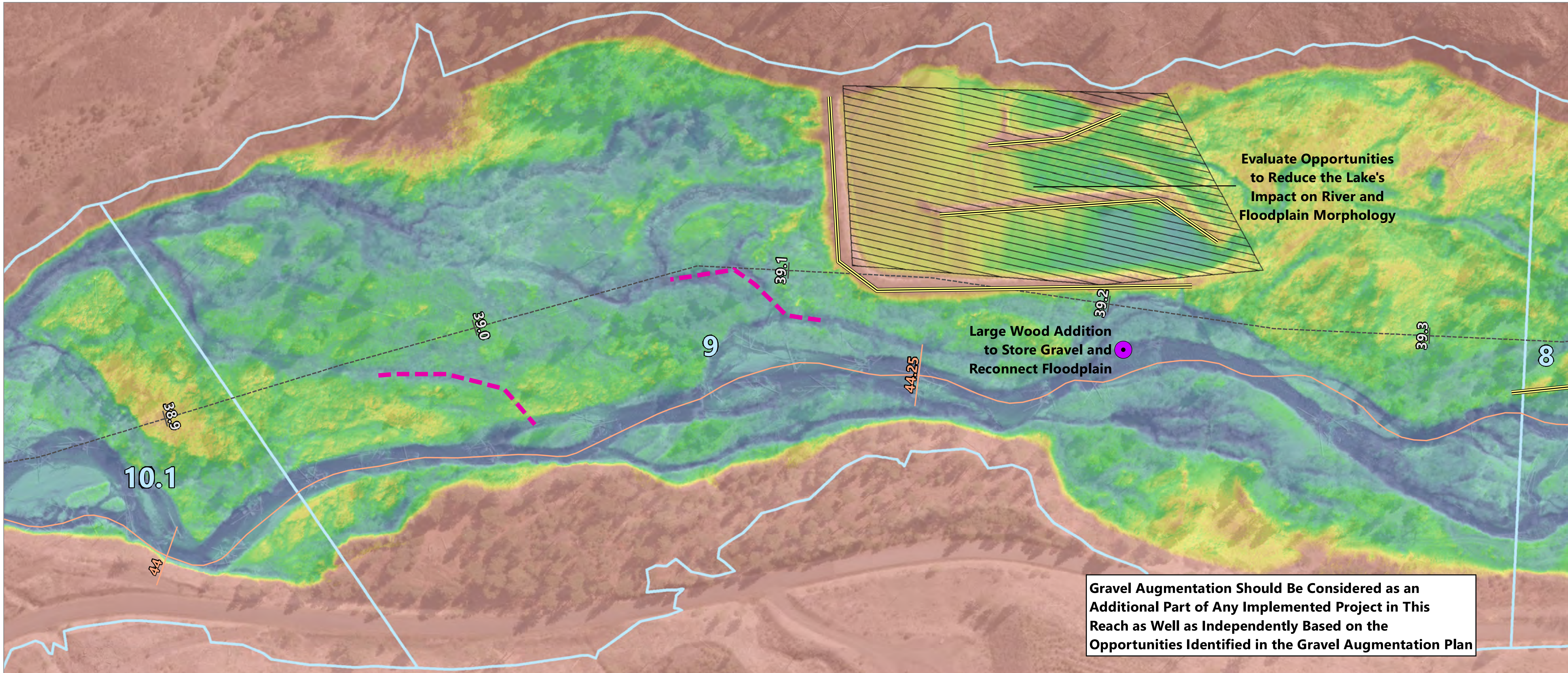
PA 9 Prioritization Scoring Summary

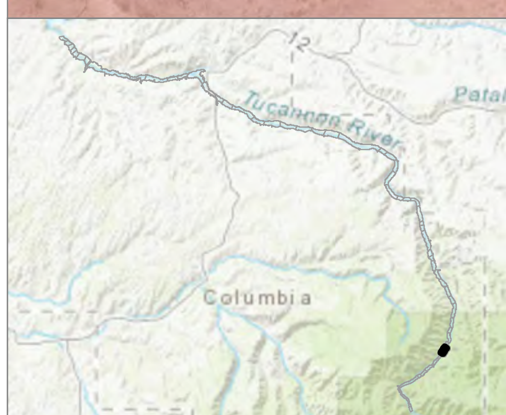


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 9 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.261	16	40%	Complexity	0.310	20	10% to 40%	2 of 5	3	40%	3.2	9	1	Treated	3	1
Mean-Winter Flow Complexity	0.315	19	40%													
1-year Complexity	0.401	19	20%													
Channel Aggradation FP Potential	0.106	54	40%	Connectivity	0.256	11	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.265	4	40%													
Total FP Potential	0.538	7	20%													
Existing Connected FP	0.462	54	0%													
Excess Transport Capacity	-0.03	34	100%	Excess Transport Capacity	0.000	34	52% to 100%	4 of 4	0	20%						
Pool Frequency	9.99	36	100%	Pool Frequency	0.256	36	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Side Channel
- Reconnect Floodplain

Relative Elevation in Feet

High : 15

Low : -0

NOTES:
1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 44.05
RIVER MILE END: 44.45
VALLEY MILE START: 38.92
VALLEY MILE END: 39.33

0 500
Feet

Publish Date: 2021/01/25, 3:44 PM | User: mgieschen
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ANCHOR QEA

Project Area 9
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 14.2 Description

PA 14.2 begins at a bridge crossing for the Tucannon Road at VM 33.64 and extends upstream to VM 34.26. The 2017 RM length is 0.82 mile. Field observations for PA 14.2 were conducted on September 27, 2018, when flow at the Starbuck gage was approximately 82 cfs.

For this assessment update, PA 14 as defined in the 2011 prioritization was separated into three project areas (PA 14.1, PA 14.2, and PA 14.3). In 2014, the upper sections of this project area (PA 14.1 and PA 14.2) were the subject of a restoration project, while PA 14.3 has remained untreated. PA 14.1 and PA 14.2 represent distinct parts of the restoration project and were therefore separated for distinct analysis.

At the upstream end of PA 14.2 is a sharp meander bend with a deep pool with overhanging cover. On the left bank behind this pool, the immediate floodplain is high, but approximately 200 feet along the meander bend is the start of a side channel that at the downstream end has water flowing, likely from groundwater. It is possible this side channel could cut off the large meander bend and become the main channel if it cuts through the left bank.

After this first sharp meander bend, the channel runs along the right bank valley wall for a long reach. It was noted during site observations that this reach had very little instream wood because it was not treated due to difficulty in access, except for

Project Area 14.2
Engineered log jam with channel-spanning recruits likely from upstream structure losses.

Project Area 14.2 Reach Characteristics

VM Start (mi)	33.64
VM Length (mi)	0.61
Valley Slope	1.56%
RM Start (mi)	37.88
RM Length (mi)	0.82
Average Channel Slope	1.13%
Sinuosity	1.34
Connected FP (ac/VM)	8.81
Encroachment Removal (ac/VM)	0.51
Channel Aggradation (ac/VM)	2.49
Total FP Potential (ac/VM)	3.37
Encroaching Feature Length (ft)	640.77
Connected FP Rank	54

a large structure on the right bank that is causing erosion on the left bank and creating several split flows.

After the reach along the valley wall, at approximately VM 34.13, a large apex jam has accumulated a lot of wood recruits and is forcing a split flow onto the left bank. Just downstream, there are several individual wood pieces and the side channel from the pool at the upstream end of the reach returns in a low swampy area on the left bank.

Downstream of the swampy area, a very large ponderosa pine log has fallen in and is spanning the channel. This tree is relatively well entrenched, and scour and erosion are occurring on the left bank at this location. Just above this ponderosa pine, the right bank is beginning to cut off the meander with a side channel running down to the next meander.

The channel goes through another straight, uniform stretch with little instream wood until VM 34.01 where the channel goes through another sharp meander bend. A large apex jam here is causing split flow and erosion on the right bank, followed closely by a massive channel-spanning log jam and a bank barb jam on the left bank as the channel makes a sharp turn close to the road. The channel-spanning log jam is creating good complexity with deeper pools and multiple side channels. The bank barb jam appears to have collected a lot of wood recruits and is also creating good complexity.

Between VM 34 and VM 33.89, the channel is straight and uniform with little instream wood except for a few small engineered bank barbs that appeared to be mostly disconnected at the time of the site visit.

At VM 33.89, a large log is controlling the grade with a large drop-off, which could make the structure a possible fish impediment, but a large V-notch has been cut into the center of the log to allow a low-flow path over the log.

At VM 33.87 and 33.77, there are two large channel-spanning log jams that are creating good complexity but apparently with relatively little geomorphic change.

At the downstream end of the project area, Cummings Creek joins the Tucannon River and was flowing during the site visit. The area just downstream of Cummings Creek appears to have some of the most dynamic channel forms in the reach, with several side channels and split flows through the trees.

For almost all of the log jams through this reach, there is some localized geomorphic change, but very few have deep scour pools and, given the size of the log jams, the amount of geomorphic change occurring seems relatively low. The bed material through this reach is relatively large, with mostly large cobbles and boulders and very little transportable gravel. This may be an important factor in the lack of deep scour pools and complexity around these large log jams.

Riparian vegetation through the bottom half of the reach is relatively poor up until the area around Cummings Creek, consisting of mostly mature coniferous species with some undergrowth, but large stretches of grassy upland areas. At the upstream end, the riparian vegetation provides more cover and woody material. After the first bend on the upstream side, the left bank and the second bend on the right bank are large wetland complexes with younger deciduous tree stands and large areas of canary grass.

Restoration Actions and Geomorphic Changes

In 2014, restoration work in PA 14.2 included placing 34 LWD structures within the reach using 303 key LWD pieces. The restoration project targeted connecting approximately 1,700 feet of ephemeral side channels. The goal for this reach was to increase channel complexity and floodplain connectivity at a 2-year level and less.

Analysis of the difference between the 2010 and 2017 LiDAR data shows multiple locations of significant geomorphic change, many of which were likely caused by the restoration actions in the reach. At the beginning of the reach, a large erosional area in a sharp bend has formed a deep pool and is associated with bar building on the right bank. This change does not appear to be forming as a result of a restoration structure (box 1).

Near the middle of the reach, a large mid-channel engineered log jam has caused a large depositional area both immediately upstream of the log jam and downstream on the left bank. A small area of bank erosion likely from scour is located on the left bank next to the log jam (box 2). This log jam is one example of several mid-channel structures in this reach that have caused localized geomorphic change, not all of which have been highlighted for this narrative.

Immediately downstream of here, a bank barb type structure on the left bank has cause some localized erosion on the left bank and a depositional bar building on the right bank (box 3). The next highlighted area occurs around the next bend, and includes another mid-channel log jam, but this time with a large depositional area immediately upstream. On the bank immediately behind this log jam in the same area, erosion has occurred in the start of a floodplain side channel (box 4).

At VM 34, a series of channel-spanning log jams and a left bank log jam has caused bank erosion on the right bank and deposition on the left bank. Some minor bar building has occurred immediately downstream of these log jams on the right bank and is associated with erosion on the left bank (box 5). The next channel-spanning jam has also caused erosion and a minor avulsion to the right bank (box 6).

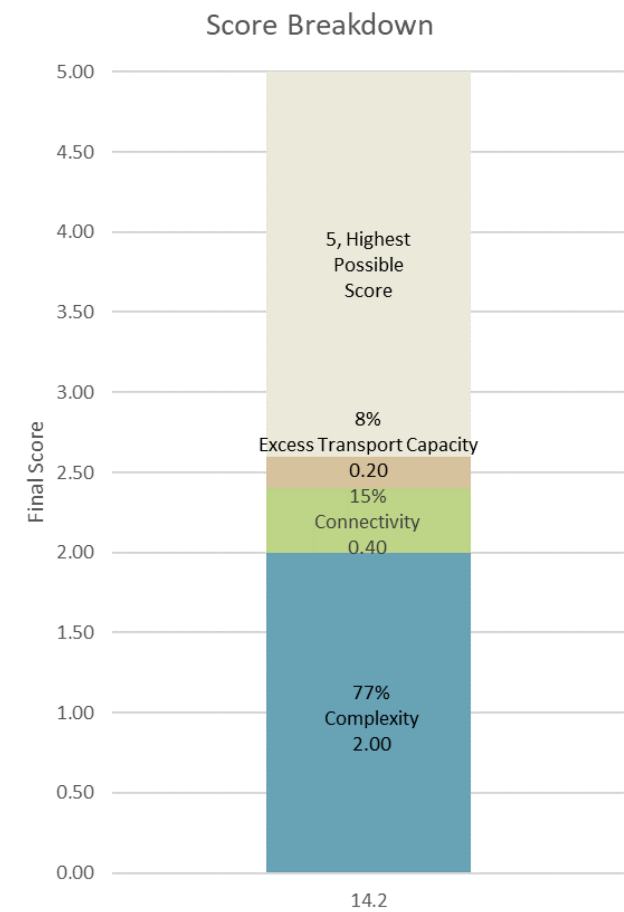
Finally, at the downstream end of the reach and downstream of Cummings Creek, two large engineered log jams have caused a major avulsion towards the right bank (box 7).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 14.2 receives most of its prioritization score from the Complexity prioritization metric. The Complexity metric for PA 14.2 ranks within the 40th to 60th percentile of project areas, a range which receives the highest score for this metric. Project areas in this range have been identified as having moderate complexity and have the most opportunity for improvement. This complexity score is driven mostly by moderate ranks in complexity for all three flows. At the low-winter flow, complexity comes in the form of several mid-channel bars, almost exclusively the result of placed wood structures. At the mean-winter and 1-year flows, an additional side channel is connected mid-reach, providing slightly higher complexity scores. This channel has been reported as being perennially connected in recent years.

However, based on the relative elevation map, several side channel opportunities exist between the bends in these reaches. While wood structure has already been added to this reach, it was noted during field observations that several long stretches could benefit from more wood structure. The primary enhancement strategy for this reach should be to connect

PA 14.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

these side channels, by strategically placing wood structures in conjunction with pilot channel cuts. Adding wood structure will also contribute to more in-channel complexity.

This project area does not receive any prioritization points for floodplain connectivity, but the Channel Aggradation Floodplain Potential analysis result is ranked near the middle of all reaches. Furthermore, while side channel opportunities appear accessible on the relative elevation map, it may be possible that channel-forming flows do not reach elevations sufficient to allow erosion and flow down these channels. Channel aggradation through gravel augmentation would allow these side channels to be more regularly inundated and achieve some of the floodplain potential indicated through the Channel Aggradation Floodplain Potential analysis result. Gravel augmentation should be pursued as an additional restoration strategy in this reach. The Excess Transport Capacity metric ranks well above average but still falls in a range where the transport capacity is not significantly more than would be expected of the slope, and thus receives a low prioritization score. Adding some wood structure will help to store and maintain any sediment added through gravel augmentation.

Finally, the Pool Frequency analysis result indicates that this project area ranks relatively high for number of pools per valley mile. The enhancement strategies of adding instream wood and gravel augmentation should assist in maintaining and increasing the number of pools in the reach in the future.

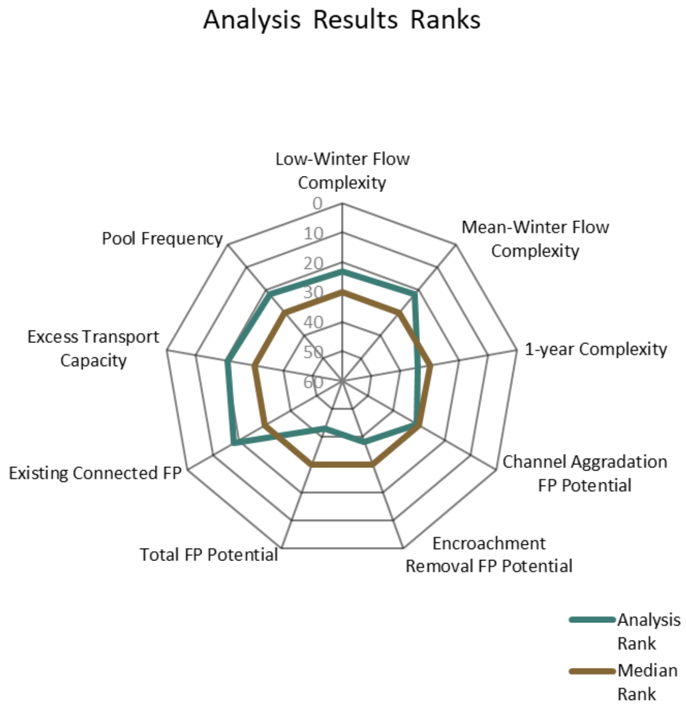
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

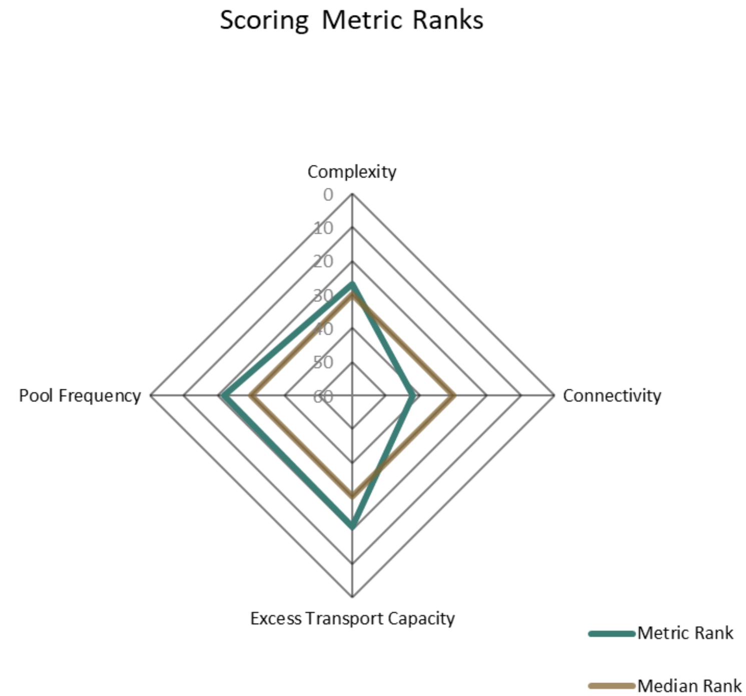
- Set back road and relocate parking areas out of left floodplain for more floodplain connection and channel migration area.

PA 14.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

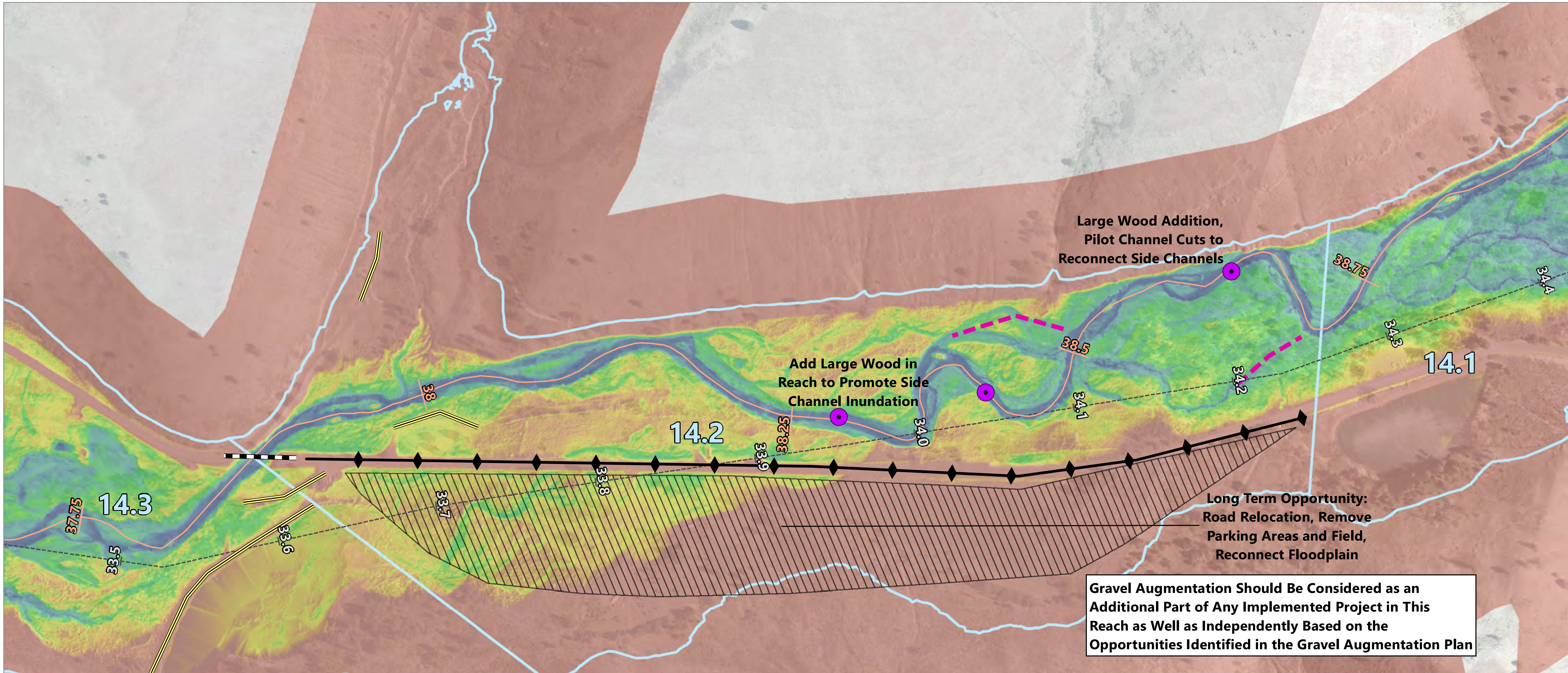
PA 14.2 Scoring Metric Ranks

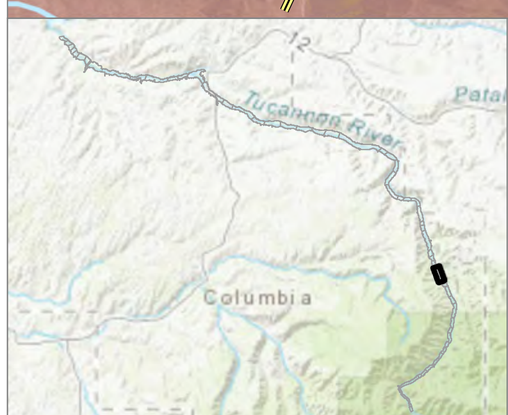


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 14.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.202	23	40%	Complexity	0.255	27	40% to 60%	3 of 5	5	40%	2.6	18	1	Treated	6	1
Mean-Winter Flow Complexity	0.294	22	40%													
1-year Complexity	0.280	34	20%													
Channel Aggradation FP Potential	0.205	31	40%	Connectivity	0.154	42	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.042	38	40%													
Total FP Potential	0.277	43	20%													
Existing Connected FP	0.723	18	0%													
Excess Transport Capacity	0.11	21	100%	Excess Transport Capacity	1.000	21	30% to 52%	3 of 4	1	20%						
Pool Frequency	13.38	22	100%	Pool Frequency	0.343	22	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Side Channel
- Reconnect Floodplain
- Long Term: Relocate Road

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 37.88
RIVER MILE END: 38.71
VALLEY MILE START: 33.64
VALLEY MILE END: 34.26

0 500
Feet

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ANCHOR QEA

Project Area 14.2
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 23 Description

Project Area 23 begins at VM 25.06 and extends upstream to VM 25.87. The 2017 RM length is 1.05 miles. Field observations for PA 23 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

The channel through PA 23 is a single-thread, plane-bed channel that is highly confined to a straight alignment between infrastructure and the valley wall. Levees and spoil piles confine the upper quarter-mile of the project area, and much of the right bank downstream of this point is lined by levees. Approximately 0.7 mile from the upstream end, a series of rock barbs are located along the bank, followed by a large rock weir after another 0.15 mile. Levees confine the channel between the weir and the downstream end of the project area. One small spring or tributary is present in the left floodplain near VM 25.76, and a small alcove is present at the downstream end of this area. The low-lying floodplain area is disconnected from the channel at the upstream end by a large armored levee along the left bank that constricts the channel to a tight bend at VM 25.14.

Project Area 23
No site photograph available.

Project Area 23 Reach Characteristics

VM Start (mi)	25.06
VM Length (mi)	0.81
Valley Slope	1.16%
RM Start (mi)	28.28
RM Length (mi)	1.05
Average Channel Slope	0.89%
Sinuosity	1.29
Connected FP (ac/VM)	10.28
Encroachment Removal (ac/VM)	1.23
Channel Aggradation (ac/VM)	5.60
Total FP Potential (ac/VM)	9.76
Encroaching Feature Length (ft)	4,900.44
Connected FP Rank	46

The quality and availability of instream habitat in this reach is limited by lack of complexity and hydraulic conditions that prevent the retention of sufficient volumes of LWD and sediment. The channel is wide and shallow with little complexity except at rock placements that provide some pool habitat for adult fish. Field observations noted very little LWD and little opportunity for cover except for some overhanging vegetation and undercut root masses along the channel margins. The project area lacks an adequate quantity of secondary flow paths and off-channel areas that are preferred by juvenile fish. The straight, confined channel likely has high instream velocities during spring runoff and floods. Very few opportunities were identified for fish to seek refuge.

Floodplain connectivity is poor and highly impacted by infrastructure. Relative to upstream project areas, the amount of low-lying floodplain in PA 23 is relatively high and the channel is less incised. Approximately half a mile of the reach is low lying and much of this area is currently used as a horse pasture and contains many wetland plants.

The riparian zone is in poor to moderate health. Riparian trees are predominantly deciduous species, including dogwood, alder, willow, and cottonwood. Some mature trees are present in the floodplain near the upstream end with a moderately diverse understory. The remainder of the project area mostly contains smaller trees, with many patches of immature trees in poor health and a sparse understory dominated by groundcover. Along the levees at the downstream end of the project area, there is little shading except for willows that have been planted along the banks.

Restoration Actions and Geomorphic Changes

In 2015, restoration work in PA 23 included placing a total of 12 LWD structures using 54 LWD key pieces, and removing 520 feet of levee and associated riprap. The expected response was to include increased channel complexity such as pools, gravel bar development, floodplain inundation, side channel development, and reduced incision.

Analysis of the difference between the 2010 and 2017 LiDAR data shows significant geomorphic change, much of which is a direct result of restoration actions in the reach. To begin with, at the upstream end of the reach, the levee removal as part of the restoration actions is clearly evident on the left bank (box 1).

Near the middle of the reach, the channel has avulsed and caused erosion toward the right bank, deposition has occurred in the main channel in this area, and a large patch of trees has fallen into the main channel (box 2). Immediately downstream, the left bank has experienced some minor but consistent erosion (box 3).

Near the downstream end of the reach, some significant erosion has occurred along the valley wall, on the outside of a sharp meander bend, and a side channel appears to be forming that cuts off the meander bend in this location (box 4). Erosion at the downstream end of the side channel area is also evident along with deposition due to several large log jams (box 5).

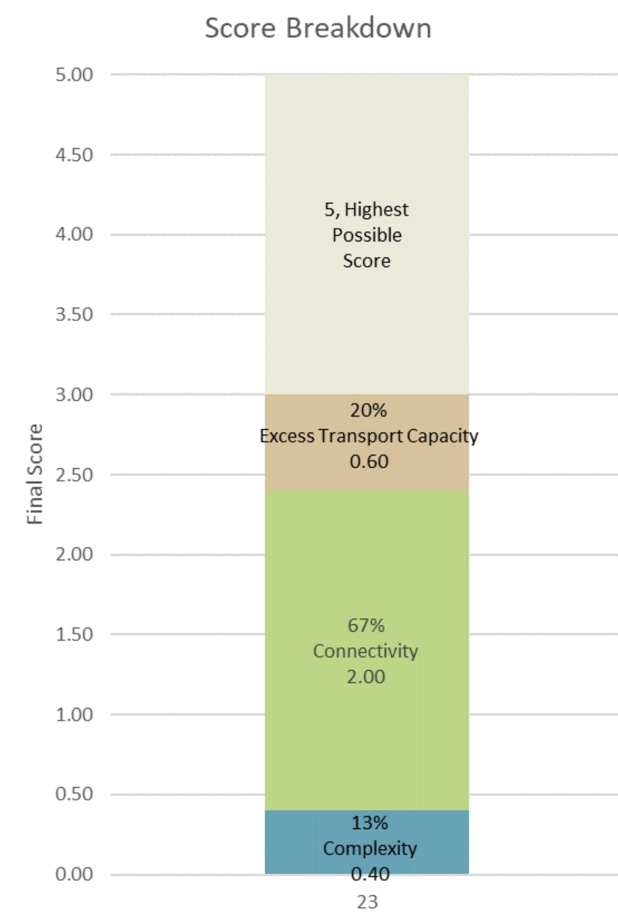
Finally, at the very downstream end of the reach just before and continuing into PA 24, significant deposition has occurred in the main channel and on the left bank floodplain (box 6).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 23 receives equal low scores in the Connectivity and Complexity metrics, and a moderate score in the Excess Transport Capacity metric. The low score in Complexity indicates that PA 23 ranks low among project areas in the 10th to 40th percentile. This range has been identified as having some small existing complexity but would likely require a large restoration effort to achieve higher levels. The low score in the Connectivity metric indicates that PA 23 ranks below average in the 25th to 50th percentile of project areas for connectivity potential.

This connectivity score is driven mostly by the Channel Aggradation score, which ranks near the average for project areas, although the Total Floodplain Potential analysis result ranks PA 23 very highly. This indicates that there is some floodplain that can be accessed through channel aggradation, but there is also a good amount of floodplain that can only be

PA 23 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

accessed through both channel aggradation and encroachment removal. Based on the GIS layer for connectivity, most of the Channel Aggradation Floodplain Potential is located in pockets of floodplain near the middle and bottom of the reach. The Total Floodplain Potential area is mostly driven by a long side channel and narrow floodplain area on the left bank floodplain that is disconnected at the upstream and downstream end. There is some additional disconnected area in the left bank pasture area that appears to be associated with a spring or runoff area. The primary restoration strategy for this reach should be to reconnect the pockets of floodplain through channel aggradation and gravel augmentation, along with added instream structure and wood. The moderate score in the Excess Transport Capacity metric indicates that this reach transports sediment more easily than others in the assessment area, likely because the channel is mostly straight and moderately confined. The addition of instream wood should be aggressive and dense to ensure sediment material from gravel augmentation is trapped and maintained in the reach.

While it may be initially difficult to achieve more complexity, opening these floodplain areas should give room for the channel to form more complexity. Pilot channel cuts should be considered an additional enhancement action to adding wood and gravel augmentation in order to open these reconnected floodplains to more perennial flows.

Finally, PA 23 ranks slightly below the average in the Pool Frequency metric, indicating a moderate amount of pools per valley mile. The enhancement actions of adding instream structure and gravel augmentation should promote geomorphic change towards more in-channel complexity and conditions where pools are forced more frequently with the natural processes of the reach.

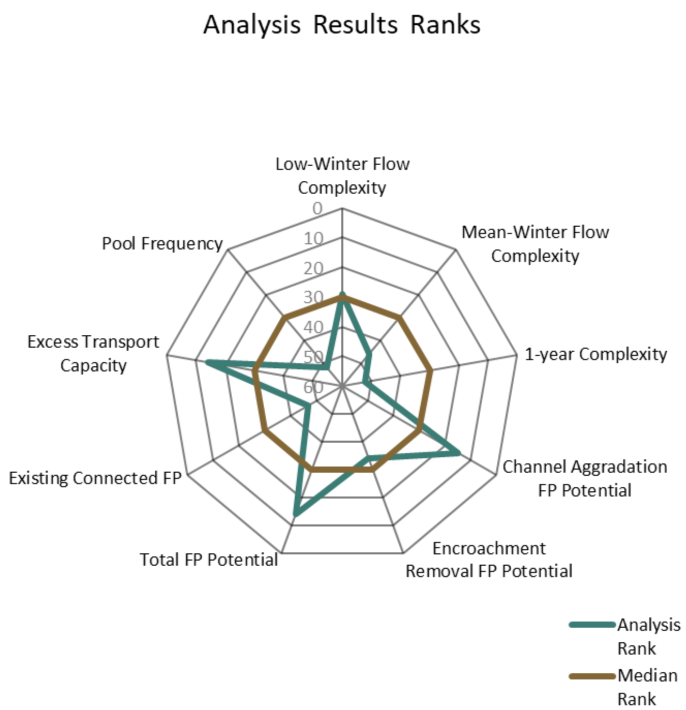
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

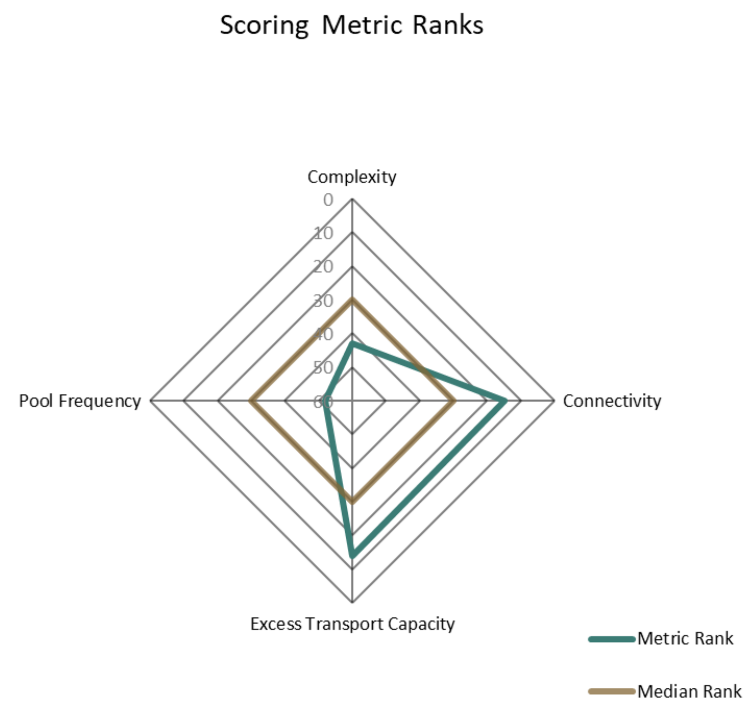
- Large-scale road setback project to relocate road onto right valley wall. The road crosses the river twice in quick succession here and relocating the road would allow both bridges to be removed, and necessitate less channel confinement, increasing floodplain connection and channel migration area through this reach.

PA 23 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

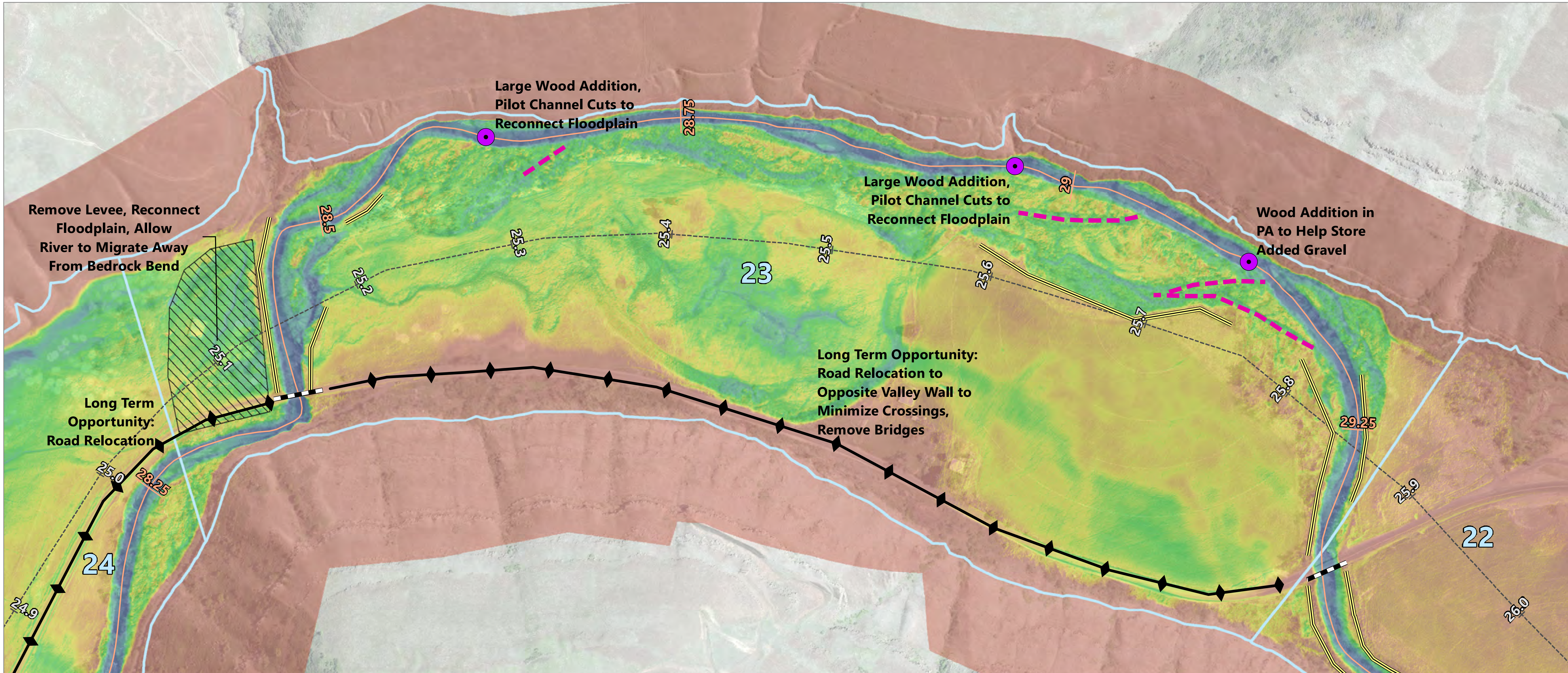
PA 23 Scoring Metric Ranks

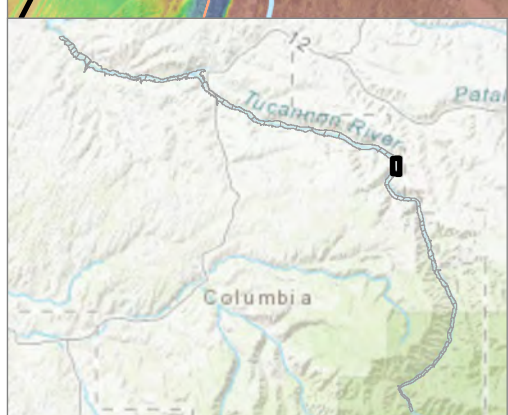


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 23 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.161	29	40%	**Complexity**	0.144	43	60% to 90%	4 of 5	1	40%	3.0	15	1	Treated	5	1
Mean-Winter Flow Complexity	0.135	46	40%													
1-year Complexity	0.128	52	20%													
Channel Aggradation FP Potential	0.279	15	40%	**Connectivity**	0.234	15	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.061	34	40%													
Total FP Potential	0.487	14	20%													
Existing Connected FP	0.513	47	0%													
Excess Transport Capacity	0.14	14	100%	**Excess Transport Capacity**	3.000	14	10% to 30%	2 of 4	3	20%						
Pool Frequency	4.75	52	100%	**Pool Frequency**	0.122	52	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Side Channel
- Reconnect Floodplain
- Long Term: Relocate Road

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 28.28
RIVER MILE END: 29.33
VALLEY MILE START: 25.06
VALLEY MILE END: 25.87

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Feet

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ANCHOR QEA

Project Area 23
Conceptual Adaptive Management and Restoration Opportunities

Project Area 26 Description

Project Area 26 begins at VM 21.11 and extends upstream to the Turner Road bridge at VM 23.90. The 2017 RM length is 2.99 miles. Field observations for PA 26 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

The channel through PA 26 contains sections of dynamic and complex channel networks as well as wide, plane-bed stretches with little complexity. In the upper portion of the project area, the river is confined to a single-thread, plane-bed channel against the valley wall by bank armoring and levees. The levee materials are typically composed of angular armor rock, as well as a rock/wood revetment just downstream of the Turner Road bridge. Three large vortex rock weirs mid-reach control the channel grade.

Downstream the active channel becomes wider and less confined, except for a short section where the channel contains multiple rock weirs and barbs that control the grade and planform. Within this portion of the channel, the 2011 assessment noted that there was a higher amount of temporary sediment storage in the form of islands and gravel bars, multiple-channel pathways, and active channel migration. This

Project Area 26
Looking downstream near the upper end of the 3-mile project area in July 2019. Note mobile gravel material forming the mid-channel bar.

Project Area 26 Reach Characteristics

VM Start (mi)	21.11
VM Length (mi)	2.79
Valley Slope	1.00%
RM Start (mi)	23.99
RM Length (mi)	2.99
Average Channel Slope	0.92%
Sinuosity	1.07
Connected FP (ac/VM)	18.61
Encroachment Removal (ac/VM)	1.02
Channel Aggradation (ac/VM)	5.20
Total FP Potential (ac/VM)	6.07
Encroaching Feature Length (ft)	14,586.28
Connected FP Rank	19

was confirmed by recent CHaMP and AEM surveys, which noted change in gravel movement and pool formation. Multiple rock placements and restoration features were also observed through this section. For approximately a half mile, the channel becomes wide and shallow where it is lined on either bank by a large levee. Multiple rock weirs and rock barbs control the grade throughout this section.

The channel is braided with many channel pathways and a high amount of sediment deposition. The river makes a tight bend around a resistant fine-grained deposit and is confined against the valley wall by a levee. Downstream, the main channel flows parallel to the valley wall but has a wide, aggrading active channel area. The 2011 assessment noted that moderate to high LWD was present in this section where wood was being recruited in the channel. Several deep alcove pools were present along the margins of the channel, as well as pools that had scoured out at fallen LWD and root masses of standing trees.

For a half mile the river is characterized as a highly dynamic, meandering, forced pool-riffle channel. The 2011 assessment noted that the channel had multiple secondary flow paths and side channels and contained many deep pools at LWD and along the outside of meander bends. Remnant alluvial fans and terraces, which are relatively resistant to erosion compared to the recent alluvium in the active channel, had created tight bends in the channel planform.

Instream habitat conditions in the main channel were generally good in the dynamic portions of the channel due to the presence of large recruited LWD, active channel migration, and the availability of side channels. Ample deep holding pools were present at LWD and along eroding bends. The riffles formed between the pools and sediment deposits in the lee provided good spawning areas. The alcoves and side channels are preferred habitat for juvenile fish, and field observations noted several juvenile fish using these areas.

The plane-bed and confined sections of the project area have limited complexity and, therefore, poor habitat quality. Deep pools were typically only present at rock weirs and fallen riprap boulders. The confined conditions of the channel likely result in high-velocity conditions during spring runoff and high flows that may scour redds and flush small fish downstream. These areas have very few off-channel areas for juvenile rearing and high-flow refuge. There was little LWD or other forms of cover noted during the 2011 assessment.

Restoration Actions and Geomorphic Changes

In 2011, restoration work in PA 26 included removing or breaching and setting back 8,305 feet of river levee, with the purpose of connecting about 120 acres of disconnected low floodplain. In 2013, 17 LWD structures were placed within the reach using 84 key pieces.

The purpose of removing and setting back river levees and berms in this project area was to increase river access to disconnected floodplain while protecting existing landowner infrastructure. LWD structures were intentionally delayed to observe river response following levee removal. In 2013, a limited number of engineered log jam structures were placed to encourage gravel deposition, pool formation, and floodplain connectivity.

Analysis of the difference between the 2010 and 2017 LiDAR data shows a relatively large amount of geomorphic change, with nine major locations highlighted in this assessment along with multiple minor locations. The levee removals conducted in 2011 are identified in boxes 1, 2, and 5. Geomorphic change behind these levee removals has been mixed. At the upstream end, the high-flow channel behind the short section of levee removal has experienced some scour and erosion, which could indicate that high flows are reaching this part of the floodplain and could cause more significant change (box 1). The next portion of levee removal has almost no change associated with it, although this does not mean high flows are not passing it, only that no significant erosional or depositional change has occurred (box 2). The third identified levee removal location is by far the longest and, interestingly, there appears to have been some floodplain deposition behind it, although this is unconfirmed by field observations, which would indicate that high flows do pass the levee. The area should be watched to ensure a natural high bank does not form in place of the levee (box 5). It should be noted that the setback levees put in place as part of the restoration work in this project area are easily visible in the LiDAR change analysis but are not included in this discussion.

In addition to the three locations of levee removal, several areas of natural geomorphic change were noted, as well as multiple others that are too small to describe here. Before the most downstream levee removal location a significant split flow has occurred, mid-channel, and appears to be the result of a log jam, with aggradation on the center bar and erosion to either side (box 3).

Just upstream of, and partially coinciding with, the major levee removal, a large channel avulsion has occurred towards the right bank, with aggradation seen in the former main channel and erosion on the right bank floodplain. The new channel appears to return to the old channel location just as the levee removal starts, and in the future this channel migration could be working its way into the area where the levee has been removed, which could provide additional floodplain connection (box 4).

Just downstream of the major levee removal, two former meander bends have been cut off, with the new channel location going straight between them. A large amount of sediment has been deposited in these former channels, which is visible on the 2018 aerial imagery. Despite this there appears to have been some meander migration at the downstream end before the channel cut off the meanders, and a side channel off the right bank of the most downstream meander appears to still be in place (box 6). Along the most downstream setback levee, the reach has experienced a large amount of floodplain deposition along the right bank; within this area there are several areas of channel avulsion with the channel initially moving left towards the valley wall. There also appears to be a new split flow and side channel forming seen in the aerial imagery. Google images show that the channel-spanning jam led to channel aggradation and then to floodplain deposition, which killed the alder trees on the floodplain. In 2017, the spanning jam failed and the channel cut back to its current configuration. This is a good example of what geomorphic change can occur on the Tucannon River, as well as how unstable alder LWD can be (box 7).

Immediately downstream of this area, a quarter-mile-long channel avulsion into the right bank floodplain has occurred likely as a result of several large log jams that appear to be a combination of engineered and natural recruits. Large amounts of sediment have been deposited in the abandoned channel and it appears to be mostly disconnected at low flows. Multiple split flows and side channels exist in the new main channel and there is a high degree of in-channel complexity. At the downstream end of this avulsion, a large erosional area is occurring on the right bank into the forest floodplain and could be the source of much of the wood in this reach. Immediately downstream of the erosional area, the channel has aggraded and there are signs of flow onto the surrounding floodplain. This is an excellent example of channel dynamics releasing sediment stored in the floodplain and causing downstream geomorphic change (box 8).

Finally, at the very downstream end of the project area, a large split flow and side channel has been pushed into the left bank floodplain, possibly by a log jam, and another split flow has occurred right at the project area boundary and extends into PA 27 (box 9).

The downstream half of PA 26 has had a large amount of geomorphic change and appears to be responding to the additional wood placement, as well as a supply of easily transportable material. In contrast, on the upstream end where levee removals have occurred, not much geomorphic change has occurred in the newly accessible floodplain. However, it appears that higher flow events have accessed these areas, but field observations suggest this has not happened in recent years.

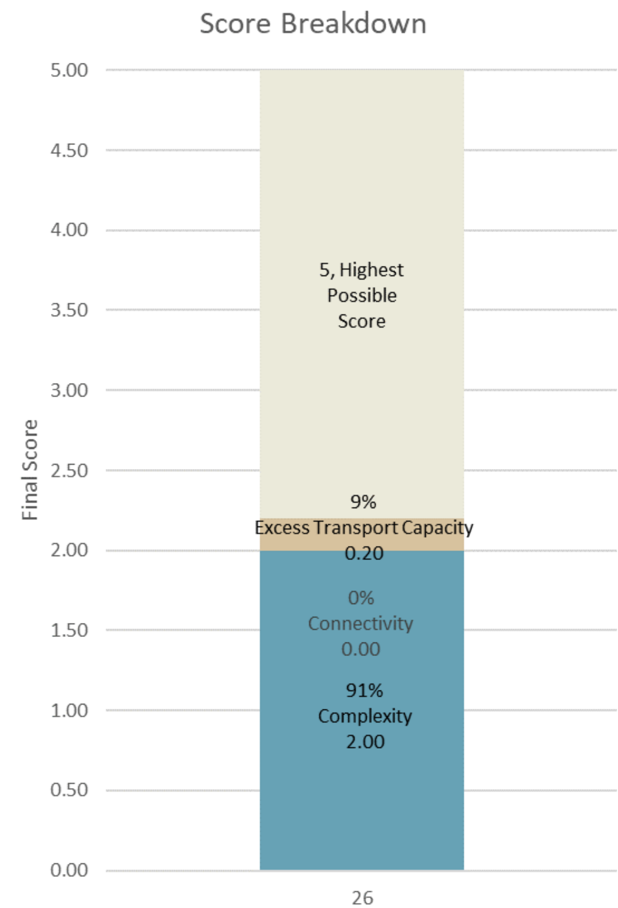
Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 26 received the highest possible scores in both the Connectivity and Complexity metrics, but a low score for the Excess Transport Capacity metric. PA 26 ranks near the average in the 40th to

60th percentile for Complexity, which is the range that has been identified as having the most potential for restoration focused on complexity. This score is reflected across all three flows of the complexity analysis results, ranking near the average across the assessment area for each flow. Both Encroachment Removal and Channel Aggradation analysis results rank PA 26 highly for floodplain connectivity potential, with a slightly higher rank in Encroachment Removal.

The levee removals have had moderate success in this project area, particularly the levee removed just upstream of VM 23, which appears to have connected most of the low-lying floodplain at the 2-year event. The levee removal at VM 22.5 appears to need some channel aggradation before the floodplain behind it can be accessed at the low-winter flow event, and the levee breach at the top of the project has not yet allowed flows behind it in order for that area to be connected. However, the primary potential for additional floodplain connection is a right bank low-lying area just downstream of the levee removal at VM 22.4. This low-lying area is behind a high right bank at the upstream end, that is too high for the 2-year flow to inundate, as well as a small levee at the downstream end. Management and enhancement strategies should include attempting to raise the channel bed in this area through upstream gravel augmentation, along with some strategic breaches or removal of the high right bank coinciding with existing wood structures, to promote geomorphic change in the areas were encroachments have

PA 26 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

been removed. There is some additional potential for connection of this floodplain area via high bank breaches or channel aggradation at the location of the 2011 levee removal at VM 22.4. Several other encroachments exist through the project area, and removing or breaching these may connect some floodplain at the 2-year event but will also serve to allow an increase in complexity in these areas.

Several pockets of high complexity are spread throughout the entire project area. However, there are also long stretches with little to no complexity such as at VM 22 and upstream of VM 23. Enhancement strategies should include adding instream structures to these long, straight reaches to help create bars and split flow to create more instream complexity. Several of these sections have floodplain channel opportunities that should be targeted with pilot channel cuts and strategic placement of large wood structures to promote geomorphic change. Gravel augmentation in this reach does not appear to be necessary because the complex pockets and locations of geomorphic change should be causing sufficient geomorphic change to release transportable material, as long as enough instream structure is available to store and trap sediment moving downstream.

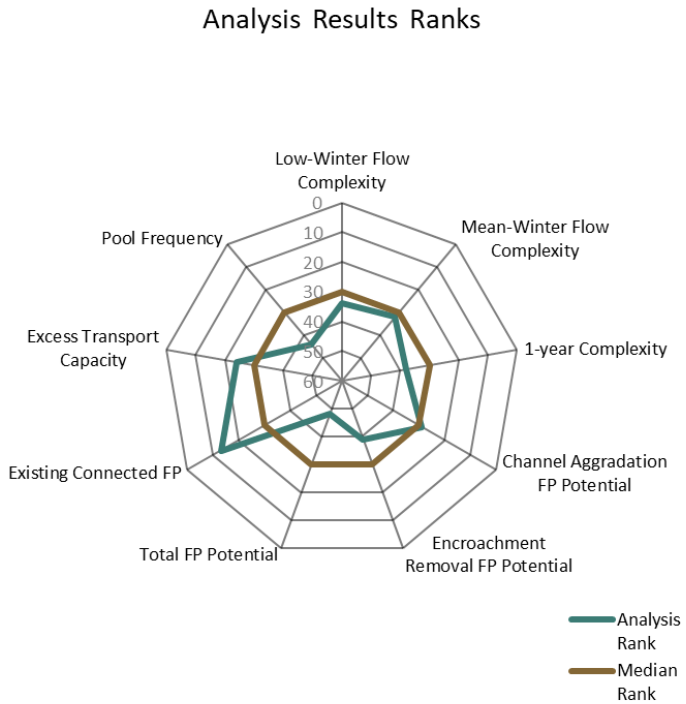
Some of the targeted floodplain area is currently vegetated with only riparian grasses and small shrubs, so riparian vegetation enhancement will be an additional necessary enhancement strategy in these areas.

Finally, the pool frequency in this reach appears to be well below average for the basin. More pools are likely to form as a result of the recent restoration actions. However, similar to complexity, should these changes not occur, gravel augmentation will allow for more frequent pool formation around any instream structure.

Summary of Restoration Opportunities Identified

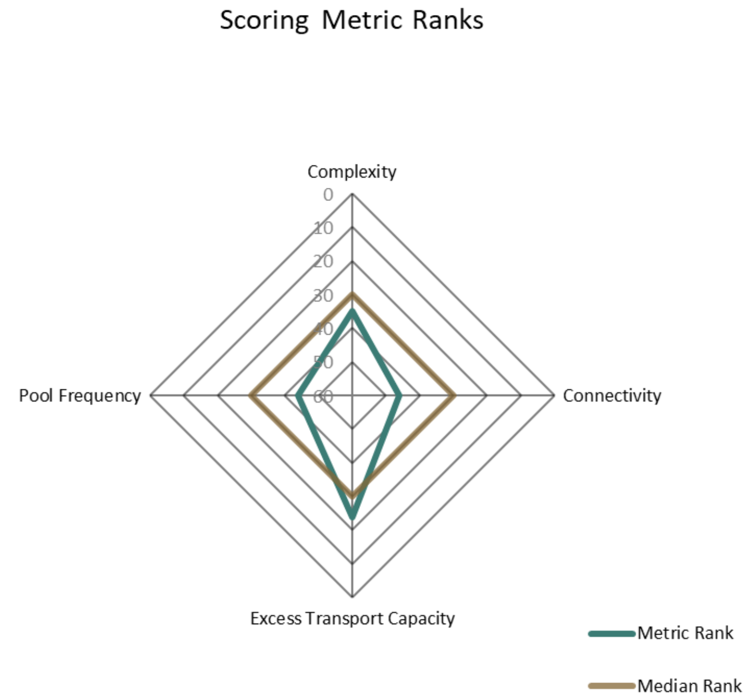
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 26 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

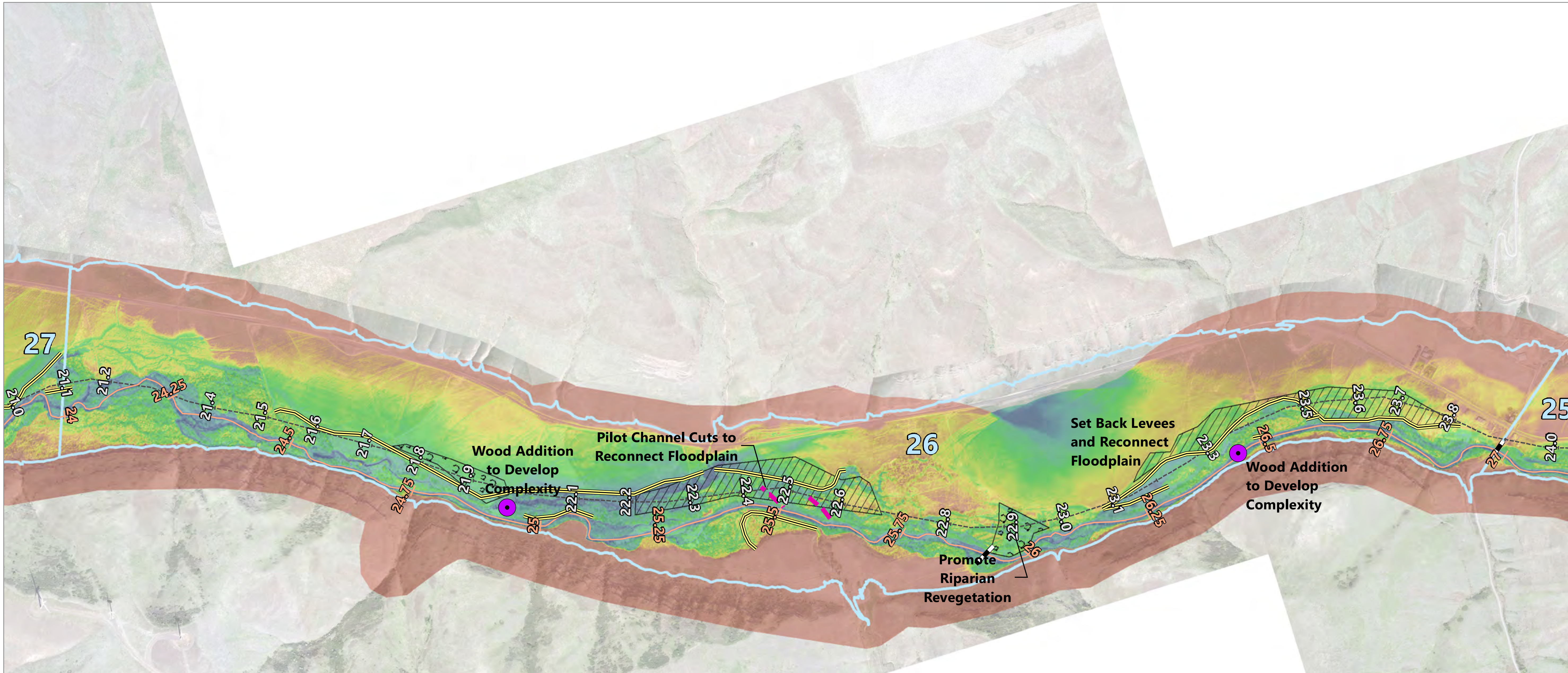
PA 26 Prioritization Scoring Summary



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 26 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.138	34	40%	Complexity	0.180	35	40% to 60%	3 of 5	5	40%	2.2	27	2	Treated	8	1
Mean-Winter Flow Complexity	0.204	32	40%													
1-year Complexity	0.215	38	20%													
Channel Aggradation FP Potential	0.211	29	40%	Connectivity	0.150	46	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.041	39	40%													
Total FP Potential	0.246	48	20%													
Existing Connected FP	0.754	13	0%													
Excess Transport Capacity	0.08	24	100%	Excess Transport Capacity	1.000	24	30% to 52%	3 of 4	1	20%						
Pool Frequency	6.70	44	100%	Pool Frequency	0.172	44	60% to 90%	4 of 5	1	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Side Channel
- Reconnect Floodplain
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 23.99
RIVER MILE END: 26.98
VALLEY MILE START: 21.11
VALLEY MILE END: 23.9

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Feet

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ANCHOR QEA

Project Area 26
Conceptual Adaptive Management and Restoration Opportunities

Project Area 40 Description

PA 40 begins at VM 3.16 and extends upstream to VM 3.68. The 2017 RM length is 0.57 mile. Field observations were conducted on October 10, 2018, when flow at the Starbuck gage was approximately 115 cfs. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

PA 40 is a short project area at only 0.57 mile long and can be largely characterized as one reach. Near the upstream end of the project area, the restoration work of the large levee removal and setback is evident, resulting in a split flow and the beginning of a meander bend. This levee was removed in 2015 as part of the PA 40 project to increase channel complexity and floodplain connectivity.

In the middle of the reach, the entire left bank is exposed to the nearby agricultural field and has only a few patches of trees at the upstream and downstream ends and in places is heavily riprapped. The right bank is the inside of a meander bend and is forested with alder stands and a few cottonwoods with heavy undergrowth. The levee remnants on the right bank are from a levee that was removed and set back as part of the restoration project in this reach, which connected several side channels. However, some of these side channels may have been blocked and several additional side channel opportunities exist in this area.

Project Area 40
Side channel opened up as part of PA 40 project, no flow was present at time of site walk but would be connected at a slightly high-flow stage.

Project Area 40 Reach Characteristics

VM Start (mi)	3.16
VM Length (mi)	0.52
Valley Slope	0.55%
RM Start (mi)	4.03
RM Length (mi)	0.57
Average Channel Slope	0.48%
Sinuosity	1.10
Connected FP (ac/VM)	30.61
Encroachment Removal (ac/VM)	4.76
Channel Aggradation (ac/VM)	16.06
Total FP Potential (ac/VM)	22.14
Encroaching Feature Length (ft)	4,686.38
Connected FP Rank	4

A high-flow channel splits off on the right bank in a location where the old levee has been breached. At the head of this channel is a large rootwad structure that has accumulated some debris and sediment that is partially blocking the side channel. While this channel was not flowing at the time of the site visit, it likely sees slightly higher flows than what were noted when the 2017 aerials were taken in April. This channel runs along another old levee on the right bank that separates it from another low spot in the floodplain before reaching the new, well-maintained levee that currently protects the field on the right bank. There is a large amount of in-channel wood, structures, and channel complexity when there is flow. This channel has been opened up to high flows, but more floodplain on the right bank is available for access.

Bed material through this reach is a mix of cobbles and boulders with little transportable material. It should be noted that just downstream of this project area, in the upper reach of PA 41, a large avulsion and debris jam has trapped large amounts of gravel material, and it is likely the material had simply been transported quickly through PA 40 to this area. PA 40 has very little instream wood or structure in the main channel, and placing this structure could serve to trap some of this gravel material and cause geomorphic change to the right bank floodplain.

Restoration Actions and Geomorphic Changes

In 2014, the main river in PA 40 between RM 4.5 and RM 4 was treated by removing 1,335 feet of confining gravel berms, reconnecting a disconnected flow path that was approximately 0.32 mile long to perennial flow, and placing 52 structures to maintain stability and provide complexity within the side channel. Although the river levees and gravel berms were removed, only one structure was placed within wetted channel to maintain a split flow into the reconnected side channel. The geomorphic goal was to increase side channel length and complexity as well as increase floodplain connectivity through levee and berm removal.

Analysis of the difference between the 2010 and 2017 LiDAR data shows only a few locations of geomorphic change in PA 40, which is a short reach. The most notable change is not natural geomorphic change, but the setback levee installed as part of the restoration project is easily recognizable, along with the apparent bar deposition at the downstream end on the right bank (box 1).

The right bank side channel that was reconnected during restoration has seen significant erosion in the channel, which indicates it is likely seeing a large portion of flow during higher flow events. There is also a depositional area in the floodplain surrounding the side channel part of the way down the channel that could be a result of high flows (box 2).

At the downstream end of the reach, there is a large depositional area in the left and right floodplains along with the beginnings of a channel avulsion that occurs in PA 41. While this change is driven by processes just downstream in PA 41, the aggradation and deposition in this reach could cause some backwater effect allowing more side channels and floodplain to be accessed (box 2).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 40 received the highest possible score for floodplain connectivity potential, indicating it is in the top 25% of all project areas. This project area also has a moderate score for the Complexity metric, indicating it falls in the 60th to 90th percentile of project areas. This is a range that still shows moderate complexity but does not place it in the top 10% of project areas; this project area likely only needs a little restoration work to reach that mark. PA 40 also received a moderate score for Excess Transport Capacity.

The potential indicated by the Connectivity metric for PA 40 exists entirely within the low-lying area of two agricultural fields that border the active floodplain terrace on the left and right bank floodplains. However, much of the available area on the right bank floodplain is behind the setback levee installed during the 2014 restoration effort and may not be desirable for additional connection. On the left bank, the low-lying

PA 40 Score Breakdown

This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

floodplain is behind a large levee, and a targeted enhancement strategy to activate this area should be to breach or remove this levee and install wood structure to promote geomorphic change into the floodplain. It should be noted that the left bank of the river is currently running along this levee and has almost no vegetation cover. Active erosion is happening here and the pivot is nearly undercut by the river at this point. Enhancing the riparian vegetation on the left bank should be a targeted enhancement strategy but will be especially necessary if the left bank floodplain is reconnected.

The opening to the side channel established during the last restoration effort was observed to be partially blocked during the 2018 site visit. To address the complexity in this project area, a management strategy should be to ensure that this side channel allows perennial flows. In addition, the island created by this side channel contains several low-winter flow paths easily visible in the relative elevation model. Some high banks may need to be removed to establish perennial connection. Reconnecting these side channels through pilot cuts and adding instream wood to push flow into these channels should be a targeted enhancement strategy. Finally, the main channel through PA 40 is plane-bed and uniform with very little in-channel structure. Regardless of other restoration enhancement strategies that may be pursued, adding instream structure and LWD should be the primary restoration enhancement strategy pursued in this project area.

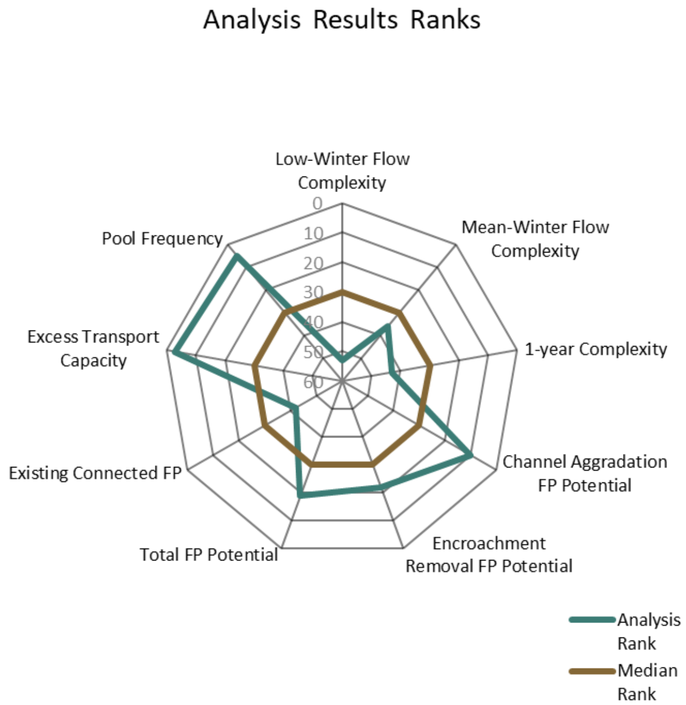
Gravel augmentation can be considered in this reach should the above enhancement strategies not have the desired effect in a timely manner. The addition of easily transportable material should allow geomorphic changes to occur more rapidly and effectively. However, it should be noted that because this area has such high excess transport capacity, a large amount of wood and instream structure should be added to maintain and store this sediment.

Finally, the Pool Frequency analysis result indicates that this project area ranks relatively high for number of pools per valley mile. The enhancement strategies of adding instream wood, connecting pilot channels, and gravel augmentation should assist in maintaining and increasing the number of pools in the reach in the future.

Summary of Restoration Opportunities Identified

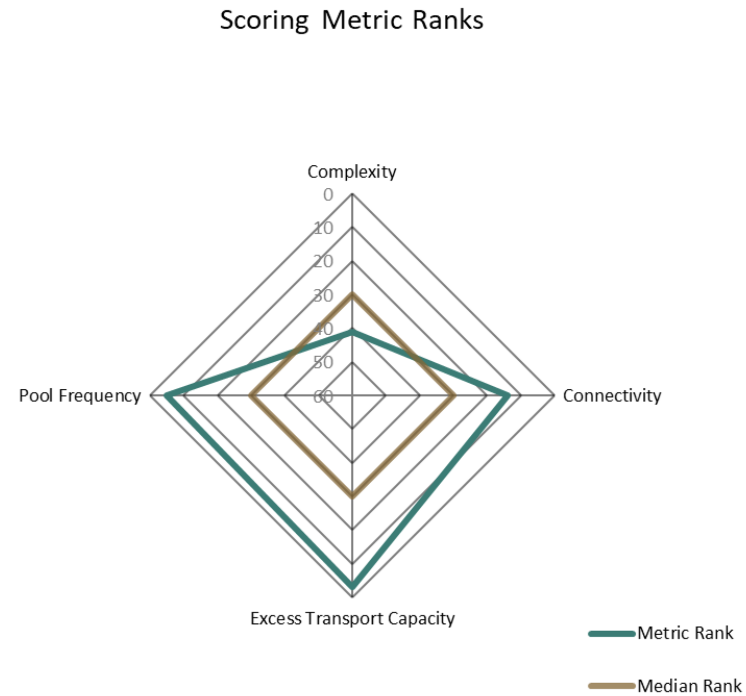
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 40 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

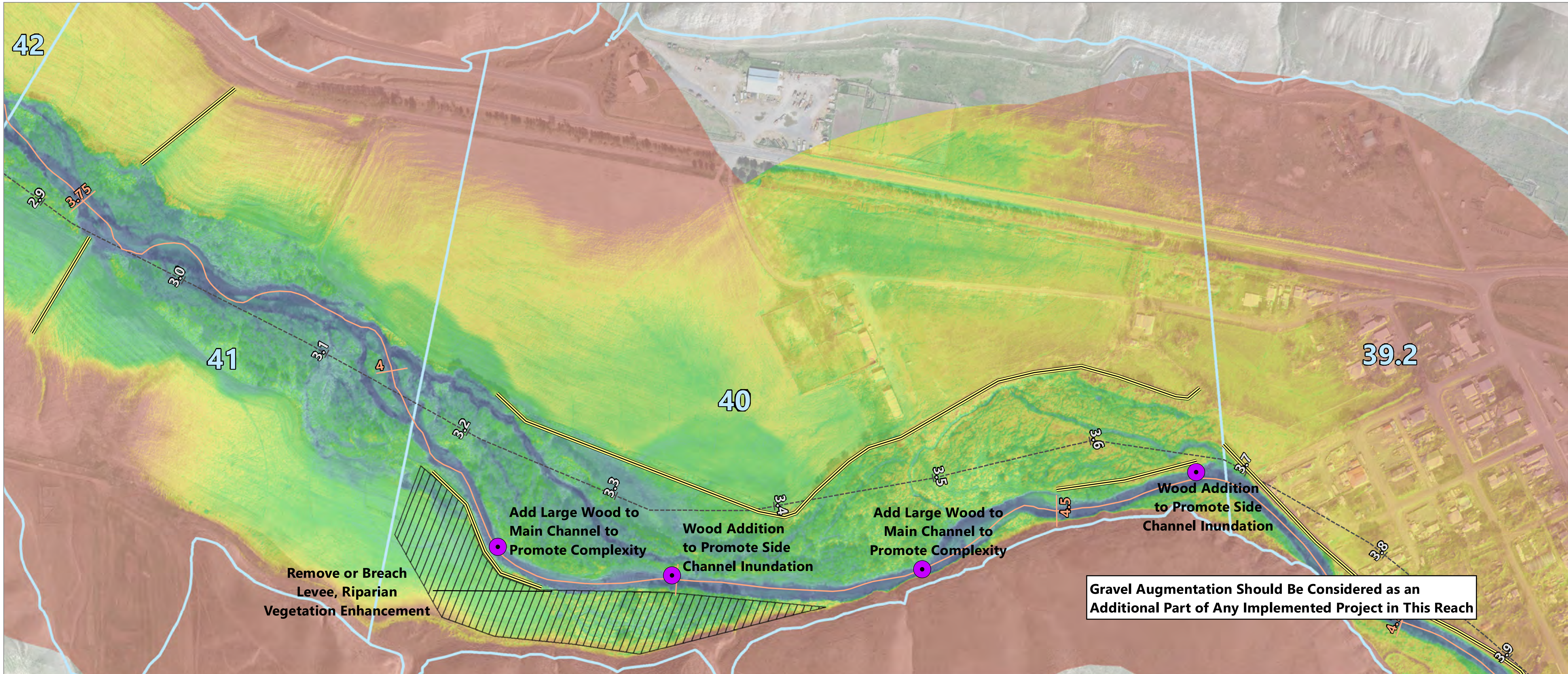
PA 40 Prioritization Scoring Summary

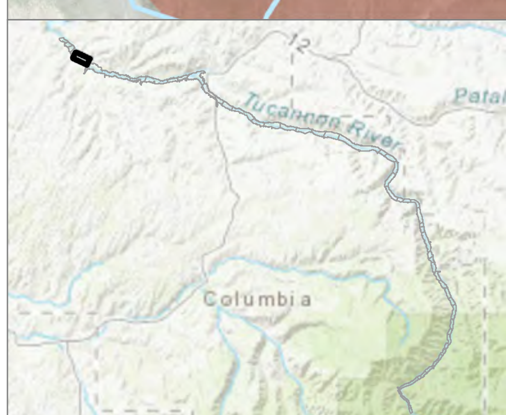


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 40 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.091	53	40%	Complexity	0.148	41	60% to 90%	4 of 5	1	40%	3.4	5	1	Treated	1	1
Mean-Winter Flow Complexity	0.181	36	40%													
1-year Complexity	0.195	43	20%													
Channel Aggradation FP Potential	0.304	10	40%	Connectivity	0.242	14	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.090	22	40%													
Total FP Potential	0.420	19	20%													
Existing Connected FP	0.580	42	0%													
Excess Transport Capacity	0.31	3	100%	Excess Transport Capacity	5.000	3	1% to 10%	1 of 4	5	20%						
Pool Frequency	28.71	5	100%	Pool Frequency	0.737	5	1% to 10%	1 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Floodplain

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 4.03
RIVER MILE END: 4.61
VALLEY MILE START: 3.16
VALLEY MILE END: 3.68

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Feet

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ANCHOR QEA

Project Area 40
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

APPENDIX J.1
TIER 2: TREATED PROJECT AREAS

Project Area 8 Description

Project Area 8 begins at VM 39.33 and extends upstream to VM 39.74. The 2017 RM length is 0.45 mile. Field observations for PA 8 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

Throughout the project area, the single-thread channel is typically wide, shallow, and plane-bed. A few local high-velocity areas occur along the toe of the bedrock valley wall. Levees are present along much of the left bank, confining the active channel and low floodplain to the far side of the valley. No side channels or secondary flow paths were identified. A large engineered log jam is present on the right bank and provides some cover and pool habitat. The channel contains little other LWD except small, transient material. Although juvenile fish may use the shallow margins of the channel, the lack of cover, complexity, and pools results in generally poor habitat conditions throughout this section of the river.

Floodplain connectivity in this project area is poor due the incised condition of the channel and the presence of infrastructure that confines and disconnects the channel from a majority of the low-lying floodplain. A narrow corridor of low floodplain is present from approximately the upstream end of

Project Area 8
Large engineered log jams interacting with flow at the upstream end of PA 8.

Project Area 8 Reach Characteristics

VM Start (mi)	39.33
VM Length (mi)	0.41
Valley Slope	1.30%
RM Start (mi)	44.45
RM Length (mi)	0.45
Average Channel Slope	1.08%
Sinuosity	1.09
Connected FP (ac/VM)	13.23
Encroachment Removal (ac/VM)	0.53
Channel Aggradation (ac/VM)	4.01
Total FP Potential (ac/VM)	5.72
Encroaching Feature Length (ft)	2,926.19
Connected FP Rank	34

the project area to the Curl Lake outfall, but it is cut off from the channel by levees. A groundwater spring located near VM 39.41 appears to originate west of Tucannon Road, where several wetland plants were observed but no flowing water. East of the road, the spring becomes a surface water channel, eventually flowing into a wetland. The channel is lined with ferns, sedges, and rushes that provide good shading and cover. The spring flows into a portion of the disconnected low floodplain, consisting of a muddy to ponded wetland area vegetated with rushes, sedges, ferns, and cattails. Several dead or dying trees are present in this area. The spring channel has a poor downstream connection with the river and no fish were observed in the channel.

Adjacent to Curl Lake, another disconnected floodplain area is present that is fed by seepage through the lake berm. The water accumulates into a small side channel and meets the river, providing a minor amount of off-channel habitat. Downstream of Curl Lake, a ponded wetland dominated by cattails and grasses makes up a majority of the floodplain. Trees and other cover or shading is sparse.

In general, the riparian zone is in a moderately healthy condition, but conditions adjacent to the main channel provide little cover or shading. Few mature riparian trees are present along the channel margins.

Restoration Actions and Geomorphic Changes

In 2017, restoration work in PA 8 included placing LWD in the downstream 1,200 feet of PA 7 and all of PA 8. Treatment actions involved the placement of 26 LWD structures within approximately 0.55 stream miles using 153 key pieces of LWD. This action increased LWD volumes from 1.4 key pieces per bankfull width to 3.6 key pieces.

LWD structures were placed to capture approximately 0.3 mile of new side channel. Objectives for the project included increasing channel complexity to increase pool frequency and increasing side channel complexity and floodplain connectivity.

Analysis of the difference between the 2010 and 2017 LiDAR data shows that even though these restoration actions took place shortly before the LiDAR data for this reach were collected, several of the targeted responses have occurred. Just downstream of Curl Lake, a mid-channel log jam has triggered a split flow and bar, although it is unclear if the bar-forming material is natural deposition or was placed as part of the restoration actions (box 1).

A large log jam has caused a split flow towards the left bank, where bank erosion has occurred as the channel pushes into the left bank floodplain. Before the side channel confluence, a mid-channel bar has formed with noticeable deposition. Just downstream of the confluence, a channel-spanning log jam has promoted substantial erosion on the right bank and deposition on the left (box 2).

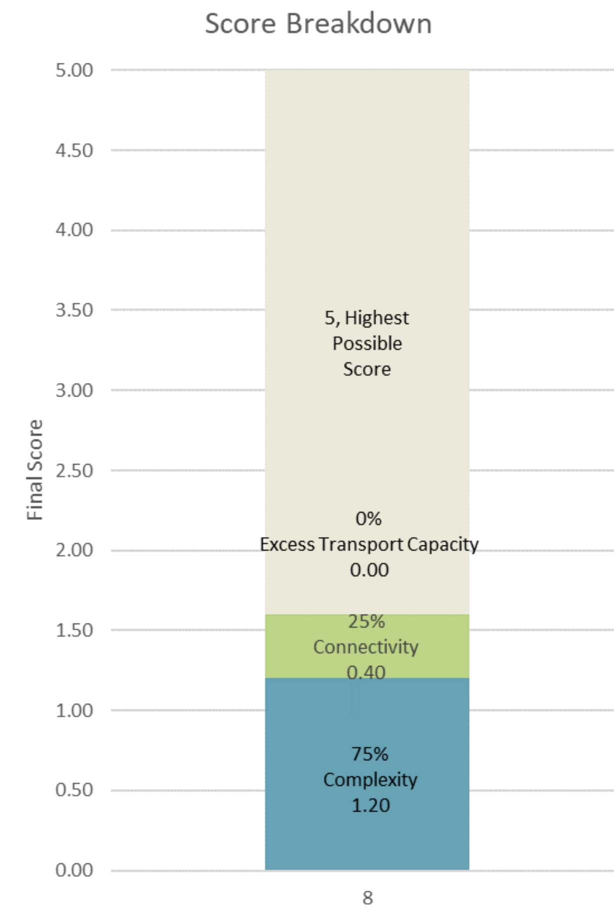
Finally, just before the downstream boundary of the reach, deposition has occurred in the left bank floodplain where there appears to be a side channel that starts upstream near box 2. This deposition area continues into PA 9, and appears to have pushed a side channel into the right bank floodplain (box 3).

It should be noted that, while many large log jams evident from the 2018 aerial imagery were placed throughout the project area, no significant geomorphic change has occurred in the reach above or coincident with Curl Lake within this project area. This reach is highly confined by the left bank levee for Curl Lake and the right bank valley wall, and is downstream of the diversion structure for Curl Lake. It is possible this reach has geomorphically resistant bed material, although gravel material was reportedly placed as part of restoration actions in the area in an effort to increase spawning area.

Geomorphic Characteristics and Management and Enhancement Strategies

The management and enhancement opportunities identified here are based on the 2018 LiDAR and aerial data. However, it should be noted that the restoration actions in this reach occurred shortly before the data were collected and geomorphic response may not have occurred yet and may not yet be reflected in the prioritization score.

PA 8 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

As shown in the following graphs and table, the Complexity metric makes up the majority of the score for PA 8, placing this project area in the 60th to 90th percentile for complexity. This range still shows moderate complexity but does not place it in the top 10% of project areas; this project area may only need some minor additional restoration work to reach that mark.

This good complexity is spread out across the analyzed flow regime, ranking highest in low-winter and mean-winter flows, with a slightly lower ranking in complexity for the 1-year flow. Complexity across all three flows is driven by several split flows and side channels downstream of Curl Lake. Upstream and coincident with Curl Lake, only a minor split flow at the low-winter flow adds complexity to the reach. Because restoration actions have already added a large amount of wood to this reach, more time may be required to see significant geomorphic change. However, should geomorphic changes not begin to happen, a gravel augmentation plan should be considered as a primary enhancement strategy. More transportable material will allow geomorphic changes to form at regular flow events, forcing in-channel and floodplain complexity.

The Connectivity score, while overall relatively low, is almost entirely driven by the Channel Aggradation Potential analysis result. Based on this and the connectivity GIS layers, most of this potential immediately surrounds the active channel and existing 2-year floodplain. A restoration strategy of gravel augmentation should help raise the average channel bed elevation through this reach and allow 2-year flood events to access more of the floodplain.

Because a large amount of wood has already been added to this reach, and floodplain potential is available via channel aggradation, gravel augmentation should be considered as a primary enhancement strategy. The reach has a low Excess Transport Capacity score, indicating that gravel material added here is likely to be retained with little additional wood added.

The pool frequency in this reach appears to be around average for the basin. More pools are likely to form as a result of the recent restoration actions. However, similar to complexity, should these changes not occur, gravel augmentation will allow for more frequent pool formation around any instream structure.

Modification of Big Four lake is another potential long-term opportunity in PA 8 and PA 9. A lot of the right floodplain area on the lower end of PA 8 is blocked by a riprap levee and diversion structure to the impoundment. Long-term restoration should target removal of this diversion structure to reconnect the floodplain.

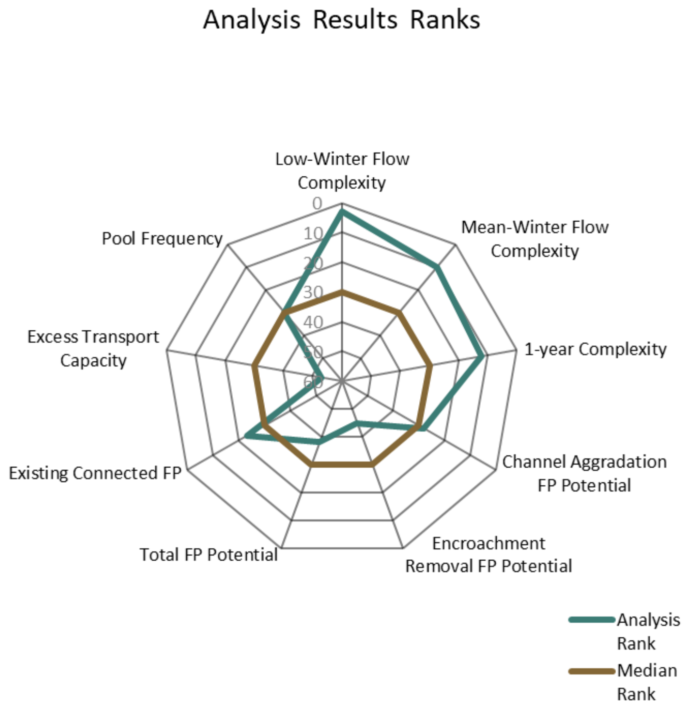
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats

Long-Term Opportunities in this Project Area

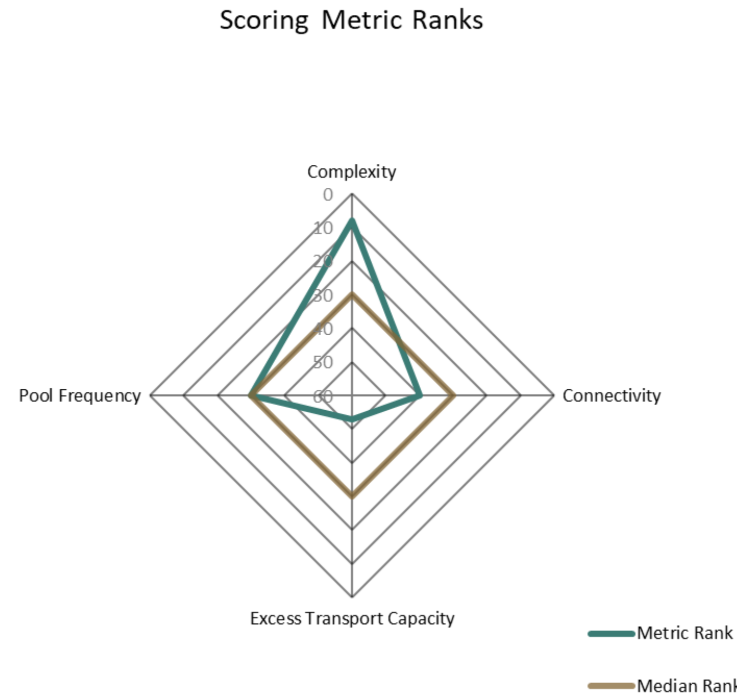
- Remove or reconfigure Big Four Lake diversion structure and levee.
- Reconfigure Curl Lake to reconnect floodplain and consider decommissioning and removing if ever feasible.

PA 8 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

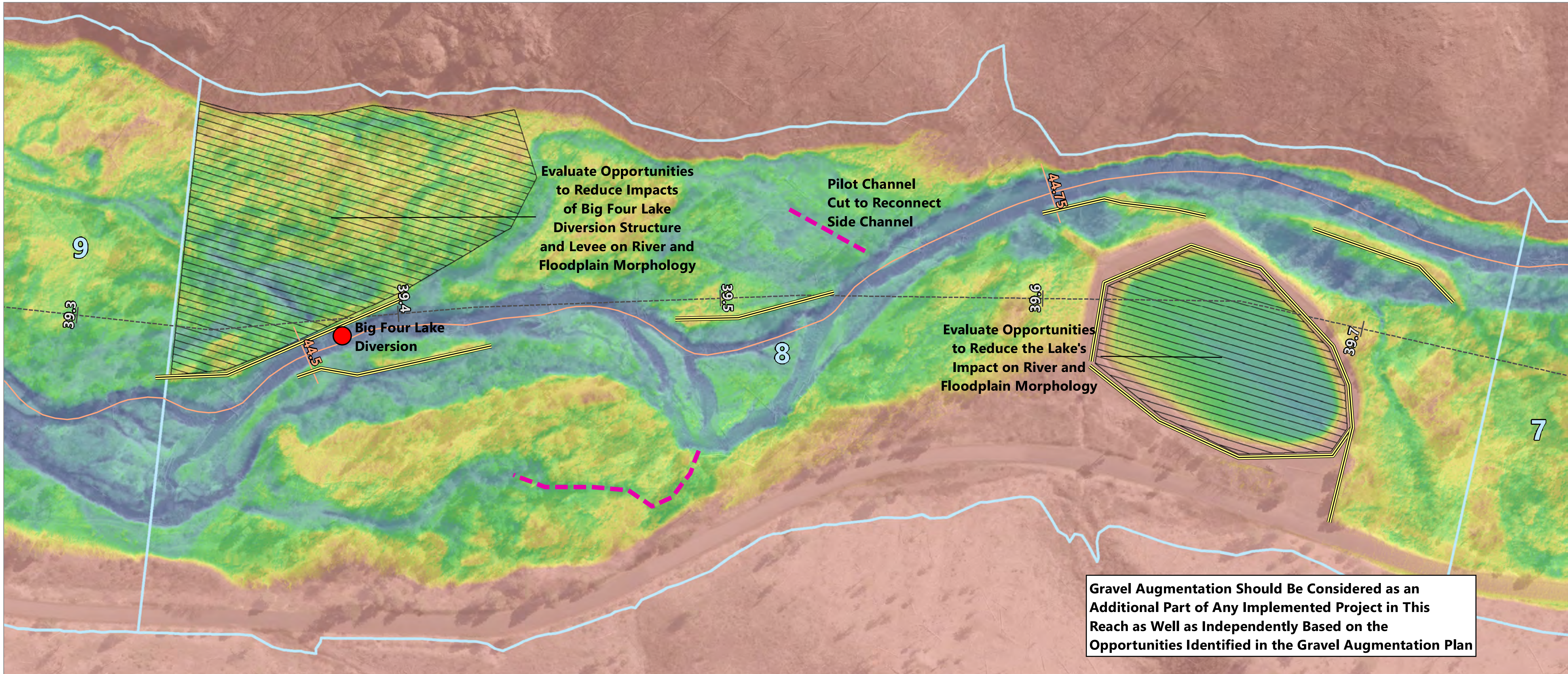
PA 8 Scoring Metric Ranks

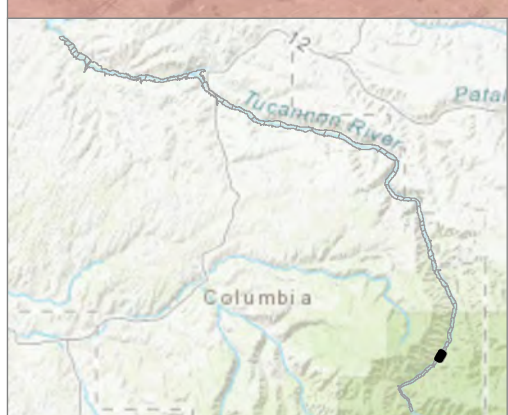


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 8 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.376	3	40%	Complexity	0.424	8	10% to 40%	2 of 5	3	40%	1.6	37	2	Treated	14	2
Mean-Winter Flow Complexity	0.433	10	40%													
1-year Complexity	0.501	12	20%													
Channel Aggradation FP Potential	0.212	28	40%	Connectivity	0.156	40	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.028	45	40%													
Total FP Potential	0.302	38	20%													
Existing Connected FP	0.698	23	0%													
Excess Transport Capacity	-0.17	53	100%	Excess Transport Capacity	0.000	53	52% to 100%	4 of 4	0	20%						
Pool Frequency	11.10	30	100%	Pool Frequency	0.285	30	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Reconnect Side Channel
- Reconnect Floodplain
- Current Infrastructure in River Corridor

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 44.45
RIVER MILE END: 44.9
VALLEY MILE START: 39.33
VALLEY MILE END: 39.74

0 500
Feet

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ANCHOR QEA

Project Area 8
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 10.3 Description

Project Area 10.3 begins at VM 37.51 and extends upstream to VM 37.89. The 2017 RM length is 0.41 mile. Field observations for PA 10.3 were conducted on September 28, 2018, when flow at the Starbuck gage was approximately 80 cfs.

The defining characteristic of PA 10.3 is the nearly half-mile-long side channel on the right bank floodplain. This side channel starts at the top of the reach and returns at the bottom of the reach, with a maximum distance from the main channel of 500 feet. At the start of the reach, a massive channel-spanning log jam, which appears to be engineered with multiple additional log recruits, serves to backwater the channel and direct water into the side channel.

At the time of the site visit, the side channel was not flowing, although evidence of recent flow was abundant with several pools still holding small fish. It is likely that this side channel flows the majority of the year. The side channel has multiple large engineered structures with a mix of bank and apex structures. Large pools have formed on the sides of many of these structures, and it is evident that this side channel receives a large portion of the flow at higher flows. Bed material through the side channel is mostly gravel and fine sands with occasional cobbles and boulders mixed in.

In the main channel downstream of the large channel-spanning log jam, the channel becomes more plane-bed and uniform.

Project Area 10.3
Floodplain structure near the upstream end of the long side channel that was reconnected as part of restoration work in PA 10.3.

Project Area 10.3 Reach Characteristics

VM Start (mi)	37.51
VM Length (mi)	0.38
Valley Slope	1.70%
RM Start (mi)	42.45
RM Length (mi)	0.41
Average Channel Slope	1.53%
Sinuosity	1.09
Connected FP (ac/VM)	16.62
Encroachment Removal (ac/VM)	0.27
Channel Aggradation (ac/VM)	5.23
Total FP Potential (ac/VM)	6.14
Encroaching Feature Length (ft)	0.00
Connected FP Rank	21

There is much less instream wood in the main channel compared to the side channel. An apex log jam near VM 37.72 splits the flow for about 200 feet and is the most complex feature on the mainstem. Bed material in the main channel is a mix of cobbles and boulders with some amount of transportable gravel material mixed in, and may be resistant to geomorphic change.

This project area was heavily affected by the 2005 School Fire, and mature riparian vegetation through this reach is extremely sparse. A few coniferous species make up the majority of large vegetation, but dense stands of young to middle-aged alders, dogwoods, and cottonwoods populate much of the immediate riparian area and the island formed by the long side channel. Based on the floodplain characteristics described in the previous report (Anchor QEA 2011), it is likely the vegetation in this reach is in the process of recovering.

Restoration Actions and Geomorphic Changes

In 2012, restoration work in PA 10.3 included placing a total of 14 LWD structures in the channel, with the three structures at the downstream end being catcher mitt configuration. The furthest upstream structure was designed to be a porous channel plug, which would allow bed load over it during high flow to allow gravel to accumulate in the downstream incised channel. The channel plug aimed to reconnect approximately 0.42 mile of side channel. The three segments of this project focused on more than 5,000 feet of side channel and approximately 5.8 acres of floodplain.

Analysis of the difference between the 2010 and 2017 LiDAR data shows several major changes as a direct result of the restoration actions. The side channel targeted by the restoration actions in this reach begins at the upstream end and runs for the majority of PA 10.3. This porous channel plug log jam shows up in the 2018 aerial imagery, and there appears to be channel aggradation and deposition in this area, which would be expected even despite the porous design. The side channel shows some minor erosion and downcutting at the head of the channel in this area as well (box 1). This side channel shows almost no other geomorphic change besides some sediment deposition at log jams at the very downstream end of the side channel (box 4).

In the main channel, some wood structures are visible and have minor geomorphic change associated with them. The most significant of these occurs mid-reach and has a small area of sediment deposition behind it (box 3).

Finally, at the confluence with the side channel, a split flow has formed and a large area of sediment deposition is forming an island around the log jam located there. Some additional minor erosion has occurred at the outside of the bend on the left bank behind a bank barb style jam (box 4).

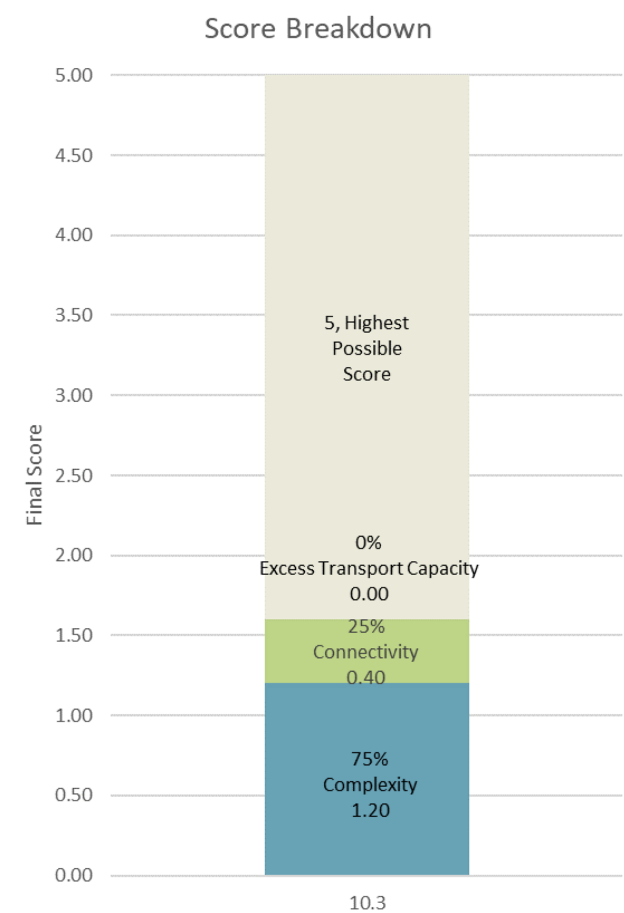
Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, Complexity makes up most of the score for PA 10.3, placing this project area in the top 25% of project areas. PA 10.3 scores 0.4 in the Connectivity metric, which makes up 25% of its total score. Excess Transport Capacity for this project area scores 0 and therefore does not receive prioritization points either.

The Connectivity potential metric in this reach is driven almost entirely by the Encroachment Removal Potential ranking near the top in this analysis result and the Channel Aggradation Potential ranking near the bottom. A large disconnected floodplain area on the right bank floodplain at the top of the reach drives this high ranking. This area is connected at the downstream end to the main side channel in this project area, and likely receives some backwater during the 2-year flow event but appears to be disconnected at the upstream end. The primary enhancement strategy should be to reconnect this area by adding instream wood and cutting pilot channels or removing the high right bank in general. Field observations also indicate more floodplain may be available on the left bank. Flow paths there remain wet into the summer some years and may originate in PA 10.2. Identifying and reconnecting these channels should be target of restoration.

The project area already ranks higher than average in the Pool Frequency metric and this is not a primary enhancement target.

PA 10.3 Score Breakdown



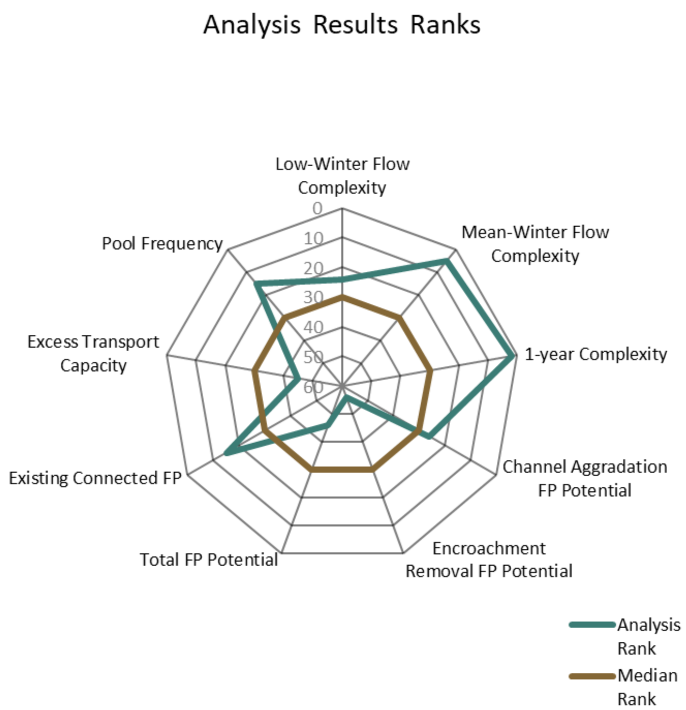
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

However, adding more instream structure and wood will help to maintain and increase the frequency of pools in the reach.

Summary of Restoration Opportunities Identified

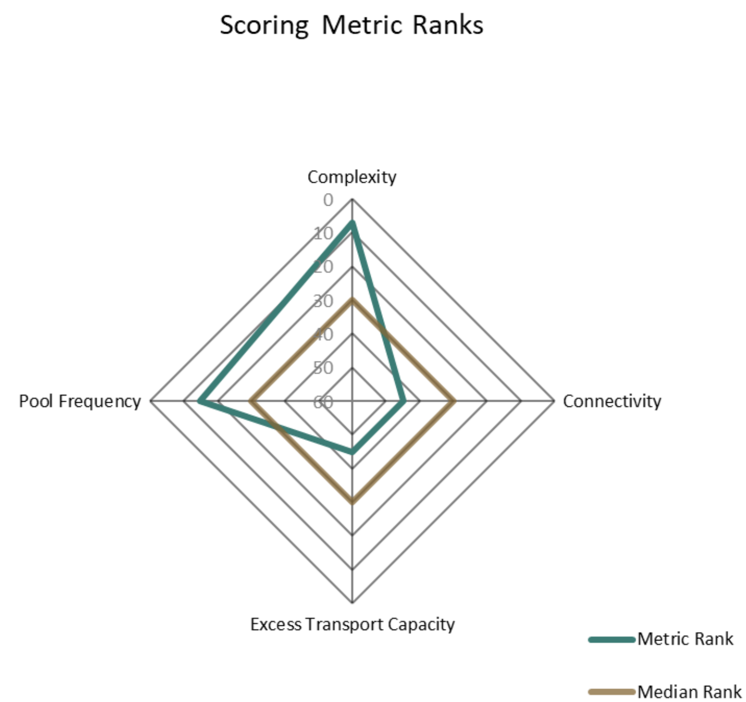
- Reconnect side channels and disconnected habitats
- Gravel augmentation
- Add instream structure (LWD)

PA 10.3 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

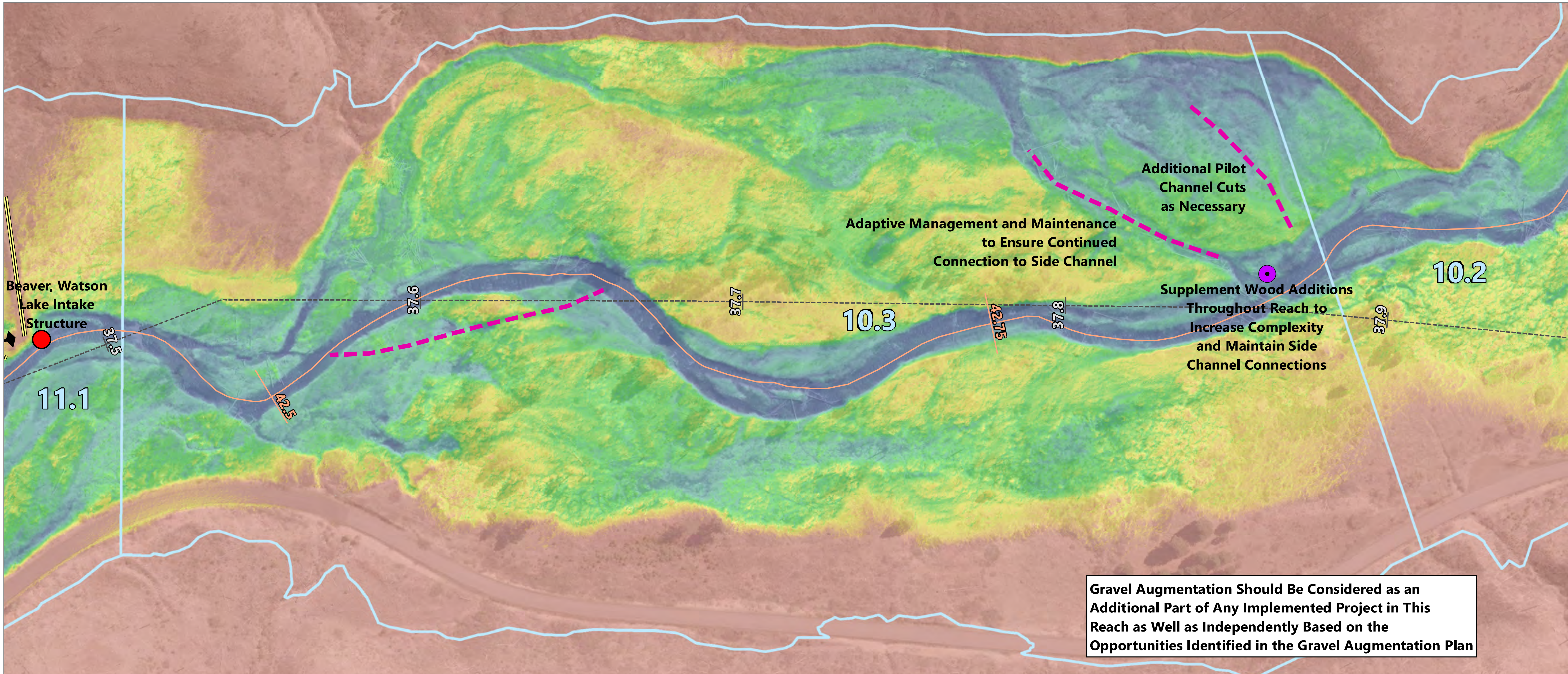
PA 10.3 Scoring Metric Ranks

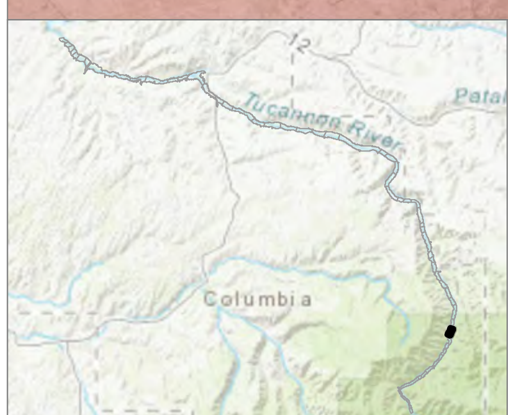


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 10.3 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.199	24	40%	**Complexity**	0.459	7	10% to 40%	2 of 5	3	40%	1.6	38	2	Treated	15	2
Mean-Winter Flow Complexity	0.518	5	40%													
1-year Complexity	0.863	2	20%													
Channel Aggradation FP Potential	0.230	26	40%	**Connectivity**	0.151	45	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.012	56	40%													
Total FP Potential	0.270	46	20%													
Existing Connected FP	0.730	15	0%													
Excess Transport Capacity	-0.11	45	100%	**Excess Transport Capacity**	0.000	45	52% to 100%	4 of 4	0	20%						
Pool Frequency	16.87	15	100%	**Pool Frequency**	0.433	15	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Side Channel
- Long Term: Relocate Road
- Current Infrastructure in River Corridor

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 42.45
RIVER MILE END: 42.86
VALLEY MILE START: 37.51
VALLEY MILE END: 37.89

0 500
Feet

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ANCHOR QEA

Project Area 10.3

Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 14.1 Description

PA 14.1 begins at VM 34.26 and extends upstream to the Rainbow Lake Road bridge at VM 34.81. The 2017 RM length is 0.61 mile. Field observations for PA 14.1 were conducted on September 27, 2018, when flow at the Starbuck gage was approximately 82 cfs.

For this assessment update, PA 14 as defined in the 2011 prioritization was separated into three project areas (PA 14.1, PA 14.2, and PA 14.3). In 2014, the upper sections of this project area (PA 14.1 and PA 14.2) were the subject of a restoration project, while PA 14.3 has remained untreated. PA 14.1 and PA 14.2 represent distinct parts of the restoration project and were therefore separated for distinct analysis.

At the time of the site visit, the first engineered log jam at VM 34.71 had split flow as was designed, but accumulated woody material prevented any significant flow on one side. The side channel at VM 34.68 carries perennial flow. However, at VM 34.65, a side channel that was intended to be inundated for most of the year was completely dry and did not appear to be inundated during yearly flow events. A log jam on the right bank just downstream from this side channel opportunity was noted to be disengaged from the channel at this flow level but was close enough that it would likely be engaged during higher flow events.

Project Area 14.1
Looking downstream at an apex engineered log jam, a small amount of flow is present on the right side of the structure but has been partially blocked by woody material.

Project Area 14.1 Reach Characteristics

VM Start (mi)	34.26
VM Length (mi)	0.56
Valley Slope	1.35%
RM Start (mi)	38.71
RM Length (mi)	0.61
Average Channel Slope	1.23%
Sinuosity	1.10
Connected FP (ac/VM)	12.77
Encroachment Removal (ac/VM)	0.46
Channel Aggradation (ac/VM)	3.31
Total FP Potential (ac/VM)	5.15
Encroaching Feature Length (ft)	1,021.04
Connected FP Rank	38

Further downstream, a long, uniform section stretches for approximately 400 feet before the next major log jam. This section also includes a protected right bank for hatchery infrastructure. The bed material through the reach is relatively large with only small amounts of easily transportable gravel material, which may explain the lack of geomorphic pools around some of these log jams.

The next major log jam at VM 34.56 had several large pieces of woody material, and the channel had aggraded on the left side, disconnecting it at this flow. However, groundwater still seeped through to the alcove on the bank side of the log jam. The next log jam just downstream was splitting flow as designed at the time of the site visit, although reports indicate that this channel does disconnect at low flows. A 2019 rapid habitat survey indicates that this channel had reduced to subsurface flow. This may be due to the fact that the log jam has deteriorated from design conditions and is not adequately splitting flow.

For the next tenth of a mile, the channel goes through another uniform stretch to the next set of large log jams near where the hatchery return flow joins with the river at VM 34.46. The large channel-spanning log jam just downstream is providing good complex flow with the rootwads providing cover, but pool depths were not as deep as would be expected with this kind of structure.

PA 14.1 ends near where the parking lot for Blue Lake is located in the left bank floodplain. The channel goes through a major horseshoe bend into PA 14.2 where cut-off side channels might be expected on the right bank. These channels appear to be slowly eroding with higher flows but do not currently convey flow. The structure on the left bank here was noted to be disengaged from flow at the time of the site visit. Also, on the left bank is the location where the upstream side channels should be returning to the main flow; this area was low, wet, and swampy, indicating some groundwater flow or possibly seepage from Blue Lake across the road. Estimates are that 0.5 cfs of flow comes from Blue Lake and 2 to 3 cfs from the upstream side channel.

Floodplain vegetation in this reach is a good mix of conifers and deciduous species with many large ponderosas in the riparian area. Some canary grass was noted in this reach, particularly around the hatchery return flow, and there are several stretches with no good riparian cover.

Bed material in the channel consists of mostly large cobbles and boulders in this reach. This may be due in part to the reach’s location just downstream of the dam on PA 13, which likely is a sediment transport barrier.

Restoration Actions and Geomorphic Changes

In 2014, restoration work in PA 14.1 included placing 51 LWD structures within the reach using 396 key log pieces. About

2,709 feet of perennial and 1,272 feet of ephemeral side channels were reconnected through pilot cuts and LWD was placed in the main channel to redirect flow. The goal for this reach was to increase channel complexity and floodplain connectivity at a 2-year level and less.

Analysis of the difference between the 2010 and 2017 LiDAR data shows four areas of significant geomorphic change in PA 14.1. At the upstream end of the project area, a large apex engineered log jam has caused a small amount of erosion into the left bank, along with some wood accumulation at the front of the structure (box 1).

Downstream, another large apex engineered log jam has caused some bar building and sediment deposition on the left bank and some minor erosion on the right bank. The sediment deposition on the right bank appears to be blocking a flow path towards one of the targeted pilot cuts, which was not flowing during field observations (box 2).

Further downstream is the area with the most significant geomorphic change in this reach: engineered log jams on the left bank have triggered significant erosion on the right bank. Just downstream of this area is a split flow around a large log jam that comes together again at a large, channel-spanning log jam. The area between the erosion and channel-spanning log jam has seen some aggradation, especially in the former main channel, which likely is a driving factor behind the split flow in this location. This area is a good example of channel dynamics releasing sediment stored in the floodplain and forcing downstream geomorphic change and complexity. Much of the rest of the reach is likely starved of transportable matter, because only this log jam has caused significant change when some transportable material is available (box 3).

Finally, an apex engineered log jam has caused a split flow along with a small area of erosion on the left bank near the downstream end of the project area. This is the type of log jam and location where more geomorphic change would be expected (box 4). In general, PA 14.1 has seen very little geomorphic change for the amount of wood structure installed, and pilot side channels have not been eroded further into the floodplain as expected. It was noted during field observations that sediment sizes in this reach are too large to be easily transportable; the geomorphic change analysis supports the idea that more change would occur with a supply of transportable material.

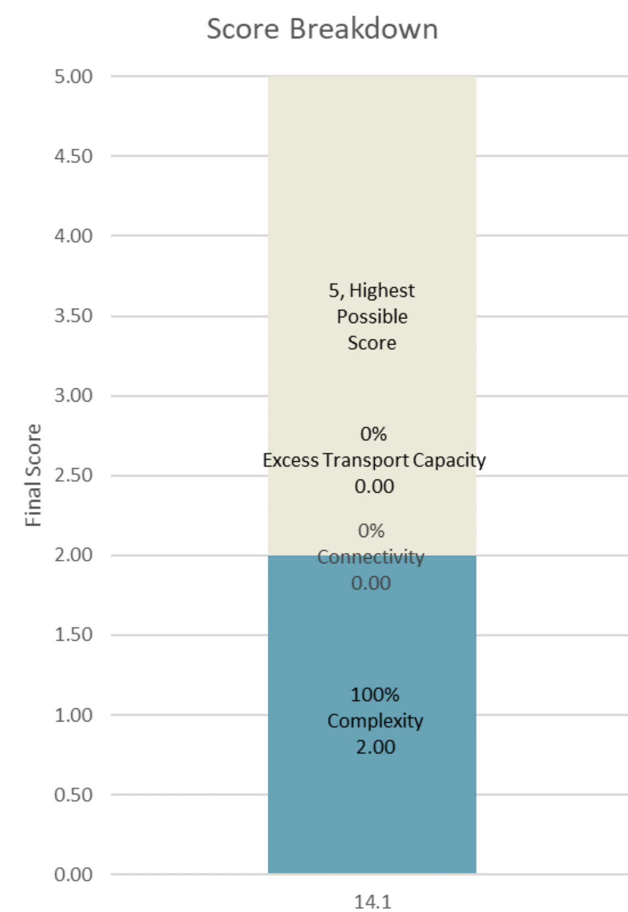
Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 14.1 received the highest possible scores in the Complexity metric, but scored 0 for the Excess Transport Capacity metric. PA 14.1 ranks in the 40th to 60th percentile for Complexity, which is the range in which reaches have the most potential for improving complexity. This score is reflected across all three flows of the complexity analysis results, ranking near the average across the assessment area for each flow.

Complexity in this reach is entirely driven by the in-channel bars and split flows formed by the apex and channel-spanning log jams in this reach. While this type of complexity does provide some habitat benefit, the more ideal situation would be for these log jams to promote geomorphic change in the floodplain, causing longer side channels, floodplain flow, and recruiting additional wood. This should be the primary goal for enhancing the complexity of restoration features in this reach. Since the lack of transportable material is likely the primary reason why these changes are not occurring, gravel augmentation in this reach should be a high priority for restoration management and enhancement. Wood structures could be added to help gravel augmentation by providing additional sediment storage.

Finally, PA 14.1 ranks very low among project areas in the Pool Frequency metric. Adding instream wood and gravel augmentation will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target increasing pool frequency in the reach.

PA 14.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

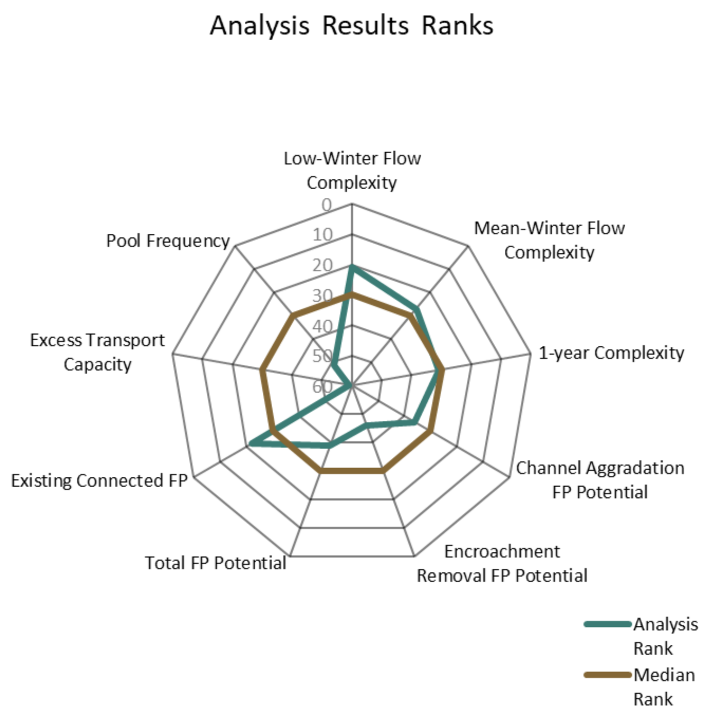
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

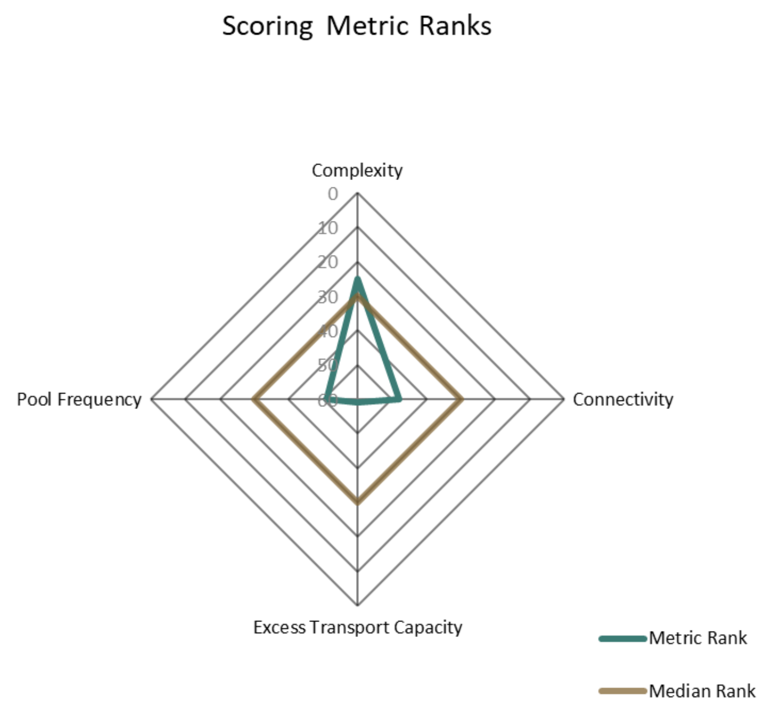
- Set back road against the left valley wall for more floodplain connection and channel migration area.

PA 14.1 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

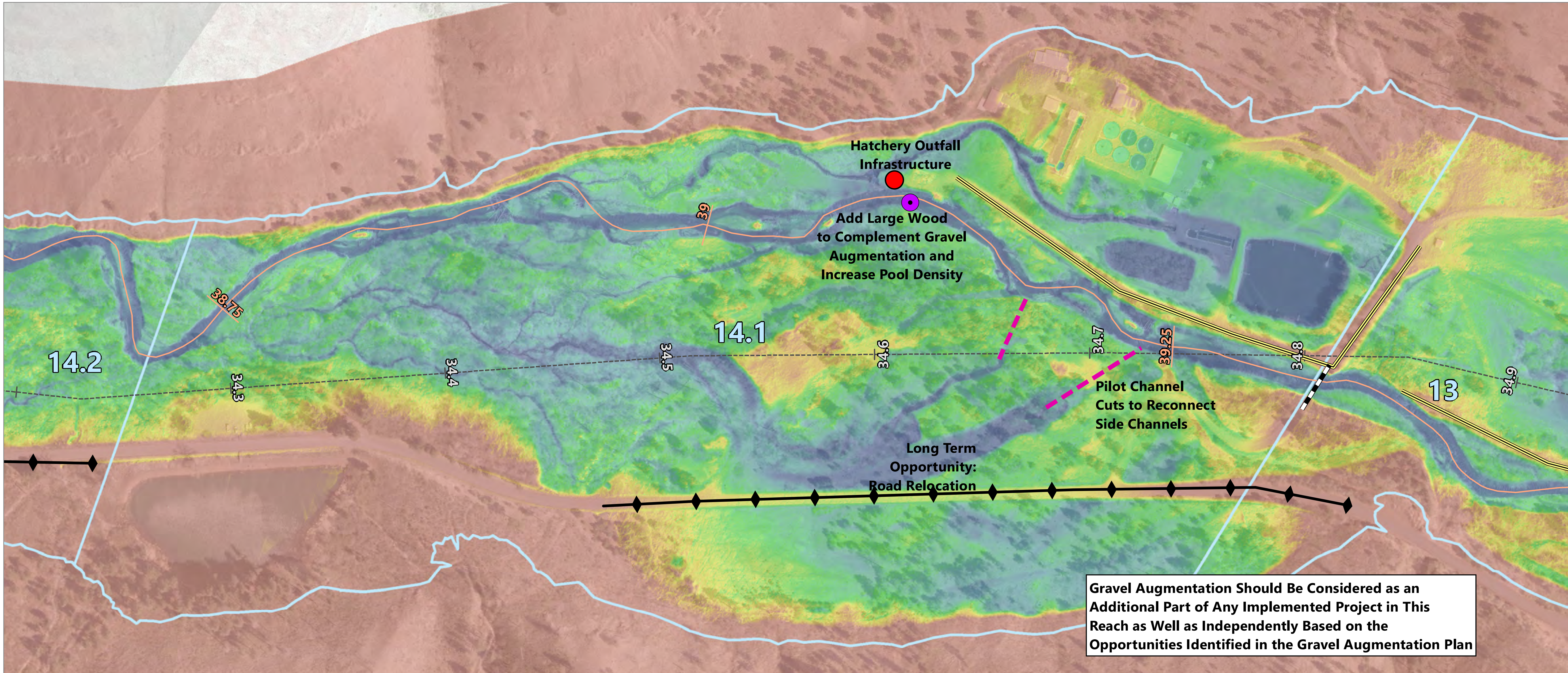
PA 14.1 Prioritization Scoring Summary

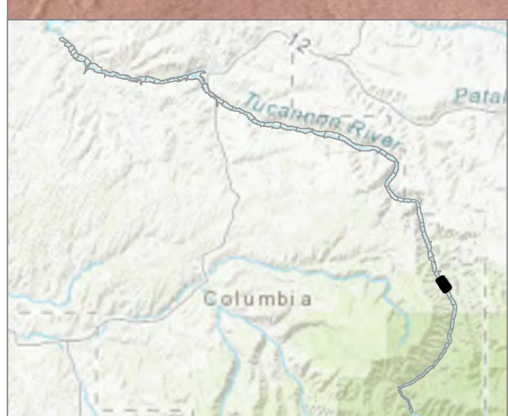


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 14.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.219	21	40%	**Complexity**	0.259	25	40% to 60%	3 of 5	5	40%	2.0	28	2	Treated	9	2
Mean-Winter Flow Complexity	0.272	27	40%													
1-year Complexity	0.315	31	20%													
Channel Aggradation FP Potential	0.185	36	40%	**Connectivity**	0.142	48	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.026	46	40%													
Total FP Potential	0.287	39	20%													
Existing Connected FP	0.713	22	0%													
Excess Transport Capacity	-0.32	59	100%	**Excess Transport Capacity**	0.000	59	52% to 100%	4 of 4	0	20%						
Pool Frequency	4.91	51	100%	**Pool Frequency**	0.126	51	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Side Channel
- Long Term: Relocate Road
- Current Infrastructure in River Corridor

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 38.71
RIVER MILE END: 39.32
VALLEY MILE START: 34.26
VALLEY MILE END: 34.81

0 500
Feet

Publish Date: 2021/01/25, 3:47 PM | User: mgieschen
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ANCHOR QEA

Project Area 14.1
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 15.2 Description

Project Area 15.2 begins at VM 32.29 and extends upstream to VM 32.68. The 2017 RM length is 0.42 mile. Field observations for PA 15.2 were not conducted in 2018, but the majority of the reach was viewed from a lookout point on the road on September 26, 2018, when flow at the Starbuck gage was approximately 80 cfs. The remainder of this site description reflects observations made from the lookout point as well as information from the 2011 prioritization.

For this assessment update, PA 15 as defined in the 2011 prioritization was separated into two project areas (PA 15.1 and PA 15.2) for distinct analysis. Since the 2011 assessment, PA 15.2 has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

PA 15.2 is largely characterized by having a uniform plane-bed channel with a large, left bank floodplain and multiple large apex engineered log jams.

The upstream end of the reach begins just below the large side channel in PA 15.1 and has little instream complexity until the first large apex engineered log jam at VM 32.60, which appears to be causing a shallow scour pool and alcove on the left bank. Further downstream, the channel is mostly plane-bed and uniform, with one small split flow and bar, until the next apex engineered log jam at VM 32.48.

Project Area 15.2
Apex engineered log jams in PA 15.2, as seen from a nearby high vantage point.

Project Area 15.2 Reach Characteristics

VM Start (mi)	32.29
VM Length (mi)	0.39
Valley Slope	1.31%
RM Start (mi)	36.36
RM Length (mi)	0.42
Average Channel Slope	1.18%
Sinuosity	1.08
Connected FP (ac/VM)	9.83
Encroachment Removal (ac/VM)	1.17
Channel Aggradation (ac/VM)	4.94
Total FP Potential (ac/VM)	5.69
Encroaching Feature Length (ft)	415.50
Connected FP Rank	51

At VM 32.38, two large apex engineered log jams are forcing large split flow and erosion into the left bank. The majority of geomorphic activity for this reach is occurring here. The channel through this section borders the valley wall on the right bank but has a large floodplain area on the left bank with mature vegetation. The vegetation in this area has been affected by a recent fire but many of the large trees still remain, including a mix of cottonwoods and coniferous species.

The bed material for the whole reach was not noted during field observations, but at the upstream end the bed material was mostly cobble and boulder with little gravel and transportable material.

Restoration Actions and Geomorphic Changes

In 2015, restoration work in PA 15.2 included placing 24 engineered log jams and single logs using 181 key LWD pieces. Restoration work also included removing 190 feet of rock levee/berm and placing LWD to increase flooding into that area. The goal of the restoration work in this reach is to increase channel complexity and over time connect floodplain.

Analysis of the difference between the 2010 and 2017 LiDAR data shows several significant locations of geomorphic change, many of which are likely a direct result of the restoration efforts in the reach.

The first two locations of significant geomorphic change are related to the two large engineered log jams located in the main channel. Both log jams exhibit deposition in the wake of the structure and scour erosion along the sides. There are other examples of this type of change but not all have been noted in this narrative (boxes 1 and 2).

Downstream of here, more geomorphic change has occurred as a direct result of restoration efforts. Two engineered log jams have triggered a channel avulsion towards the left bank by the downstream log jam. Near the upstream log jam, there is some erosion and deposition on the left bank floodplain that indicates high flows are being pushed onto the floodplain. Additional deposition has occurred in the wake of the structures as well (box 3).

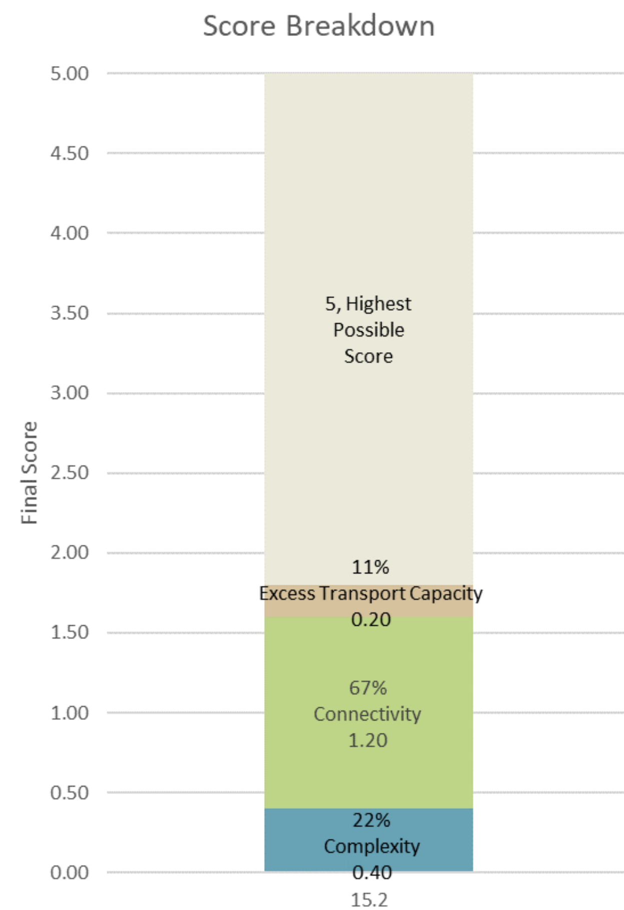
Finally, the last geomorphic change noted for this narrative occurs at the downstream end of the reach and does not appear to be a direct result of restoration efforts. A meander pattern is starting to form with first erosion on the left bank and bar building deposition on the right bank followed downstream by deposition on the left bank (box 4).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, Connectivity makes up the majority of the score for PA 15.2; this project area ranks near the top for Channel Aggradation and just below average for Encroachment Removal, which contribute to the overall score as well. Based on the floodplain mapping, this potential for connectivity comes mostly from a low-lying former channel or side channel on the left bank floodplain. Some of this area is low enough to be connected at the 2-year event, but a large additional amount of area could be connected given a rise in channel bed elevation. Enhancement strategies in this reach should target connecting this side channel area through strategic pilot channel cuts and wood placement to reconnect the low-lying area. Channel aggrading techniques such as gravel augmentation and strategic wood placement should also be considered as enhancement techniques to target the additional potential area to be connected. PA 15.2 receives a low score in Excess Transport Capacity, indicating that the shear stress is only slightly above the slope predicted value, and any gravel augmentation in this reach is likely to be easily stored and maintained with the addition of instream wood.

PA 15.2 receives a low score in the Complexity metric, indicating that the existing complexity in this reach is low enough that achieving additional complexity through restoration might be difficult. However, connecting the low-

PA 15.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

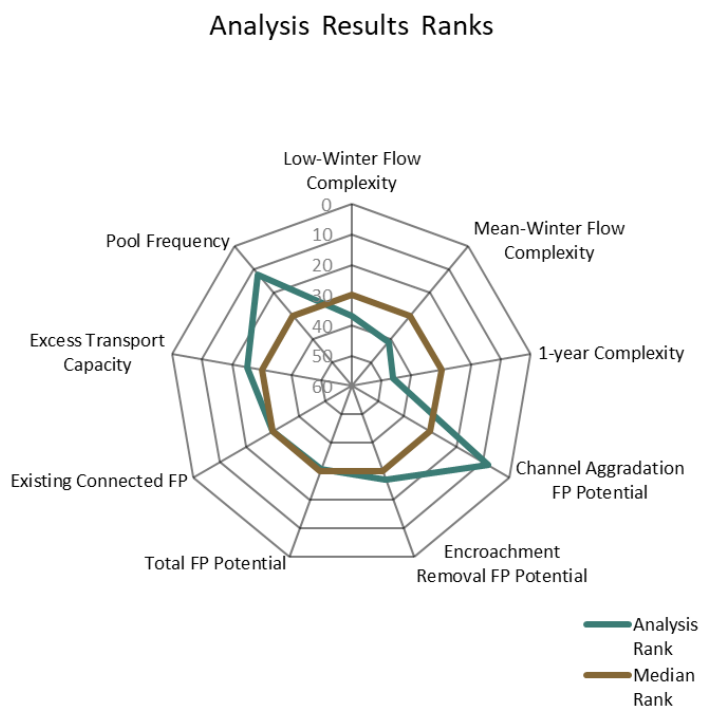
lying area targeted for floodplain connectivity could present a good opportunity to increase complexity as well. Cutting pilot channels low enough that perennial flow can access this area as well as adding instream wood should be considered as an enhancement strategy to increase complexity in this reach.

Finally, the Pool Frequency analysis result indicates that this project area ranks relatively high for number of pools per valley mile. The enhancement strategies of adding instream wood and gravel augmentation should assist in maintaining and increasing the number of pools in the reach in the future.

Summary of Restoration Opportunities Identified

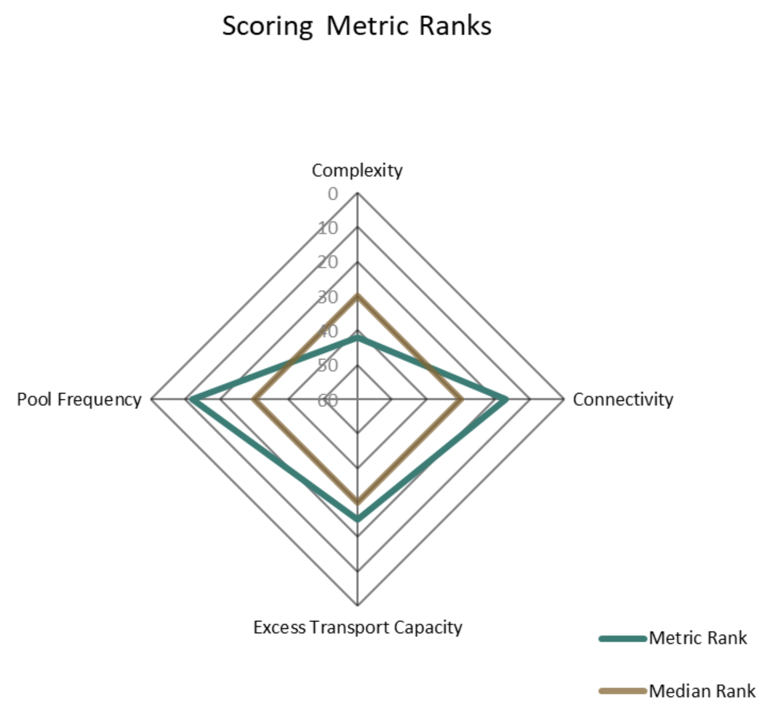
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 15.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

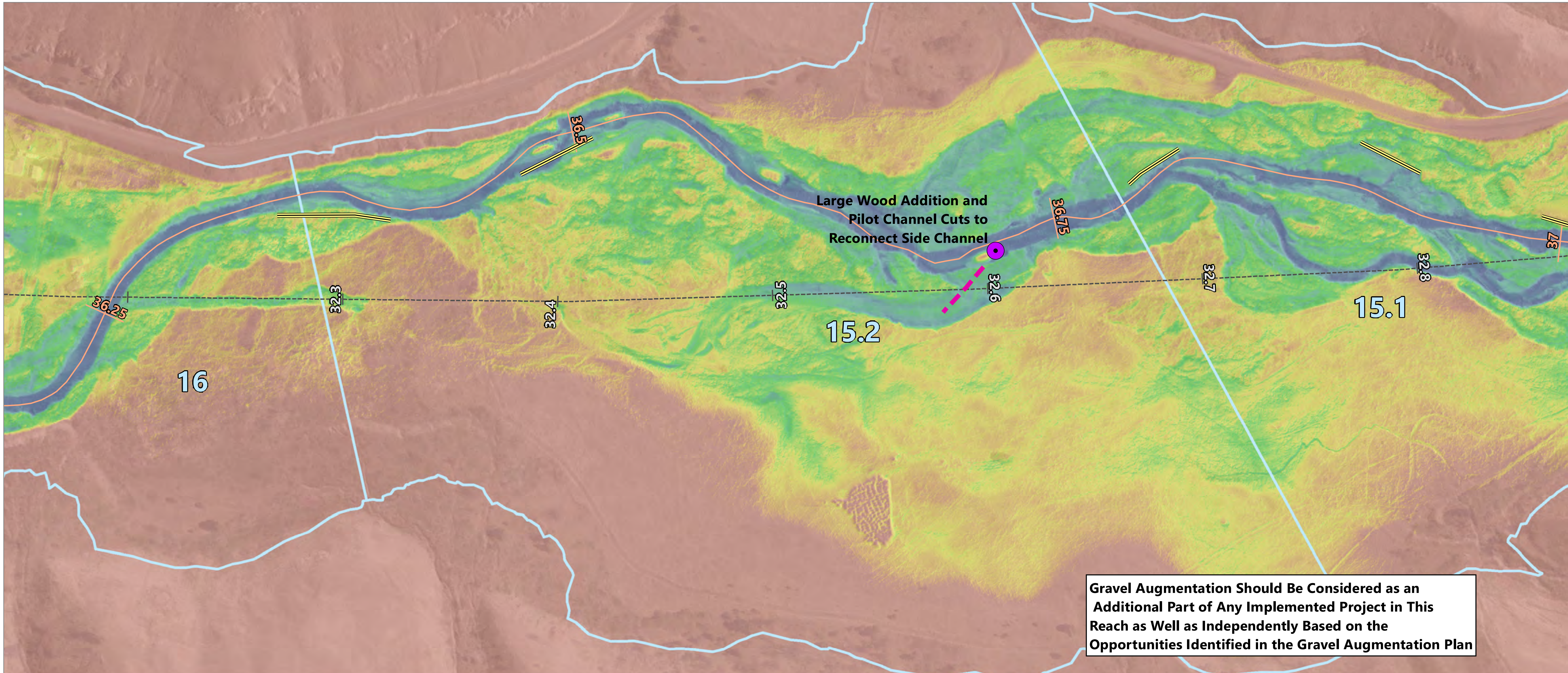
PA 15.2 Scoring Metric Ranks

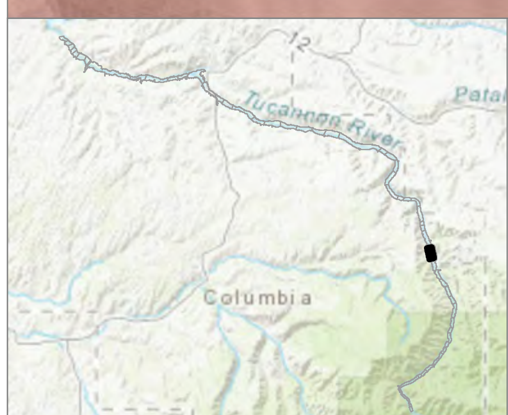


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 15.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.127	37	40%	**Complexity**	0.147	42	60% to 90%	4 of 5	1	40%	1.8	31	2	Treated	11	2
Mean-Winter Flow Complexity	0.154	41	40%													
1-year Complexity	0.172	46	20%													
Channel Aggradation FP Potential	0.318	8	40%	**Connectivity**	0.231	17	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.075	27	40%													
Total FP Potential	0.367	31	20%													
Existing Connected FP	0.633	30	0%													
Excess Transport Capacity	0.06	25	100%	**Excess Transport Capacity**	1.000	25	30% to 52%	3 of 4	1	20%						
Pool Frequency	18.90	12	100%	**Pool Frequency**	0.485	12	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 36.36
RIVER MILE END: 36.78
VALLEY MILE START: 32.29
VALLEY MILE END: 32.68

0 500
Feet

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ANCHOR QEA

Project Area 15.2

Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 18.1 Description

Project Area 18.1 begins at the bridge crossing at Tucannon Road at VM 29.48 and extends upstream to VM 30.45. The 2017 RM length is 1.08 miles. Field observations were conducted on September 26, 2018, when flow at the Starbuck gage was approximately 80 cfs.

For this assessment update, PA 18 as defined in the 2011 prioritization was separated into two project areas (PA 18.1 and PA 18.2) for distinct analysis because only PA 18.1 was treated; this project area also exists entirely above the Tucannon Road bridge. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization. However, restoration actions in this project area were very recent and occurred just before the raw data for this report were collected in 2017.

During field observations, the project area was accessed via the left bank floodplain near the upstream end. A floodplain spring has been reconnected from near the upstream end of the project area and was flowing at the time of field observations. Large woody material has been added to these side channels and is interacting with flow. Vegetation in the area of this side channel is primarily canary grass.

The channel itself was accessed near a point that had obviously recently aggraded. Surface flow is evident on much of the

Project Area 18.1
Recently installed rootwad logs and large woody debris structures interacting with flow.

Project Area 18.1 Reach Characteristics

VM Start (mi)	29.48
VM Length (mi)	0.96
Valley Slope	1.25%
RM Start (mi)	33.24
RM Length (mi)	1.08
Average Channel Slope	1.12%
Sinuosity	1.12
Connected FP (ac/VM)	20.45
Encroachment Removal (ac/VM)	0.50
Channel Aggradation (ac/VM)	8.78
Total FP Potential (ac/VM)	9.54
Encroaching Feature Length (ft)	3,201.32
Connected FP Rank	16

floodplain and multiple side channels are beginning to flow through the trees.

Downstream of this area on the main channel, a large amount of instream wood has been added to the channel. It appears the wood is a mix of single log placements and larger structures, which are secured with a mix of large boulder and roper, or piles. A side channel is flowing through the riparian area on the left bank, and at the time of the site visit, the outfall had significant flow.

Bed material throughout the reach is a mix of transportable gravel material and cobbles and boulders. Gravel material locations are patchy at times, and it appears that some upstream avulsion or event has recently transported material into the reach.

Because of this recent avulsion, the geomorphic reaction to many of the structures has been mixed. Several structures have deep scour pools even around single log placements, often associated with a stretch of gravel bed material. Other structures have been placed on cobble and boulder material and have not caused much pooling. Because restoration work was so recent, it is possible that there has not been enough time or enough transport flow events to have caused significant change.

Several redds from a recent spawning survey were noted in this project area, especially in the reaches where gravel material is more prevalent.

Mid-reach, a large channel-spanning log jam has recruited several additional pieces of woody material, and the channel begins to be confined on the right bank by the bedrock valley wall before returning to the center of the floodplain. Bank scour and erosion are evident on both banks and multiple natural wood recruits have fallen into the channel.

Near the downstream end of the reach, several return flows are on the left bank. On the right bank, multiple rootwad logs have been keyed into the long bridge levee that is confining the river on that side. There appears to be additional low-lying area behind the levee that is not being accessed. In this area, multiple very large pile structures are preventing wood recruits or lost structure wood from moving any further downstream.

Throughout this reach, vegetation around the channel is relatively dense, with large stands of alders and some cottonwoods with a few conifers mixed in. The riparian buffer around the stream is large in most places with several hundred feet of forest area on either side of the stream, except for where the channel runs along the valley wall on the right bank. Near the bridge at the downstream end of the project area, overhanging vegetation is slightly sparser.

Between this riparian area and the road is a large grass field where the side channel from the downstream end of the project area is mostly located.

Restoration Actions and Geomorphic Changes

In 2017, restoration work in PA 18.1 included placing 49 structures within the wetted width and 29 floodplain structures using 590 key LWD pieces. Additionally, 41 single log structures were incorporated into the wetted width. A 146-foot river levee was removed and used as gravel and cobble supplementation. Three side channels were cut and LWD structures were added to reconnect 1.66 miles of side channel and enhance 0.66 mile. The targeted geomorphic response focused on reconnecting large portions of the existing 5-year floodplain to a greater than 2-year flood interval (approximately 300 cfs) floodplain by removing confining features, connecting side channels, and placing high density LWD structure to increase bank erosion and stream bed deposition.

This assessment assumes that restoration work and geomorphic changes are unrelated due to the timing of the restoration work, which occurred just before the raw data were collected for this assessment. With so little elapsed time, it is not expected that any geomorphic changes resulting from the restoration project would be apparent in the LiDAR or aerial imagery data, which occurred shortly after construction.

At the upstream end of the project area, a large mid-channel bar is building on the right bank and associated erosion is evident on the left bank (box 1). Just downstream, areas of major deposition are evident in a location that was noted during field observations to be extremely complex even at the low-winter flow. Deposition in the main channel appears to be associated with the presence of LWD and has allowed flow onto the floodplain where several side channels are evident in the 2018 aerial imagery (box 2).

At VM 30.11, meander bends are beginning to form as first the left bank and then the right bank have experienced major erosion since 2010. No associated inside bar formation is apparent but may form eventually as the meander wavelength increases. LWD is apparent in these locations and could be forcing some of this change, but it is likely this process had begun before the 2017 restoration effort (box 3).

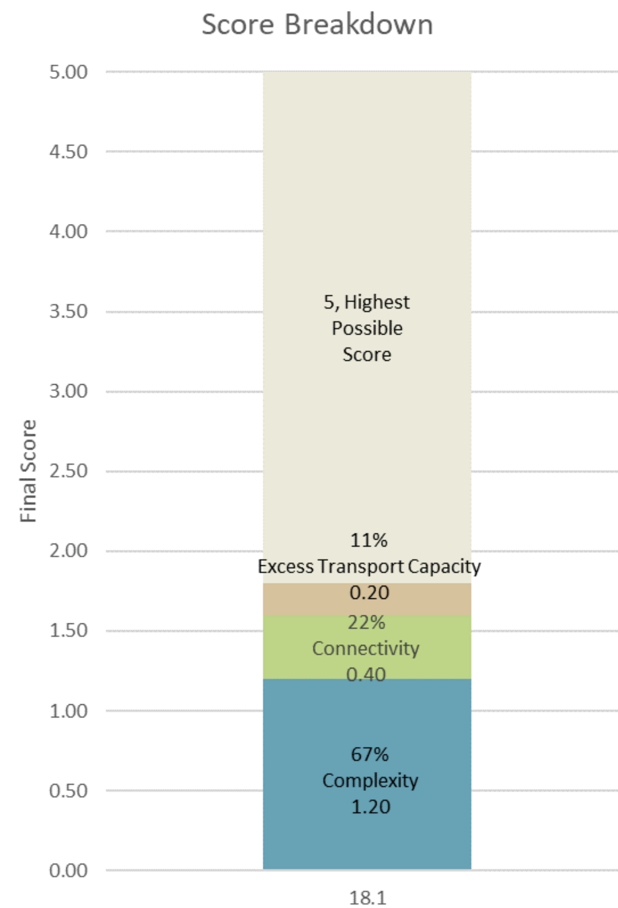
At VM 29.96, there appears to be some erosion associated with the downstream end of a side channel, along with deposition immediately to the side of the erosion. The source of the deposition was a gravel berm removal used as gravel augmentation as well as backfill for an apex ELJ upstream (box 4). Just downstream of here, a large amount of erosion on the left bank is apparent just upstream of a side channel, although this may just indicate inundation from backwatering. The side channel has evident elevational loss that were side channel cuts performed in the restoration effort, and it appears this side channel is connected at most flows (box 5).

Further downstream on the main channel, there is erosion on the right bank as well as significant erosion in the unnamed tributary. (box 6). The next reach immediately downstream shows apparent erosion on first the left bank and then the right bank over a long stretch. There is LWD in this area, but it is not clear whether this has caused these erosional stretches. Field observations suggest gravel materials were deposited in spring 2017 and subsequently mobilized following wood placement in fall 2017. However, because some of this area is within the area of the channel in 2010, it is possible some of these apparent changes may be an error due to the differences in the 2010 LiDAR and the 2017 blue/green LiDAR. See the Geomorphic Assessment for a more detailed explanation of this effect (box 7). The final reach of note shows a similar effect but with more area outside of the former channel and some evidence of increasing channel meander (box 8).

Geomorphic Characteristics and Management and Enhancement Strategies

The management and enhancement opportunities here are based on the 2018 LiDAR and aerial imagery data. However, it should be noted that the restoration actions in this reach occurred shortly before the data were collected and geomorphic response may not have occurred yet and may not yet be reflected in the prioritization score.

PA 18.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

As shown in the following graphs and table, PA 18.1 receives moderate scores in both the Complexity and Connectivity metrics, with a small score for the Excess Transport Capacity metric. The Complexity in this reach ranks above average in the 60th to 90th percentile, a range that still shows moderate complexity but does not place it in the top 10% of project areas; this project area likely only needs a little restoration work to reach that mark.

The floodplain area that drives the Connectivity score is a large low-lying area on the left bank floodplain. While the connectivity analysis shows that this area is disconnected by a by high bank floodplain, field observations noted flow in this area during low flow. This area does have a spring connection as well, and a 2019 field survey indicates that this area is inundated already at very low flow (75 cfs). A few other side channel areas are shown as disconnected, but all appear to have been targeted during restoration in 2017. The identified enhancement strategies for this reach would be to monitor the reconnection of disconnected side channels and low floodplain and supplement woody material to the main channel and side channels if needed. Because these actions match the restoration that was performed just before these data were collected, this area should be monitored for future changes. Should the reach respond to the restoration actions and the channel bed is raised, more disconnected floodplain area may become available and should be targeted.

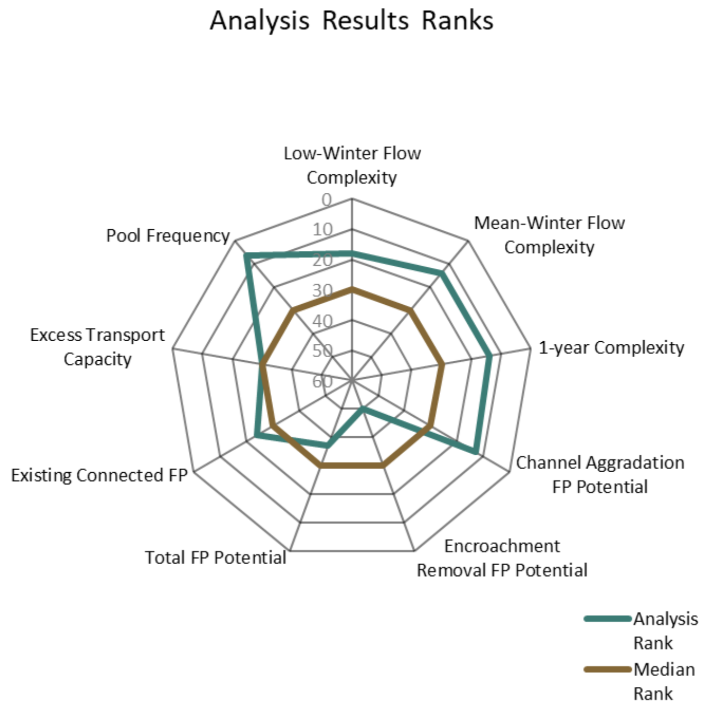
Finally, this project area already ranks higher than average in the Pool Frequency metric and this is not a primary enhancement target. The number, size, and frequency of pools should be monitored to ensure that geomorphic processes continue to exist that will force and maintain pools.

The complexity in this reach scores very close to the top 10% of project areas and, considering the amount of geomorphic response already noted in this reach, that complexity target should be easily reached. Management strategies for this reach should be to monitor the geomorphic response to the addition of wood and gravel augmentation already performed. Should the channel begin to disconnect from some side channels, it is possible that additional gravel augmentation could be warranted.

Summary of Restoration Opportunities Identified

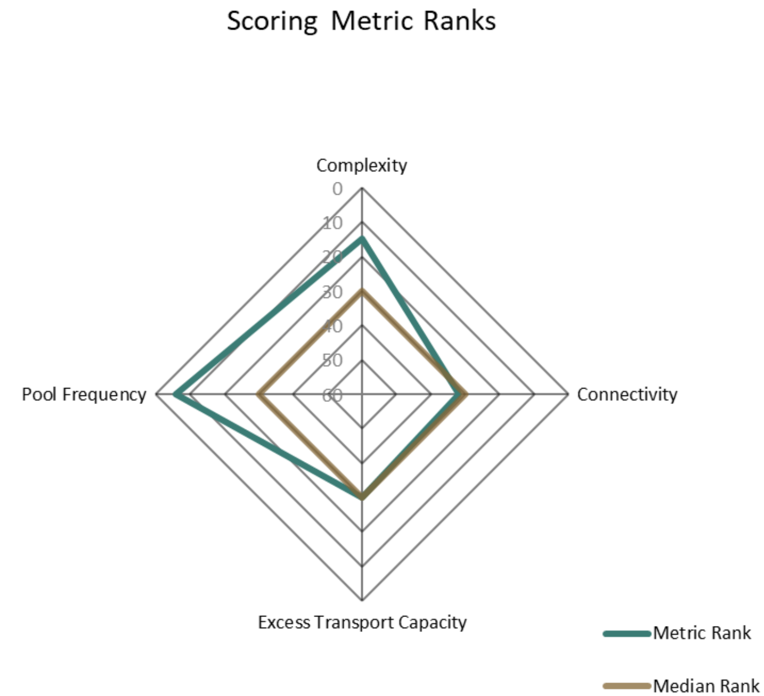
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features

PA 18.1 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

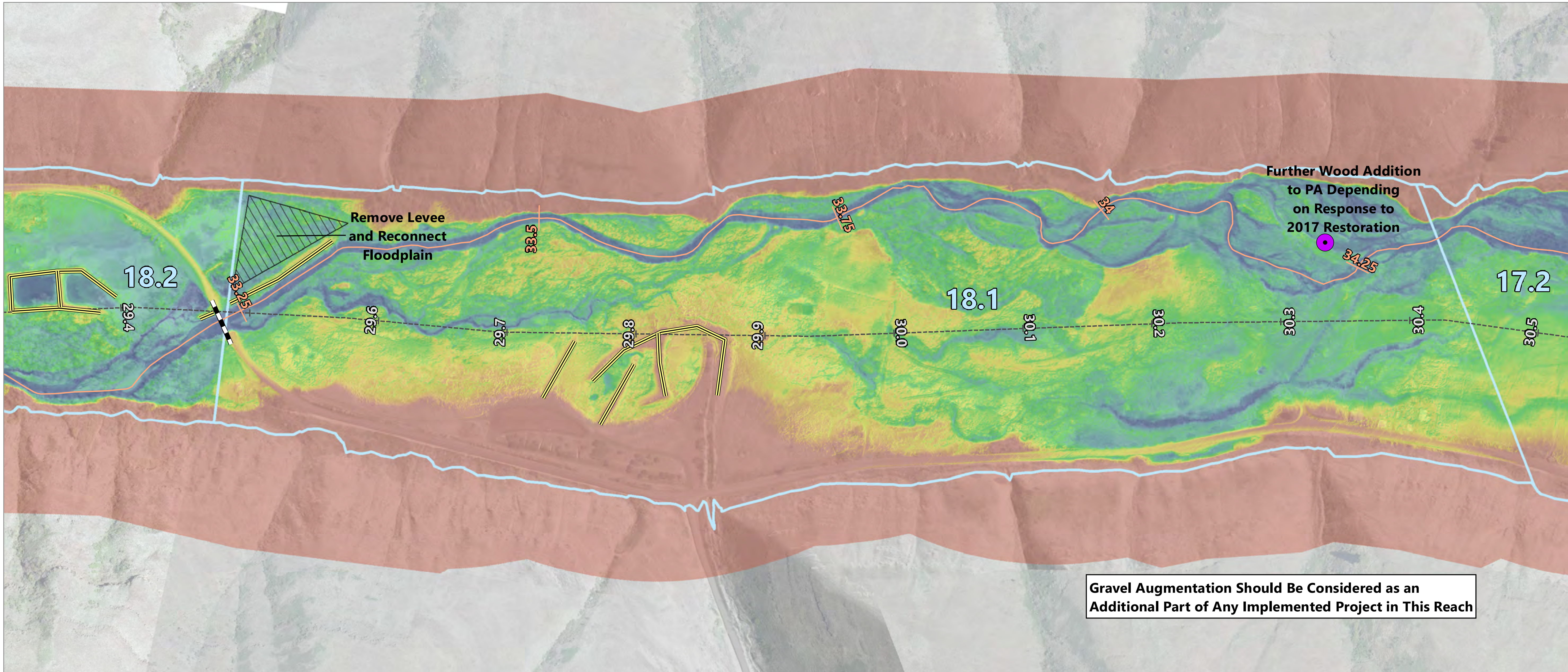
PA 18.1 Prioritization Scoring Summary

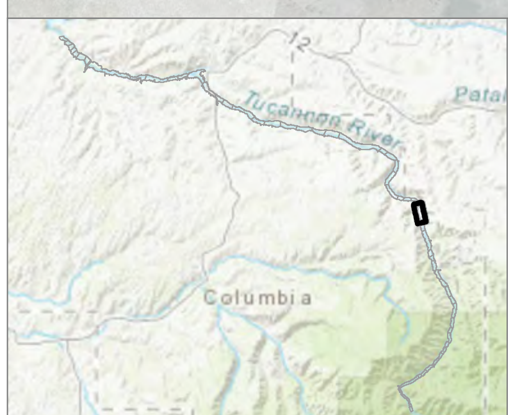


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 18.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.243	18	40%	Complexity	0.376	13	10% to 40%	2 of 5	3	40%	2.6	14	1	Treated	7	1
Mean-Winter Flow Complexity	0.422	13	40%													
1-year Complexity	0.549	11	20%													
Channel Aggradation FP Potential	0.169	38	40%	Connectivity	0.214	25	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.143	17	40%													
Total FP Potential	0.444	18	20%													
Existing Connected FP	0.556	43	0%													
Excess Transport Capacity	0.02	29	100%	Excess Transport Capacity	1.000	29	30% to 52%	3 of 4	1	20%						
Pool Frequency	26.83	6	100%	Pool Frequency	0.689	6	1% to 10%	1 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Floodplain

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 33.24
RIVER MILE END: 34.32
VALLEY MILE START: 29.48
VALLEY MILE END: 30.45

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Feet

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ANCHOR QEA

Project Area 18.1
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 28.2 Description

Project Area 28.2 begins at VM 18.41 and extends upstream to VM 19.42. The 2017 RM length is 1.17 miles. Field observations for PA 28.2 were conducted on September 25, 2018, when flow at the Starbuck gage was approximately 85 cfs.

For this assessment update, PA 28 as defined in the previous assessment (Anchor QEA 2011) was separated into three project areas (PA 28.1, PA 28.2, and PA 28.3. In 2016, the lower sections of this project area (PA 28.2 and PA 28.3) were the subject of a restoration project, while PA 28.1 has remained untreated. PA 28.2 and PA 28.3 represent distinct parts of the restoration project and were therefore separated for distinct analysis.

The upstream 0.25 mile of PA 28.2 was not walked but appears from the LIDAR and aerial imagery to be mostly confined by a levee on the right bank and the valley wall on the left bank.

At VM 19.17, a small, complex flow area with several log jams is pushing some flow out through the trees, making it unclear where the main channel is. At about VM 18.96, a large, complex area with several engineered and natural log jams was forcing flow into several side channels and floodplain flow at the time of the site walk. These side channels flow for a long way through the forested floodplain and create extremely complex juvenile habitat for nearly half a mile to the end of the reach.

Project Area 28.2
Complex flow around an engineered log jam near the upstream end of PA 28.2.

Project Area 28.2 Reach Characteristics

VM Start (mi)	18.41
VM Length (mi)	1.01
Valley Slope	0.91%
RM Start (mi)	20.91
RM Length (mi)	1.17
Average Channel Slope	0.78%
Sinuosity	1.16
Connected FP (ac/VM)	23.53
Encroachment Removal (ac/VM)	5.02
Channel Aggradation (ac/VM)	15.67
Total FP Potential (ac/VM)	24.11
Encroaching Feature Length (ft)	5,120.78
Connected FP Rank	10

Throughout these side channels and the floodplain, there are multiple log and debris jams that often are forcing large scour pools and in-channel complexity. The main channel on the left bank runs mostly along the valley wall and has less wood and complexity than the side channels, with a few plane-bed uniform sections. Near the end of the main channel, a large, constructed log jam is creating multiple split flows and complexity.

At VM 18.51, all of the floodplain side channels rejoin the main channel and there are several more log jams forcing deep pools, particularly where the largest side channel rejoins the main channel.

This reach is defined by excellent complexity in the floodplain. Bed material is difficult to characterize but the side channels appear to have a good amount of gravel material that is easily transported, and geomorphic pools are forced easily.

Riparian vegetation through this reach is very good because the large floodplain area has many large deciduous trees throughout. One side channel does border the right bank levee closely where there is an abundance of reed canary grass and little other overhanging cover.

Restoration Actions and Geomorphic Changes

In 2016, VM 19 downstream was treated with 22 structures and 4 single logs using 135 key LWD pieces. In 2017, an additional 10 structures were added using 62 LWD key pieces, and 11 floodplain structures using 22 LWD key pieces were added to a reconnected high-flow channel. A 120-foot gravel berm was removed to help reconnect the floodplain. LWD structures were placed in two strategic locations to reconnect 2,400 feet of side channel as perennial channel and 690 feet to be captured as annual high-flow side channel. Restoration work included connecting approximately 22 acres of low floodplain that had been isolated by incision.

The geomorphic goal was to encourage increased flooding on an annual basis (approximately 300 cfs). This was attempted using LWD structures to capture gravel and create bars, as well as reduce channel capacity to cause flooding and side channel development. It is anticipated that with this restoration the number of pools would double and the perennial length of the channels would double as well.

Analysis of the difference between the 2010 and 2017 LiDAR data shows that PA 28.2 has seen some of the most significant change in the Tucannon River basin over the last 7 years. Much of the change discussed here can be attributed to the removal of levees as part of restoration efforts, as well as a large amount of sediment deposited throughout the reach.

At the upstream end, several log jams have promoted sediment deposition and several split flows causing complex flow throughout the floodplain (box 1). It is possible this avulsion could be the source of some of the sediment seen deposited downstream.

The next highlighted location marks a long section of sediment deposition in the main channel. Part way through this depositional reach, a split flow has formed a long side channel that continues on for the remainder of the reach forming multiple islands and very complex flow. It should be noted that this deposition and change is a good example of the type of response targeted with the gravel augmentation plan included as part of this prioritization (box 2).

Downstream of here, another depositional reach occurs in one of the channels as well as on the floodplain on both sides. Split flows and side channels have formed as a result and there are several erosional areas where new side channels have formed in this area, creating very complex flow (box 3).

Finally, a large channel-spanning log jam and engineered apex jams have allowed deposition in the floodplain to either side of the log jam in one of the channels. Additionally, scour pools and erosional areas can be seen behind the two main log jams. (box 4). It should be noted this reach has a large amount of geomorphic change, not all of which is discussed as part of this narrative. For a complete picture of the geomorphic change analysis, see the GIS layers provided as part of this assessment.

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 28.2 receives very high scores in the Connectivity metric. PA 28.2 ranks within the 90th percentile for complexity, indicating that it is one of the most complex project areas and therefore receives a Complexity score of 0. Management strategies should work to ensure that complexity in this reach remains and does not degrade. While the low-winter, mean-winter, and 1-year flow complexity analysis results all rank PA 28.2 very highly, the 1-year complexity is slightly lower, which is not necessarily undesirable. PA 28.2 has seen very recent deposition and complex flow formation and the slightly lower 1-year flow complexity could indicate that some island and gravel bars are being "washed out" and inundated at the 1-year flow event. One management strategy to the restoration already completed in this reach should be to continue wood loading over time to maintain existing islands and split flows to ensure complexity at low flows does not wash out at the higher flows.

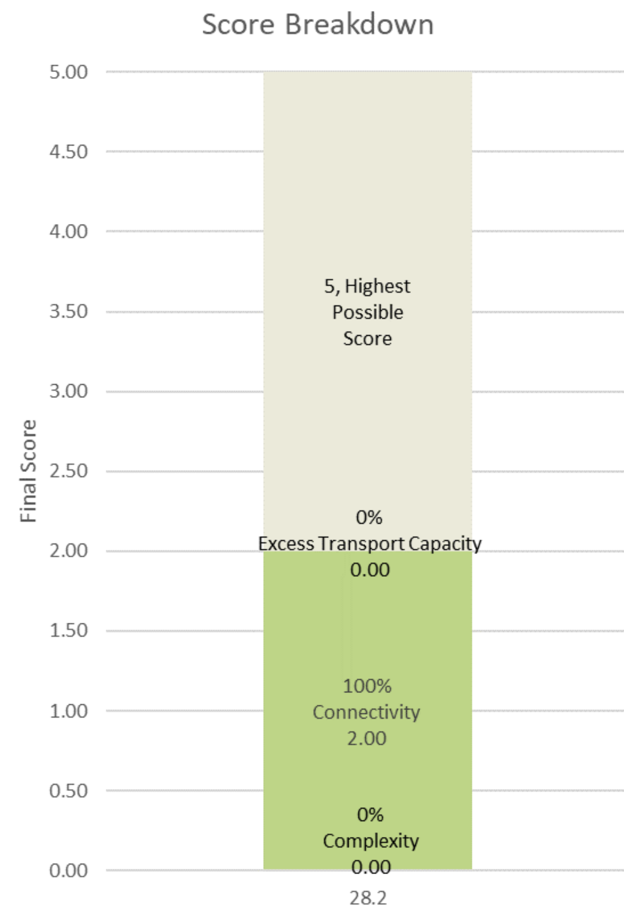
PA 28.2 also receives a moderate score for Connectivity, indicating that it falls within the 50th to 75th percentile of all project areas. This score is driven primarily by a large, low-lying area in the upstream end of the left bank floodplain. There is additional disconnected area in several former channels and meanders just upstream of this low-lying area. These areas could be reconnected with strategic pilot channel cuts and placement of instream wood near the heads of these new channels to promote geomorphic change. Placing instream wood and cutting pilot channels to connect these areas should be the primary enhancement strategies for this reach, in addition to the management strategies suggested for complexity.

Finally, the Pool Frequency analysis result indicates that this project area ranks relatively high for number of pools per valley mile. The management strategies of adding instream wood, if necessary, should help to ensure this number of pools is maintained in the future. Should the depositional trend in this reach ever reverse, adopting gravel augmentation may be necessary to maintain the high number of pools in the reach.

Summary of Restoration Opportunities Identified

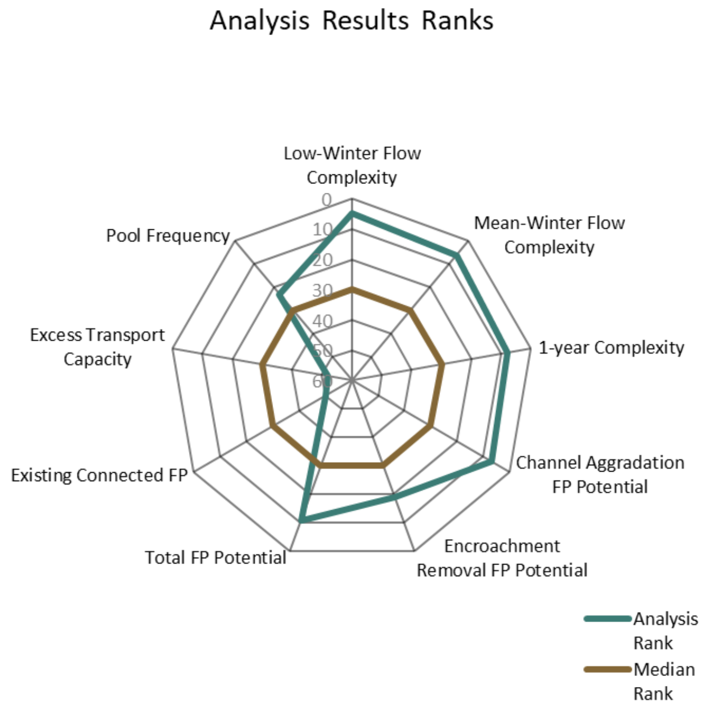
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 28.2 Score Breakdown



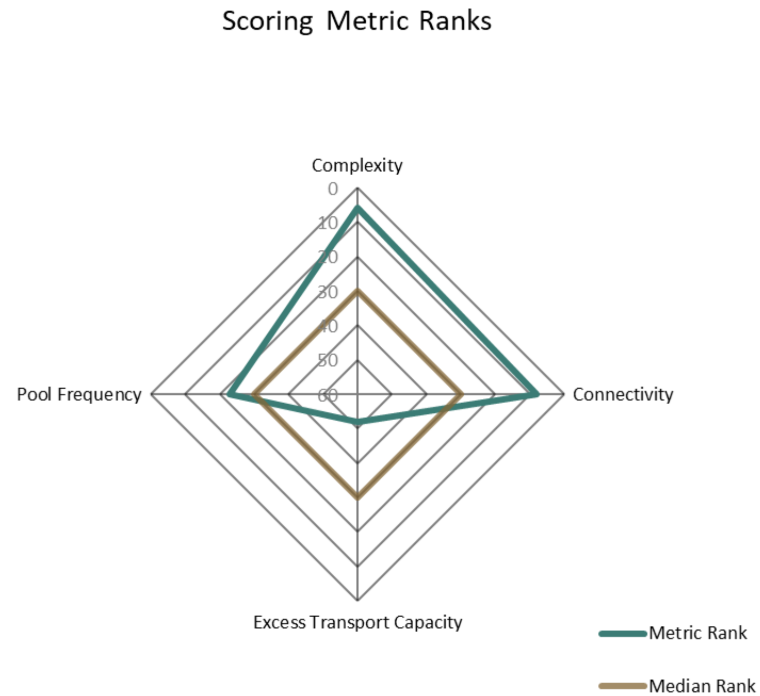
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 28.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

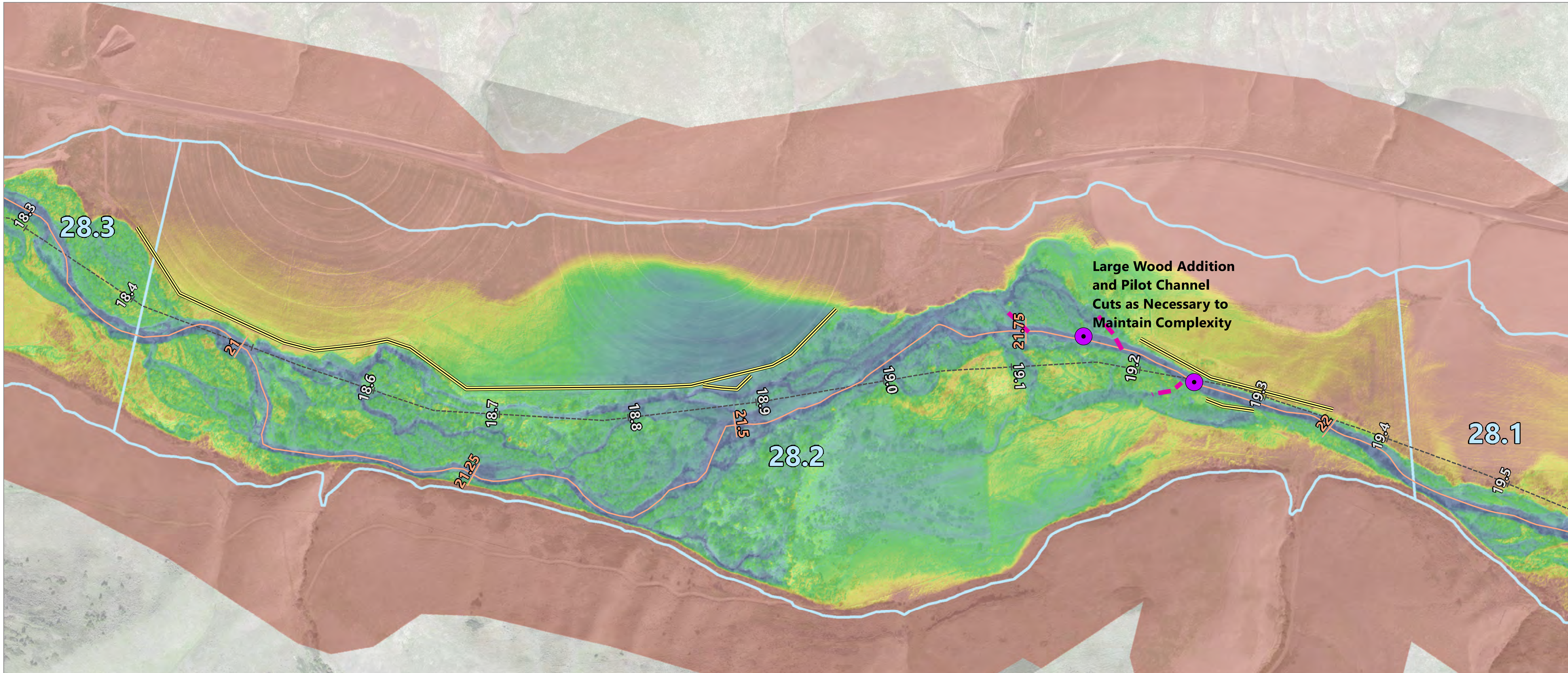
PA 28.2 Scoring Metric Ranks

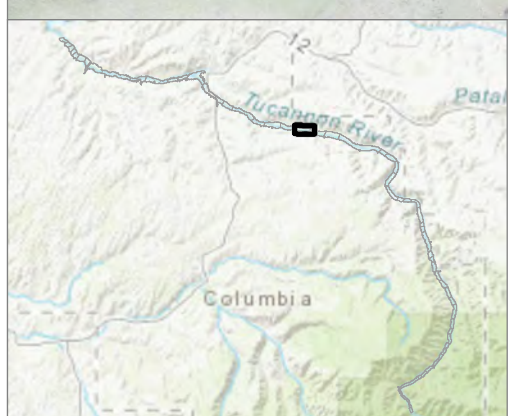


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 28.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.333	5	40%	Complexity	0.460	6	1% to 10%	1 of 5	0	40%	2.0	29	2	Treated	10	2
Mean-Winter Flow Complexity	0.500	6	40%													
1-year Complexity	0.635	8	20%													
Channel Aggradation FP Potential	0.329	7	40%	Connectivity	0.275	8	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.105	19	40%													
Total FP Potential	0.506	11	20%													
Existing Connected FP	0.494	50	0%													
Excess Transport Capacity	-0.16	52	100%	Excess Transport Capacity	0.000	52	52% to 100%	4 of 4	0	20%						
Pool Frequency	12.85	23	100%	Pool Frequency	0.330	23	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 20.91
RIVER MILE END: 22.08
VALLEY MILE START: 18.41
VALLEY MILE END: 19.42

0 500
Feet

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Filepath: \\orcas\gis\Jobs\TucannonRiver_1006\Maps\Conceptual Maps\Tucannon Treated Project Areas_mg.mxd

ANCHOR QEA

Project Area 28.2
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 28.3 Description

Project Area 28.3 begins at VM 17.38 and extends upstream to VM 18.41. The 2017 RM length is 1.16 miles. Field observations for PA 28.3 were conducted on September 25, 2018, when flow at the Starbuck gage was approximately 85 cfs.

For this assessment update, PA 28 as defined in the previous reports was separated into three project areas (PA 28.1, PA 28.2, and PA 28.3). In 2017 and 2018, the lower sections of this project area (PA 28.2 and PA 28.3) were the subject of a restoration project, while PA 28.1 has remained untreated. PA 28.2 and PA 28.3 represent distinct parts of the restoration project and were therefore separated for distinct analysis.

PA 28.3 is characterized by a mostly single-thread channel with some planform complexity. Several sections along this reach have a bedrock bottom, and there is a small bedrock falls at VM 17.78. The bedrock continues upstream and downstream of this point for some distance.

At the upstream end of the project area, there are multiple log jams on either bank of the channel. At about VM 18.33, an apex jam creates a split flow and protects an island with some established vegetation.

For the next 0.23 mile, the river is mostly a uniform plane-bed channel with good instream wood in the form of log jams on alternating banks. At VM 18.1, a large channel avulsion has

Project Area 28.3
Alternating engineered bank structures in a confined section of PA 28.3.

Project Area 28.3 Reach Characteristics

VM Start (mi)	17.38
VM Length (mi)	1.03
Valley Slope	1.01%
RM Start (mi)	19.75
RM Length (mi)	1.16
Average Channel Slope	0.90%
Sinuosity	1.13
Connected FP (ac/VM)	18.92
Encroachment Removal (ac/VM)	0.40
Channel Aggradation (ac/VM)	10.88
Total FP Potential (ac/VM)	11.30
Encroaching Feature Length (ft)	830.19
Connected FP Rank	17

occurred on the right bank and multiple trees have naturally fallen in the river, creating a deep scour pool. At VM 18, large woody material jam is protecting a location with right bank erosion, and a short distance downstream a side channel is visible on the relative elevation map.

At the time of the site visit, the next section was straight and plane-bed with alternating engineered log jam bank structures. This entire location has very little vegetation and the entire left bank is steep bank field. At the bend at the end of this section, large log jams have been placed near the left bank to push flow off of a fine sand material bank with little vegetative cover.

Immediately downstream of this bend, the channel bottom becomes mostly bedrock and goes over the small bedrock falls. At the downstream end of the falls, multiple locations show evidence of avulsions through the trees that are scouring to bedrock. The channel here is confined by a large, high-elevation area on the right bank. The remainder of the channel is mostly straight and uniform but with alternating structures placed on the left and right banks to increase channel complexity to the downstream end of the reach.

Bed material near the downstream end of the reach consists of mostly cobbles and boulders, which are resistant to being transported, as might be expected just downstream of a bedrock falls. Upstream, moderately more gravel material has allowed some scour pools to form near structures, but this reach could definitely benefit from more easily transportable material.

Vegetation in this reach is also mixed, with pockets of well-established trees in the riparian areas including cottonwood and alder, and long stretches of exposed areas with sparse, large, overhanging vegetation, particularly near the middle of the project area. The very downstream end of the project area has mature vegetation in a narrow band of riparian vegetation on either side of the channel.

Restoration Actions and Geomorphic Changes

Between 2017 and 2018, restoration work in PA 28.3 included placing 30 LWD structures using 328 LWD key pieces and 55 floodplain structures using 55 key pieces. Two side channel pilot cuts totaling 150 feet were excavated to reconnect 0.98 mile of high-flow channel. Two channel-spanning structures were placed to backwater the falls near the downstream end of the project area. The goal was to connect more than 5 acres of poorly connected floodplain at a less than 2-year flood and connect 14 acres disconnected floodplain at a less than 2-year flood. Over time it is anticipated the 0.98 mile of connected flow paths will improve riparian growth and increase perennial length. The long-term goal is to increase floodplain connectivity and channel complexity.

Analysis of the difference between the 2010 and 2017 LiDAR data shows several areas of significant geomorphic change in

PA 28.3. However, given that some restoration actions occurred just before or after these raw data were collected, it is unlikely that these changes are a result of restoration efforts and there may have been other significant changes that were not a result of the restoration efforts. However, restoration actions performed in 2017 have reportedly responded very quickly and are likely reflected in these results. Reports indicated that a significant amount of change occurred in 2018 after the data collection and the floodplain may be inundated after RM 20 at the yearly event.

The first area of significant change is located at VM 18.33 where a significant split flow has occurred around a vegetated island. The island appears to be a depositional area, with erosion occurring in the main and side channel to either side. A small log jam at the head of the island, visible in the 2018 aerial imagery, may have propagated this split flow (box 1).

The next significant location occurs just downstream at VM 18.13 where a major channel avulsion has occurred and left a large meander scar in the nearby agricultural field along with deposition on the island in between. The 2018 aerial imagery shows an engineered log jam has been placed at the head of this meander scar, although the log jam does not appear to have caused the meander scar because it was placed to encourage flow into that channel but not to let it capture the channel. Immediately downstream of this area, bank erosion has occurred on the right bank and LWD has fallen and caused the channel to migrate towards the left bank where there has been significant erosion, and sediment has been deposited in the former channel bed. This channel migration appears to have put extra erosional pressure on the right bank of the meander bend downstream where a significant bank erosion has occurred along with bar building inside of the bend. The 2018 aerial imagery shows large woody material recruited in this erosional bank area (box 2).

Finally, at VM 17.6 the channel trace comparison from 2010 to 2018 shows an avulsion towards the left bank. However, based on the LiDAR differencing it appears that since then the channel has migrated back towards its original position with erosion on the right bank and bar building on the left bank (box 3).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 28.3 receives the majority of its prioritization score from a moderate score in the Connectivity metric. PA 28.3 also receives a low score in both the Excess Transport Capacity metric and the Complexity metric, which make up its entire prioritization score. The high Connectivity score consists of high ranks in both the Channel Aggradation and Encroachment Removal analysis results, both of which are defined by two primary areas.

The channel aggradation potential comes from an area mid-reach that is connected at the 5-year event but not the 2-year event. An avulsion in this area was noted as having been reinforced with large woody material as part of recent restoration actions and may help to connect this area given more time for geomorphic change. Reports indicate that some of this change has occurred; however, if the ELJs begin to fail or disintegrate, remediation actions should be taken to maintain this inundation.

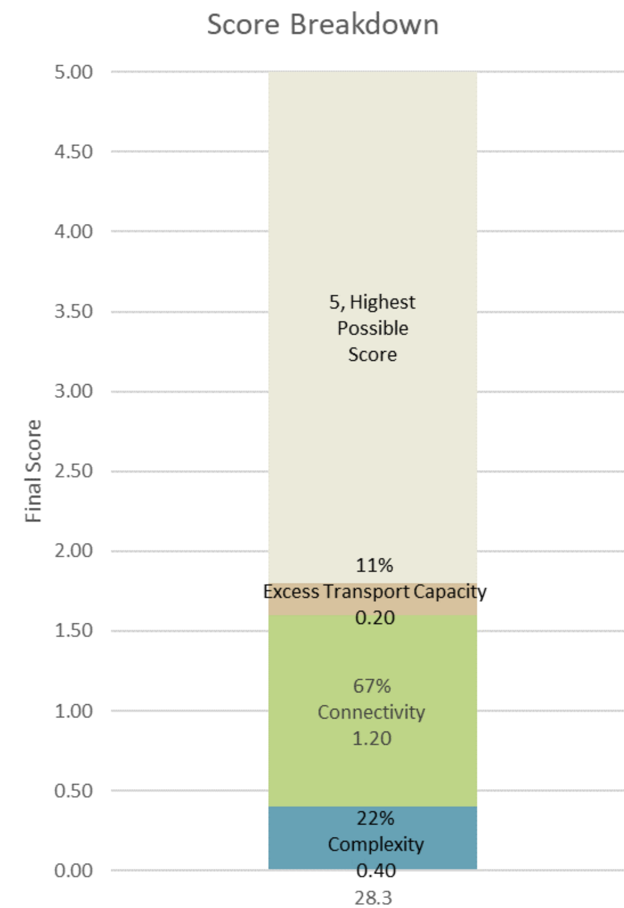
The encroachment removal potential is driven by a very large floodplain area disconnected on the right bank. There appears to be several connected side channels that do not quite reconnect this area. Restoration actions have occurred near this area and reports indicate that they are connected semiannually. However, should this area begin to become disconnected at the 2-year event, it should be targeted with pilot channel cuts and adding instream wood to reconnect the side channels that feed this large floodplain area.

Finally, the Pool Frequency analysis result indicates that this project area ranks relatively high for number of pools per valley mile. The management strategies of adding instream wood, and gravel augmentation if necessary, should help to ensure the number of pools is maintained in the future.

Summary of Restoration Opportunities Identified

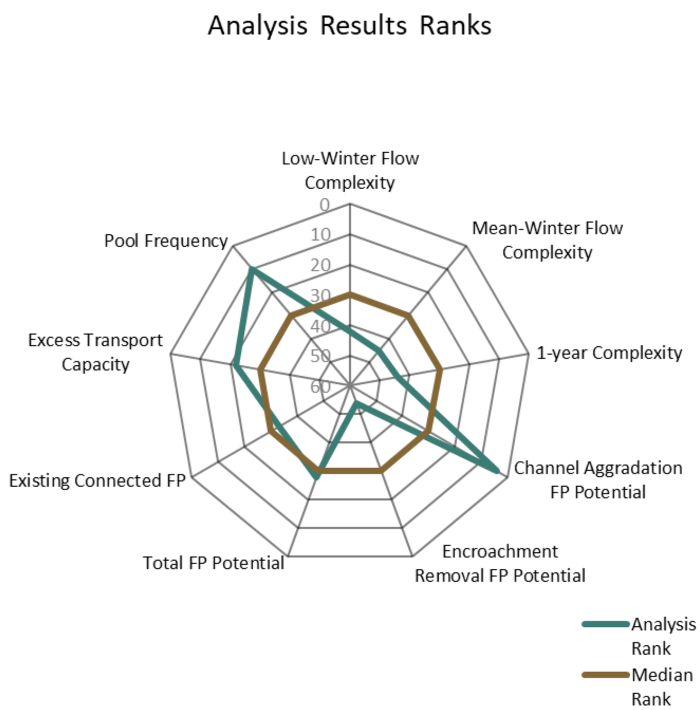
- Gravel augmentation
- Maintain side channels and LWD structures.

PA 28.3 Score Breakdown



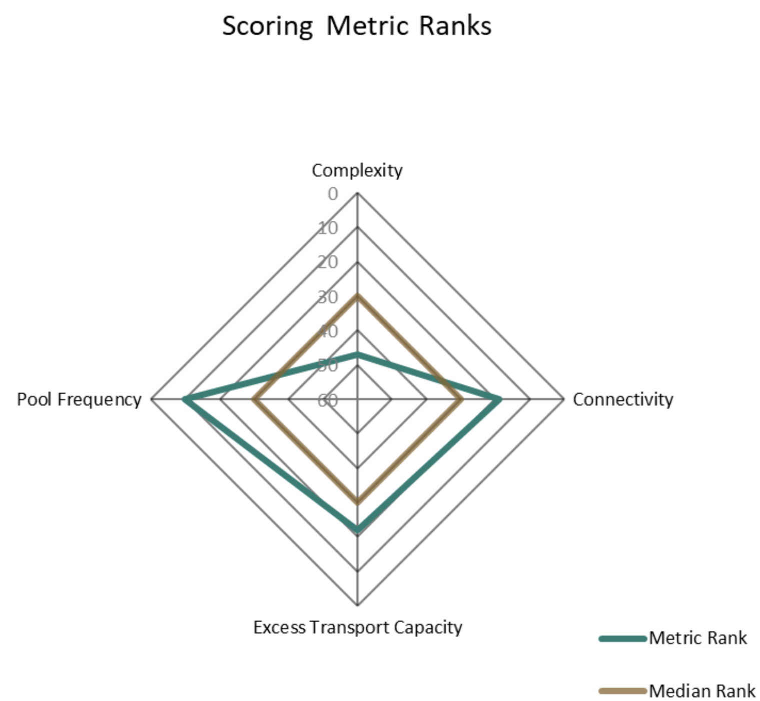
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 28.3 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

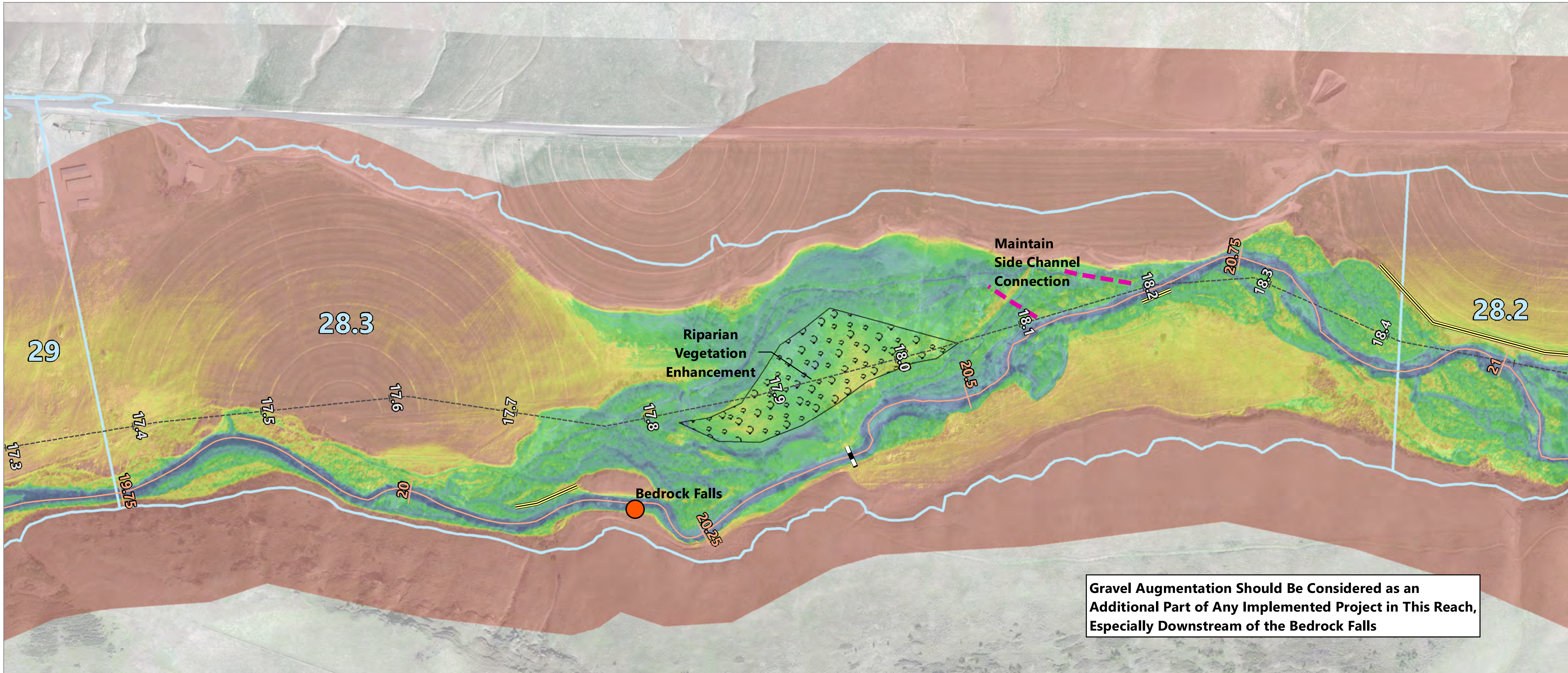
PA 28.3 Prioritization Scoring Summary

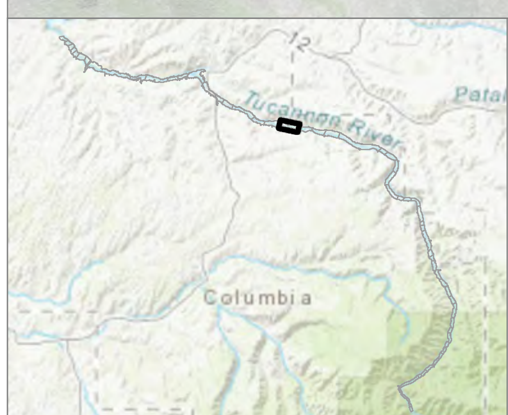


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 28.3 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.109	42	40%	Complexity	0.134	47	60% to 90%	4 of 5	1	40%	1.8	33	2	Treated	13	2
Mean-Winter Flow Complexity	0.137	45	40%													
1-year Complexity	0.177	44	20%													
Channel Aggradation FP Potential	0.360	4	40%	Connectivity	0.224	19	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.013	54	40%													
Total FP Potential	0.374	28	20%													
Existing Connected FP	0.626	33	0%													
Excess Transport Capacity	0.09	22	100%	Excess Transport Capacity	1.000	22	30% to 52%	3 of 4	1	20%						
Pool Frequency	20.61	10	100%	Pool Frequency	0.529	10	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Reconnect Side Channel
- Riparian Enhancement
- Placemark

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 19.75
RIVER MILE END: 20.91
VALLEY MILE START: 17.38
VALLEY MILE END: 18.41

0 500
Feet

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ANCHOR QEA

Project Area 28.3
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

APPENDIX J.1
TIER 3: TREATED PROJECT AREAS

Project Area 10.1 Description

Project Area 10.1 begins at VM 38.52 and extends upstream to VM 38.92. The 2017 RM length is 0.47 mile. Field observations for PA 10.1 were conducted on September 28, 2018, when flow at the Starbuck gage was approximately 80 cfs.

PA 10.1 is characterized by extremely well-connected floodplain and high amounts of instream wood. At the upstream end of the project area, flow on the floodplain comes in from the downstream portion of PA 9. A side channel is visible in the 2018 aerial imagery that extends the entire length of the floodplain in PA 10.1. Where the site visit started on PA 10.1, flow was visible through the forest floodplain for a good distance and a large backwater area was formed near a large log jam.

The channel has a high amount of wood loading with large rootwad logs that appeared to be both placed and natural recruits. At VM 38.67, a large channel-spanning log jam has triggered a split flow around an island with established vegetation. This channel-spanning log jam appears to have captured much of the wood that would otherwise be moving further downstream, but some natural and placed log jams are still apparent.

There appeared to be an abundance of gravel material through the reach and many of the log jams had large scour pools associated with them. It is possible that much of this material

Project Area 10.1
Placed large woody material interacting with flow at the upstream end of PA 10.1, near where a large avulsion has caused much of the downstream aggregation, complexity, and floodplain connection.

Project Area 10.1 Reach Characteristics

VM Start (mi)	38.52
VM Length (mi)	0.41
Valley Slope	1.82%
RM Start (mi)	43.58
RM Length (mi)	0.47
Average Channel Slope	1.51%
Sinuosity	1.15
Connected FP (ac/VM)	21.40
Encroachment Removal (ac/VM)	1.24
Channel Aggradation (ac/VM)	4.82
Total FP Potential (ac/VM)	6.74
Encroaching Feature Length (ft)	0.00
Connected FP Rank	12

was sourced from a large avulsion that appeared to have happened at the upstream end of the project area, and is being transported downstream.

Throughout the reach are stands of mature vegetation, and in places where there are fewer large trees dense stands of young to middle-aged alders, dogwoods, and cottonwoods populate much of the immediate riparian area and new gravel bars.

Restoration Actions and Geomorphic Changes

PA 10.1 has been treated three times since 2008. Restoration work in 2008 involved dropping 15 to 20 cut trees into the river at the upstream 600 feet of the project reach to aid in recovery following the 2006 forest fires. In 2012, a larger effort to wood load the reach involved placing 8 additional LWD structures and 4 mobile LWD racking bundles 20 feet long but smaller than the key piece diameter criteria.

Analysis of the difference between the 2010 and 2017 LiDAR data shows one major change that extends for a large portion of the PA 10.1 reach. At the upstream end of the reach, a major channel avulsion has occurred into the right bank floodplain and significant erosion is evident in this area. A split flow has formed in this location with a large mid-channel bar. Downstream of here for approximately 700 feet, major deposition has occurred in the main channel, which was likely sediment released from the floodplain in the upstream avulsion. This deposition has resulted in multiple side channels and flow through the floodplain in this area (box 1).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 10.1 receives its entire prioritization score in the Complexity prioritization metric. The Complexity score is moderate, indicating that PA 10.1 ranks above average in the 60th to 90th percentile of all project areas, a range that still shows moderate complexity but does not place it in the top 10% of project areas; this project area likely only needs a little restoration work to reach that mark.

In the analysis results for the three flows of complexity, PA 10.1 ranks well above average for all three with very similar scores, indicating that complexity is relatively stable across flows. Looking at the GIS layer for islands and complexity, this complexity is achieved evenly across the whole reach with a particularly large complex pocket near the middle of the reach. Based on the relative elevation map, there are multiple side channel opportunities throughout the reach that appear to be already within the 2-year connected floodplain. Reconnecting these low-lying side channel opportunities should be the main target for enhancing the existing restoration efforts in this reach. Primary enhancement strategies should be the placement of instream wood to promote geomorphic change, in conjunction with cutting strategic pilot channels to connect perennial flow in disconnected side channels.

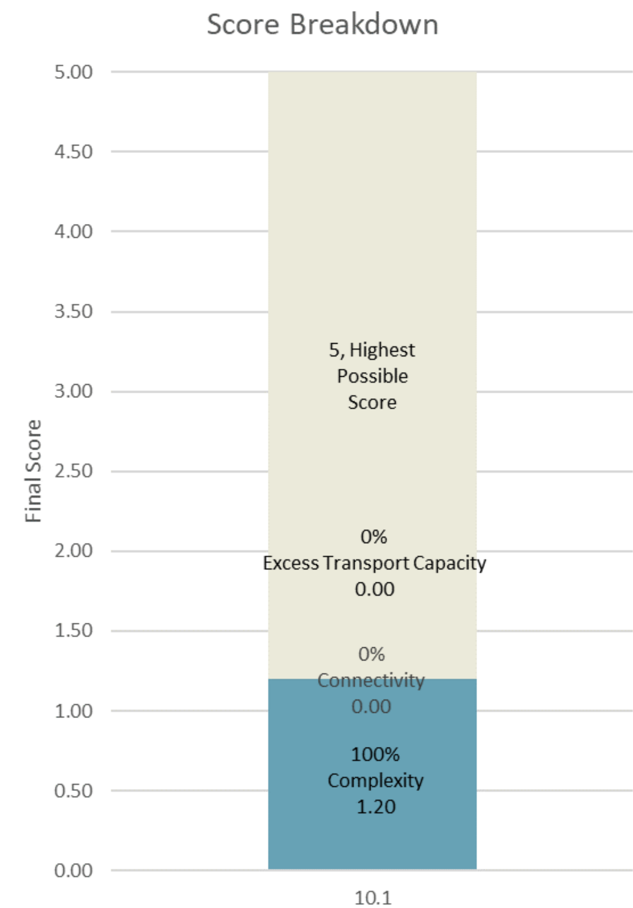
Based on the geomorphic change analysis, this reach is already depositional in nature and should respond quickly to the addition of instream wood. However, it appears the source of this sediment is an isolated avulsion at the upstream end of the reach that may not sustain the necessary sediment load for long without more geomorphic changes upstream. If this is the case, gravel augmentation should be considered as a restoration strategy, in addition to placement of instream wood and pilot channel cuts, to promote geomorphic change in the reach. PA 10.1 receives no score in the Excess Transport Capacity metric, indicating sediment added to the reach should be easily stored and maintained with the addition of instream wood.

Finally, PA 10.1 ranks around the average in the Pool Frequency metric, indicating a moderate amount of pools per valley mile. The restoration action of adding instream structure and wood, along with sediment deposition from gravel augmentation, should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

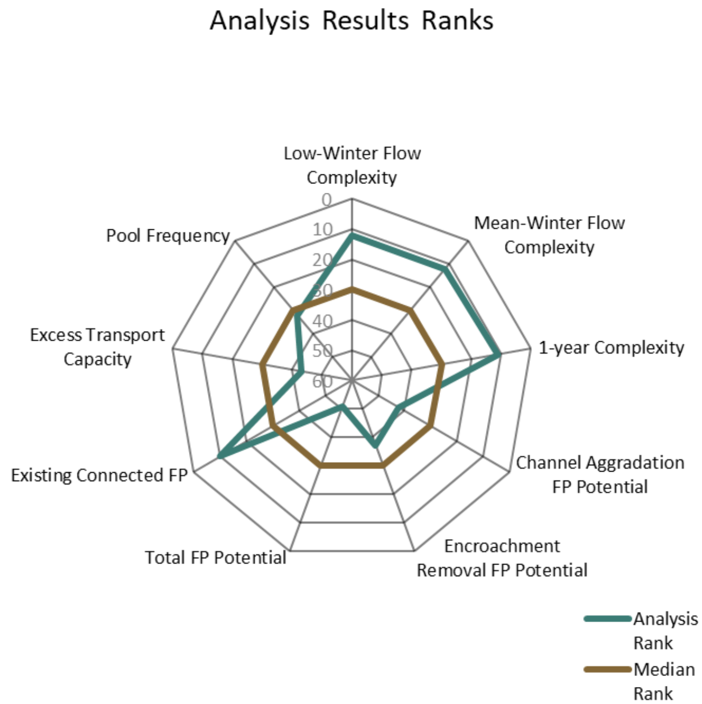
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 10.1 Score Breakdown



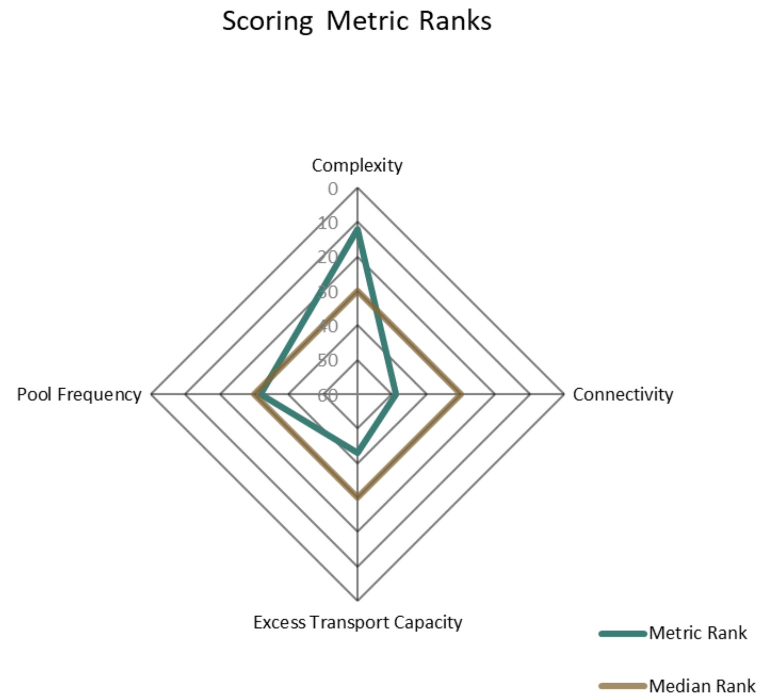
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 10.1 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

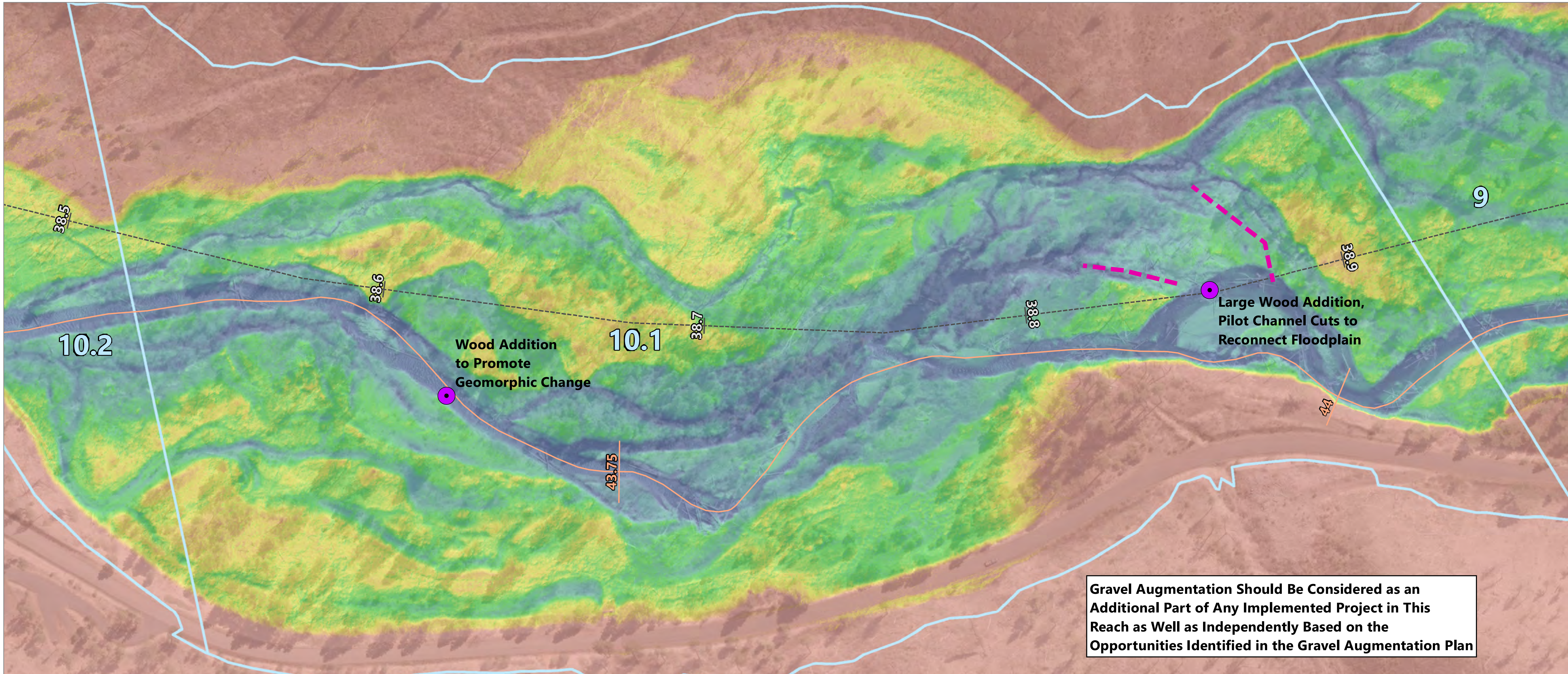
PA 10.1 Scoring Metric Ranks

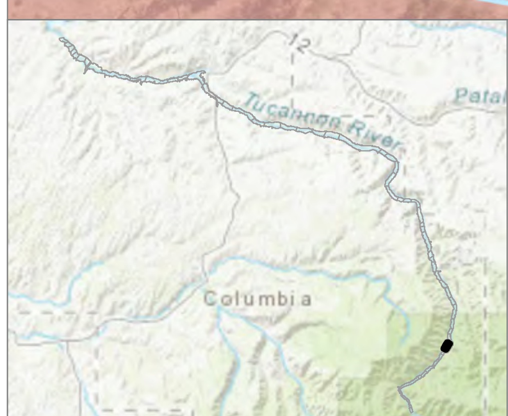


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 10.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.273	12	40%	Complexity	0.379	12	10% to 40%	2 of 5	3	40%	1.2	44	3	Treated	18	3
Mean-Winter Flow Complexity	0.410	12	40%													
1-year Complexity	0.530	11	20%													
Channel Aggradation FP Potential	0.171	42	40%	Connectivity	0.134	49	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.044	37	40%													
Total FP Potential	0.239	51	20%													
Existing Connected FP	0.761	10	0%													
Excess Transport Capacity	-0.09	43	100%	Excess Transport Capacity	0.000	43	52% to 100%	4 of 4	0	20%						
Pool Frequency	10.69	32	100%	Pool Frequency	0.274	32	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Wood Addition
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 43.58
RIVER MILE END: 44.05
VALLEY MILE START: 38.52
VALLEY MILE END: 38.92

0 500
Feet

Publish Date: 2021/01/25, 3:44 PM | User: mgieschen
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ANCHOR QEA

Project Area 10.1
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 10.2 Description

Project Area 10.2 begins at VM 37.89 and extends upstream to VM 38.52. The 2017 RM length is 0.72 mile. Field observations for PA 10.2 were conducted on September 28, 2018, when flow at the Starbuck gage was approximately 80 cfs.

PA 10.2 is more uniform and plane-bed than PA 10.1 just upstream, but a large amount of wood loading has added considerable complexity to this reach. A large camping area in the left bank floodplain limits the amount of riparian area available for a large portion of this reach, which for the most part is confined by the valley wall on the right bank. This camping area could be a good target for floodplain inundation and riparian plantings.

There are multiple LWD structures throughout this reach, but many are lacking significant scour pools; the bed material through PA 10.2 consists of cobble and boulder material, which seems to be coarser than just upstream.

At VM 38.28, a massive channel-spanning log jam has created upstream backwater and several split flows to either side and through the log jam, forming several small islands in its wake. However, a tenth of a mile upstream, field observations noted that a side channel through the left bank floodplain was not activated at this flow, and it appeared to be slightly clogged with debris and sediment.

Project Area 10.2
Engineered log jam on left bank with wood recruits forcing flow towards the right bank.

Project Area 10.2 Reach Characteristics

VM Start (mi)	37.89
VM Length (mi)	0.63
Valley Slope	1.40%
RM Start (mi)	42.86
RM Length (mi)	0.72
Average Channel Slope	1.22%
Sinuosity	1.14
Connected FP (ac/VM)	14.61
Encroachment Removal (ac/VM)	0.26
Channel Aggradation (ac/VM)	3.13
Total FP Potential (ac/VM)	3.75
Encroaching Feature Length (ft)	651.23
Connected FP Rank	24

At VM 38.24, the channel is up against the right bank valley wall and a channel-spanning log jam has been almost cut around except for a small amount of flow around the backside of the structure. However, a large pool has formed and decent complexity is maintained through this area.

At VM 38.1, a series of log jams has created split flow complexity but again failed to activate the low-flow path on the left bank, although from the 2017 aerials taken in April, the side channel appears to be flowing at that flow level. Reports indicate that it flows perennially and has a small beaver dam and pond.

Further downstream, the channel again flows right against the valley wall, which is steep with little to no vegetative cover. Several more jams were apparent for the last portion of the reach causing decent localized channel complexity, but with little floodplain interaction.

Vegetation through this reach was sparser with some large-growth conifers. Most of the immediate riparian area was dominated by young deciduous species such as alder and cottonwood; this reach appears to be in recovery from the 2005 School Fire based on several large burned trees that were visible in the floodplain. Instream wood loading was high but not as much as PA 10.1 and more wood could jumpstart some geomorphic process and floodplain connection at the lowest flows.

Restoration Actions and Geomorphic Changes

In 2012, restoration work in PA 10.2 included placing 24 LWD structures within the reach. Approximately 1,305 feet of river levee were perforated and 0.31 mile of perennial side channel was reconnected on the left bank.

Analysis of the difference between the 2010 and 2017 LiDAR data shows several major locations of geomorphic change that are likely the direct result of restoration actions. At VM 38.3, a channel avulsion and split flow has occurred on the left bank, coincident with a large engineered log jam. Bank scour is also seen immediately downstream of this area on the left bank, and the aerials show the formation for several in channel bars (box 1).

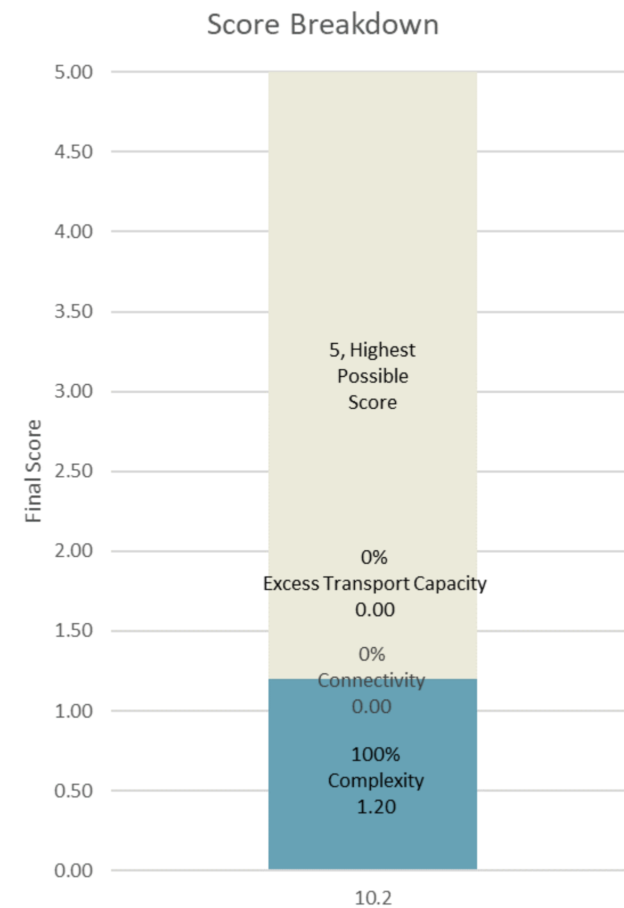
Downstream of here, a bank barb type log jam has caused bar building and channel aggradation immediately upstream of the log jam along with erosion on the outside bank (box 2). There are several more minor instances of similar processes occurring that are evident but have not been highlighted for discussion here. At VM 38.06, it appears the steep right valley wall is experiencing some bank failure and the material falling off the bank is evident as aggradation in the change analysis. It is unclear if this is occurring due to the log jam placed near the bend (box 3).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, Complexity makes up the majority of the score for PA 10.2, placing it in the 60th to 90th percentile of project areas. This range still shows moderate complexity but does not place it in the top 10% of project areas; this project area may only need some minor additional restoration work to reach that mark. This Complexity score is driven mostly by high ranks in the mean-winter and 1-year complexity analysis results, while the low-winter flow complexity ranks around average. This indicates that there are flow paths and complex areas, near the channel or on the floodplain, that are accessed at the mean-winter flow but not the low-winter flow. These opportunities are seen in the GIS layers for islands and water surface and exist mostly near the downstream half of the reach.

This reach has already been treated with wood placements and engineered log jams; however, based on field observations and the aerial imagery, it is likely that more wood and instream structure is needed in this reach. The work here was completed when unanchored wood placement was very new and at a density not tried in southeastern Washington at the time. Wood placement was conservative by current standards. Additionally, some of the placed materials are beginning to deteriorate and supplementation to the amount of wood would

PA 10.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

be beneficial to the reach. Adding instream structure should be a primary enhancement strategy.

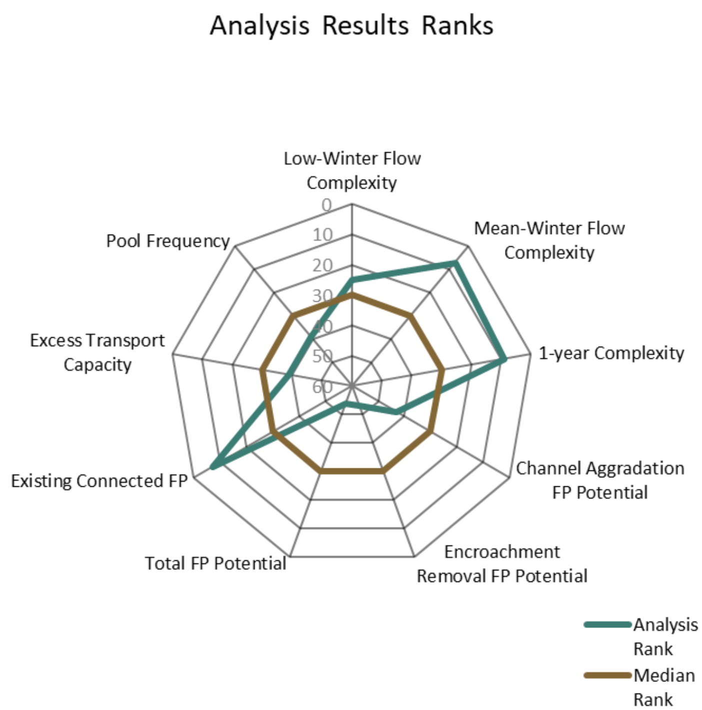
PA 10.2 also receives a small portion of its prioritization score from the Connectivity Potential metric. Although this is a low overall score, indicating that this project area ranks in the 25th to 50th percentile of all project areas, the analysis results for channel aggradation potential and encroachment removal potential both rank above average. These scores are driven mostly by several low-lying areas that could be connected by side channels on the right bank. Connecting these areas with pilot channel cuts and adding instream wood should be strongly considered as an enhancement strategy, given that these features will also contribute to complexity.

Finally, this project area ranks below average for the Pool Frequency metric. Pools in this reach can be increased through the addition of instream wood as an enhancement strategy. However, it may be possible that this reach also requires additional instream gravel material to form around the instream structure. Gravel augmentation in this reach should be considered as a second enhancement strategy that could help precipitate geomorphic changes. The project area ranks below average in Excess Transport Capacity, indicating that this reach should be able to hold and store sediment added via gravel augmentation. Local sourcing of gravel augmentation may be a challenge at this site although a stranded gravel bar at the upstream end of the project area, near box 1, has been noted as a possible source.

Summary of Restoration Opportunities Identified

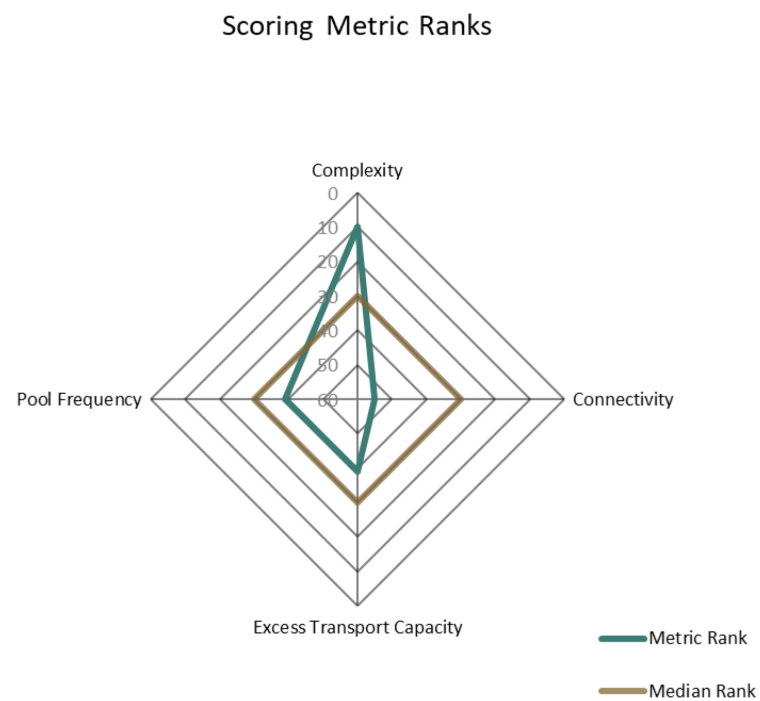
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)
- Riparian zone enhancement

PA 10.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

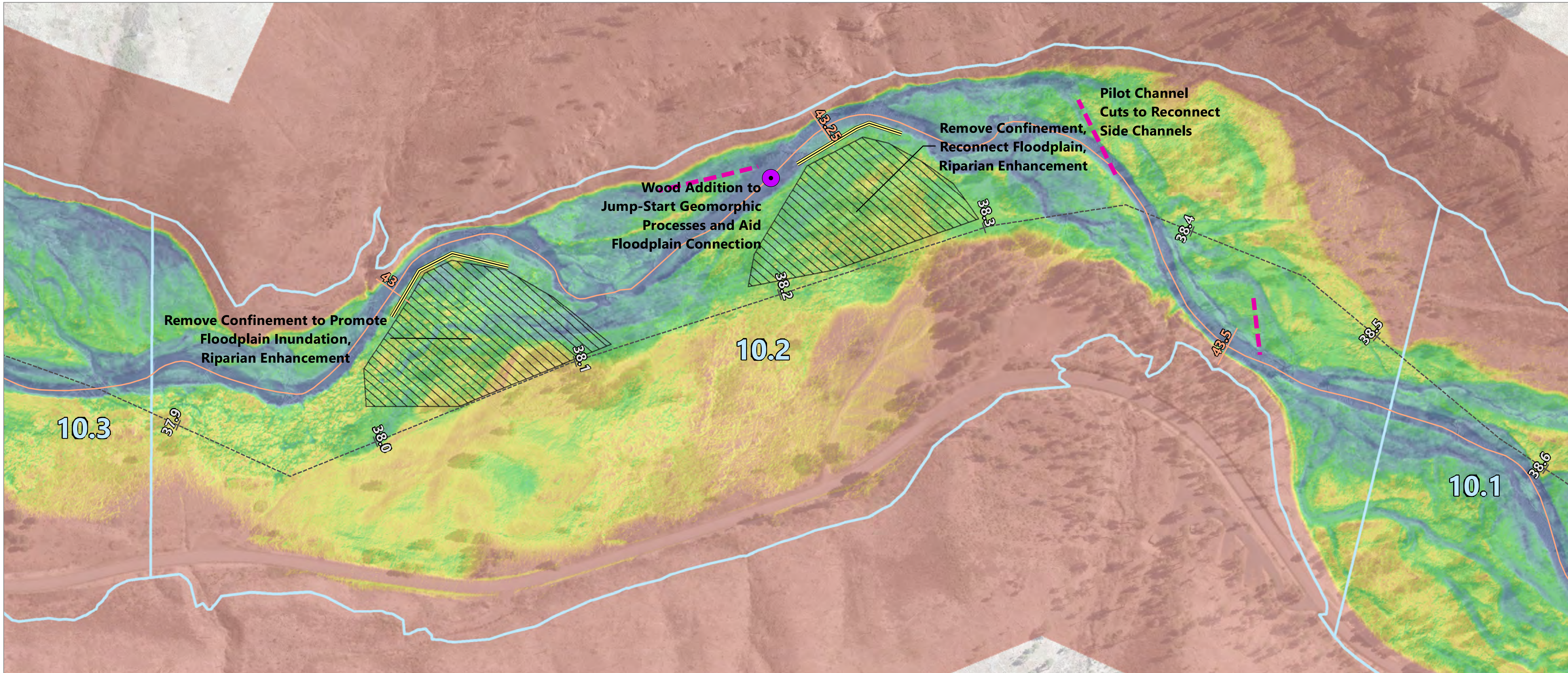
PA 10.2 Scoring Metric Ranks

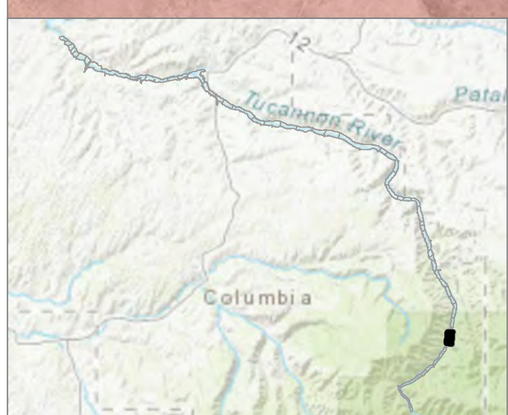


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 10.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.187	25	40%	**Complexity**	0.391	10	10% to 40%	2 of 5	3	40%	1.2	45	3	Treated	19	3
Mean-Winter Flow Complexity	0.483	7	40%													
1-year Complexity	0.612	9	20%													
Channel Aggradation FP Potential	0.170	43	40%	**Connectivity**	0.115	55	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.014	53	40%													
Total FP Potential	0.204	54	20%													
Existing Connected FP	0.796	7	0%													
Excess Transport Capacity	-0.05	39	100%	**Excess Transport Capacity**	0.000	39	52% to 100%	4 of 4	0	20%						
Pool Frequency	8.33	39	100%	**Pool Frequency**	0.214	39	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Side Channel
- Reconnect Floodplain

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 42.86
RIVER MILE END: 43.58
VALLEY MILE START: 37.89
VALLEY MILE END: 38.52

0 500
Feet

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ANCHOR QEA

Project Area 10.2
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 11.1 Description

Project Area 11.1 begins at VM 36.88 and extends upstream to VM 37.51. The 2017 RM length is 0.75 mile. Field observations for PA 11.1 were conducted on October 31, 2018, when flow at the Starbuck gage was approximately 95 cfs.

The upper reach of PA 11.1 is still relatively plane-bed and uniform. At VM 37.35, a foot bridge from a parking lot to Watson Lake limits the floodplain with large riprap levees. Watson Lake itself takes up a large portion of the floodplain, loosely confining the channel in this section. At VM 37.25, just across the from the lake, the channel flows very close to Tucannon Road. Just downstream, a large mid-channel bar introduces some complexity. Further downstream, left bank erosion is evident were some instream wood has been placed.

VM 37.1 marks an increase in instream wood density, much of which was placed as part of a restoration project. Several large gravel bars were evident on the insides of meander bends near the instream wood. After several large log jams on alternating banks around VM 37, the channel becomes more uniform with low complexity again to the end of the project area.

The bed material in PA 11.1 is mostly transport-resistant boulders and large cobbles with some gravel bars beginning to form in locations of recent geomorphic change.

Project Area 11.1
Looking upstream, an engineered bank barb promotes flow towards the right bank, but was not causing split flow at the time of this photograph.

Project Area 11.1 Reach Characteristics

VM Start (mi)	36.88
VM Length (mi)	0.62
Valley Slope	1.52%
RM Start (mi)	41.70
RM Length (mi)	0.75
Average Channel Slope	1.23%
Sinuosity	1.21
Connected FP (ac/VM)	13.30
Encroachment Removal (ac/VM)	0.66
Channel Aggradation (ac/VM)	4.10
Total FP Potential (ac/VM)	4.50
Encroaching Feature Length (ft)	2,671.05
Connected FP Rank	31

Floodplain vegetation does not appear to have changed much from the 2011 assessment. Large trees were extremely limited by the 2005 School Fire and burned logs are still evident on the floodplain. However, in addition to invasive species throughout the reach, multiple stands of willow and alder were observed particularly on some of the newer gravel berms.

Restoration Actions and Geomorphic Changes

In 2015, restoration work in PA 11.1 included placing 21 LWD structures, including 5 additional floodplain structures, starting at RM 42 and continuing downstream. The geomorphic objectives for this restoration treatment included improving channel connectivity and channel complexity.

Analysis of the difference between the 2010 and 2017 LiDAR data shows that geomorphic change has begun to occur as a result of some of these restoration actions. However, much of the change is small in scale and isolated, indicating this reach is slow to respond to restoration efforts.

Just past the foot bridge is a location where gravel bars have been built and meander erosion has occurred on alternative sides of the reach as a direct result of added wood (box 1). Immediately downstream of here, major erosion has occurred on the left bank and the channel seems to be moving towards the road (box 2).

A large placed log jam has also formed a large depositional area in its wake with a minor channel avulsion and erosion towards the left bank (box 3).

Finally, at the downstream end of the reach, deposition is beginning to occur in the main channel, likely as a result of a very large channel-spanning log jam further downstream in PA 11.2 (box 4).

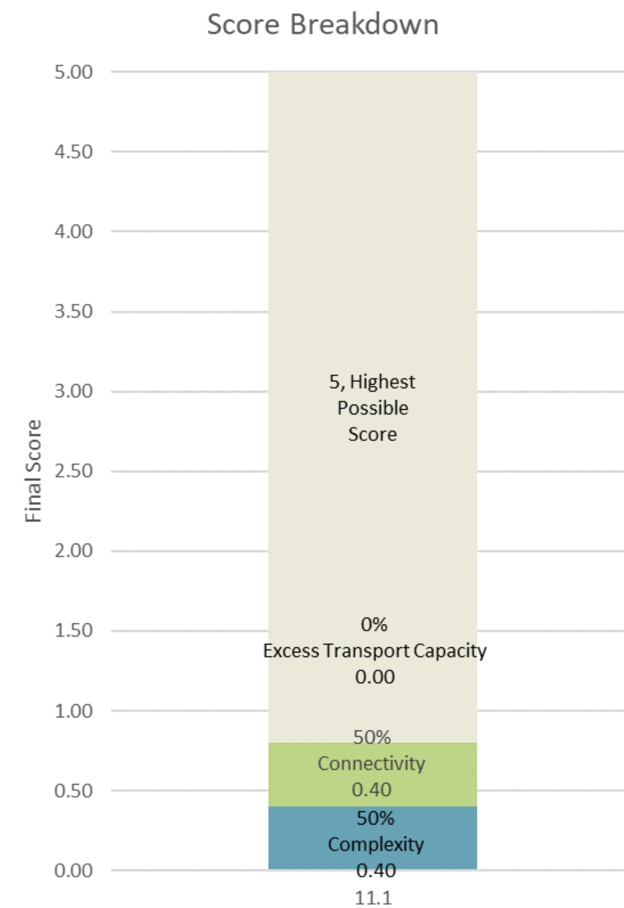
Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 11.1, receives low scores in both the Complexity and Connectivity prioritization metric, which makes up its entire prioritization score. The low score in Complexity indicates that PA 11.1 ranks low among project areas in the 10th to 40th percentile. This range has been identified as having some small existing complexity but would likely require a large restoration effort to achieve higher levels. The low score in Connectivity indicates PA 11.1 ranks below average in the 25th to 75th percentile for potential floodplain reconnection. This rank is driven almost entirely by the Channel Aggradation analysis result, which ranks above average for project areas. The Encroachment Removal analysis result ranks as one of the lowest; however, this does not include the Beaver-Watson Lake Complex, which encroaches on the floodplain and could be a major opportunity for floodplain encroachment removals. Additionally, field reports indicated that there are spoils from reservoir excavation upstream, which could increase the floodplain area if they were removed. Finally, the Tucannon Road below the lakes is a major encroachment to the floodplain. While it would be difficult to move the road, if the opportunity ever arises to move the road out of the floodplain it should be strongly considered.

Channel aggradation potential exists almost entirely in areas surrounding the existing 2-year floodplain. This indicates that this reach is slightly incised and raising the bed elevation could have a large benefit in terms of connecting more of the available floodplain at the 2-year event. Because the lower half of the reach has already been treated with instream structure and wood, a primary enhancement strategy should be gravel augmentation. Sediment material from gravel augmentation can be trapped and stored by the existing instream wood and should help to reverse the effects of incision and connect more of the floodplain. It is likely that with gravel augmentation more structure and instream wood would be desirable to maximize the effects and ensure sediment is entrained in the reach.

Existing complexity is low across all three flows and is driven by several small pockets of split flows and in-channel bars throughout the reach. Again, since instream wood already exists, gravel augmentation would likely have a positive effect on the in-channel complexity in the reach, regularly creating complex channel forms and side channels. Additionally, raising the channel bed elevation should help to reconnect several side channel areas evident on the relative elevation map and already

PA 11.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

connected at the 2-year event, which would boost complexity across the reach. Pilot channel cuts should also be considered as a secondary restoration strategy, along with adding instream wood and gravel augmentation, to ensure these side channels are quickly and perennially reconnected.

PA 11.1 receives no score in the Excess Transport Capacity metric, indicating that added sediment material should be easily trapped and stored behind instream structure and wood.

Finally, PA 11.1 ranks slightly below average in the Pool Frequency metric, indicating a moderate amount of pools per valley mile. The enhancement action of adding sediment deposition from gravel augmentation, along with adding instream structure and wood, should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

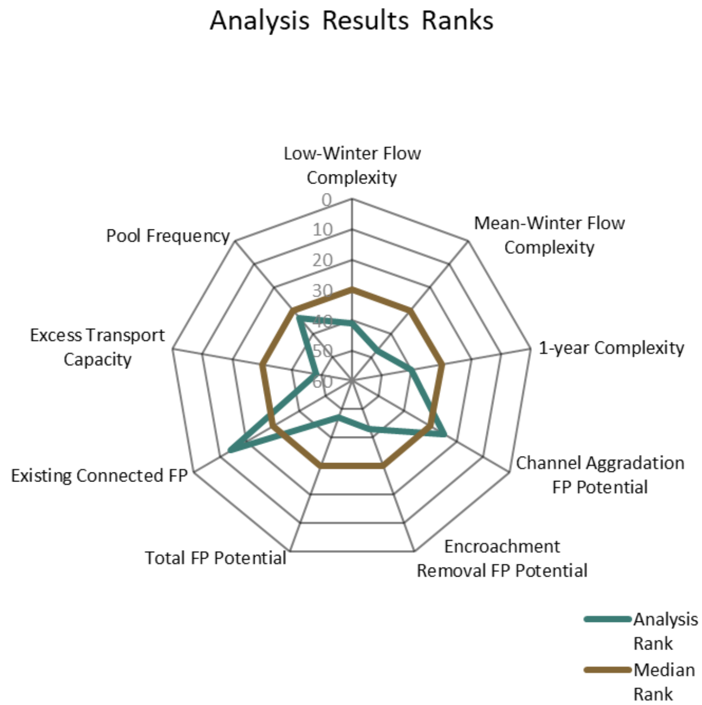
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

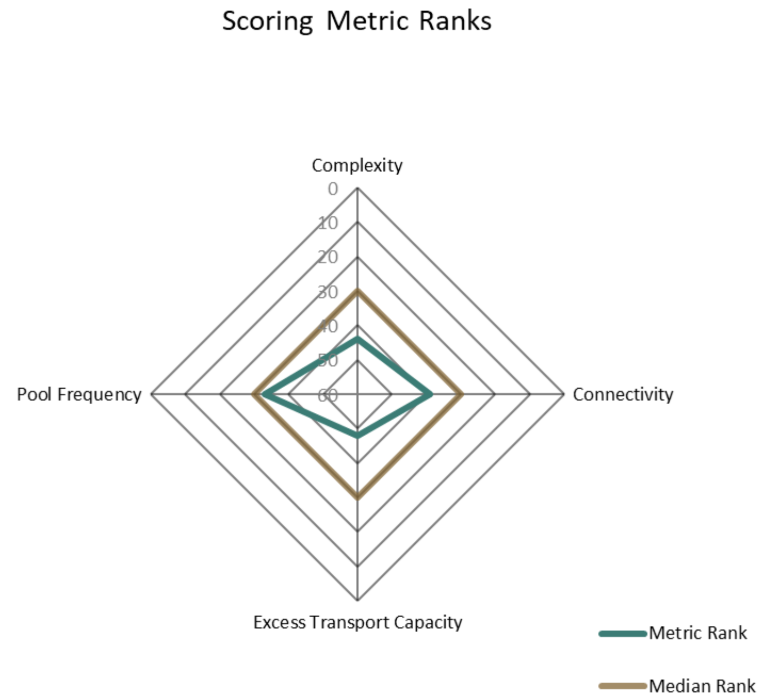
- Set back road against the left valley wall for more floodplain connection and channel migration area.
- Relocate the parking area and walking bridge for lake access.
- Reconfigure Watson Lake and Beaver Lake to reconnect floodplain and consider decommissioning and removing if ever feasible.

PA 11.1 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

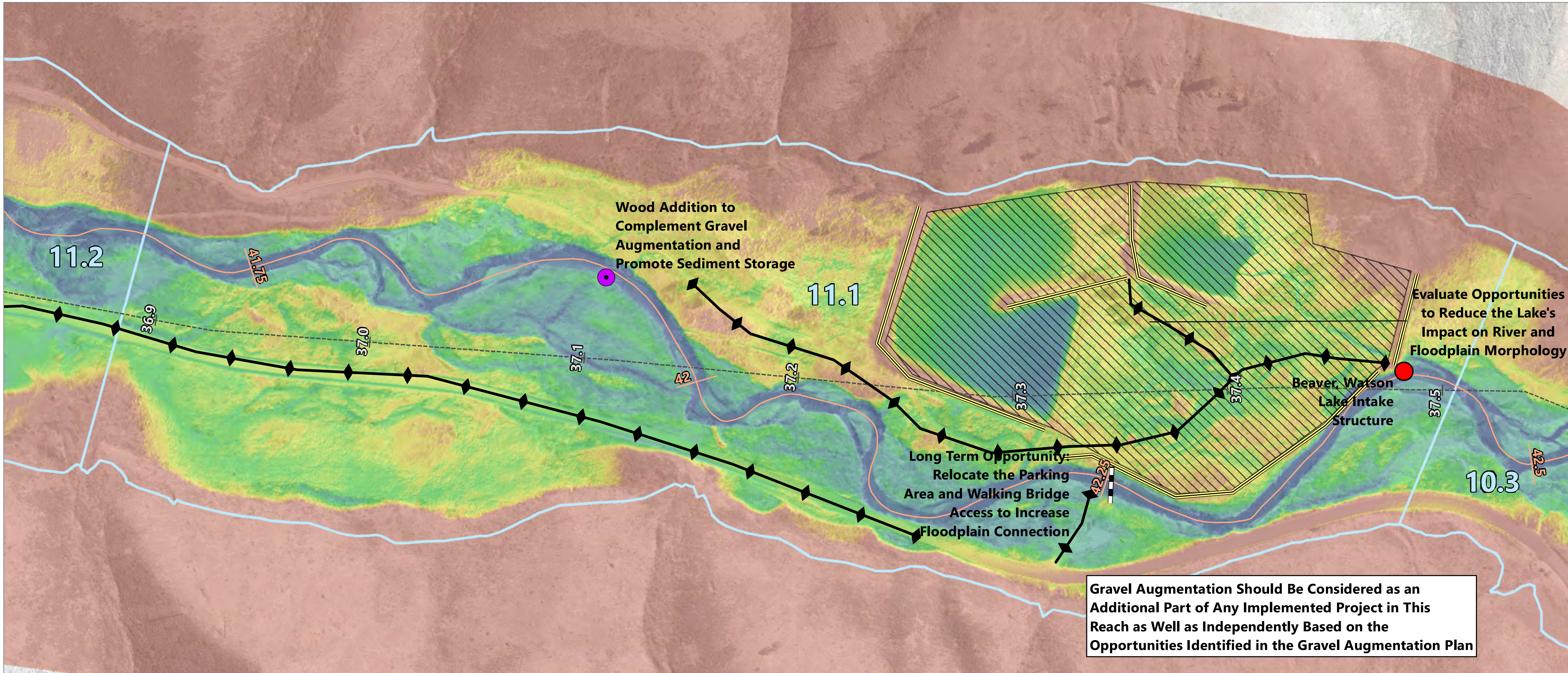
PA 11.1 Scoring Metric Ranks

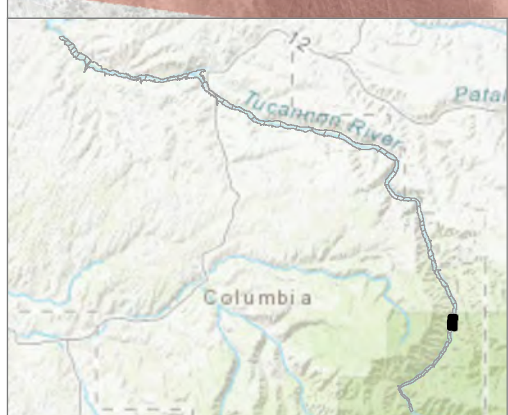


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 11.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.113	41	40%	**Complexity**	0.140	44	60% to 90%	4 of 5	1	40%	0.8	53	3	Treated	21	3
Mean-Winter Flow Complexity	0.129	47	40%													
1-year Complexity	0.213	40	20%													
Channel Aggradation FP Potential	0.230	25	40%	**Connectivity**	0.158	39	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.037	43	40%													
Total FP Potential	0.253	47	20%													
Existing Connected FP	0.747	14	0%													
Excess Transport Capacity	-0.12	48	100%	**Excess Transport Capacity**	0.000	48	52% to 100%	4 of 4	0	20%						
Pool Frequency	10.66	33	100%	**Pool Frequency**	0.274	33	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Floodplain
- Long Term: Relocate Road
- Current Infrastructure in River Corridor

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 41.7
RIVER MILE END: 42.45
VALLEY MILE START: 36.88
VALLEY MILE END: 37.51

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ANCHOR QEA

Project Area 11.1
Conceptual Adaptive Management and Restoration Opportunities

Project Area 11.2 Description

Project Area 11.2 begins at VM 36.00 and extends upstream to VM 36.88. The 2017 RM length is 0.96 mile. Field observations for PA 11.2 were conducted on October 31, 2018, when flow at the Starbuck gage was approximately 95 cfs.

PA 11.2 is an extremely complex reach with multiple long-flow side channels and a large amount of instream wood. At the upstream end of PA 11.2, a massive channel-spanning log jam has caused visible aggradation and is associated with a large downstream pool, but has caused little geomorphic change around either bank. Over the next tenth of a mile, multiple channel-spanning log jams eventually cause a long split flow at VM 36.82. At this same location, field observations noted additional flow paths on the floodplain with multiple log jams. This side channel runs close to the main channel, and the narrow island between the two channels is mostly covered in grasses, indicating that it is inundated at high flows.

At VM 36.66 is a massive log jam in the floodplain on the right bank and several split flows and side channels just upstream of this location. A major flow path was observed to the right of this structure and a split flow to the left with several associated log jams. The side channel to the right flows for most of the remainder of the project area before joining with the main channel. A second side channel bisects the island at VM 36.45 and flows into this side channel, increasing the amount of

Project Area 11.2
Engineered log jam with accumulated woody material is causing a deep scour pool, split flow, and floodplain inundation.

Project Area 11.2 Reach Characteristics

VM Start (mi)	36.00
VM Length (mi)	0.89
Valley Slope	1.36%
RM Start (mi)	40.73
RM Length (mi)	0.96
Average Channel Slope	1.21%
Sinuosity	1.09
Connected FP (ac/VM)	20.98
Encroachment Removal (ac/VM)	2.19
Channel Aggradation (ac/VM)	5.89
Total FP Potential (ac/VM)	8.03
Encroaching Feature Length (ft)	665.70
Connected FP Rank	14

water. This side channel has multiple wood structures and deep pools, but at VM 36.4 it is confined on the right by the valley wall and an old riprap levee on the left bank.

The main channel has multiple large log jams, and another long side channel forms at VM 36.65 on the left bank. At VM 36.6, a large log jam is at the head of another long side channel on the left bank. At the time of the site visit, this channel was not flowing, although standing water was visible and likely flows at a slightly high flow event.

For the next tenth of a mile, the main channel has multiple large log jams but is relatively plane-bed before it reaches a large left bank log jam on the outside of a meander that appears to be getting close to the Tucannon Road. On the right bank in this area, there is a large split flow around a vegetated island.

At VM 36.3, there is a water supply diversion channel and infrastructure in the right bank floodplain that eventually leads to Deer Lake one-half mile downstream in PA 12.

At VM 36.15 and downstream, several log jams with large gravel bars are forcing split flow and meanders; at the end of the project area, another side channel starts on the left bank and continues into PA 12 downstream.

The vegetation through the reach is similar to PA 11.1 and does not appear to have changed much from the 2011 assessment.

Large trees were extremely limited by the 2005 School Fire and burned logs are still evident on the floodplain. However, in addition to invasive species throughout the reach, multiple stands of willow and alder were observed particularly on some of the newer gravel berms. In PA 11.2, large locust stands were noted around several of the side channels and are reportedly regenerating growth following the fire. It should be noted that locusts are not native and a control action to remove them and reestablish native vegetation should be considered.

Restoration Actions and Geomorphic Changes

In 2015, restoration work in PA 11.2 included placing approximately 53 LWD structures and 18 floodplain structures. The primary objective was to increase channel roughness to increase channel complexity and maintain existing connectivity.

Analysis of the difference between the 2010 and 2017 LiDAR data shows several significant locations of geomorphic change that have occurred as a direct result of restoration efforts.

At the upstream end of the reach, a long in-channel depositional area has occurred as a result of a large channel-spanning log jam (box 1). Just downstream of here, another smaller depositional area has occurred as a result of another log jam (box 2). After this, the channel splits into a long side channel although no significant erosion is seen in the side channel. This side channel was the 2008 main channel and was cut off in 2009 when the large log jam at the upstream end formed following wood loading in fall 2008 as part of the WDFW and USFS efforts to cull hazard trees following the fire. In the main channel, a log jam has triggered a minor channel avulsion and erosion towards the left bank (box 3).

Culling fire killed trees in 2008, dropping them into the river channel in box 2.

Further downstream in the main channel, a log jam has caused a split flow with erosional areas on both banks and deposition in the wake of the log jam forming a small bar (box 4).

After the confluence of the two channels and near the downstream end of the reach, a log jam has caused a minor avulsion and erosion towards the right bank and deposited sediment on a bar in the wake (box 5). At the very downstream end of the reach, two large channel-spanning log jams have allowed deposition in the main channel and caused a small cut-off side channel into the right bank floodplain (box 6).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 11.2 receives a low score in the Connectivity prioritization metric, but this makes up the entire prioritization score for this project area. The low Connectivity score indicates that PA 11.2 ranks below average in the 25th to 50th percentile of all project areas for connectivity potential. This score is driven by an above average rank in the Channel Aggradation analysis result and an average rank in the Encroachment Removal analysis result, but well below average in the Total Floodplain Potential result, which in this case indicates the potential areas are relatively separate.

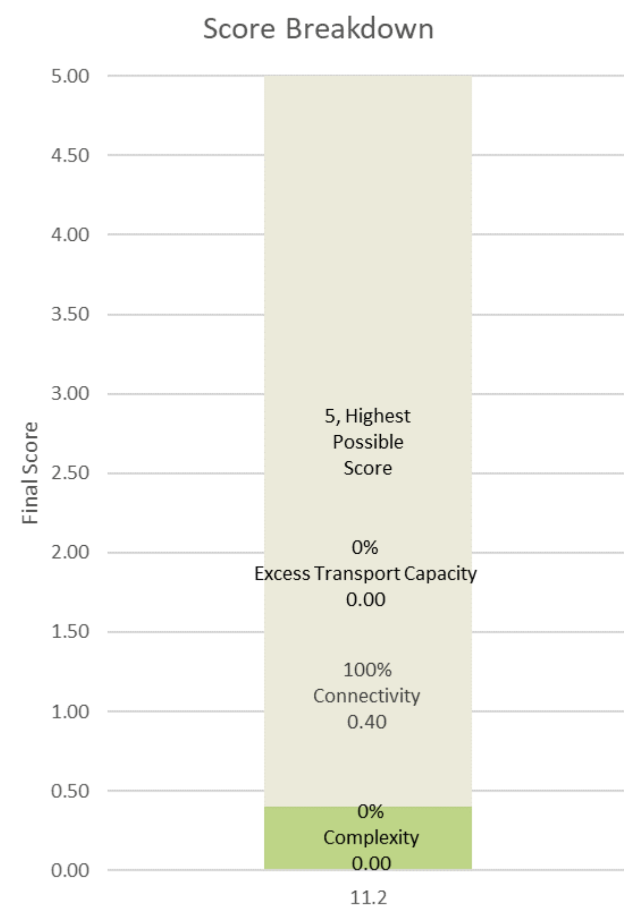
The Channel Aggradation Floodplain Potential exists mostly as the additional area around the existing 2-year floodplain that can be reconnected with channel aggradation. The Encroachment Removal Floodplain Potential exists as a small disconnected area on the left bank near the upstream end of the project area. This does not appear to be an anthropogenic disconnection and would be most effectively reconnected by established a side channel flow through this area.

PA 11.2 received no score in the Complexity metric, which in this case indicates that PA 11.2 ranks among the top project areas in the 90th to 99th percentile. This range has been identified as having enough complexity to warrant no further restoration work targeting complexity. PA 11.2 is extremely complex with a long side channel existing for almost the entire reach at all three flows, and multiple other side channels and split flows that create a very complex and well-connected reach, with ample habitat opportunity.

PA 11.2 would most benefit from a restoration management strategy, monitoring the connectivity and complexity of the reach and making changes if these levels are not maintained. Should complexity ever begin to decrease, it may be necessary to supplement the sediment supply to the reach with gravel augmentation and it may be possible that this reach is included as a larger gravel augmentation plan including multiple reaches, which would not damage the existing good complexity of the reach.

It should be noted that PA 11.2 is in a state of recovery from a fire in 2005, and much of the riparian vegetation still has not been reestablished. For this reason, an enhancement strategy of riparian vegetation plantings should be considered in this reach. The project area already ranks higher than average in the Pool Frequency metric and this is not a primary enhancement target. Should pool frequency ever decrease, enhancement strategies of wood placement and gravel augmentation should be considered.

PA 11.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PROJECT AREA 11.2 TIER 3: TREATED

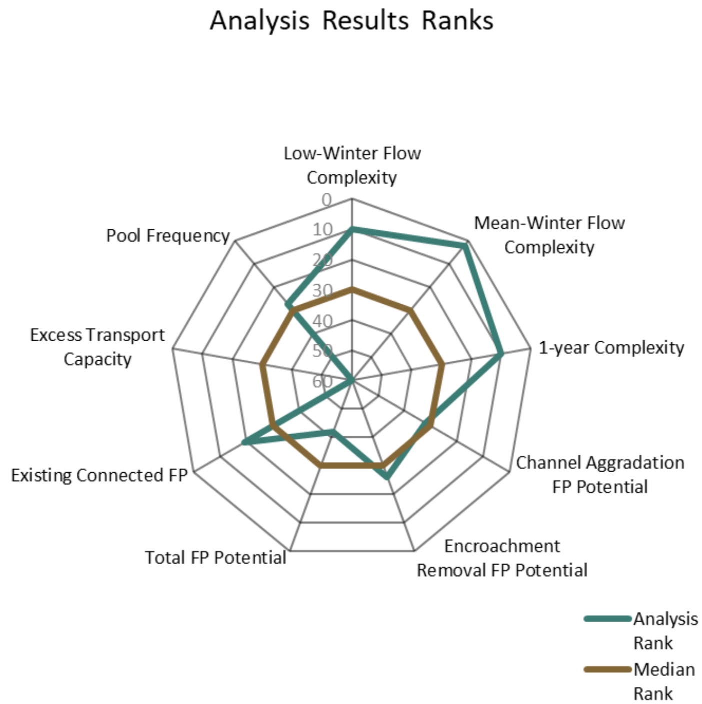
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Riparian zone enhancement

Long-Term Opportunities in this Project Area

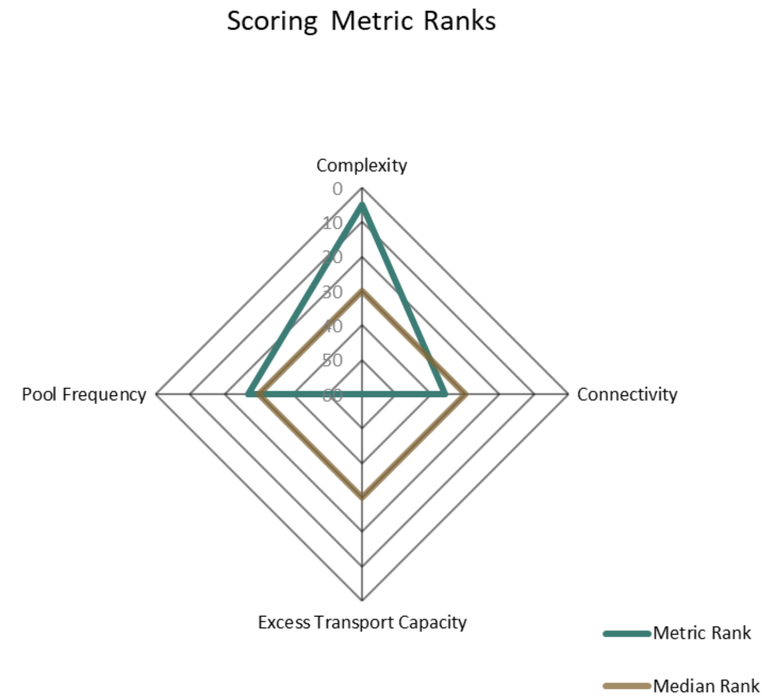
- Set back road against the left valley wall and relocate or remove parking area to expand channel migration area.

PA 11.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

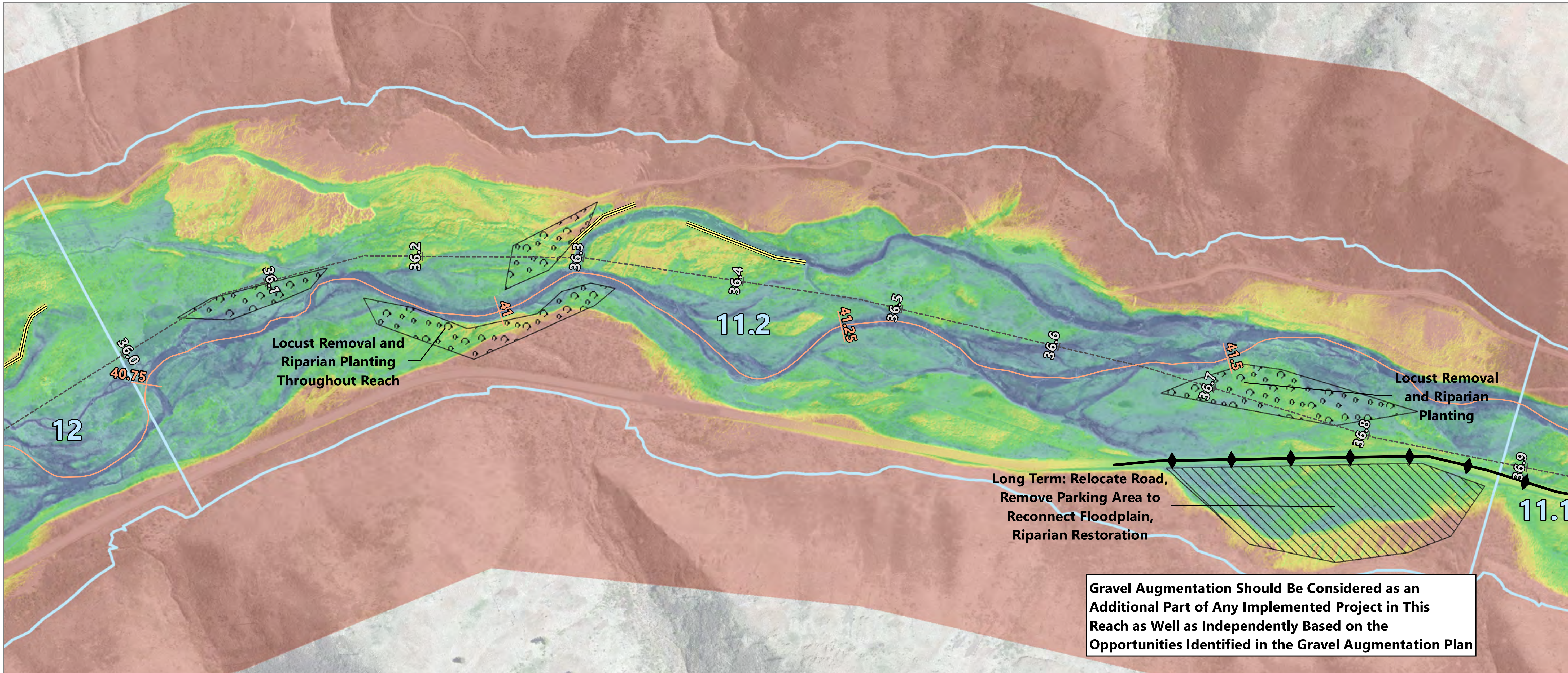
PA 11.2 Scoring Metric Ranks

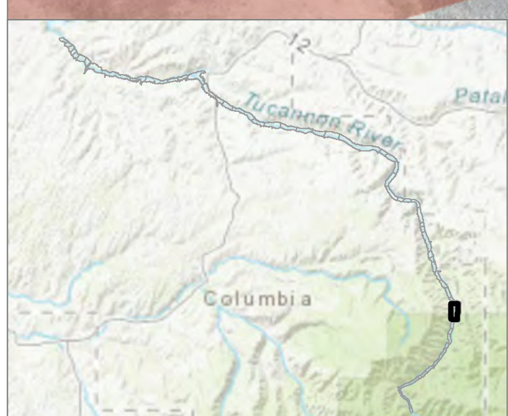


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 11.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.289	10	40%	Complexity	0.463	5	1% to 10%	1 of 5	0	40%	0.4	59	3	Treated	23	3
Mean-Winter Flow Complexity	0.571	2	40%													
1-year Complexity	0.596	10	20%													
Channel Aggradation FP Potential	0.203	32	40%	Connectivity	0.167	36	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.075	26	40%													
Total FP Potential	0.277	42	20%													
Existing Connected FP	0.723	19	0%													
Excess Transport Capacity	-0.38	60	100%	Excess Transport Capacity	0.000	60	52% to 100%	4 of 4	0	20%						
Pool Frequency	11.44	27	100%	Pool Frequency	0.294	27	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Reconnect Floodplain
- Long Term: Relocate Road
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 40.73
RIVER MILE END: 41.7
VALLEY MILE START: 36
VALLEY MILE END: 36.88

0 500
Feet

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ANCHOR QEA

Project Area 11.2
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 15.1 Description

Project Area 15.1 begins at VM 32.68 and extends upstream to VM 33.00. The 2017 RM length is 0.38 mile. Field observations for PA 15.1 were conducted on September 26, 2018, when flow at the Starbuck gage was approximately 80 cfs.

For this assessment update, PA 15 as defined in the 2011 prioritization was separated into two project areas (PA 15.1 and PA 15.2) for distinct analysis. Since the 2011 assessment, PA 15.1 has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

PA 15.1 is largely categorized by the long side channel that forms near the top of the project area and carries nearly half the flow to the end of the reach. Upstream of the channel split, the channel is straight and uniform with almost no wood loading for about a tenth of a mile. The right bank has low floodplain through this section and at the time of the site visit even appeared to be slightly swampy with riparian vegetation.

At the channel split, a large channel-spanning log jam, in conjunction with the channel-spanning woody material, has maintained this split flow and the flow seems to be running through the wood structures on both sides. The right channel (looking downstream) had slightly more flow at the time of the site visit, and is likely the main channel. However, just upstream of this structure, some left bank erosion into the floodplain may

Project Area 15.1
Placed large woody material is interacting with flow in the side channel that has opened up as part of restoration work.

Project Area 15.1 Reach Characteristics

VM Start (mi)	32.68
VM Length (mi)	0.32
Valley Slope	1.52%
RM Start (mi)	36.78
RM Length (mi)	0.38
Average Channel Slope	1.29%
Sinuosity	1.19
Connected FP (ac/VM)	13.90
Encroachment Removal (ac/VM)	0.54
Channel Aggradation (ac/VM)	3.99
Total FP Potential (ac/VM)	5.25
Encroaching Feature Length (ft)	790.85
Connected FP Rank	27

be cutting around this structure, which could possibly make the left flow path the main channel.

Both channels have decent instream wood; the left channel structures appear to be more engaged and creating more complexity and the right channel structures appear to be a little undersized. Most of the structures in either channel do not have large scour pools associated with them, indicating that neither channel seems to be undergoing much geomorphic change.

Bed material throughout this reach consists of mostly large cobbles and boulders with very little gravel material; this transport-resistant material is likely preventing pools from forming too quickly. The channel-spanning structure could possibly be blocking sediment transport, given that this area seems to be aggrading with gravel material on a large bar that is forming on the right bank.

The right main channel runs along and is confined by a large riprap levee for most of its length. A low spot near the center of the island formed by the two channels was not receiving flow and appears to have some sediment deposit associated with it.

Riparian vegetation through this reach is relatively healthy with large deciduous trees covering much of the accessible floodplain. Near the upstream end of the channel split, the right bank levee is protecting a field or lawn that does not provide much overhanging cover other than a thin strip of coniferous trees. On the left bank at the upstream end, the channel runs along a field and the valley wall that provide little cover or mature vegetation as well.

Restoration Actions and Geomorphic Changes

In 2014, restoration work in PA 15.1 included placing 47 LWD structures in a combination of anchored and mobile key pieces using approximately 244 key LWD pieces. This treatment created a 0.31-mile perennial side channel. Project goals included increasing channel complexity and floodplain connectivity.

Analysis of the difference between the 2010 and 2017 LiDAR data shows several significant geomorphic changes that have occurred as a direct result of restoration actions.

At the upstream end of the project area, erosion is actively occurring on the left bank towards a low-lying area and a bar is building from deposition on the right bank (box 1). These changes are likely due to the large, channel-spanning log jams just downstream, which appear to be locally forcing some erosion on the right bank (box 2).

These channel-spanning log jams have triggered a long side channel to the left of the main channel. In the side channel, erosion and downcutting has occurred for a large portion of the channel, which could indicate this side channel is starting to take more flow (box 3). Just downstream in the side channel, a log jam has caused erosion on the right bank and some deposition on the left (box 4).

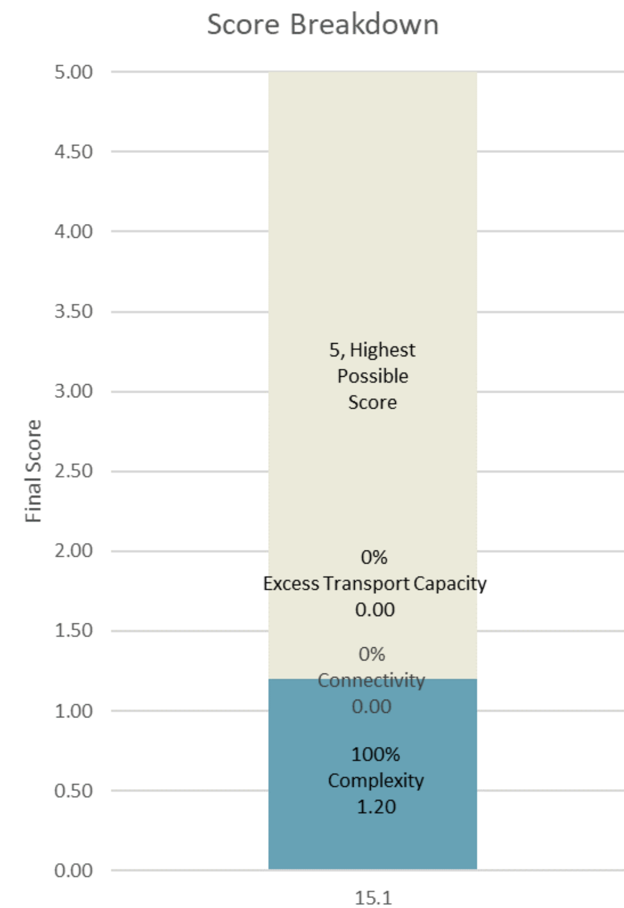
In the main channel, a mid-channel bar has caused erosion on both banks with a small amount of deposition in the wake (box 5). Finally, at the downstream end of the reach, several log jams have forced scour pools in the side channels directly behind the log jams, with some associated deposition on the island in this area (box 6).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 15.1 receives its entire prioritization score from a moderate score in the Complexity metric. This moderate score indicates that PA 15.1 ranks above average in the 60th to 90th percentile of project areas, a range that still shows moderate complexity but does not place it in the top 10% of project areas; this project area likely only needs a little restoration work to reach that mark.

The complexity in PA 15.1 is driven almost entirely by the long side channel that defines the reach and was the target of the initial restoration. The two channels create above average complexity at all three flows. However, the 1-year flow complexity is ranked slightly lower than mean-winter and low-winter flows. The actual complexity values show that complexity does not change much between the mean-winter and 1-year flow; the ranking is lower in the 1-year flow simply because

PA 15.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

most project areas have a higher complexity at the 1-year flow than the mean-winter flow. The complexity in this reach is basically limited to the one large side channel. A primary management strategy for this reach should be to monitor and ensure that both the main channel and side channel remain connected to some degree as geomorphic changes occur.

At the upstream end of the project area, erosion is occurring towards a low-lying forested area on the left bank, and there are several other low-lying areas on both banks at the downstream end of the reach based on the relative elevation map. Adding instream wood and strategic pilot channel cuts should be the primary enhancement strategy to connect these areas and boost complexity across all three flows. The upper area may reconnect through the natural geomorphic processes that are occurring. If this is the case, instream wood should be added to this new avulsion area to ensure in-channel complexity and stability. Additionally, if this change occurs, steps should be taken to ensure both of the existing channels remain connected and continue to provide complexity.

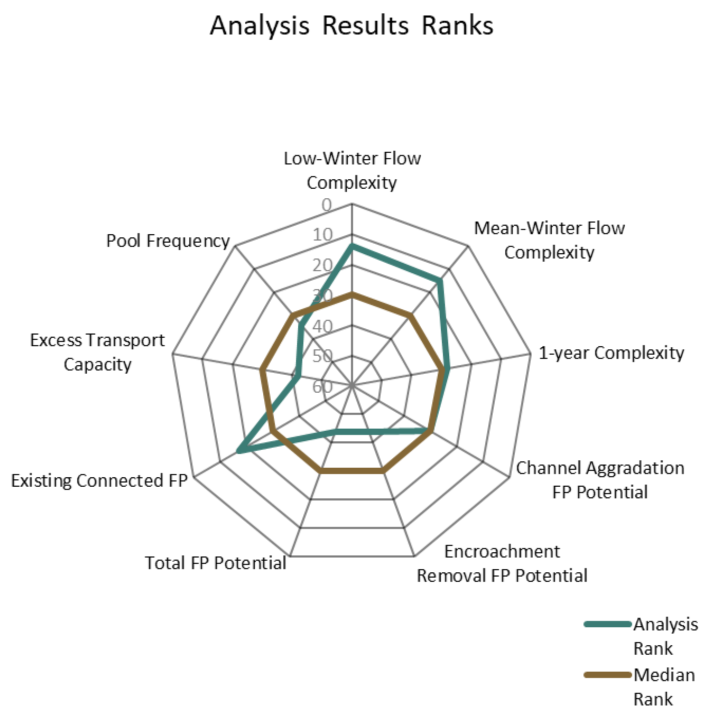
If the addition of instream wood and pilot channel cuts do not prompt the expected geomorphic response, the addition of sediment material might be necessary and gravel augmentation should be considered as a secondary enhancement strategy.

Finally, PA 11.1 ranks slightly below the average in the Pool Frequency metric, indicating a moderate amount of pools per valley mile. The enhancement action of adding instream structure and wood, and possibly gravel augmentation, should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

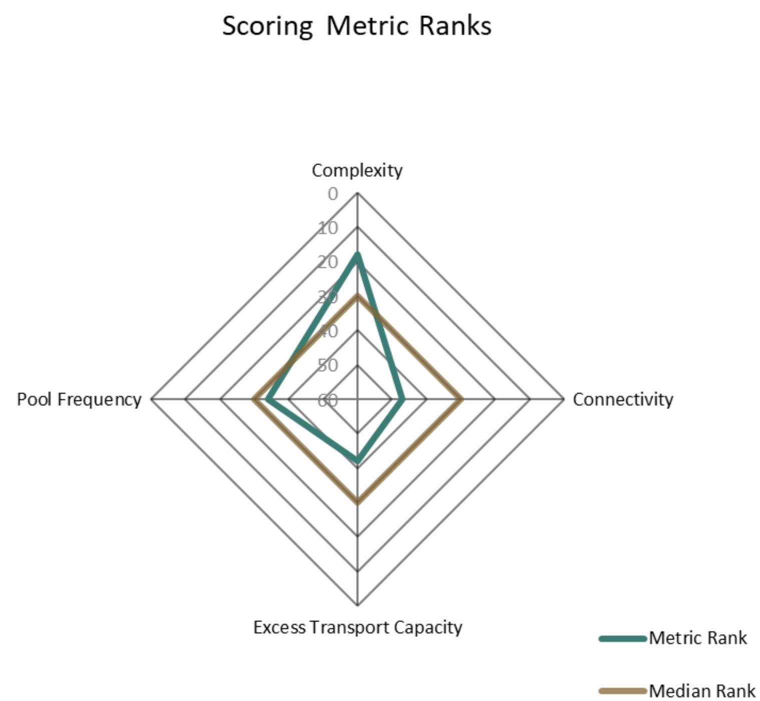
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 15.1 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

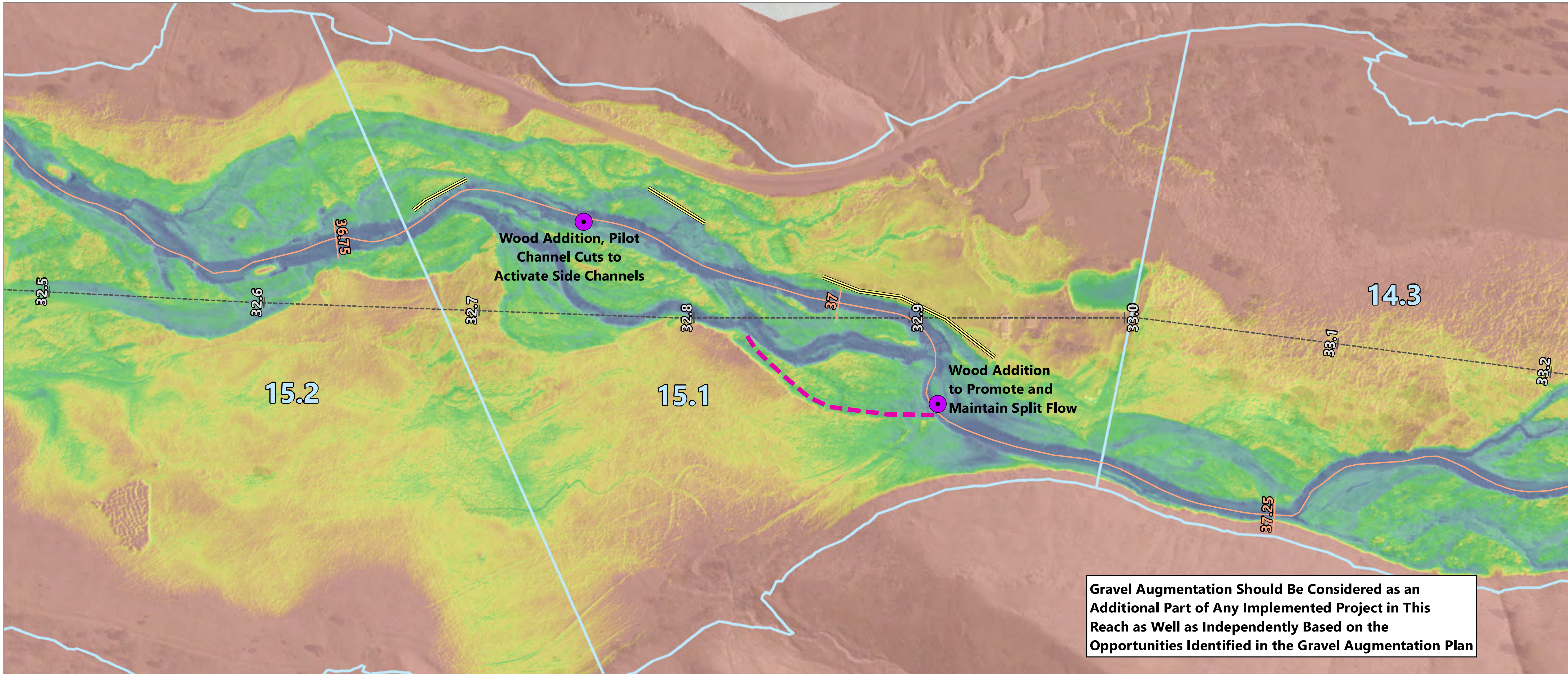
PA 15.1 Scoring Metric Ranks

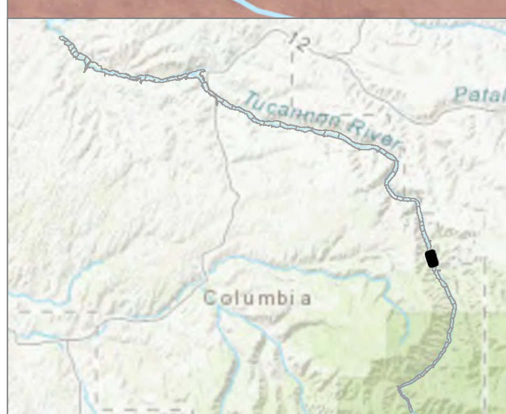


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 15.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.265	14	40%	Complexity	0.315	18	10% to 40%	2 of 5	3	40%	1.2	46	3	Treated	20	3
Mean-Winter Flow Complexity	0.359	15	40%													
1-year Complexity	0.329	28	20%													
Channel Aggradation FP Potential	0.208	30	40%	Connectivity	0.149	47	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.028	44	40%													
Total FP Potential	0.274	44	20%													
Existing Connected FP	0.726	17	0%													
Excess Transport Capacity	-0.09	42	100%	Excess Transport Capacity	0.000	42	52% to 100%	4 of 4	0	20%						
Pool Frequency	10.50	34	100%	Pool Frequency	0.270	34	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 36.78
RIVER MILE END: 37.16
VALLEY MILE START: 32.68
VALLEY MILE END: 33

0 500
Feet

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ANCHOR QEA

Project Area 15.1

Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 22 Description

Project Area 22 begins at VM 25.87 and extends upstream to VM 26.85. The 2017 RM length is 1.08 miles. Field observations for PA 22 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

The channel through PA 22 is characterized as a single-thread, plane-bed channel with local rapid sections and forced pools at weirs placed in the channel. The sinuosity of the channel is very low. The channel is primarily wide and shallow throughout the project area, except for a few local areas with boulder weirs and large plunge pools at rock weirs. From the bridge to the first rock weir, the channel is incised where it is confined between two large levees, as evidenced by undercutting of the bridge abutments.

Throughout the project area, the channel is confined between the valley wall and levee and riprap infrastructure along adjacent farmland. Large levees are located along the majority of the right bank. Riprap and boulders were also observed throughout the project area, along both banks, and in the channel bed. Remnant spoil piles indicate that dredging and channel straightening may have occurred historically. At least

Project Area 22
No site photograph available.

Project Area 22 Reach Characteristics

VM Start (mi)	25.87
VM Length (mi)	0.98
Valley Slope	1.06%
RM Start (mi)	29.33
RM Length (mi)	1.08
Average Channel Slope	0.96%
Sinuosity	1.11
Connected FP (ac/VM)	8.61
Encroachment Removal (ac/VM)	0.04
Channel Aggradation (ac/VM)	1.31
Total FP Potential (ac/VM)	1.63
Encroaching Feature Length (ft)	4,247.37
Connected FP Rank	56

nine rock weirs are located in the first half mile of the reach that control the channel grade throughout the area. There are multiple irrigation pumps located throughout the project area, which are typically correlated with levees or bank armoring. A few small side channels are present, but overall off-channel areas are limited.

Instream habitat is limited by lack of complexity and by hydraulic conditions that result in accelerated velocities during high flows that prevent the retention of LWD and sediment. Throughout much of the project area, the channel is wide and shallow. There are several deep pools at the rock weirs, but very little cover or other complexity. A majority of the weirs appeared to be passable by adult fish but may present difficulty for juvenile passage. The straight, confined channel likely has high instream velocities during spring runoff and floods, and very few opportunities for fish to seek refuge were identified.

Floodplain connectivity is poor within a majority of the project area. The low-lying floodplain is narrow and disconnected in many places by levees and armoring. A low area in the right floodplain that is currently used as a burn pile is disconnected from the channel by a large, armored levee.

The riparian zone is moderately healthy but is generally limited to a narrow corridor. Local areas have been degraded by development and poor floodplain connectivity. The riparian area in the last half mile of the project area generally has poor species diversity, sparse understory, and many invasive plants, including dense patches of poison hemlock.

Restoration Actions and Geomorphic Changes

In 2013, restoration work in PA 22 included placing a total of 8 LWD structures using 24 LWD key pieces, for the purpose of increasing pool frequency and cover habitat. The primary object was to create gravel deposition and minor bar development with improvement in pool frequency.

Analysis of the difference between the 2010 and 2017 LiDAR data shows there has been no significant geomorphic change in PA 22, likely because the reach is highly confined and leveed. There are several locations of very minor deposition on the floodplain and some minor erosion, but none have been highlighted for this discussion. It should also be noted that there is a long area of apparent erosion at the upstream end of the reach in the channel. This could possibly be a false indicator resulting from the 2017 LiDAR detecting bathymetry that the 2011 LiDAR could not, especially where rock weirs have forced deep pools. However, channel downcutting and incision might be expected in this type of confined reach so this apparent erosional area could be real.

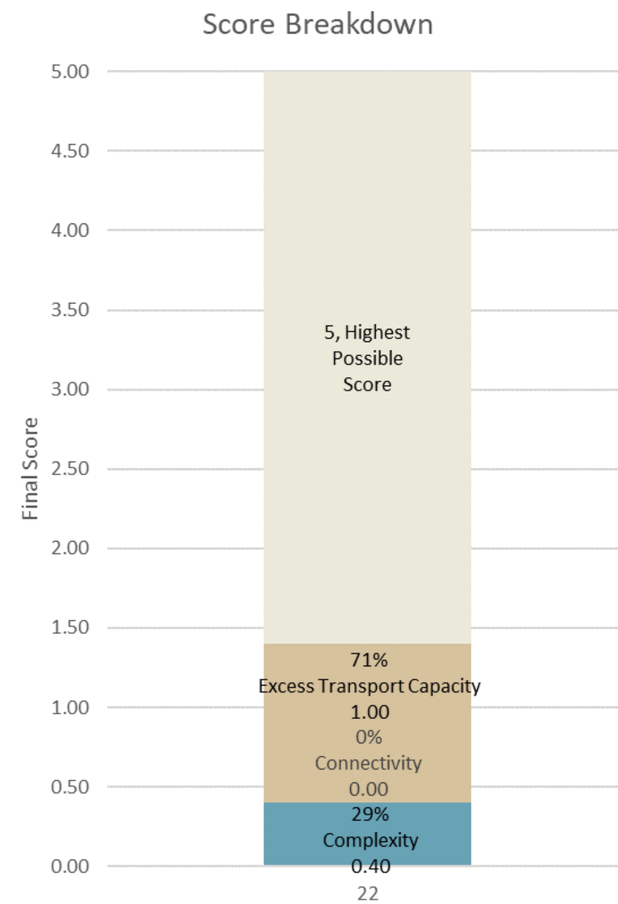
Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 22 receives the majority of its prioritization score from the highest possible score for the Excess Transport Capacity metric. This high score indicates that this project area is in the 90th to 99th percentile and the transport capacity for this reach is much higher than would be expected from the slope of the reach. This high transport capacity would make any sort of restoration project in this reach difficult without first addressing the root cause. PA 22 is highly confined by a system of levees and high banks on the right bank and valley wall on the left bank for the entire reach, and in most places the floodplain is less than a channel-width thick. This high confinement along with channel incision is likely the root cause of the high excess transport capacity in this reach. The previous restoration project in this reach was relatively minor and did not address the confinement.

The target restoration strategy for this reach should be to give the river more floodplain area and available width for side channels. This would likely require a very large restoration effort, including levee setbacks and floodplain benching to provide a wider floodplain wherever possible. The area this would require is partially occupied by agricultural fields, making this an even more difficult restoration strategy.

Gravel augmentation could also be considered as an alternate restoration action to reduce incision. However, because of the high excess transport capacity, it is possible added sediment would be easily flushed through the system. A large amount of instream wood would be a necessary addition to this strategy to trap and retain this sediment. However, without floodplain

PA 22 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

area for natural geomorphic processes to occur, gravel augmentation cannot provide as much benefit as possible.

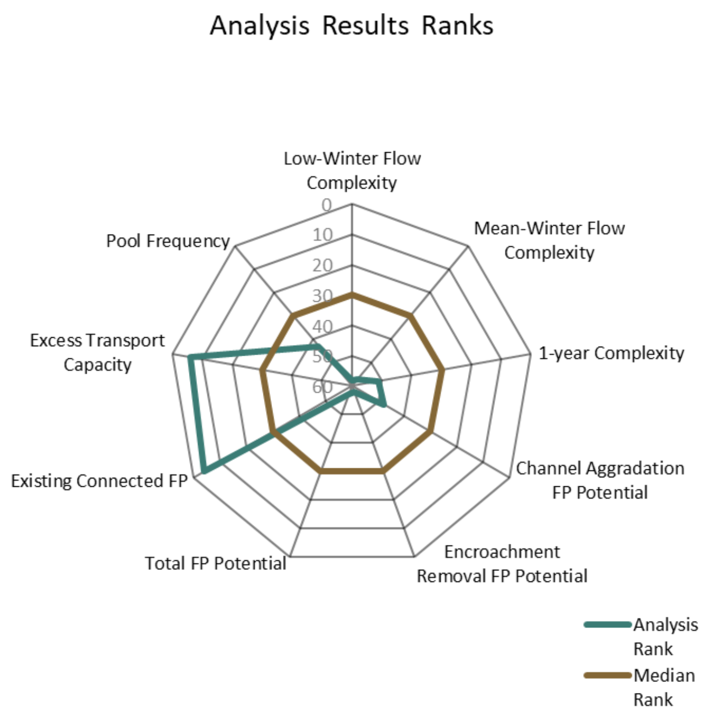
PA 22 receives a small score in the Complexity metric, indicating that it ranks below average in the 10th to 40th percentile of project areas. This complexity comes from several small pockets of floodplain with side channels. If the restoration strategies already discussed are not possible, it should be able to achieve a minor boost in complexity through the addition of instream wood to promote in-channel complexity such as mid-channel bars and small side channels.

Finally, PA 22 scores poorly in the Pool Frequency metric, indicating a low amount of pools per valley mile, although this reach has several rock weirs that force constant pools that will likely be maintained regardless of geomorphic changes. The addition of instream wood and gravel augmentation should boost pool frequency, but significant and constant gains to the number of pools is unlikely until channel incision and confinement can be addressed.

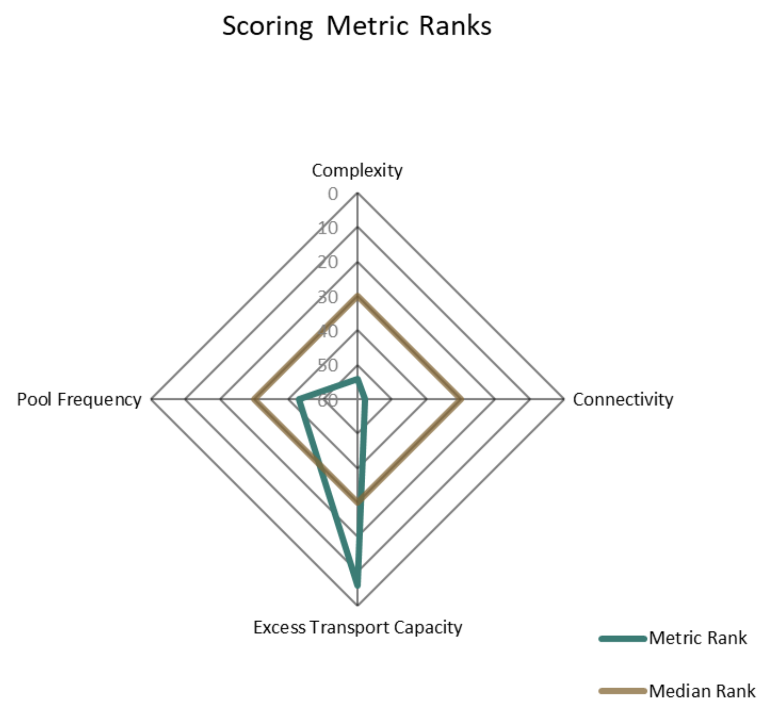
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)

PA 22 Analysis Results Ranks



PA 22 Scoring Metric Ranks

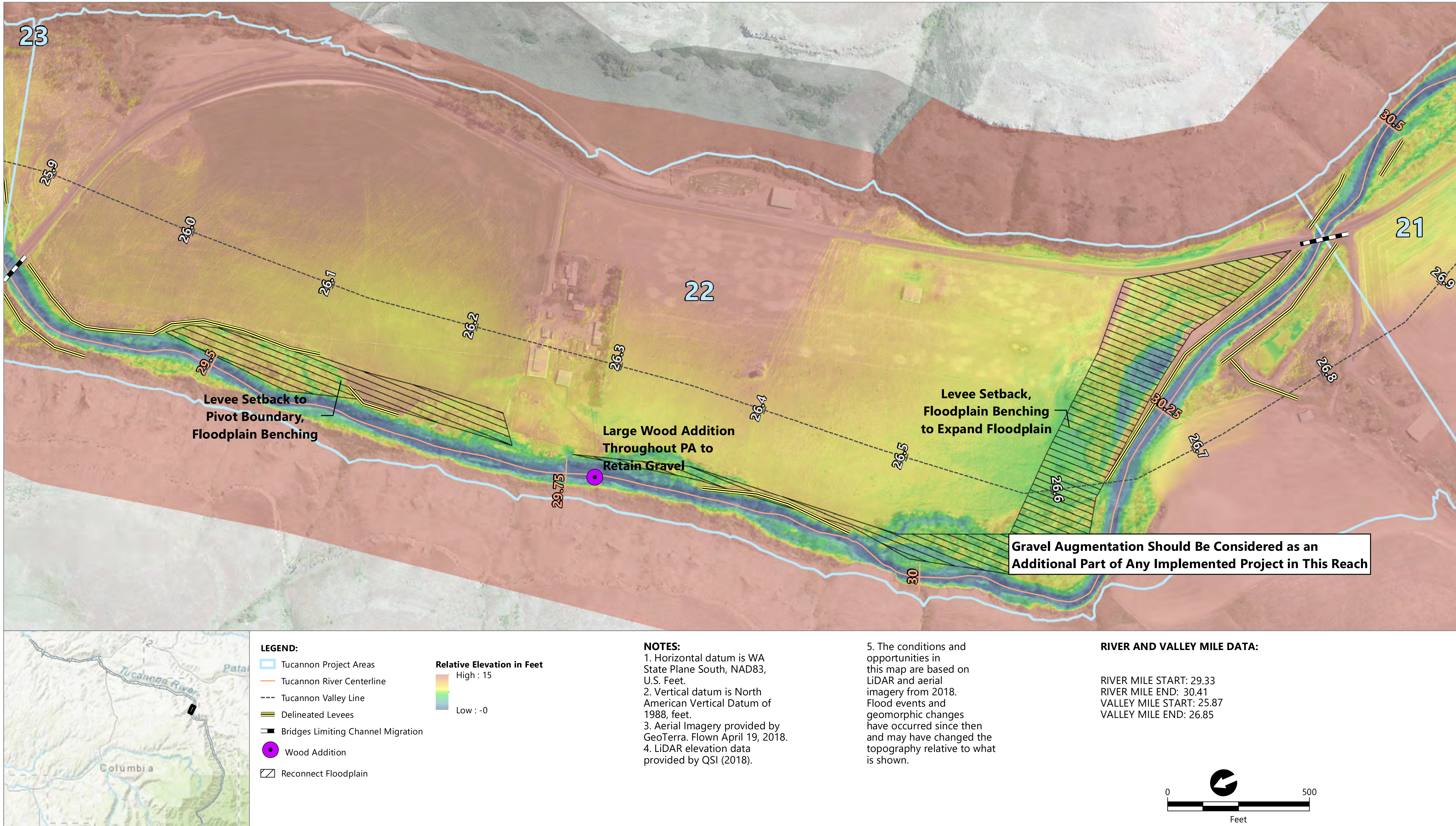


This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 22 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.082	58	40%	**Complexity**	0.098	54	60% to 90%	4 of 5	1	40%	1.4	41	3	Treated	16	3
Mean-Winter Flow Complexity	0.094	57	40%													
1-year Complexity	0.136	51	20%													
Channel Aggradation FP Potential	0.128	48	40%	**Connectivity**	0.085	58	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.004	58	40%													
Total FP Potential	0.160	57	20%													
Existing Connected FP	0.840	4	0%													
Excess Transport Capacity	0.25	6	100%	**Excess Transport Capacity**	5.000	6	1% to 10%	1 of 4	5	20%						
Pool Frequency	7.39	43	100%	**Pool Frequency**	0.190	43	60% to 90%	4 of 5	1	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Floodplain

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 29.33
RIVER MILE END: 30.41
VALLEY MILE START: 25.87
VALLEY MILE END: 26.85

0 500
Feet

Publish Date: 2021/01/25, 3:49 PM | User: mgieschen
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ANCHOR QEA

Project Area 22
Conceptual Adaptive Management and Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 24 Description

Project Area 24 begins at VM 24.35 and extends upstream to VM 25.06. The 2017 RM length is 0.76 mile. Field observations for PA 15.1 were conducted on September 24, 2018, when flow at the Starbuck gage was approximately 82 cfs.

PA 24 is characterized by a mostly highly confined single-thread channel with some pockets of complexity. At the upstream end of the reach, the first quarter-mile of the channel is confined to a single thread by levees on the left and right banks. However, large alternating log jams placed on either side of the channel have increased the stream length and provided some in-channel complexity. Moderate pools are associated with these structures, and the channel bed material is mostly cobbles and boulders with some more easily transportable gravel material. At VM 24.83, a large log jam has created a split flow on either side.

At VM 24.79, a large debris jam appears to have pushed high flows to the left into a low-lying area, but this area has subsequently filled with woody material and sediment; while a large backwater was present, it did not appear to be flowing at the time of the site visit. Downstream of this area, there appears to be some split flow and side channels in the left bank floodplain.

At VM 24.68, the channel again becomes mostly single-thread with log structures on alternating sides of the river. At

Project Area 24
Engineered log jam with accumulated small woody debris. The main flow is to the right of the structure and the backwater seen on the left forms a side channel at higher flows.

Project Area 24 Reach Characteristics

VM Start (mi)	24.35
VM Length (mi)	0.71
Valley Slope	1.03%
RM Start (mi)	27.52
RM Length (mi)	0.76
Average Channel Slope	0.97%
Sinuosity	1.07
Connected FP (ac/VM)	10.60
Encroachment Removal (ac/VM)	0.23
Channel Aggradation (ac/VM)	1.00
Total FP Potential (ac/VM)	1.68
Encroaching Feature Length (ft)	2,100.30
Connected FP Rank	45

VM 24.63, a log jam is forming a large gravel bar behind it and forcing water towards the next log jam on the left bank where a split flow is forming.

For the remainder of the project area, the channel is single-thread, with occasional log jam structures, and is confined by the road on the right of the floodplain and high bank on the left. At the very downstream end, the river meanders away from the road in two locations, leaving a large pocket of floodplain area in both locations that is not currently being accessed. The upstream area appears to be protected by a large levee, likely historically for the road. However, the downstream floodplain pocket, the bottom of which is actually in PA 25, shows some low areas and side channel potential.

In general, bed material in this reach is relatively large, and structures have not formed large scour pools in this reach.

The riparian vegetation in the floodplain includes large galleries of alders and some cottonwoods, but in several places the riparian corridor is relatively narrow between a field on the left bank or the road on the right bank.

Restoration Actions and Geomorphic Changes

In 2015, restoration work in PA 24 included placing 28 LWD structures and 33 single logs in the main channel and perennial side channels using 498 key pieces. Approximately 380 feet of river levee were removed to connect 5 acres of low floodplain, connect 0.32 mile of disconnected and new side channel, and enhance an additional 0.13 mile of side channel.

Project objectives were to increase LWD key pieces to greater than 2 pieces per bankfull width, increase pool frequency to more than 50% (more than 26 pools), increase low floodplain connectivity by 5 acres, and increase side channel length by 0.32 mile.

Analysis of the difference between the 2010 and 2017 LiDAR data shows several locations of significant geomorphic change, some of which are a result of restoration actions. At the upstream end of the reach, left bank deposition continues from PA 23 upstream (box 1). This could be due to a backwater effect from the large ELJ on the left bank.

Downstream, many of the restoration actions are clearly visible. Levee removal locations show up as erosional areas, and there have been several pocket areas of deposition where side channels and split flows have formed (box 2).

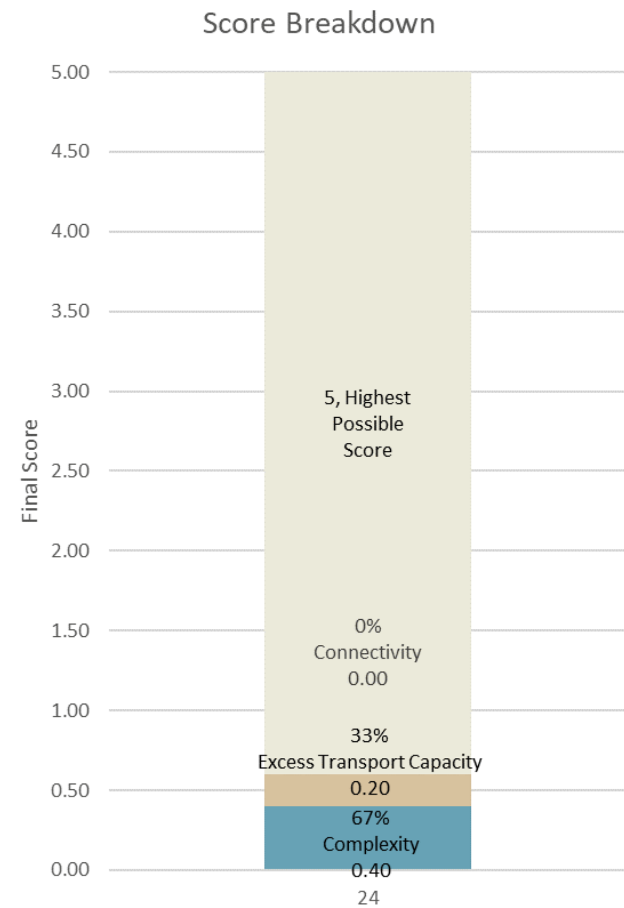
Finally, near the downstream end of the reach, the channel has avulsed and eroded significantly into the left bank as the result of a log jam on the right bank, behind which deposition has occurred (box 3).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 24 receives a low score in the Complexity metric, which makes up the majority of the prioritization score. The low score in Complexity indicates that the restoration actions in PA 24 may have already captured most or all of the complexity possible in this reach. This range has been identified as having some small additional complexity potential but would likely require a large restoration effort to achieve higher levels.

Complexity in this reach ranks well below average in all three flows but ranks the lowest in the low-winter flow analysis result and slightly higher in the analysis results for the other two flows. However, based on aerial imagery and local knowledge, several more side channels exist at the low-winter and winter mean flows that do not appear in this analysis and should be considered as part of the complexity of the reach. There may be some side channels that could be better connected for more perennial flow at the low-flow event. Based on the relative elevation map and island complexity GIS layer, most of these areas exist around the small pocket of existing complexity targeted from the restoration efforts in this reach, as well as a pocket of floodplain on the right bank at the downstream end of the reach, not currently contributing to complexity at all.

PA 24 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

The primary enhancement strategy for this reach should be to monitor the connections to existing side channels and implement remediation actions if maintenance is needed.

Finally, the Pool Frequency analysis result indicates that this project area ranks relatively high for number of pools per valley mile. The management strategies of adding instream wood and gravel augmentation should help to ensure this number of pools is maintained in the future.

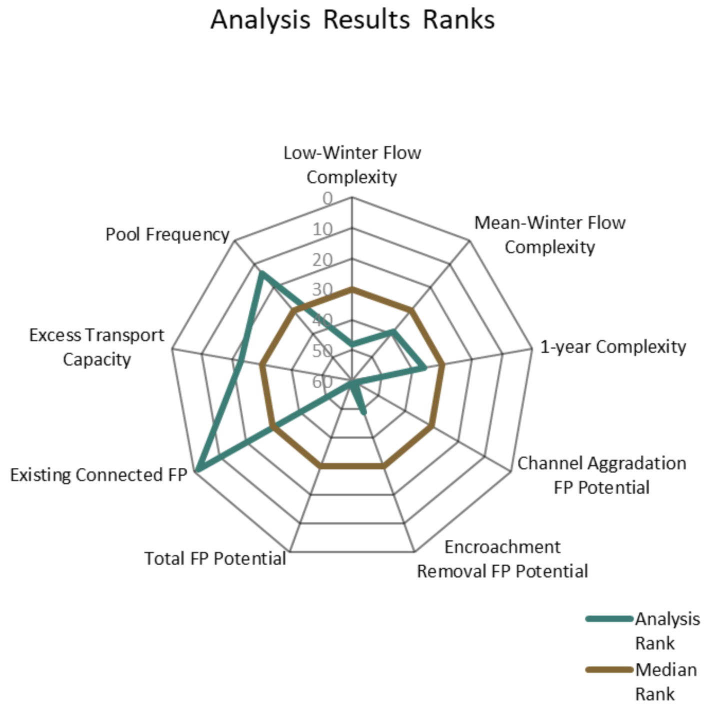
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

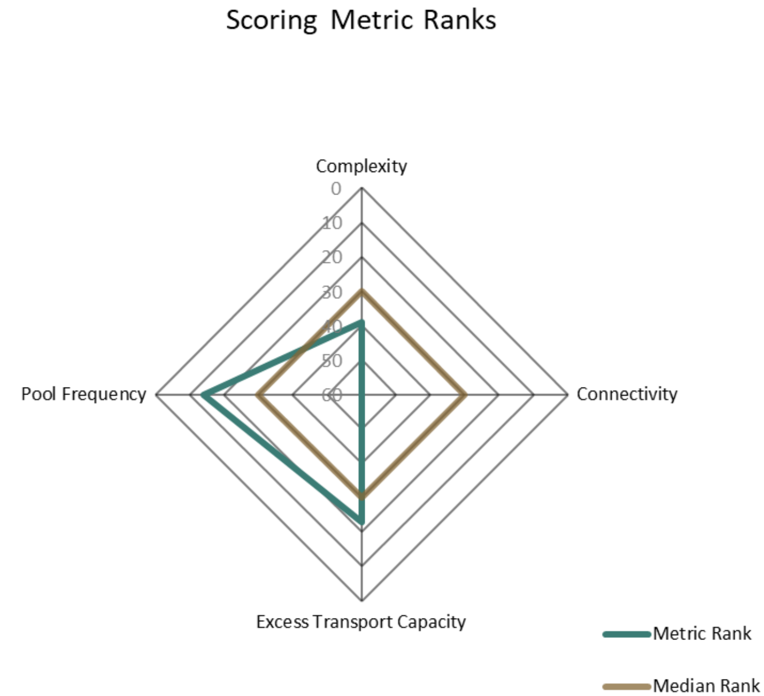
Long-Term Opportunities in this Project Area

- Set back road against the right valley wall for more floodplain connection and channel migration area.

PA 24 Analysis Results Ranks



PA 24 Scoring Metric Ranks

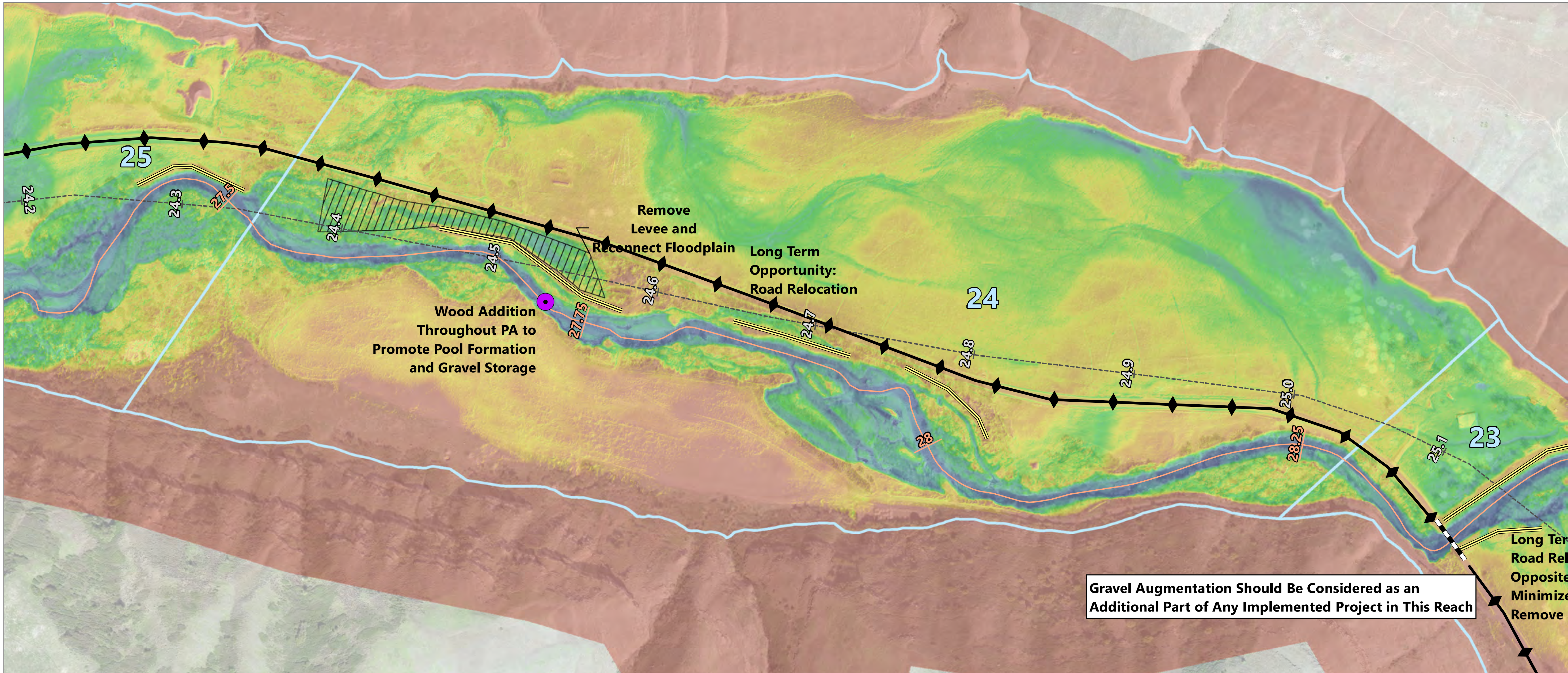


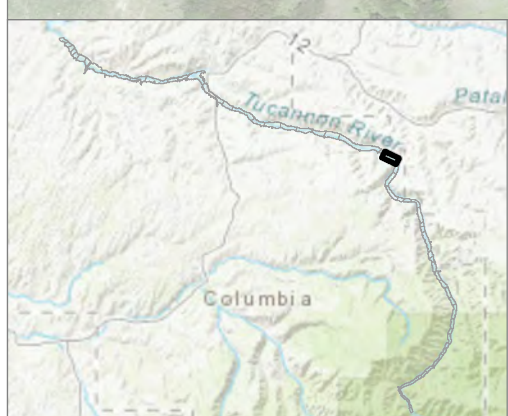
This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 24 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.096	48	40%	**Complexity**	0.155	39	60% to 90%	4 of 5	1	40%	0.6	57	3	Treated	22	3
Mean-Winter Flow Complexity	0.174	39	40%													
1-year Complexity	0.235	36	20%													
Channel Aggradation FP Potential	0.081	59	40%	**Connectivity**	0.067	60	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.019	49	40%													
Total FP Potential	0.137	59	20%													
Existing Connected FP	0.863	2	0%													
Excess Transport Capacity	0.09	23	100%	**Excess Transport Capacity**	1.000	23	30% to 52%	3 of 4	1	20%						
Pool Frequency	17.17	14	100%	**Pool Frequency**	0.441	14	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition
- Reconnect Floodplain
- Long Term: Relocate Road

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 27.52
RIVER MILE END: 28.28
VALLEY MILE START: 24.35
VALLEY MILE END: 25.06

0 500
Feet

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ANCHOR QEA

Project Area 24
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 29 Description

Project Area 29 begins at the Brines Road bridge crossing at VM 16.37 and extends upstream to VM 17.38. The 2017 RM length is 1.12 miles. Field observations for PA 29 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. Since the 2011 assessment, this reach has undergone a restoration project based in part on the opportunities identified in the 2011 prioritization.

The river through PA 29 is primarily characterized by a low-sinuosity, single-thread, plane-bed channel, with local areas of split flow and LWD or bedrock-forced pools. At the upstream end of this project area, the first mile is highly influenced by bedrock outcrops along the left bank and in the channel bed. The bedrock maintains the grade of the channel and creates local rapid sections and deep pools. Boulders that have eroded from the hillside also create rapid conditions and are present in much of the channel where it flows along the toe of the valley wall. Short plane-bed sections are located between the bedrock-dominated portions of the channel and generally contain sparse LWD and armored substrate conditions.

A forested island with split flow is located half a mile from the upstream end and appears to be maintained for irrigation purposes. The channel on the right side of the island contains armor rock in the bed and banks at the head of the island and

Project Area 29
No site photograph available.

Project Area 29 Reach Characteristics

VM Start (mi)	16.37
VM Length (mi)	1.01
Valley Slope	0.80%
RM Start (mi)	18.63
RM Length (mi)	1.12
Average Channel Slope	0.71%
Sinuosity	1.11
Connected FP (ac/VM)	10.21
Encroachment Removal (ac/VM)	1.43
Channel Aggradation (ac/VM)	2.19
Total FP Potential (ac/VM)	10.47
Encroaching Feature Length (ft)	1,689.61
Connected FP Rank	49

additional armoring along the length of the right bank. Just downstream is another short split flow adjacent to an armored bank that restricts channel migration.

Downstream of the first mile of this reach, the channel is dominantly plane-bed with little complexity. There is evidence of recent migration along the right bank over the next quarter-mile; cabled LWD toe stabilization has been placed 0.35 mile upstream of the downstream end of the project area and a concrete block wall in the floodplain protects a residence and driveway. For the last quarter mile, Tucannon Road and Einrich/Brines Road bridge abutments are armored with angular riprap. Spoils are located in the left floodplain near a constructed rock/LWD barb feature. A low-lying wetland area near the Einrich/Brines Road bridge is connected at the downstream end and contains flowing water and juvenile fish.

Instream habitat conditions are generally characterized by a lack of LWD and cover, low hydraulic complexity, and poor bedload sediment distribution. Bedrock pools in the upper reach provide good holding habitat for adult fish but the bedrock-dominated and plane-bed channel has a low amount of potential spawning area. Potential spawning is better suited to the lower reach; however, the confined and plane-bed conditions likely result in high velocities during high flows and the channel lacks hydraulic refuge.

This project area is characterized by low to moderate floodplain connectivity. Although the upper project area contains a small area of low-lying floodplain, it is not disconnected by any significant infrastructure. The lower project area contains a large area of low-lying floodplain that is primarily irrigated and non-irrigated fields. No apparent infrastructure prevents flooding of these areas except for minor features such as the spoil berm at the downstream end.

The riparian zone is in generally poor to moderate health. Overall, the riparian corridor is relatively narrow and flanked by fields and pastures. Riparian trees are predominantly mature alders with few cottonwoods. The alders provide good shading in some portions of the project area, particularly along the channel margins. Understory vegetation is dominated by invasive groundcover and several areas of thick reed canary grass.

Restoration Actions and Geomorphic Changes

In 2018, restoration work in PA 29 included placing 25 LWD structures and 129 LWD key pieces. Treatment stopped just upstream from VM 17. Structures were placed at a high density, alternating in a relatively confined and incised channel reach, to increase gravel bar frequency and thereby increase pool frequency and depth. The anticipated response will be increased pool frequency and gravel bar development and sorting in this previous transport reach. Structures were placed to maintain existing forested bars and to encourage the development of additional ones.

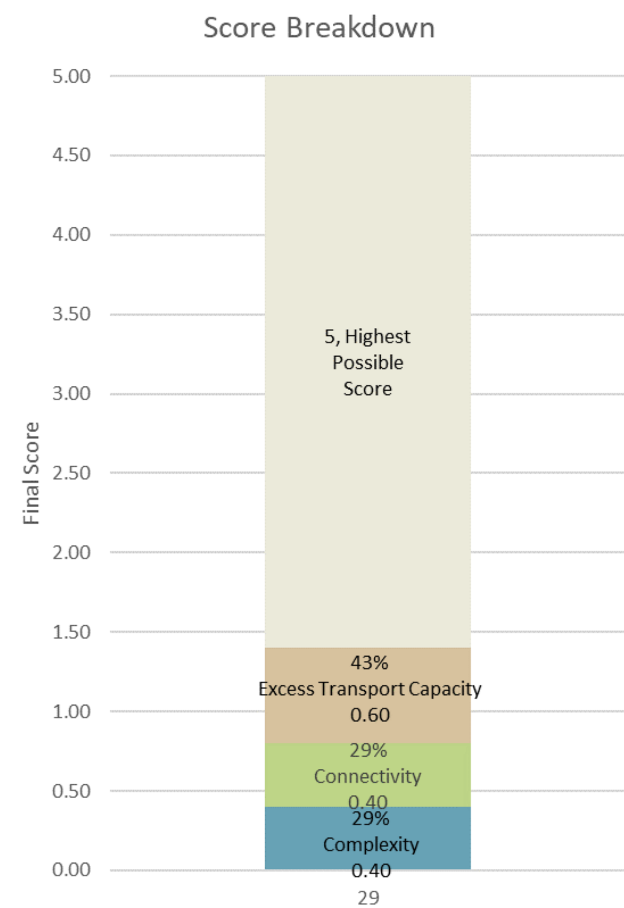
Analysis of the difference between the 2010 and 2017 LiDAR data shows several locations of significant geomorphic change, some of which can be attributed to the restoration actions taken in this reach. Near the upstream end of the project area, significant erosion has occurred on the right bank, although the cause of this erosion is not immediately clear (box 1). Immediately downstream, the channel has avulsed toward the left bank and deposition has occurred in the former main channel (box 2). From the 2018 aerial imagery, it appears the channel used to continue straight through a bar on the left bank, but deposition here has pushed the channel towards the right bank were erosion is evident. A mid-channel log jam has caused a significant avulsion and erosion in the right bank floodplain and formed a mid-channel bar with deposition (box 3).

Further downstream, two mid-channel log jams have caused alternating erosion on the left and right banks along with significant depositional bars in the wake of the log jams. A side channel through the right bank floodplain appears to have formed here as well (box 4). Finally, near the downstream end of the reach, a depositional bar has formed on the left bank and erosion is occurring on the opposite right bank (box 5).

Geomorphic Characteristics and Management and Enhancement Strategies

As shown in the following graphs and table, PA 29 receives a low score in the Complexity metric, indicating that PA 29 ranks low among project areas in the 10th to 40th percentile. This

PA 29 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

range has been identified as having some small existing complexity but would likely require a large restoration effort to achieve higher levels.

Complexity in this reach ranks well below average in all three flows but ranks the lowest in the low-winter flow analysis result and slightly higher in the analysis results for the other two flows. This indicates there are some side channels that could be better connected for more perennial flow at the low-flow event. Based on the relative elevation map and island complexity GIS layer, most of these areas exist in several small pockets of complexity in the form of small side channels in the available floodplain, some of which are only connected at the mean-winter and 1-year flows. The primary enhancement target for this reach should be to ensure these flow paths are connected to boost complexity at the low-winter flow. This can be accomplished through both pilot channel cuts and the addition of instream wood. The existing instream wood has caused in-channel complexity, but this reach could likely benefit from a higher density of wood.

This reach has shown minor geomorphic changes to the existing restoration, but gravel augmentation could be considered as a secondary restoration action for a greater response to the addition of instream wood. This would boost in-channel complexity as well as promote geomorphic changes into the side channels targeted for reconnection. This reach receives a moderate score in Excess Transport Capacity so adding more wood should be considered to ensure any added sediment is trapped and entrained in the active channel. Because this reach is moderately confined, setting back levees where possible should be considered to reduce some of the excess transport capacity for the reach.

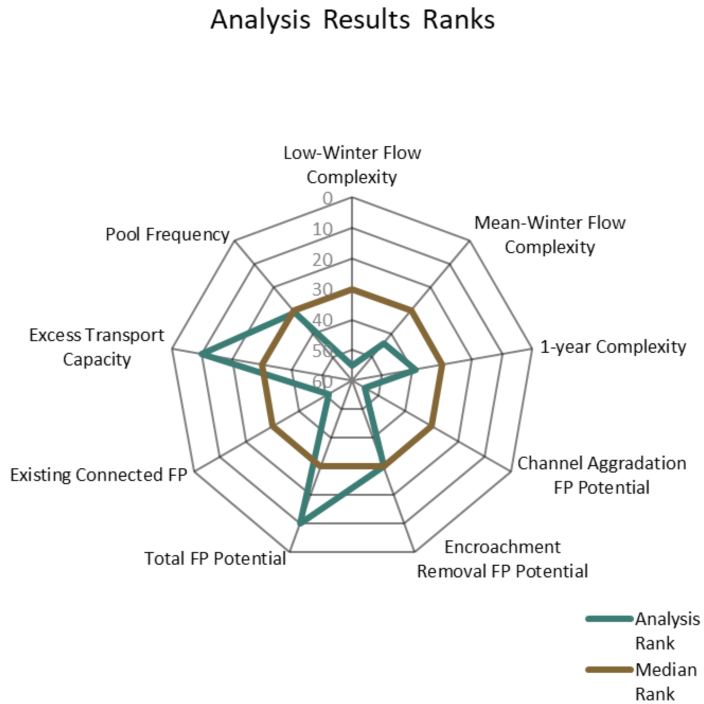
This reach scores poorly in Connectivity potential, partly due to a large, low-lying area in the left bank floodplain that is marked as unobtainable due to the presence of irrigation infrastructure. Should this area of the floodplain become available in the future, reconnecting it would provide large benefits to multiple aspects of the geomorphic processes in the reach.

Finally, PA 29 ranks slightly below the average in the Pool Frequency metric, indicating a moderate amount of pools per valley mile. The enhancement action of adding instream structure and wood, and possibly gravel augmentation, should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

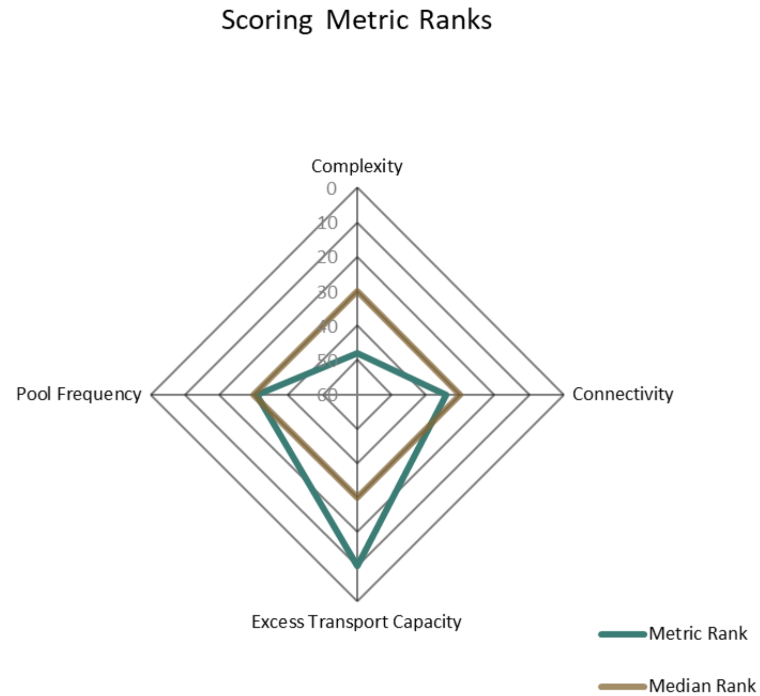
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

PA 29 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

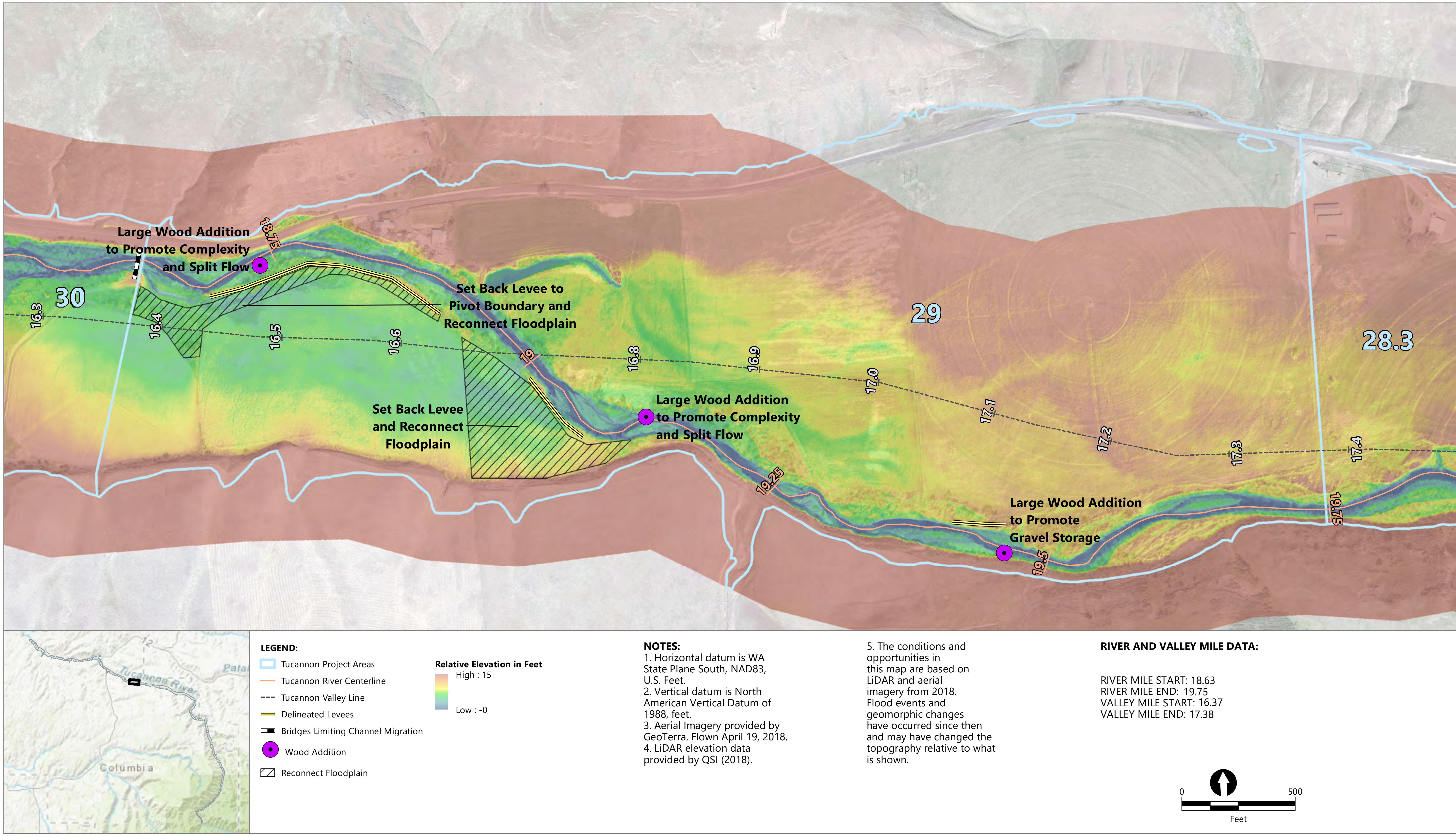
PA 29 Scoring Metric Ranks



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 29 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.088	55	40%	**Complexity**	0.133	48	60% to 90%	4 of 5	1	40%	1.4	42	3	Treated	17	3
Mean-Winter Flow Complexity	0.137	44	40%													
1-year Complexity	0.214	39	20%													
Channel Aggradation FP Potential	0.106	55	40%	**Connectivity**	0.171	34	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.069	30	40%													
Total FP Potential	0.506	10	20%													
Existing Connected FP	0.494	51	0%													
Excess Transport Capacity	0.18	10	100%	**Excess Transport Capacity**	3.000	10	10% to 30%	2 of 4	3	20%						
Pool Frequency	10.74	31	100%	**Pool Frequency**	0.276	31	40% to 60%	3 of 5	5	0%						



NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 18.63
RIVER MILE END: 19.75
VALLEY MILE START: 16.37
VALLEY MILE END: 17.38

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ANCHOR QEA

Project Area 29
Conceptual Adaptive Management and Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

LIST OF PROJECT AREAS

Tier 1

Tier 2

Tier 3

ABBREVIATIONS

PA	Project Area
VM	valley mile
RM	river mile
cfs	cubic foot per second
mi	mile
ac/VM	acres per valley mile
FP	floodplain
ft	foot/feet
LiDAR	Light Detection and Ranging
NF	National Forest (road)
LWD	large woody debris
USFS	U.S. Forest Service
GIS	Geographical Information Systems

APPENDIX J.2
TIER 1: UNTREATED PROJECT AREAS

Project Area 2 Description

Project Area 2 begins at VM 43.10 at a bridge crossing for the NF-7 road and extends upstream to VM 43.66. The 2017 RM length is 0.64 mile, which is a relatively short reach. Field observations for this reach were conducted on October 11, 2018, when flow at the Starbuck gage was approximately 100 cfs.

The reach is near the upstream end of the Tucannon River reach assessment and includes characteristics that are typical of this part of the basin, such as little land use in the floodplain, steep average channel slopes, and generally narrower valley width.

Near the upstream end of PA 2, a spring is located in the right bank floodplain approximately 200 feet from the active channel. This spring continues in a surface channel for approximately 1,200 feet before joining with the main channel. At the time of field observations, flow from the spring was extremely low and went subsurface in multiple locations. Providing perennial connection between this spring and the main channel could provide off-channel habitat with a strong hyporheic connection and prevent stranding if the flows go subsurface during low-flow times.

The main channel is relatively well connected to the floodplain in the upper half of the reach. Several higher flow channels were observed with hyporheic or groundwater connection but no surface flow, indicating they are likely connected at higher

Project Area 2
Looking downstream at a single-thread, plane-bed channel. The single piece of wood is unlikely to stay in place for long.

Project Area 2 Reach Characteristics

VM Start (mi)	43.10
VM Length (mi)	0.56
Valley Slope	1.60%
RM Start (mi)	48.60
RM Length (mi)	0.64
Average Channel Slope	1.39%
Sinuosity	1.14
Connected FP (ac/VM)	9.87
Encroachment Removal (ac/VM)	2.22
Channel Aggradation (ac/VM)	2.85
Total FP Potential (ac/VM)	5.84
Encroaching Feature Length (ft)	71.10
Connected FP Rank	50

flows and would not require much effort to connect year-round. Near the middle of the reach, a 500-foot-long side channel exists on the right bank and seems to be maintained via a natural stable apex jam. Near this same area, the left bank has a large low-lying area that was inundated but not flowing at the time of the site visit. Just downstream of this area, several channel-spanning log jams were observed but did not appear to be stable. This reach also contains two rock “vortex” weirs, forcing large plunge pools. The downstream half of the reach is mostly a straight, plane-bed channel with a few mid-channel bars. During field observations, it was noted that this portion of the project area could benefit from the addition of instream wood for both habitat complexity and geomorphic process.

Throughout the reach, the large vegetation in the floodplain appeared to be mostly coniferous species set back into floodplain where there is likely less frequent inundation. The immediate riparian area contained mostly deciduous species that were much smaller in size (up to 15 feet high and 4 inches in diameter).

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows that PA 2 experienced very little geomorphic change. The GIS layer of highlighted areas shows two locations with minor bar building and channel migration (boxes 1 and 2). One additional location near the middle of the reach shows a minor channel avulsion and corresponds to the location of a stable apex log jam and side channel observed during field observations (box 3). It is possible that this instream wood will cause lasting geomorphic complexity in this area but it may also revert to the former plane-bed channel and disconnect from the side channel should the natural apex log jam wash away.

There are several factors that likely contribute to the lack of major geomorphic change within PA 2, other than the fact that no restoration work has been attempted in this reach to date. The reach has a lower average channel transport capacity, especially compared to other reaches in the upper basin. Additionally, while this reach has large, established vegetation in the floodplain, most of it is coniferous and set back from the immediate riparian area, making wood recruitment less likely and therefore causing less geomorphic change. This is supported by the fact that relatively little large wood was observed in the channel other than a few isolated log jams that may have washed in from upstream.

Geomorphic Characteristics and Restoration Strategies

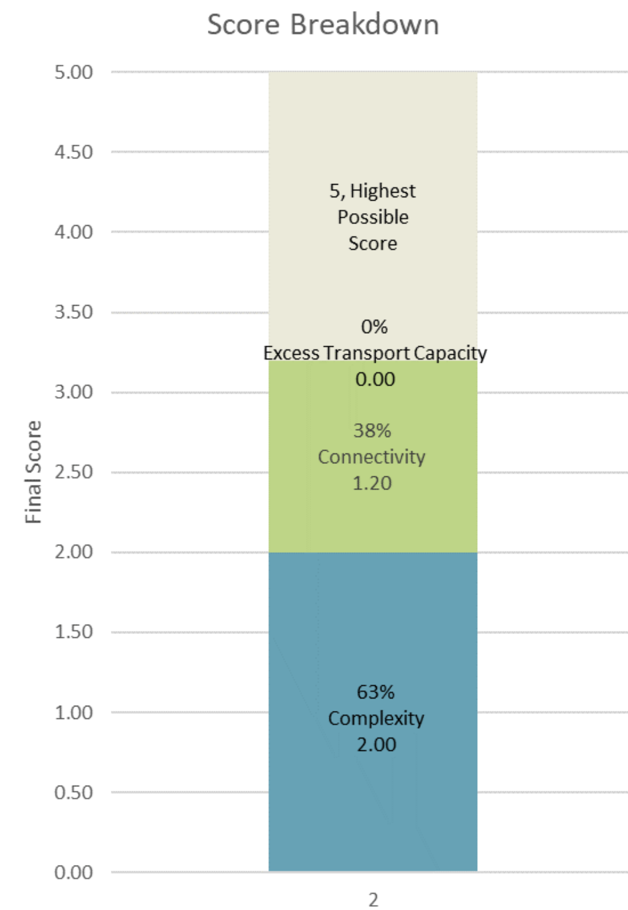
As shown in the following graphs and table, the Complexity metric makes up the majority of the score for PA 2, with a much smaller score for the Connectivity metric.

PA 2 scores in the 40th to 60th percentile for complexity, which is the range identified as having the most potential for complexity without being too confined to allow realistic projects to be completed. The existing complexity in this reach is driven mostly by one large side channel and several smaller split flows connected at the low-winter flow event. At the mean-winter and 1-year events, several more side channels are activated, but since most project areas in the assessment increase in complexity as flows increase, complexity for this project area is ranked evenly across all three flows for the Complexity analysis results.

Based on the 2-year floodplain inundation areas, and looking at the relative elevation map, there are multiple additional low-lying areas that could be activated as side channels. Excavating side channel blockages or raising water surface elevation should be the primary targets for restoration in this reach. These should be accomplished through the restoration strategies of cutting pilot channels, along with the strategic placement of instream wood to promote geomorphic change into these disconnected side channels.

Additionally, long stretches of PA 2 are a single-thread, plane-bed channel that, at a minimum, could be improved to have more in-channel complexity with split flows, mid-channel bars, and wood features. Channel dynamics in these stretches should be promoted through the addition of instream wood to the main channel, separate from pilot channel cuts. During field observations, bed material in this reach was noted to mostly consist of large cobbles and boulders. For this reason, as well as the desire to raise the bed elevation, gravel augmentation

PA 2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

should also be considered a primary restoration strategy to promote aggradation, channel dynamics, and geomorphic changes in the project reach.

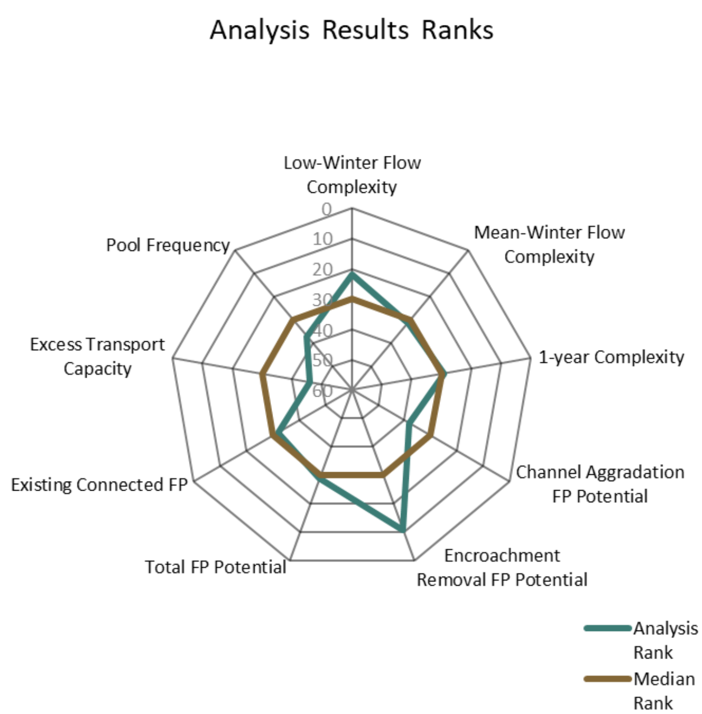
While not driven by a geomorphic metric analyzed in this assessment, PA 2 was noted during field observations to have some areas with sparse, mature vegetation in the immediate riparian area. Large woody material in the active channel is an essential part of the geomorphic process of this system; while artificially adding instream wood can jumpstart this process, in order for natural processes to be maintained long term, a supply of naturally growing wood in the accessible floodplain is essential. Riparian zone enhancement should be considered as a restoration strategy for this reach.

Finally, the pool frequency in this reach scores below average, which might reflect the fact that this reach has a very low supply of gravel material. Adding instream wood and gravel augmentation should promote the geomorphic processes that will promote and maintain pool frequency and depths throughout the reach.

Summary of Restoration Opportunities Identified

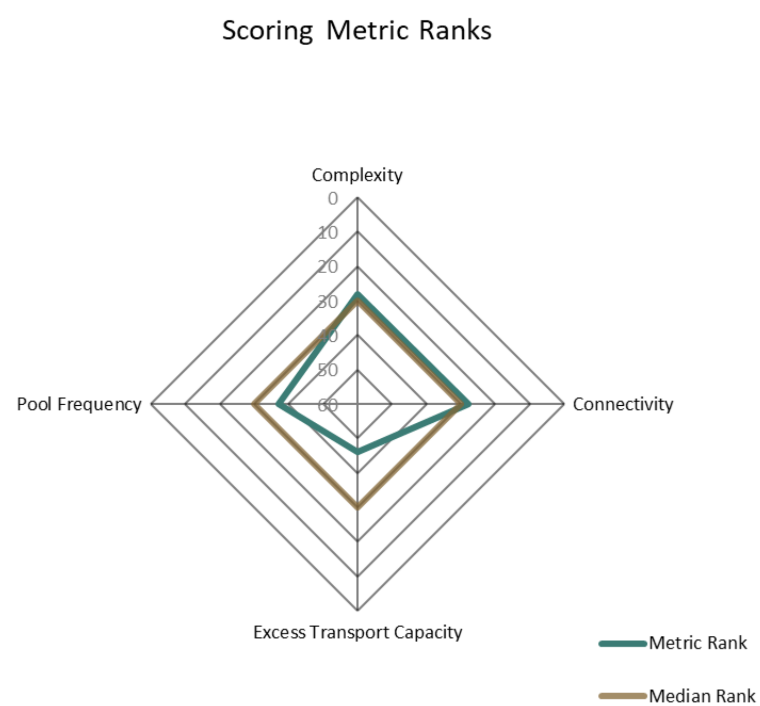
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)
- Riparian zone enhancement

PA 2 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

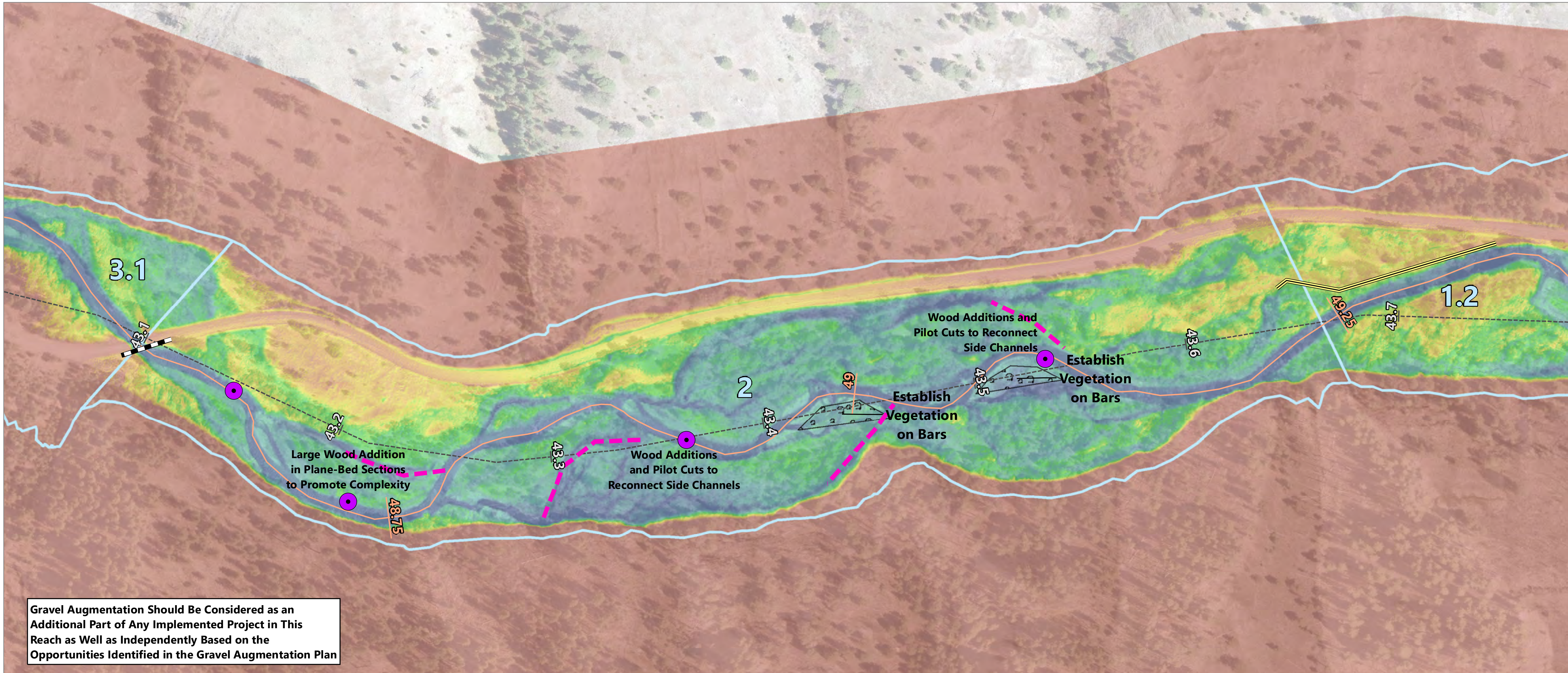
PA 2 Prioritization Scoring Summary

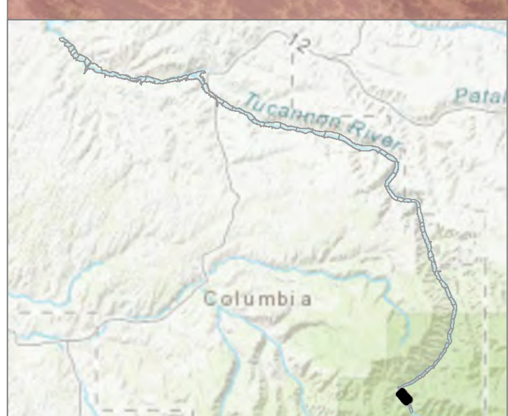


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.205	22	40%	Complexity	0.237	28	40% to 60%	3 of 5	5	40%	3.2	6	1	Untreated	5	1
Mean-Winter Flow Complexity	0.225	31	40%													
1-year Complexity	0.325	29	20%													
Channel Aggradation FP Potential	0.182	38	40%	Connectivity	0.203	28	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.141	11	40%													
Total FP Potential	0.372	29	20%													
Existing Connected FP	0.628	32	0%													
Excess Transport Capacity	-0.12	46	100%	Excess Transport Capacity	0.000	46	52% to 100%	4 of 4	0	20%						
Pool Frequency	9.33	37	100%	Pool Frequency	0.240	37	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 48.6
RIVER MILE END: 49.24
VALLEY MILE START: 43.1
VALLEY MILE END: 43.66

0 500
Feet

Publish Date: 2021/01/25, 3:42 PM | User: mgieschen
Filepath: \\orcas\gis\Jobs\TucannonRiver_1006\Maps\Conceptual Maps\Tucannon Untreated Project Areas_mg.mxd

ANCHOR QEA

Project Area 2
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 5 Description

Project Area 5 begins at the NF-160 bridge crossing for the USFS campground at VM 40.80 and extends upstream to VM 41.23. The 2017 RM length is 0.45 mile. Field observations for PA 5 were conducted on October 11, 2018, when flow at the Starbuck gage was approximately 100 cfs.

The upstream end of PA 5 begins at the end of a large levee in PA 4 for Camp Wooten. PA 5 itself is bounded on the left bank by the valley wall and Tucannon Road, and on the right bank by the road for Camp Wooten and the USFS campground.

For the majority of the reach, PA 5 is highly complex with multiple channel-spanning log jams forcing pools and side channels. A large amount of wood in PA-5 is the main contributor to this complexity throughout the entire reach. However, an abundance of easily transportable gravel material allows geomorphic change in this reach to happen easily as well.

On the right bank, the access road for Camp Wooten and the USFS campground prevent this complex reach from connecting to a large tributary and low swampy area along the valley wall. Removing the access road in its entirety may not be feasible, but at the downstream end there is some disconnected area past the USFS campground that could be reconnected.

On the left bank, several side channels or split flows come in contact with the valley wall and road prism where there is not

Project Area 5
Looking downstream at a large, natural, channel-spanning log jam forcing planform complexity, including an upstream pool and left bank high-flow path.

Project Area 5 Reach Characteristics

VM Start (mi)	40.80
VM Length (mi)	0.43
Valley Slope	1.51%
RM Start (mi)	46.09
RM Length (mi)	0.45
Average Channel Slope	1.39%
Sinuosity	1.06
Connected FP (ac/VM)	10.61
Encroachment Removal (ac/VM)	14.49
Channel Aggradation (ac/VM)	2.35
Total FP Potential (ac/VM)	21.79
Encroaching Feature Length (ft)	1,795.98
Connected FP Rank	44

much vegetation or overhanging cover, but in general riparian vegetation has large trees and good cover. In some areas of recent avulsions, gravel bars are bare but seem to be in the process of establishing vegetation.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows that a relatively large amount of geomorphic change has occurred in the last 7 years. Near the upstream end of the reach, a split flow has formed as the result of a log jam, and some minor erosion at the upstream end and deposition at the downstream end have also occurred (box 1).

Downstream, several more large, channel-spanning log jams have caused split flows, side channels, and excellent complexity. Deposition has occurred in the channel upstream of the channel-spanning log jam, and the channels downstream show signs of erosion and deposition causing more complexity and instream wood recruitment (box 2). Additional erosion and deposition as a result of another log jam has occurred just downstream of here (box 3).

Finally, at the downstream end of the reach, a large channel-spanning log jam has caused deposition in the channel and allowed flows into the floodplain, creating complex flow through this portion of the reach (box 4).

Multiple log jams and instream wood, along with an abundant supply of easily transportable material, has promoted geomorphic changes and good complexity throughout the reach.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 5 receives the majority of its score from the Complexity and Connectivity metrics. PA 5 ranks in the 60th to 90th percentile of all project areas for complexity, indicating that while good complexity already exists in the reach, only a little more work is necessary to achieve the highest level of complexity in the basin. PA 5 ranks highly in all three complexity analysis results but slightly lower in the mean-winter and 1-year complexity analysis results. This indicates that some low-flow channels and split flows may be washed out during the higher flows. The complexity in this project area is driven by multiple natural log jams, and the primary restoration strategy for this reach should be to secure these log jams via piles or large rock. Additional instream wood should be considered as an additional restoration technique to ensure the complex split flows and side channels exist during all flow events.

PA 5 receives the highest possible score in the Connectivity metric, indicating it is within the highest percentile of project areas for floodplain potential. The Encroachment Removal analysis result ranks among the highest in the basin and is driven by the area behind the levee and road for Camp

Wooten. This large, low-lying area is associated with the tributary Hixon Creek and could provide a large amount of connected floodplain. Restoration opportunities to connect this would require moving the access for Camp Wooten possibly as a bridge upstream and partially inundating the nearby campground. While these restoration opportunities would be aggressive, they should be considered if the opportunity ever arises because the potential for floodplain reconnection is one of the highest in the watershed.

This project area receives no score in the Excess Transport Capacity metric, indicating that sediment material will likely be easily stored and maintained with the addition of instream wood. This reach has been a depositional reach over the past 7 years and has achieved good complexity as a result. Gravel augmentation likely is not necessary at this time; however, should geomorphic change begin to subside, gravel augmentation could be considered to maintain complexity.

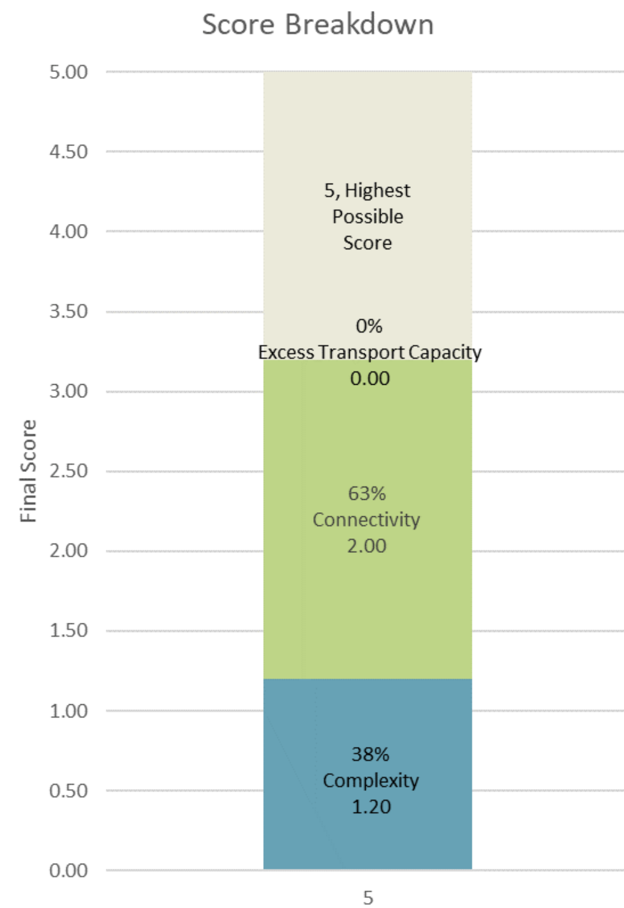
Summary of Restoration Opportunities Identified

- Remove levees and floodplain encroachments
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

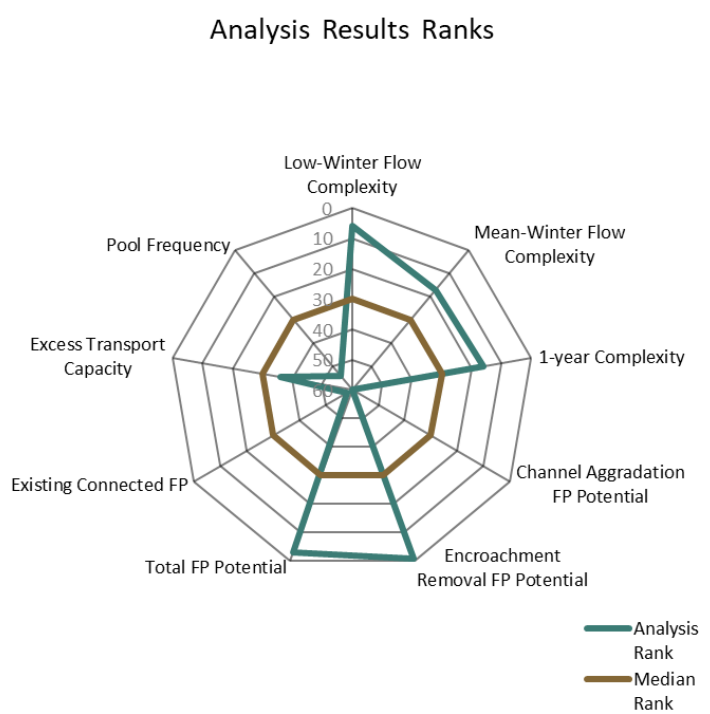
- Relocate Camp Wooten access road to PA 4 and remove road and bridge in PA 5 for more floodplain connection and channel migration area.

PA 5 Score Breakdown



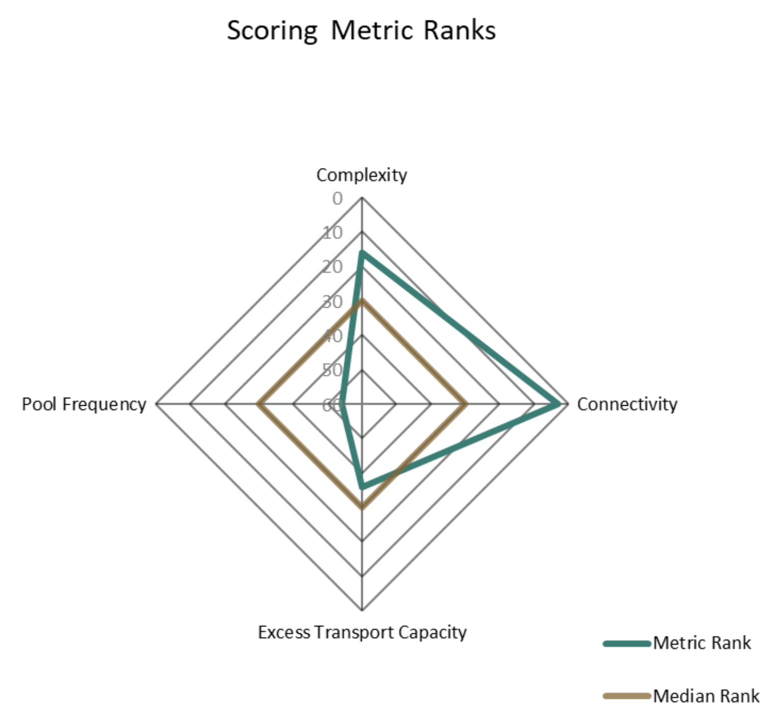
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 5 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

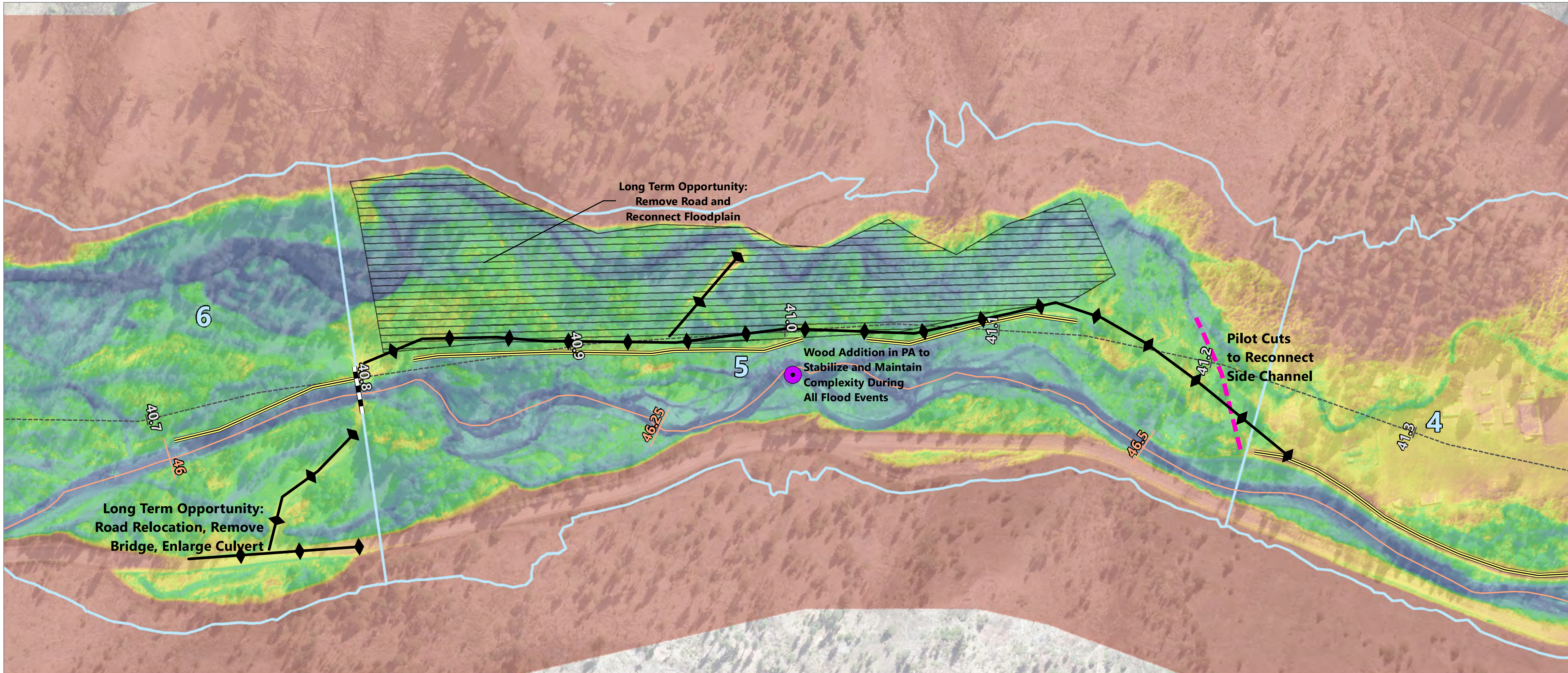
PA 5 Scoring Metric Ranks

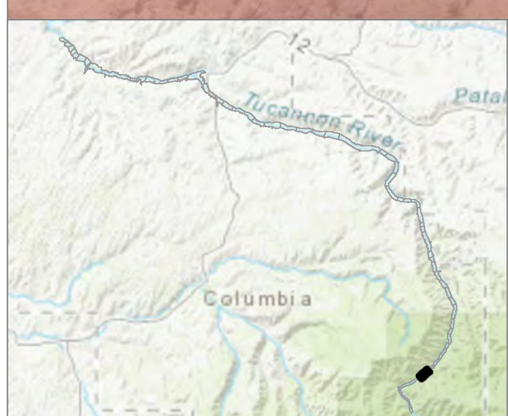


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 5 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.320	6	40%	**Complexity**	0.359	16	10% to 40%	2 of 5	3	40%	3.2	7	1	Untreated	6	1
Mean-Winter Flow Complexity	0.341	17	40%													
1-year Complexity	0.471	16	20%													
Channel Aggradation FP Potential	0.072	60	40%	**Connectivity**	0.342	3	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.447	1	40%													
Total FP Potential	0.672	3	20%													
Existing Connected FP	0.328	58	0%													
Excess Transport Capacity	-0.04	36	100%	**Excess Transport Capacity**	0.000	36	52% to 100%	4 of 4	0	20%						
Pool Frequency	4.41	54	100%	**Pool Frequency**	0.113	54	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Long Term: Relocate Road

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 46.09
RIVER MILE END: 46.55
VALLEY MILE START: 40.8
VALLEY MILE END: 41.23

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Feet

Publish Date: 2021/01/25, 3:44 PM | User: mgieschen
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ANCHOR QEA

Project Area 5
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 14.3 Description

Project Area 14.3 begins at VM 33.0 and extends upstream to a bridge crossing for the Tucannon Road near Spring Lake at VM 33.64. The 2017 RM length is 0.72 mile. In 2014, the upper sections of this project area (PA 14.1 and PA 14.2) were the subject of a restoration project; however, the section of PA 14.3 below the bridge has remained untreated and was therefore separated for a distinct analysis. Field observations for PA 14.3 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. The updated analysis performed for this assessment is described in detail as follows.

This reach is adjacent to the WFDW headquarters, and, while the channel is single thread and often plane-bed, it has well connected floodplain and was marked as "transitioning" into better habitat in 2011. During the previous assessment, channel migration, LWD recruitment, and development of instream and channel complexity were all observed through this area. In 2011, a higher amount of temporary sediment deposition and wider active channel were noted in this portion of the old PA 14.

In PA 14.3, riparian trees are mixed deciduous and conifers, dominated by alder, cottonwood, locust, and ponderosa pine. Some areas contain several snags, dying trees, or burnt mature trees. In 2011, this reach was populated by several very large mature cottonwoods, some of which were being actively

Project Area 14.3
Photograph taken from the 2011 prioritization showing wood recruitment in the channel.

Project Area 14.3 Reach Characteristics

VM Start (mi)	33.00
VM Length (mi)	0.64
Valley Slope	1.30%
RM Start (mi)	37.16
RM Length (mi)	0.72
Average Channel Slope	1.11%
Sinuosity	1.13
Connected FP (ac/VM)	13.69
Encroachment Removal (ac/VM)	2.89
Channel Aggradation (ac/VM)	7.16
Total FP Potential (ac/VM)	10.35
Encroaching Feature Length (ft)	978.96
Connected FP Rank	29

recruited to the channel. The understory was relatively dense with moderately diverse species in most areas. Some areas were dominated by invasive grasses or other weedy plants.

Geomorphic Changes

For a reach of less than 1 river mile, PA 14.3 has undergone a relatively large amount of change based on analysis of the difference between the 2010 and 2017 LiDAR data. Additionally, while not geomorphic change, the change analysis identified the removal of an old bridge embankment downstream of the current bridge on both banks (box 1). It is unclear what effect this removal has had on the remainder of the reach because this change is isolated from other change locations in the reach. Just downstream of the embankment removal, the channel appears to go through a major depositional zone for approximately 1,200 feet. Large sediment deposit areas have formed on the inside of four consecutive bends, with major corresponding bank erosion on the outsides of several of these bends. This lateral movement is likely resulting in the recruitment of floodplain wood and sediment as the river pushes into the floodplain and could be a source of more downstream deposition because the meander bend in this bow was cut off in 2018/2019 by cutting the high-flow channel leaving an alcove at the bottom of the meander (box 2).

Immediately downstream of the depositional reach, a large channel-spanning log jam is evident in the 2018 aerial imagery that corresponds to a major erosion area on the left bank. It is possible that the backwater from this log jam has resulted in lower transport capacity in the reach upstream, causing the deposition and lateral movement noted there. However, this debris jam could be unstable, and the geomorphic processes likely caused by it could be only temporary (box 3).

Downstream there is evidence of more outside bank erosion on both the left and right banks, with the more downstream location being additionally associated with deposition and bar building on the inside of the bend. This location is also associated with a high-flow channel that appears to have some minor deposition and erosion, likely formed during higher flows. If this erosion continues, it could open up a more frequently flowing side channel on the right bank (boxes 4 and 5).

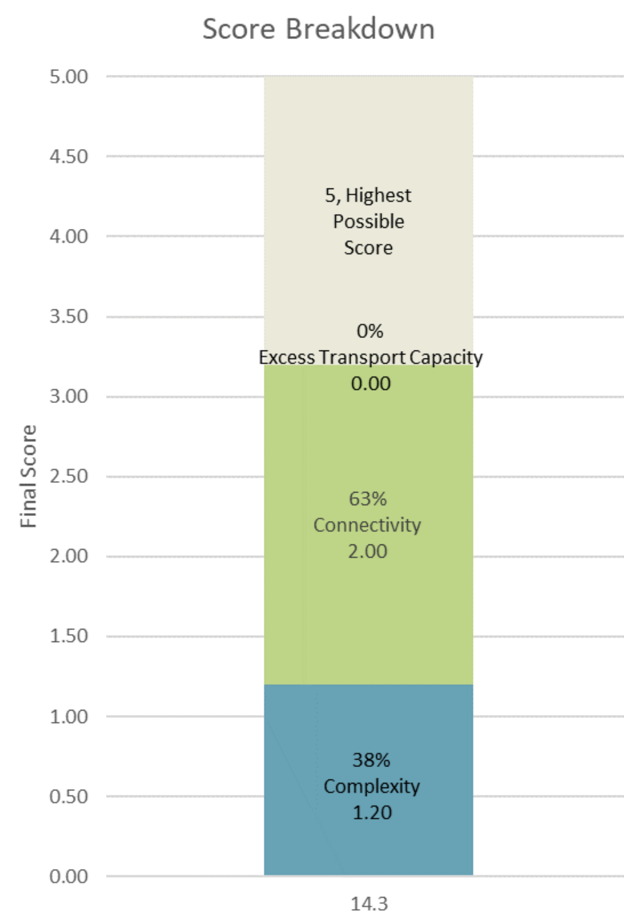
Finally, near the downstream end of the project area, a major channel migration is occurring towards the right bank with approximately 50 feet of lateral movement. This avulsion is likely the source of material found in the upper end of PA 15.1. This change occurs just upstream of a location where the channel makes a sharp bend to run along the valley wall on the left bank. Just downstream on the right bank there is a low swampy area that could be an old meander scar identified during field visits to PA 15.1. It is possible that this channel migration could eventually occupy this low elevation area, allowing flow to move away from the valley wall and possibly causing split flow. If this happens, the two channels would likely need to be stabilized and it is possible that a split flow could be accelerated with restoration work.

While this reach shows several major locations of geomorphic change and seems to be on a promising track towards recovering natural processes, it is evident that much of this change has been encouraged by a large amount of available sediment being deposited in the reach. The reaches immediately upstream were the target of restoration activities since the last assessment and it is possible that geomorphic change there could have allowed sediment stored in the floodplain to be mobilized. Regardless of the source, it is possible that much of this change is temporary in nature if the sediment supply is not continuous.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 14.3 received the highest possible score in the Connectivity metric with the most potential in restoration strategies targeting channel aggradation. In addition, PA 14.3 receives a moderate score in the Complexity metric, which indicates that it ranks above average in the 60th to 90th percentile, a range that shows good existing complexity but does not place it in the top 10% of project areas, an objective that could be achieved with relatively little effort. For PA 14.3, the low-winter flow complexity analysis result ranked very poorly, falling in the bottom 10% of project areas, and is driven by one small island near the upstream end

PA 14.3 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

of the project area. However, at the mean-winter and 1-year flow events, complexity analysis results showed greater complexity, ranking in the top 10% at the 1-year flow. This change is primarily driven by the mean-winter flow activation of several long side channels in a low-lying area on the right bank floodplain near the middle of the reach. The islands formed by these side channels are further fractured by additional channels during the 1-year event, making this an extremely complex reach during higher flows. Restoration strategies targeting complexity in this reach should focus on allowing perennial flow to access the already existing high-flow channels so that the complexity seen at the 1-year flow is realized year-round.

The high Connectivity metric score is primarily driven by the channel aggradation potential, which scores in the top 25% among project areas. This high score is likely due to a large, low-lying area on the left bank near the end of the reach that is connected at the 5-year event but disconnected at the 2-year event. Currently, this area is disconnected by a high bank, but there appears to be several high-flow paths at the upstream end. Additionally, this area could be connected either by raising the water surface elevation via channel aggradation or by encroachment removal of the high bank, but there is more potential benefit in raising the water surface elevation in this area. There are some additional areas on the right bank near the upstream end of the project area that are disconnected at both the 5-year and 2-year events, but they are generally smaller and are disconnected by a larger distance, making reconnection more difficult.

Because channel aggradation would benefit both driving metrics of complexity and connectivity potential in this reach, restoration strategies should focus on storing and retaining sediment in this reach. Transport capacity was ranked just below average, which indicates that added sediment in this reach should be easily retained, and gravel augmentation should be a primary restoration strategy. Pilot channel cuts should also be considered as a restoration option to reconnect these disconnected flow paths.

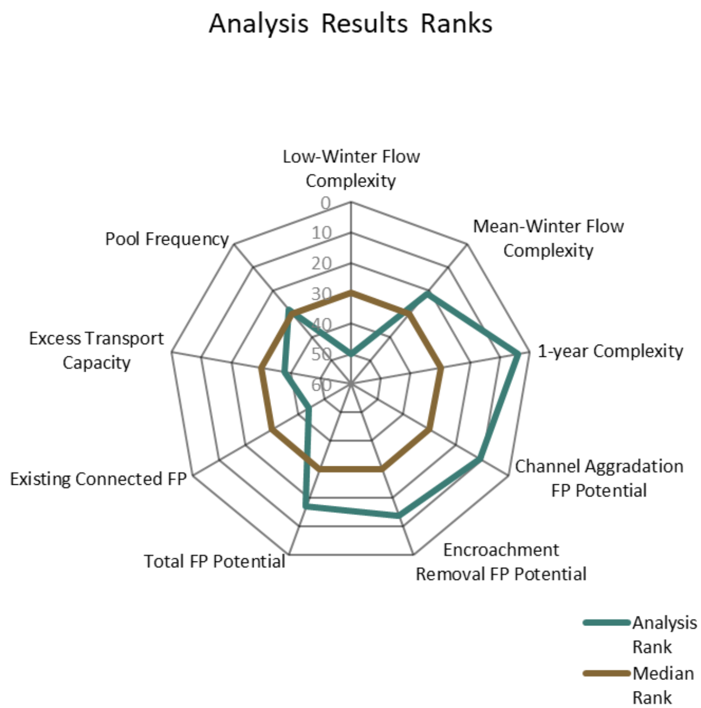
Restoration efforts should then focus on adding instream wood and floodplain structure to stabilize existing flow paths, retain sediment, and allow additional flow onto the floodplain, in addition to gravel augmentation. Because the 2018 aerials show several large log jams, instream and floodplain structure could be accomplished by either adding additional wood or securing natural recruits instream provided they are still in place.

Finally, PA 14.3 scores near the average for the assessment area in the Pool Frequency metric, indicating a moderate amount of already existing pools. The identified restoration strategies of pilot channel cuts, adding instream wood, and gravel augmentation should promote the natural processes that will encourage and maintain pool formation.

Summary of Restoration Opportunities Identified

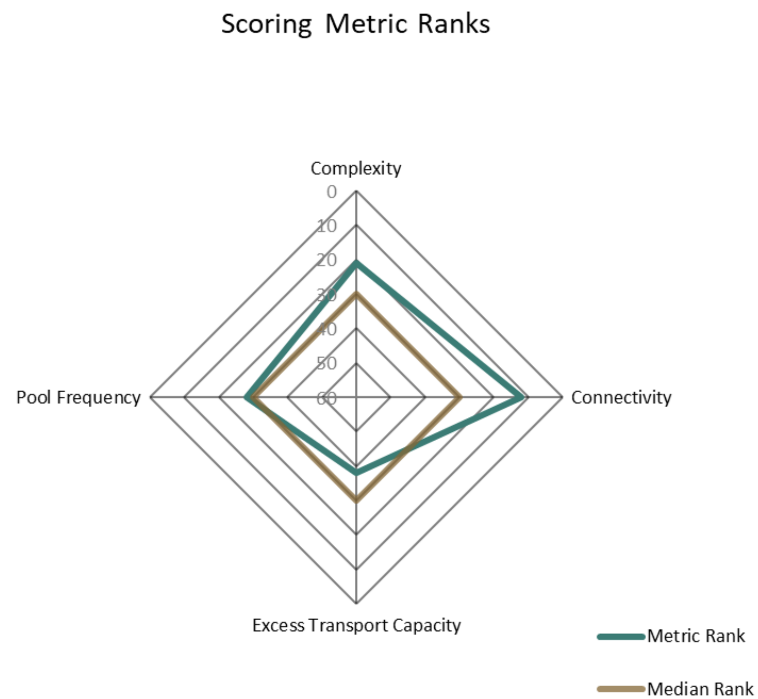
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 14.3 Analysis Results Summary s



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

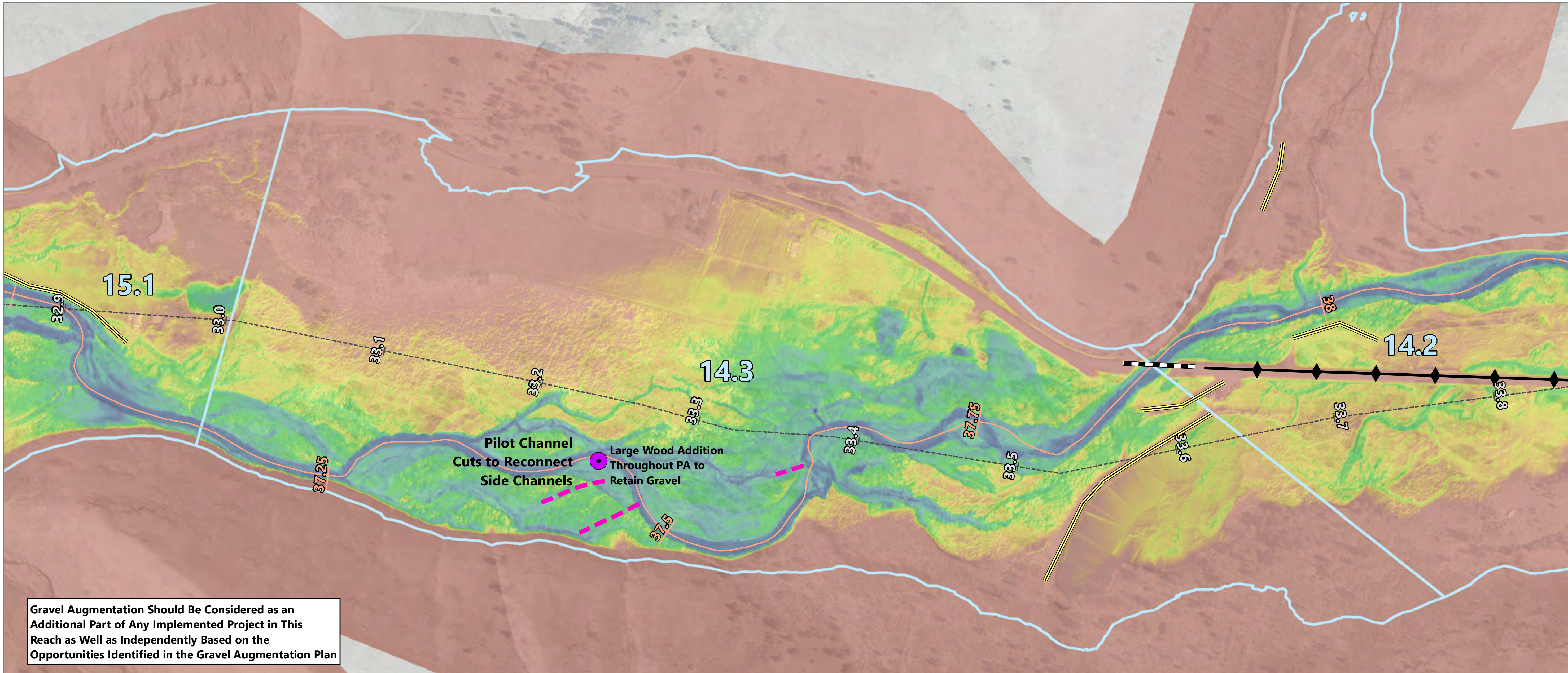
PA 14.3 Prioritization Scoring Summary

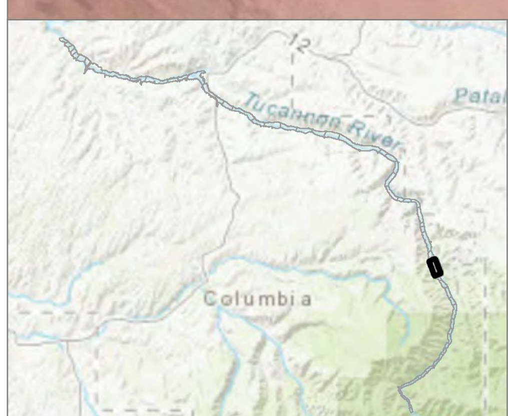


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 14.3 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.094	50	40%	Complexity	0.306	21	10% to 40%	2 of 5	3	40%	3.2	10	1	Untreated	7	1
Mean-Winter Flow Complexity	0.303	21	40%													
1-year Complexity	0.738	4	20%													
Channel Aggradation FP Potential	0.298	11	40%	Connectivity	0.253	12	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.120	14	40%													
Total FP Potential	0.431	17	20%													
Existing Connected FP	0.569	44	0%													
Excess Transport Capacity	-0.05	38	100%	Excess Transport Capacity	0.000	38	52% to 100%	4 of 4	0	20%						
Pool Frequency	11.11	28	100%	Pool Frequency	0.285	28	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Long Term: Relocate Road

Relative Elevation in Feet
High : 15
Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 37.16
RIVER MILE END: 37.88
VALLEY MILE START: 33
VALLEY MILE END: 33.64

0 500
Feet

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ANCHOR QEA

Project Area 14.3
Conceptual Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 18.2 Description

Project Area 18.2 begins at VM 28.78 and extends upstream to a bridge crossing for the Tucannon Road near Hartsock Grade Road at VM 29.48. The 2017 RM length is 0.78 mile. Field observations for PA 18.2 were not conducted in 2018 as part of this assessment update. However, the upper section of PA 18.1 was part of a restoration project and was treated recently before data were collected in 2017. This has likely had an effect on PA 18.2, immediately downstream, that is not yet reflected in the data. The remainder of this site description was taken from the 2011 prioritization.

In 2011, no significant infrastructure was observed downstream of the bridge. Aggradation and channel expansion was observed throughout much of the project area, as evidenced by bank erosion, high volumes of sediment deposition, and multiple flow path development.

The complex instream hydraulic conditions created by the presence of large wood, the ability of the river to migrate, and the high volume and supply of bed load sediments create relatively good instream habitat conditions in a majority of the project area. Deep pools at recruited trees were providing ample holding areas for adults, and cover and refuge for juvenile fish. There were several side channels, particularly downstream of the bridge, that provided excellent off-channel rearing habitat.

Project Area 18.2
No site photograph available.

Project Area 18.2 Reach Characteristics

VM Start (mi)	28.78
VM Length (mi)	0.70
Valley Slope	1.21%
RM Start (mi)	32.46
RM Length (mi)	0.78
Average Channel Slope	1.06%
Sinuosity	1.11
Connected FP (ac/VM)	13.36
Encroachment Removal (ac/VM)	2.02
Channel Aggradation (ac/VM)	5.28
Total FP Potential (ac/VM)	8.80
Encroaching Feature Length (ft)	1,457.96
Connected FP Rank	30

The floodplain in this project area was relatively well-connected and contained a large quantity of low-lying floodplain. Small sections of remnant levees and spoils were located in a few places; however, the influence of these features to natural processes appeared to be insignificant.

Downstream of the bridge, the riparian zone was wider and contained a greater number of mature trees, better species diversity, and greater plant density. Riparian trees in the project area were primarily deciduous, dominated by cottonwoods, dogwoods, and alders, with few conifers.

The wetland on the downstream side of the bridge was ponded and perched above the river water surface elevation; the source of the water was unclear. The wetland on the right bank upstream of the bridge span was disconnected from the channel by a levee and did not appear to contain surface water.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several major geomorphically induced changes in PA 18.2. At the upstream end of the reach, a large deposition of sediment is evident in the main channel for a stretch of several hundred feet. A side channel has formed on the right bank as a result and may eventually become an avulsion location, but as of the 2018 aerial imagery, flow was still present in the main channel. A large erosional reach just upstream in PA 18.1 could be the source of this sediment, although several other erosional locations are also noted in that reach (box 1).

Near the middle of the reach, a large avulsion into the right bank floodplain has occurred since 2010, with a depositional area at the head of the former main channel and erosion and channel downcutting in the new channel on the right bank floodplain. The 2018 aerial imagery shows some of the former channel is inundated, but it appears surface flow is cut off by the material deposition at the flow split. The 2018 aerial imagery also shows several large log jams in the new channel (box 2).

Just downstream of where the new channel returns to the former channel location, the channel goes through a sharp left meander bend that is scouring the right bank (box 3). It is possible that high flows are cutting off the next meander bend at this location; just downstream a side channel appears to be headcutting across the meander (box 4). It is likely these processes will cause the channel to cut off and possibly abandon this meander bend.

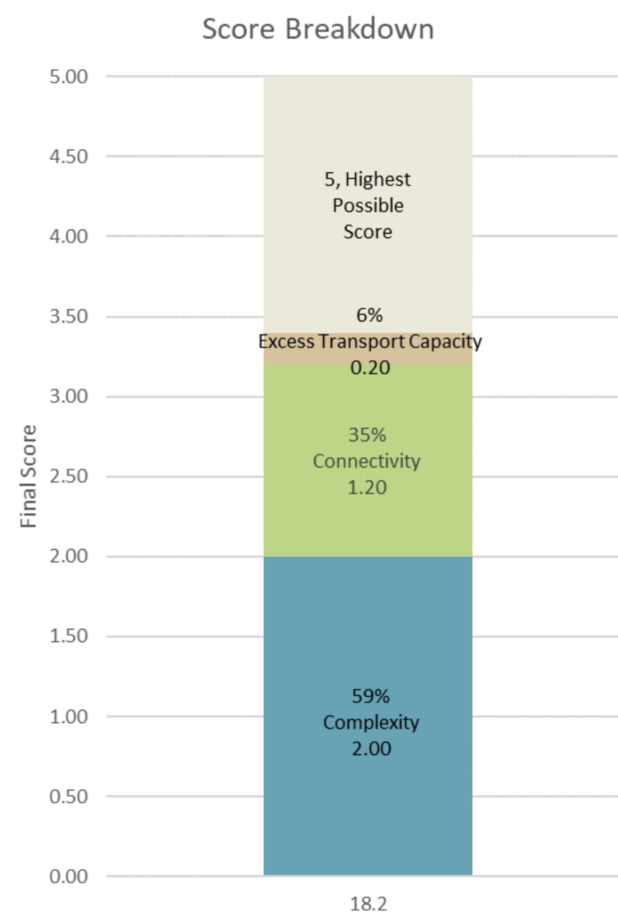
Finally, at the very downstream end of the reach, a small meander appears to have been blocked by a log jam and sediment deposition. The channel has avulsed a short distance into the left bank floodplain and now runs directly against the left bank valley wall, as it continues to do in the upper portion of PA 19 (box 5).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 18.2 receives the majority of its score from the Complexity prioritization metric. PA 18.2 ranks near average for Complexity in the 40th to 60th percentile, which is a range that has been identified as having the most potential for complexity restoration. The analysis results for complexity at all three flows are relatively average compared to the other project areas, with the low-winter flow being slightly below average and the high flow being slightly above average. At the low-winter flow, the complexity score is driven by two moderately sized side channels near the upstream end of the project area. At the mean-winter flow, these two areas become more complex with several secondary side channels splitting off and bisecting the resulting islands. However, the downstream portion of the reach remains relatively uncomplex with only one small side channel. At the 1-year flow, a long side channel is activated in the middle of the reach near the site of the avulsion discussed in the section above.

Based on the area inundated in the 2-year event, as well as the relative elevation map, PA 18.2 has much more potential for complexity throughout the reach. There appear to be several side channels, not activated at any of the three flows, that could increase complexity in this reach across the board. Restoration strategies in this reach should focus on activating these flows

PA 18.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

through adding instream structure and large woody material to promote geomorphic change as well as reconnecting some of these side channels through pilot channels or benching and removing high banks.

PA 18.2 also receives a low score in the Connectivity metric. Most of this disconnected area is located in the form of disconnected side channels and former channel locations in the floodplain. Employing the strategies of adding instream wood and cutting strategic pilot channels could have the added benefit of reconnecting the disconnected floodplain area near the downstream end of the reach. This reach receives a low score in the Excess Transport Capacity metric, indicating that any sediment transported into this reach will be easily stored and maintained with instream wood structure. While gravel augmentation is not a primary restoration strategy for this reach, the addition of gravel material could help to jumpstart geomorphic change and increase complexity and connectivity.

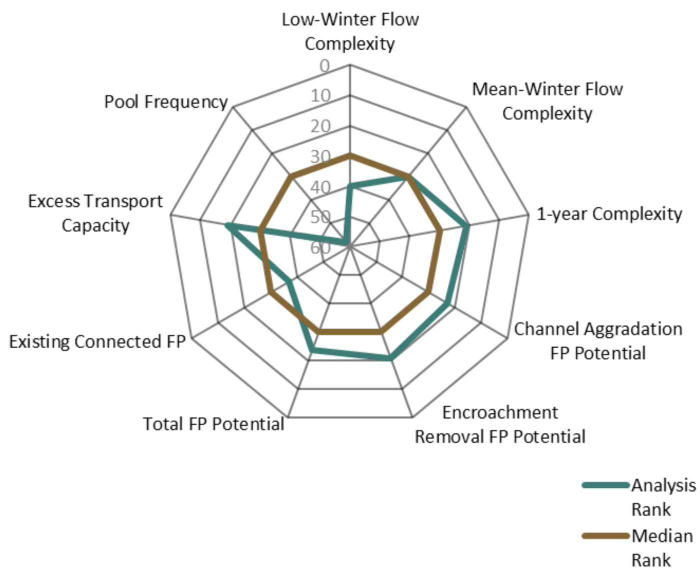
Finally, PA 18.2 ranks very low among project areas for the Pool Frequency metric. Adding instream wood and connecting side channels via pilot channel cuts will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target increasing pool frequency in the reach.

Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 18.2 Analysis Results Summary

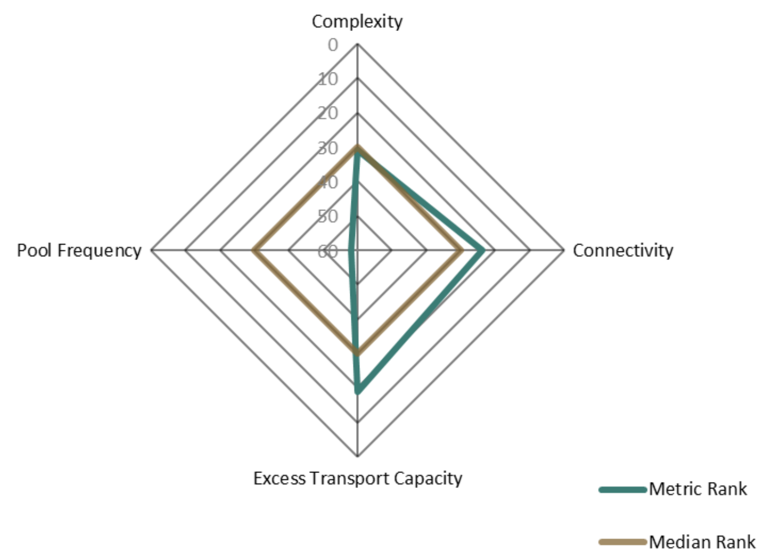
Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

PA 18.2 Prioritization Scoring Summary

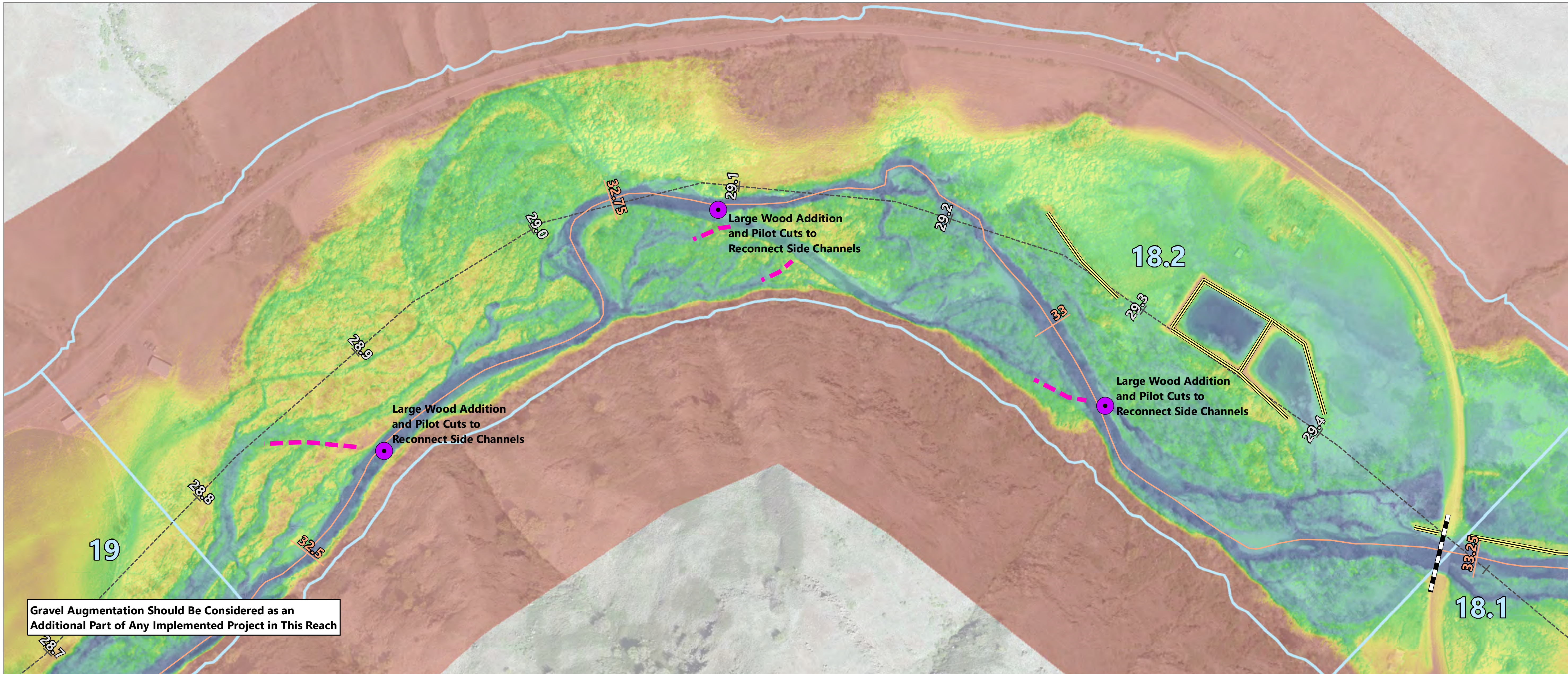
Scoring Metric Ranks



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 18.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.120	40	40%	Complexity	0.222	31	40% to 60%	3 of 5	5	40%	3.4	3	1	Untreated	3	1
Mean-Winter Flow Complexity	0.245	30	40%													
1-year Complexity	0.380	21	20%													
Channel Aggradation FP Potential	0.238	23	40%	Connectivity	0.211	24	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.091	21	40%													
Total FP Potential	0.397	24	20%													
Existing Connected FP	0.603	37	0%													
Excess Transport Capacity	0.12	19	100%	Excess Transport Capacity	1.000	19	30% to 52%	3 of 4	1	20%						
Pool Frequency	1.29	58	100%	Pool Frequency	0.033	58	90% to 100%	5 of 5	0	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 32.46
RIVER MILE END: 33.24
VALLEY MILE START: 28.78
VALLEY MILE END: 29.48

0 500
Feet

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ANCHOR QEA

Project Area 18.2
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 20 Description

Project Area 20 begins at VM 27.91 and extends upstream to a bridge crossing for the Tucannon Road at VM 28.31. The 2017 RM length is 0.44 mile, which makes PA 20 relatively short compared to the other project areas. Field observations for this reach were conducted on October 29, 2018, when flow at the Starbuck gage was approximately 110 cfs.

Field observations and aerial imagery show a large sediment deposit that is immediately evident under the bridge at the upstream end of the reach. The geomorphic change analysis supports the idea that major aggradation has occurred at the upstream end of the reach. Similar to the conditions described in the previous Conceptual Restoration Plan (Anchor QEA 2010a), the upstream half of the reach is complex and multi-threaded, with multiple alder and cottonwood trees in the channel forcing several split flows and slow-moving side channels.

The downstream portion of the reach transitions to a single-thread, plane-bed channel, which continues into the reach immediately downstream (PA 21). The high left bank at the downstream end provides limited vegetation and little habitat opportunity, possibly due to grazing practices that were evident on the left bank during field observations. At the furthest downstream end of the reach, the channel is pinned between the valley wall on the right bank and a small levee and high floodplain on the left.

Project Area 20
Looking downstream, multiple pieces of instream wood and channel avulsions have caused floodplain connectivity and complexity.

Project Area 20 Reach Characteristics

VM Start (mi)	27.91
VM Length (mi)	0.40
Valley Slope	1.43%
RM Start (mi)	31.46
RM Length (mi)	0.44
Average Channel Slope	1.30%
Sinuosity	1.08
Connected FP (ac/VM)	16.55
Encroachment Removal (ac/VM)	1.17
Channel Aggradation (ac/VM)	6.08
Total FP Potential (ac/VM)	8.42
Encroaching Feature Length (ft)	434.03
Connected FP Rank	22

Because PA 20 is a short reach, any project implemented in this area could likely include the upstream or downstream project areas (PA 19 and PA 21, respectively). PA 19 and PA 21 both rank as Tier 2 Untreated projects, although PA 19 scores higher than PA 21. Both upstream and downstream project areas are very limited in floodplain opportunities, making the availability of floodplain potential in PA 20 more significant.

From the time of the previous assessment, it appears this reach has remained relatively constant with respect to large-scale geomorphic processes. The upper part of the reach is relatively complex with active migrations and wood recruitment, while the lower end is a stable plane-bed channel. The riparian and floodplain vegetation is still largely in poor condition, likely due to grazing activities in the area.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several major geomorphic changes have occurred. At the upstream end of the reach, major aggradation of 1 to 4 feet has occurred for approximately 300 feet of the main channel. The beginning of this feature coincides with the location of the bridge at the upstream end of the reach, and it is possible that backwater and loss of energy from the bridge has caused sediment to deposit in this location. PA 20 ranks low in stream power compared to the other project areas, indicating that it may also be a depositional reach. The source of this sediment deposit is unclear; the project area just upstream (PA 19) shows some minor geomorphic change but not enough to account for the volume deposited here (box 1).

Regardless of the source, the deposition has caused major channel avulsions in the downstream half of the reach, with erosional areas on first the left bank and then the right bank as the channel begins to meander. These erosional areas are likely the source of the woody material observed during site visits throughout the reach. It is evident that the woody material has caused further erosional change downstream, and at about halfway down the reach the channel has left the location it occupied completely and moved into the right floodplain, creating split flow conditions at all but the lowest flows (boxes 2 and 3).

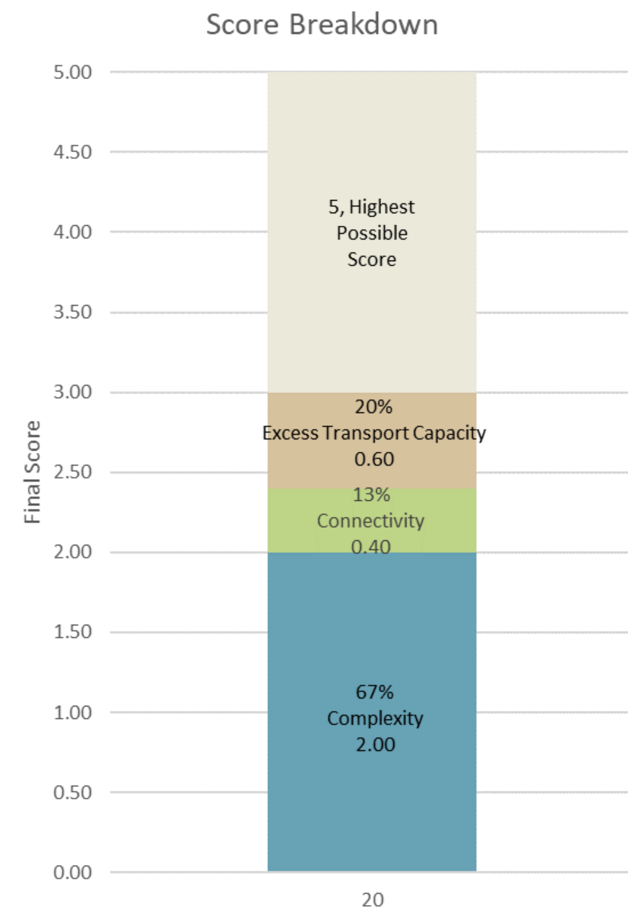
It should be noted that the processes ongoing in this reach and described here are similar to the results sought after with the gravel augmentation restoration strategy. Easily mobilized material from upstream gravel augmentation is deposited after moderate flow events, causing avulsions and erosion into the floodplain just downstream. These avulsions recruit more bedload material and woody material from the floodplain, hopefully repeating the cycle downstream.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, the Complexity and Connectivity metrics make up the majority of the score for PA 20. The project area ranks particularly high in the Encroachment Removal analysis result and much lower in the Channel Aggradation analysis result, indicating most of the potential for improving floodplain connection lies in the restoration target of reconnecting disconnected floodplain. This may be because the reach has already undergone significant channel aggradation and has already achieved most of this potential at the 2-year flow event. Pilot channel cuts or encroachment removal, along with the addition of instream wood to reconnect disconnected floodplain, should be considered as primary restoration strategies for the reach.

PA 20 also receives a high score in the Complexity metric, ranking near the average in the 40th to 60th percentile of project areas. This range has been identified as having the most potential for complexity restoration for this assessment. The low-winter, mean-winter, and 1-year complexity analysis results all fall near the median of project areas and have similar respective rankings. This indicates that existing side channels are connected at the low-winter flow event and are stable even at the higher flow events. Because the upstream end has already seen aggradation as noted in the above section, this reach could possibly have the sediment supply to affect geomorphic change but not have the physical

PA 20 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

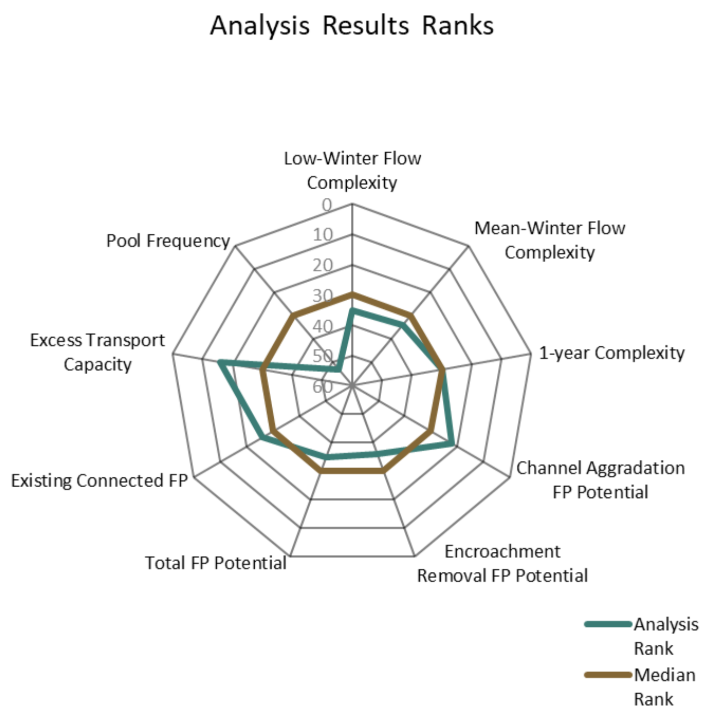
in-channel structure to hold this sediment long enough to establish vegetation on exposed islands and bars. For this reason, complexity should be increased through the addition of woody material and in-channel structural hardpoints to maintain the sediment transport process of the reach. Removing encroaching features in the reach will primarily benefit floodplain reconnection but will also allow for more complexity as secondary flow paths open up.

Finally, PA 20 ranks very low among project areas for the Pool Frequency metric. Adding instream wood and removing encroaching features will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target increasing pool frequency in the reach.

Summary of Restoration Opportunities Identified

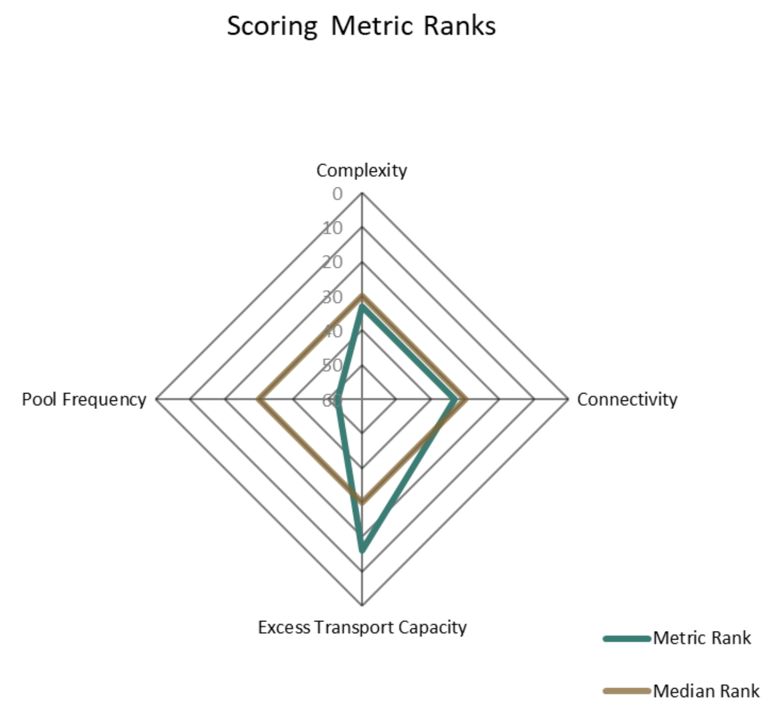
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

PA 20 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

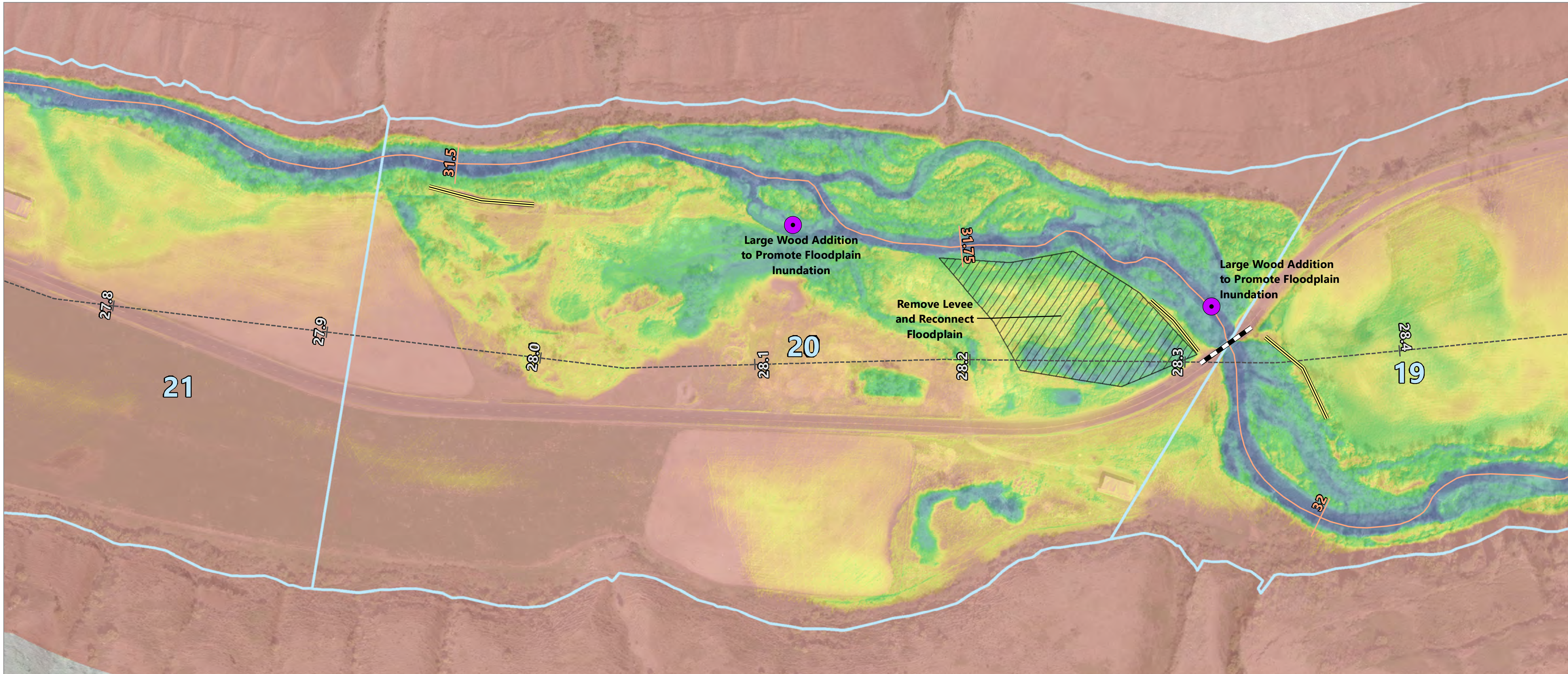
PA 20 Prioritization Scoring Summary

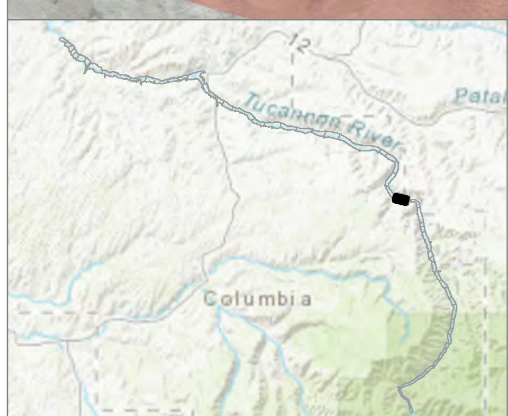


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 20 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.128	35	40%	**Complexity**	0.191	33	40% to 60%	3 of 5	5	40%	3.0	14	1	Untreated	10	1
Mean-Winter Flow Complexity	0.190	34	40%													
1-year Complexity	0.317	30	20%													
Channel Aggradation FP Potential	0.243	22	40%	**Connectivity**	0.184	33	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.047	36	40%													
Total FP Potential	0.337	35	20%													
Existing Connected FP	0.663	26	0%													
Excess Transport Capacity	0.14	16	100%	**Excess Transport Capacity**	3.000	16	10% to 30%	2 of 4	3	20%						
Pool Frequency	4.59	53	100%	**Pool Frequency**	0.118	53	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 31.46
RIVER MILE END: 31.9
VALLEY MILE START: 27.91
VALLEY MILE END: 28.31

0 500
Feet

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ANCHOR QEA

Project Area 20
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 25 Description

Project Area 25 begins at VM 23.9 at the Turner Road bridge and extends upstream to VM 24.35. The 2017 RM length is 0.54 mile, which is a relatively short reach. Field observations for this reach were conducted on November 1, 2018, when flow at the Starbuck gage was approximately 100 cfs.

At the time of the site visit, the upstream portion of the reach showed dynamic and complex bedforms and plan forms with bars and pools forming with gravel and cobble-sized substrate. One side channel was actively flowing through a stand of trees on the right bank, and other higher flow channels were apparent. The left bank had decent riparian growth with large, older cottonwoods, alders, and some willows. The right bank immediately abutted a field likely used for grazing, which was reinforced with large riprap in several locations. This field appears to be low-lying floodplain that is disconnected at the 5-year flow.

A large channel-spanning log jam near the middle of the reach had caused erosion and split flow on both the left and right banks. Large amounts of gravel and cobble-sized sediment were evident upstream of the log jam and likely contributed to the dynamic geomorphic conditions immediately upstream. Downstream of the log jam, the river makes a sharp bend and runs along the valley wall for the remainder of the reach, flowing over bedrock in several locations. On the right bank, a series of unmaintained levee sections and gravel berms prevent

Project Area 25
Location of channel erosion on the right bank and bar build on the left bank.

Project Area 25 Reach Characteristics

VM Start (mi)	23.90
VM Length (mi)	0.45
Valley Slope	1.20%
RM Start (mi)	26.98
RM Length (mi)	0.54
Average Channel Slope	1.03%
Sinuosity	1.20
Connected FP (ac/VM)	10.21
Encroachment Removal (ac/VM)	2.33
Channel Aggradation (ac/VM)	3.43
Total FP Potential (ac/VM)	11.21
Encroaching Feature Length (ft)	381.19
Connected FP Rank	48

the river from accessing several apparent meander scars. Several of these meander scars were inundated but not connected, likely from higher flows or possible spring or groundwater flows. Because of these levees, the downstream reach is much less complex than the upstream reach. Additionally, downstream of the channel-spanning log jam, sediment sizes on the channel bed were observed to increase significantly within the channel likely due to a combination of sediment being stored above the log jam, and increased transport capacity in the simplified section in the downstream reach. Finally, a rock vortex style weir with a large plunge pool is keyed into the levee and bedrock valley wall just upstream of the bridge at the downstream end of the reach.

Geomorphic Changes

PA 25 is a short reach and experienced only one significant location of geomorphic change based on analysis of the difference between the 2010 and 2017 LiDAR data. This change occurs near the middle of the reach and was noted during field observations to correspond with the location of a channel-spanning log jam, with significant deposition upstream. In this location, erosion of the left and right banks is apparent (box 1). Additionally, patches of aggradation upstream of this location are evident in both the floodplain and main channel, particularly in a right bank side channel, and may represent deposition due to the log jam. Just upstream of the log jam a point bar is building along with erosion on the left bank.

Downstream of the log jam, little to no change has occurred in the remainder of the reach to the Turner Road bridge.

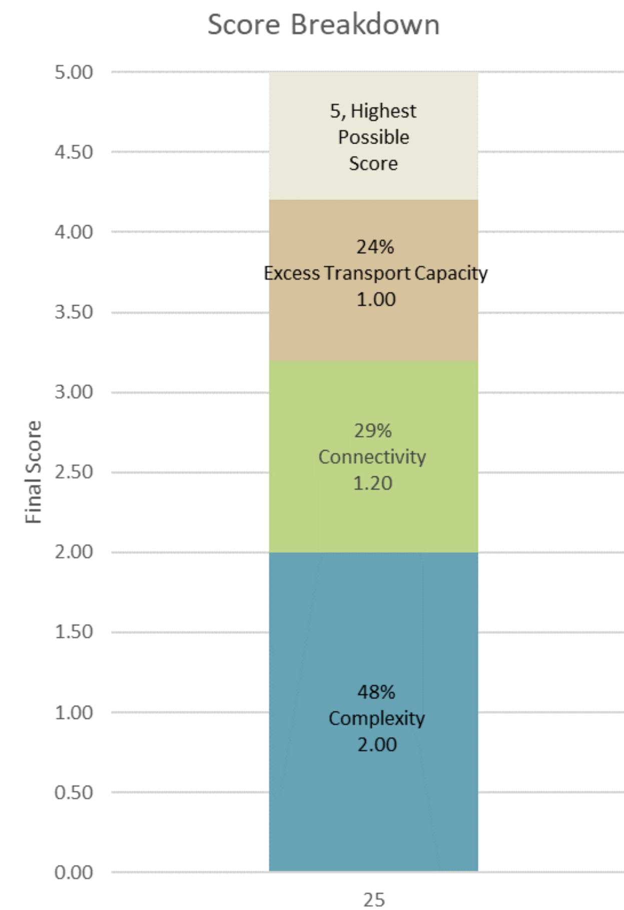
Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, high scores in the Complexity metric and the Excess Transport Capacity metric make up the majority of the score for PA 25, with a smaller score for the Connectivity metric. PA 25 ranks near average in the 40th to 60th percentile for complexity, a range identified for this assessment as having the most complexity potential. Most of the existing complexity for this reach comes at the upstream end where the channel has widened to form several mid-channel bars at the low-winter flow and activate a side channel at the mean-winter and 1-year flow events. However, based on the relative elevation map and floodplain connectivity at the 2-year event, there are several more locations for possible side channels in the upstream half of the reach. In this area, restoration strategies should include adding instream wood to promote geomorphic change and reconnecting side channels via pilot channel cuts on the floodplain.

The downstream half of the reach shows almost no complexity at any of the flows, and the relative elevation map and 2-year connectivity indicate any floodplain side channels would be difficult to access in this area. Promoting channel dynamics and fringe floodplain complexity should be the targeted restoration strategy for the downstream half of this project area. However, because this reach scores very highly in the Excess Transport Capacity metric, and field observations noted a perceived large typical bed material size, it is likely both gravel augmentation and developing instream structure will be necessary to affect any geomorphic change in this portion of the project area. Adding large woody material and other instream wood is unlikely to cause scour pools or promote channel avulsions in any timely fashion when the bed material is too large to be transported on a regular basis. In addition, any gravel added to the reach without instream structure would almost certainly be quickly transported downstream before causing any geomorphic change. These restoration techniques are both necessary and performing only one will be much less successful than performing both in tandem.

While the reach only scores in the 25th percentile for the Connectivity metric, the majority of the area that drives this is a large, low spot located on the right bank floodplain in a field with little to no mature vegetation and over 100 feet from the active floodplain. Additionally, since this score comes mostly from the Total Floodplain Potential analysis result, this area would require both channel aggradation and encroachment removal to be successful. There are several other small pockets for floodplain that could be reconnected with the removal of encroachments, but this restoration strategy should be seen as secondary to the goal of developing complexity and encouraging channel dynamics as already discussed.

PA 25 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

Finally, PA 25 ranks very low among project areas for the Pool Frequency metric. Adding instream wood and gravel augmentation will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target increasing pool frequency in the reach.

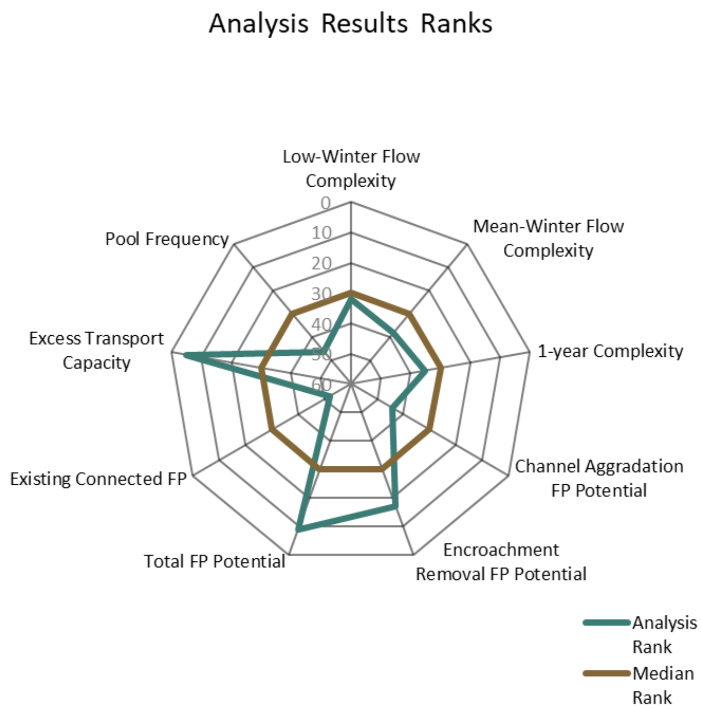
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

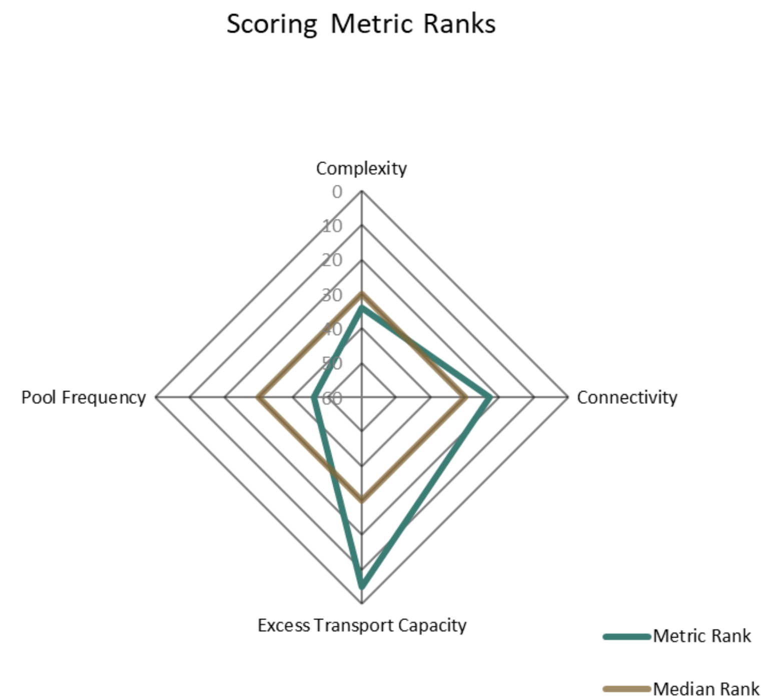
- Set back road against right valley wall for more floodplain connection and channel migration area.

PA 25 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

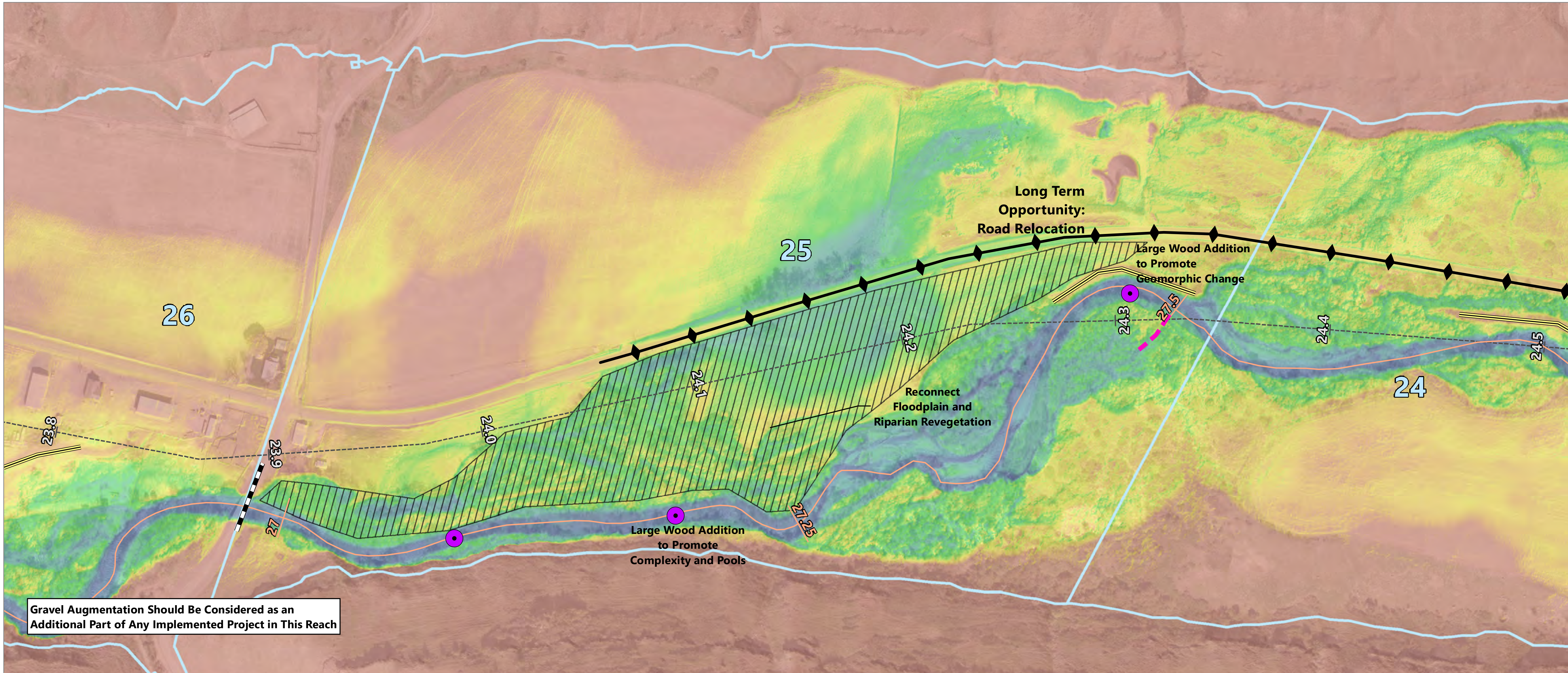
PA 25 Prioritization Scoring Summary

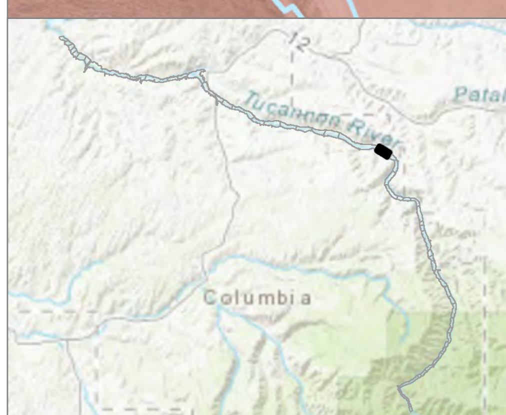


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 25 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.145	32	40%	Complexity	0.181	34	40% to 60%	3 of 5	5	40%	4.2	2	1	Untreated	2	1
Mean-Winter Flow Complexity	0.175	38	40%													
1-year Complexity	0.268	35	20%													
Channel Aggradation FP Potential	0.160	44	40%	Connectivity	0.212	23	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.109	17	40%													
Total FP Potential	0.523	9	20%													
Existing Connected FP	0.477	52	0%													
Excess Transport Capacity	0.27	5	100%	Excess Transport Capacity	5.000	5	1% to 10%	1 of 4	5	20%						
Pool Frequency	5.56	46	100%	Pool Frequency	0.143	46	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Long Term: Relocate Road

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 26.98
RIVER MILE END: 27.52
VALLEY MILE START: 23.9
VALLEY MILE END: 24.35

0 500
Feet

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ANCHOR QEA

Project Area 25
Conceptual Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 27 Description

Project Area 27 begins at VM 20.21 at the bridge for King Grade Road and extends upstream to VM 21.11. The 2017 RM length is 1.05 miles. Field observations for this reach were conducted on November 2, 2018, when a maximum daily flow of 107 cfs was recorded.

The reach is primarily characterized by an offset levee on the right bank for most of the reach; moderately accessible floodplain is evident. However, much of the floodplain has higher elevation encroachments, which may be either the remnants of old, unmaintained levees or high bank left after channel incision. These encroachments are evident both from field observations and the relative elevation map and, while they do not strictly confine the channel, they do inhibit free migration and geomorphic change into the small amount of floodplain before the primary levee.

The upper and lower sections of the reach are pinned on the left bank against the bedrock valley wall, providing poor habitat conditions and little opportunity for geomorphic processes to progress. On the right bank, and on the left bank where not bounded by the valley wall, the floodplain is moderately accessible with established vegetation including cottonwoods and alders. Some wood has been recruited recently, forcing small side channels into the floodplain. The site photograph in the sidebar shows the upstream end of one such example. One

Project Area 27
Upstream end of side channel on right bank, looking downstream on PA 27.

Project Area 27 Reach Characteristics

VM Start (mi)	20.21
VM Length (mi)	0.90
Valley Slope	0.96%
RM Start (mi)	22.95
RM Length (mi)	1.05
Average Channel Slope	0.84%
Sinuosity	1.17
Connected FP (ac/VM)	13.19
Encroachment Removal (ac/VM)	8.33
Channel Aggradation (ac/VM)	9.10
Total FP Potential (ac/VM)	21.62
Encroaching Feature Length (ft)	4,861.45
Connected FP Rank	37

rock habitat structure has been present on the right bank since before the previous geomorphic assessments.

Based on field observations, these conditions would suggest a reach that has potential for restoration via means of low-winter flow complexity development and floodplain access, as described in the Geomorphic Characterization and Restoration Strategies section below. PA 27 is bounded on the upstream end by PA 26, which has similar features such as a long bounding levee encroachment, and on the downstream side by PA 28.1, which has been worked on extensively over the past 10 years. This may provide the opportunity to combine project reaches with similar goals for management and monitoring work on the downstream project area.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows that this reach has experienced relatively little geomorphic change. The upstream end of the reach experienced some side channels and minor main channel avulsions, which are structures placed by the Columbia Conservation District in 2013 as part of a project for PA 26 (box 1).

In the middle section of the reach, the main channel has avulsed away from the bedrock wall on the left bank to form a low-winter flow bar before returning to be pinned against the bedrock wall (box 2). Further downstream, the opposite effect has happened with a gravel bar forming on the right bank pushing the main channel closer to the bedrock wall for a short distance. Immediately downstream of this avulsion, a new side channel has formed on the right bank, which, based on field observations, appears to be the product of both wood recruitment and sediment deposition and may be established for more than the immediate future (box 3). These changes are all relatively minor compared to other reaches in the system and are likely due to several factors. The downstream control of the bridge plays some role in keeping geomorphic change to a minimum but may also cause a backwater, making the reach depositional for small-sized sediment. However, the likely controlling factors for the reach are the main right bank levee, which is set only a short distance into the floodplain, the bedrock valley wall on the left bank, and the minor encroachments or old levee remnants.

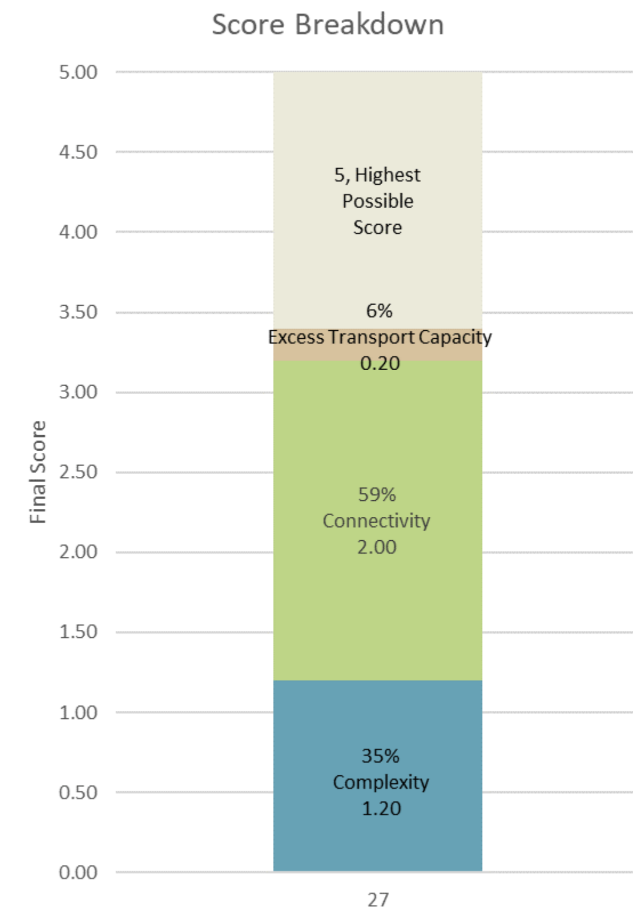
Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, the Connectivity and Complexity metrics make up the majority of the score for PA 27, along with a small score in the Excess Transport Capacity metric.

The high Connectivity score indicates this project area ranks near the top in the 75th to 99th percentile and is driven by high rankings in both the Channel Aggradation analysis result and Encroachment Removal analysis result. A large portion of the right bank floodplain in PA 27 is already low lying enough to be accessed at the 2-year event and disconnected via a high bank or old remnant levee. Breaching or removing these encroachments, along with adding structure to promote geomorphic change onto the floodplain, should be one of the highest priorities for this reach. Near the downstream end of the reach, a large portion of the right bank floodplain is connected at the 5-year event, indicating that any rise in the average water surface elevation in this reach would reconnect this area at a more frequent event. This rise could be accomplished through a combination of gravel augmentation and developing instream structure to hold and store sediment as well as increase roughness, slow flow, and create backwater. Encroachment removal can often work well in tandem with gravel augmentation; if the encroachments consist of a significant amount of transportable material, it can be easily reused after removal as a sediment source, and this could be particularly effective in PA 27.

PA 27 also receives a moderate score in the Complexity metric, ranking in the 60th to 90th percentile. While not the highest priority for complexity, this range indicates that the complexity in this reach is good enough to be nearly within the top 10% of project areas and, therefore, PA 27 receives a moderate complexity score. This Complexity score is driven by multiple side channels and split flows in the immediate floodplain, which provide good complexity but do not significantly extend into the floodplain. The restoration strategies of adding instream

PA 27 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

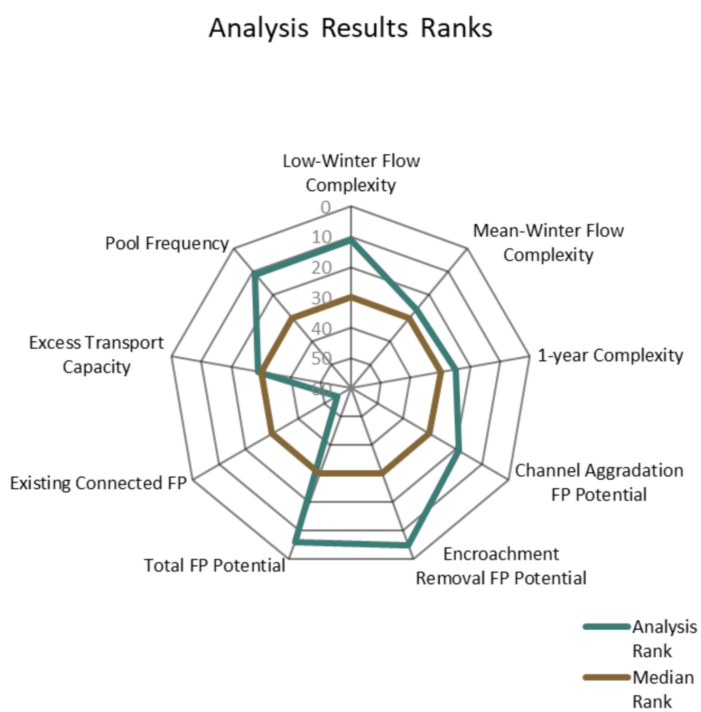
wood and gravel augmentation, as discussed previously, should allow access to more of the floodplain, and the reconnection of disconnected or abandoned side channels and flow paths in the targeted floodplain should be the priority for adding complexity. Adding wood and structure to the floodplain in this area will also be important to ensure that any activated side channels will remain in place with perennial flow.

Finally, PA 27 ranks well above average in the Pool Frequency metric, indicating a high amount of pools per river mile. The restoration strategy of adding instream structure and wood, along with gravel augmentation, should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

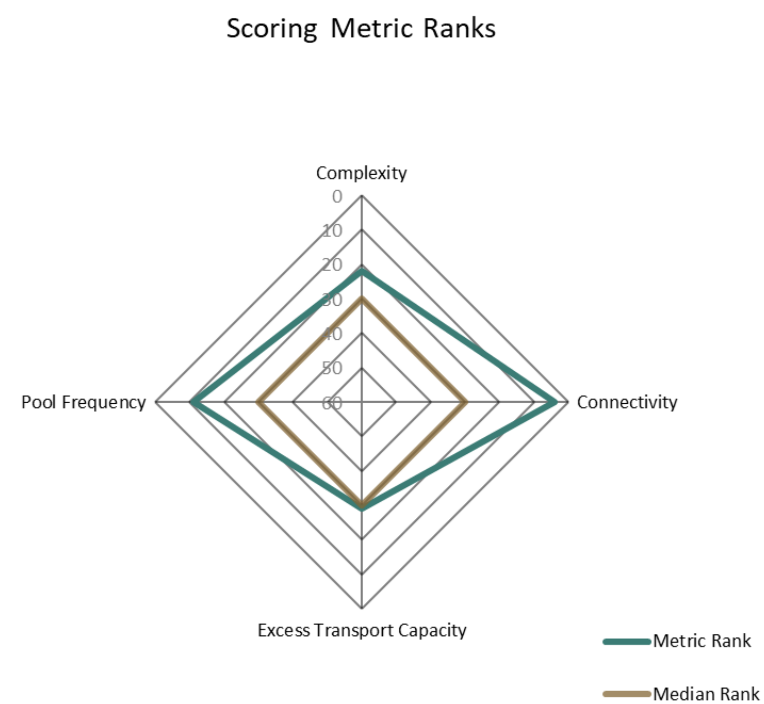
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

PA 27 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

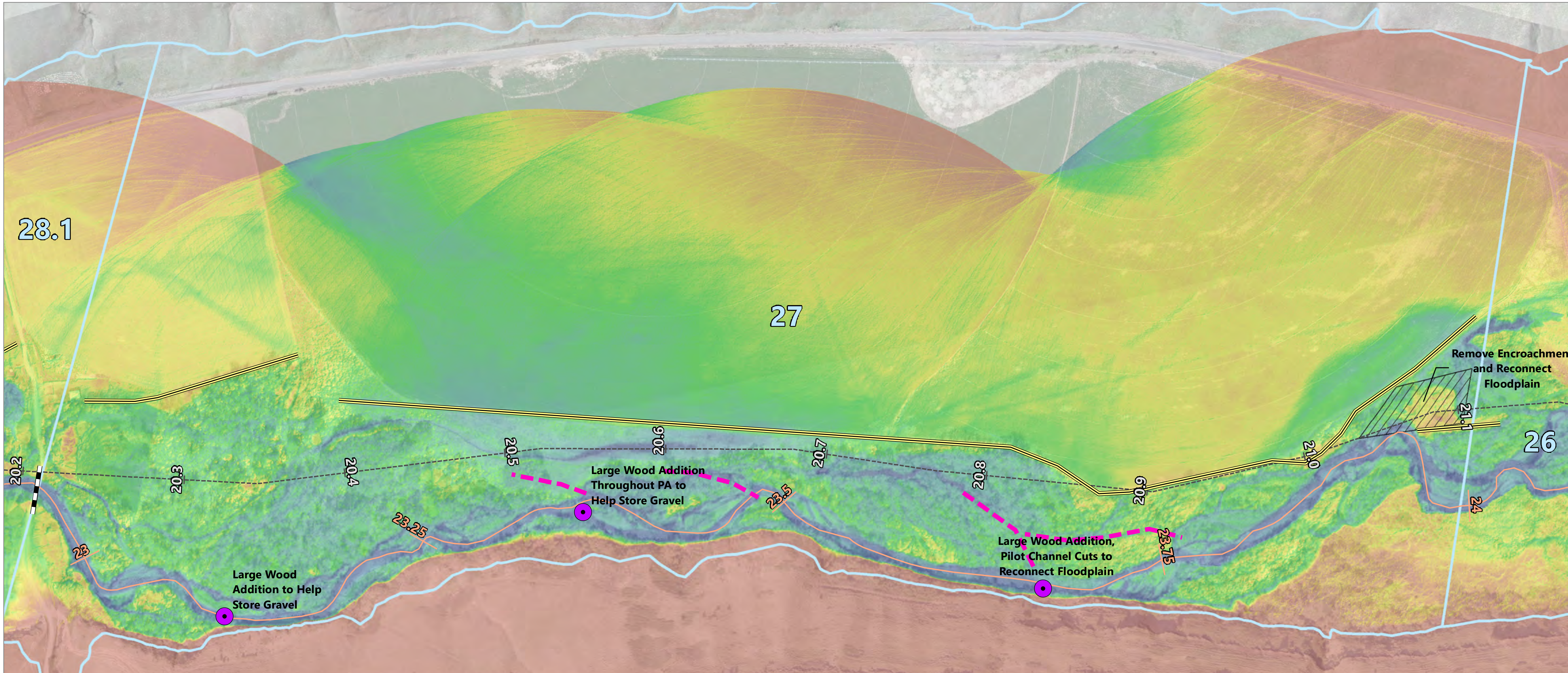
PA 27 Prioritization Scoring Summary

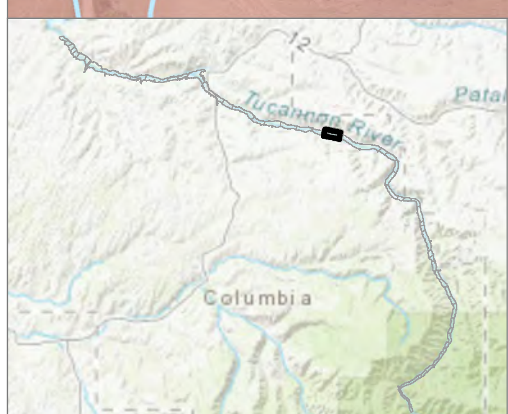


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 27 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.275	11	40%	Complexity	0.296	22	10% to 40%	2 of 5	3	40%	3.4	4	1	Untreated	4	1
Mean-Winter Flow Complexity	0.287	26	40%													
1-year Complexity	0.358	25	20%													
Channel Aggradation FP Potential	0.261	19	40%	Connectivity	0.325	4	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.239	5	40%													
Total FP Potential	0.621	6	20%													
Existing Connected FP	0.379	55	0%													
Excess Transport Capacity	0.04	29	100%	Excess Transport Capacity	1.000	29	30% to 52%	3 of 4	1	20%						
Pool Frequency	19.09	11	100%	Pool Frequency	0.490	11	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 22.95
RIVER MILE END: 23.99
VALLEY MILE START: 20.21
VALLEY MILE END: 21.11

0 500
Feet

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ANCHOR QEA

Project Area 27
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 32.1 Description

Project Area 32.1 begins at VM 13.42 at the bedrock Tucannon Falls and extends upstream to VM 14.11. The 2017 RM length is 0.79 mile. Field observations for this reach were conducted on October 10, 2018, when peak flow at the Starbuck gage was approximately 115 cfs.

For this assessment update, PA 32 as defined in the 2011 prioritization was separated into two project areas (PA 32.1 and PA 32.2) at the Tucannon Falls. The falls represent a natural geomorphic break and grade control. Upstream of the falls, PA 32.1 is almost entirely locked onto the left bank valley wall and often encounters bedrock. The reach also contains a small pocket of floodplain.

The upstream end of the reach begins on the right bank with a large swampy area in the floodplain, including multiple deep pools. A large avulsion near this area has created split flow and flow into the floodplain. Downstream of the avulsion, sediment on the floodplain is evident, indicating some material transport.

Downstream of the avulsion, the channel is migrating into the floodplain in several locations, eroding at the high bank and building bars on the inside of the bend. One of these erosion locations is threatening an irrigation pump station.

Further downstream, the channel is confined for most of the rest of the reach on the left bank by the valley wall and on the

Project Area 32.1
Sparse riparian vegetation up against the left bank valley wall. On the right a small split flow is returning from upstream.

Project Area 32.1 Reach Characteristics

VM Start (mi)	13.42
VM Length (mi)	0.69
Valley Slope	0.82%
RM Start (mi)	15.34
RM Length (mi)	0.79
Average Channel Slope	0.71%
Sinuosity	1.14
Connected FP (ac/VM)	12.40
Encroachment Removal (ac/VM)	13.74
Channel Aggradation (ac/VM)	13.72
Total FP Potential (ac/VM)	24.26
Encroaching Feature Length (ft)	3,552.17
Connected FP Rank	39

right by a high bank. However, several side channel opportunities exist behind what appears to be an old levee on the right bank. For most of the reach, a field with pivot infrastructure is set back a good distance from the old levee, and this could be a good opportunity for a setback levee.

At the downstream end of the reach, more bedrock is encountered before finally resulting in the bedrock at Tucannon Falls. While not observed during the field visit, the relative elevation map appears to show a long side channel forming on the right bank, which could circumvent the falls.

At the time of this assessment update, the Columbia Conservation District is in the process of implementing a plan that extends just past the falls into PA 32.2.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows three primary locations of geomorphic change in PA 32.1. At the upstream end, a large depositional area and associated channel avulsion and split flow formation has occurred. The depositional area extends out into the right bank floodplain, and field observations of the site revealed cobble-sized materials in the riparian area. This change seems to be driven by several natural log jams that have formed at the head of the island forcing flows to the left and allowing material to build up on the right bank (box 1).

Just downstream of this area, the channel sinuosity is starting to increase as several meander bends are beginning to form. Erosion is evident on the outside of alternating meander bends and associated bars are forming on the inside of the bends. The center meander bend has eroded up against the left bank valley wall and cannot meander any further, which occasionally causes the channel to straighten and run along the valley wall (box 2).

Finally, just downstream of the meander bends, a 200-foot section is eroding heavily at the right bank (box 3). After this section, the channel begins to encounter bedrock and no more geomorphic change is noted in the analysis of this reach.

Geomorphic Characteristics and Restoration Strategies

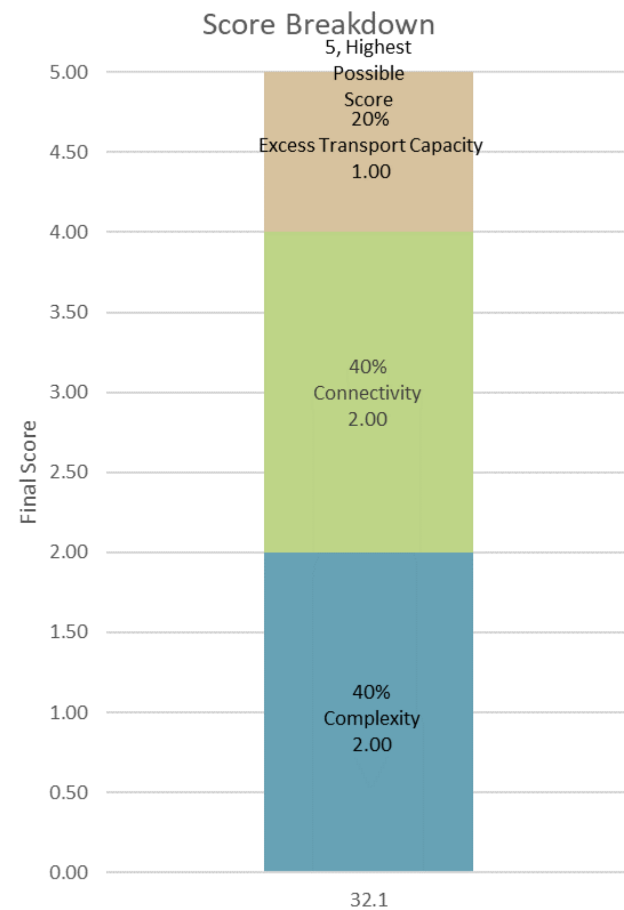
As shown in the following graphs and table, PA 32.1 scores highly in the prioritization metrics of Complexity, Connectivity, and Excess Transport Capacity. PA 32.1 ranks in the 40th to 60th percentile range for Complexity, which is the range in which reaches have the most potential for complexity without being too confined to allow realistic projects to be completed. For all three flows, this complexity is driven by the area near the upstream end of the reach, which has undergone a recent avulsion. The 1-year and mean-winter flows are both more complex than the low-winter flow, but this complexity occurs in the same general area, just activating more side channels. The downstream half of the reach shows no complexity value at any of the three flows.

The high Connectivity score in this reach is driven by high ranks in both the Channel Aggradation and Encroachment Removal analysis results. Several different areas in this reach contribute to these high ranks. First, a relatively low, swampy floodplain on the right bank is disconnected by a high bank and old levee. At the upstream end of the reach along the right bank, near where the recent avulsion has happened, there is a large disconnected wetland complex that appears to have some groundwater source, which is likely because this reach is just above a large bedrock falls. However, this area is pinned between two fields with pivot infrastructure and may be difficult to connect to the river. It should be noted that a large portion of the floodplain area in this reach was within the area of these fields with pivot infrastructure and was therefore marked "unobtainable" and not counted to any of the analyses in this assessment.

The primary area of floodplain connectivity is near the middle of the reach, where the floodplain is disconnected by high banks and possible old levees at the 2-year flow and connected, although intermittently, at the 5-year flow. This area could be connected either via channel aggradation or encroachment removal. Although the potential area to be gained with channel aggradation is greater than that of encroachment removal, it may be difficult in this reach to achieve significant floodplain aggradation.

This reach also scores very highly in the Excess Transport Capacity metric, likely due to the confined section downstream

PA 32.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

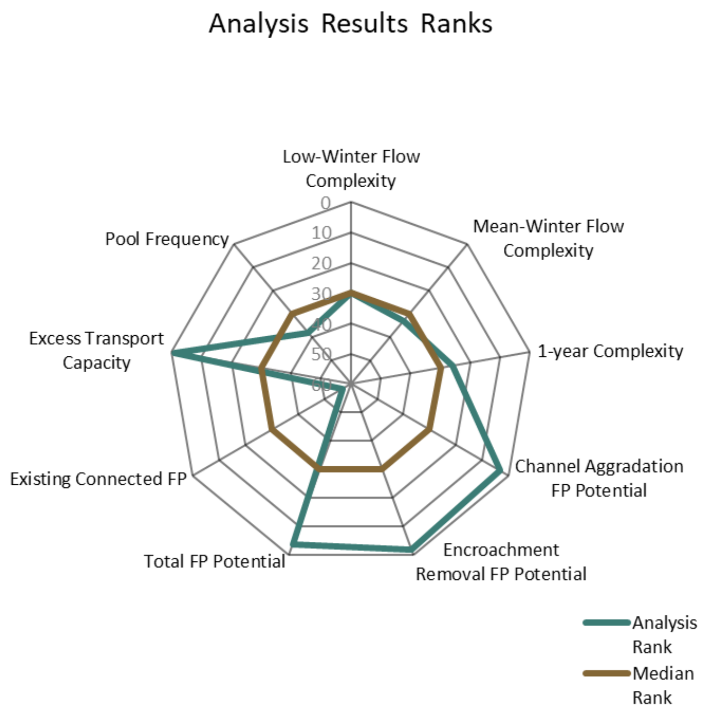
and the bedrock falls, which allows for a steep slope with no sediment transport wherever bedrock is present. Addressing this will be difficult, and the best restoration strategy will attempt to connect large portions of the floodplain upstream of the bedrock reach. This should be accomplished through cutting pilot channels and removing as much of the floodplain encroachment as possible, while adding LWD to promote geomorphic change and trap sediment where possible.

Finally, the Pool Frequency metric in this reach scores slightly below average. The identified restoration strategies of adding instream structure and wood, along with gravel augmentation, should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

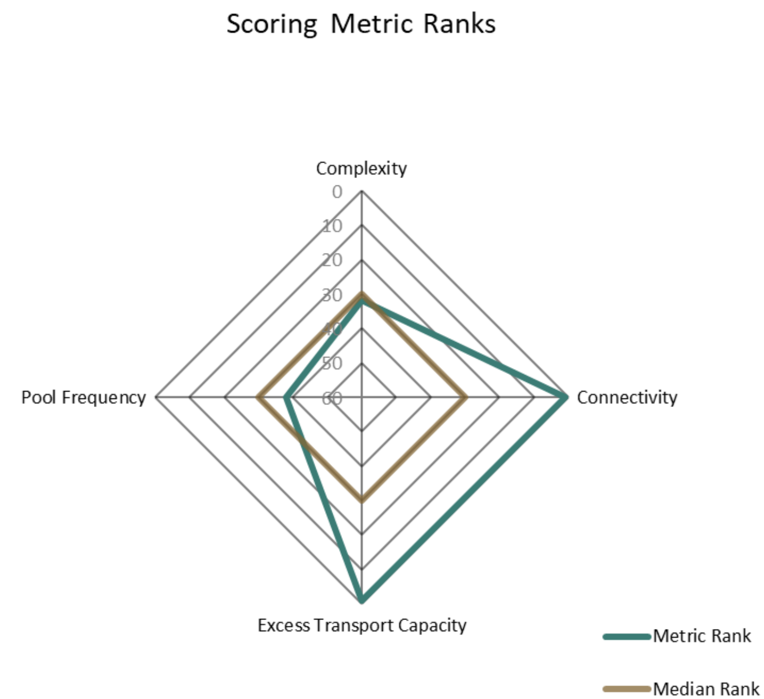
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)
- Riparian zone enhancement
- Modify or remove obstructions

PA 32.1 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

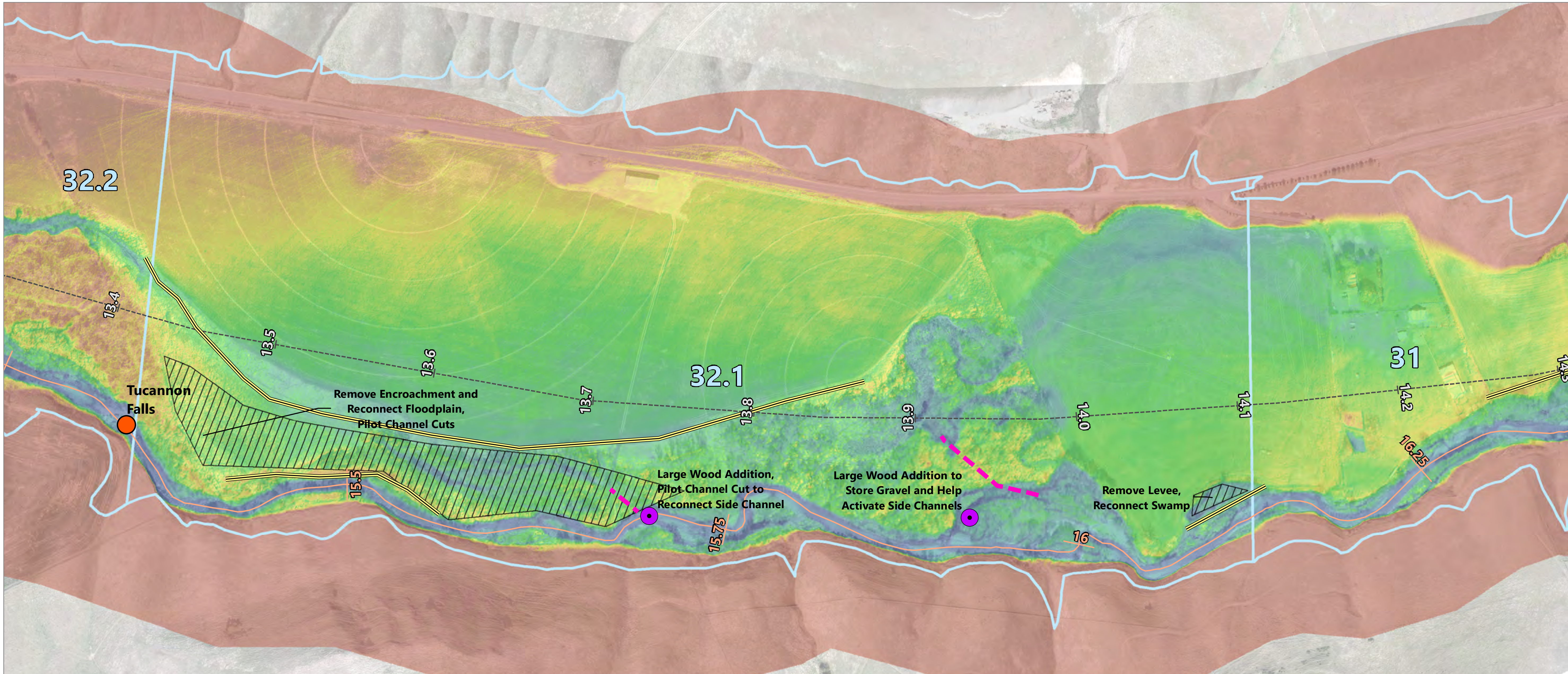
PA 32.1 Prioritization Scoring Summary

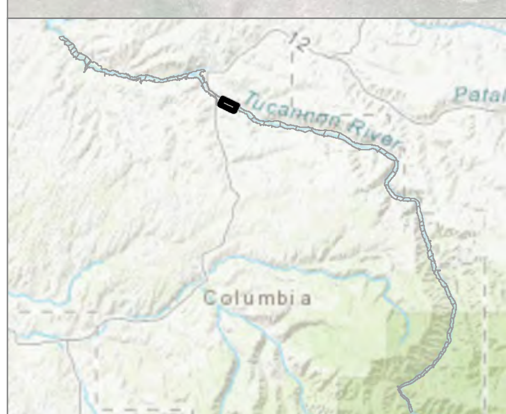


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 32.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.161	30	40%	Complexity	0.211	32	40% to 60%	3 of 5	5	40%	5.0	1	1	Untreated	1	1
Mean-Winter Flow Complexity	0.194	33	40%													
1-year Complexity	0.348	26	20%													
Channel Aggradation FP Potential	0.374	3	40%	Connectivity	0.432	1	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.375	2	40%													
Total FP Potential	0.662	4	20%													
Existing Connected FP	0.338	57	0%													
Excess Transport Capacity	0.36	1	100%	Excess Transport Capacity	5.000	1	1% to 10%	1 of 4	5	20%						
Pool Frequency	8.91	38	100%	Pool Frequency	0.229	38	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Placemark

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 15.34
RIVER MILE END: 16.13
VALLEY MILE START: 13.42
VALLEY MILE END: 14.11

0 500
Feet

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Project Area 32.1
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 32.2 Description

Project Area 32.2 begins at VM 13.42 at the Highway 12 bridge and extends upstream to VM 12.84 at the bedrock Tucannon Falls. The 2017 RM length is 0.69 mile. Field observations for this reach were conducted on October 10, 2018, when flow at the Starbuck gage was approximately 115 cfs.

For this assessment update, PA 32 as defined in the 2011 prioritization was separated into two project areas (PA 32.1 and PA 32.2) at the Tucannon Falls. The falls represent a natural geomorphic break and grade control. While not a fish barrier, these falls definitely are not ideal migration conditions. A large, low-lying side channel 500 feet into the floodplain on the right bank of PA 32.2 could provide an opportunity for a side channel that bypasses the falls.

Just downstream of the falls, the reach is relatively confined with a bedrock bottom that ends shortly downstream of the falls. Several side channel opportunities exist on the left and right banks as the channel goes through several meanders before reaching the bridge at the downstream end of the project area. Some of these meanders are migrating and causing erosion on the outside of the bends. One in particular is causing erosion behind a rock bank barb structure and could reconnect to a low-lying area.

The floodplain has patches of well-developed forested areas but also goes through large stretches of exposure with little

Project Area 32.2
Downstream end of PA 32.2 showing woody material on banks and instream complexity.

Project Area 32.2 Reach Characteristics

VM Start (mi)	12.84
VM Length (mi)	0.58
Valley Slope	0.95%
RM Start (mi)	14.63
RM Length (mi)	0.69
Average Channel Slope	0.80%
Sinuosity	1.19
Connected FP (ac/VM)	14.60
Encroachment Removal (ac/VM)	2.12
Channel Aggradation (ac/VM)	10.16
Total FP Potential (ac/VM)	10.86
Encroaching Feature Length (ft)	501.93
Connected FP Rank	20

cover, often near where the meander bends are beginning to migrate towards fields.

A large channel-spanning log jam near the downstream end of the reach has caused multiple geomorphic changes in the immediate area; while the channel here is complex with multiple flow paths, these changes may be unstable in the future.

The bridge for Highway 12 was rebuilt but the old bridge still remains. However, this does not have a large impact because the two bridges are only 200 feet apart and the confining levee for the bridge crossing encompasses both bridges and protects a field on the left bank.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several locations of geomorphic change in PA 32.2. At the very upstream end, where the Tucannon Falls are located, erosion on the right bank is cutting around the existing falls, which was also noted during field observations. While it is likely the bedrock shelf that forms the existing falls extends into the floodplain where this erosion is occurring, scouring on the right bank could increase the channel length and lower the distance of the drop (box 1).

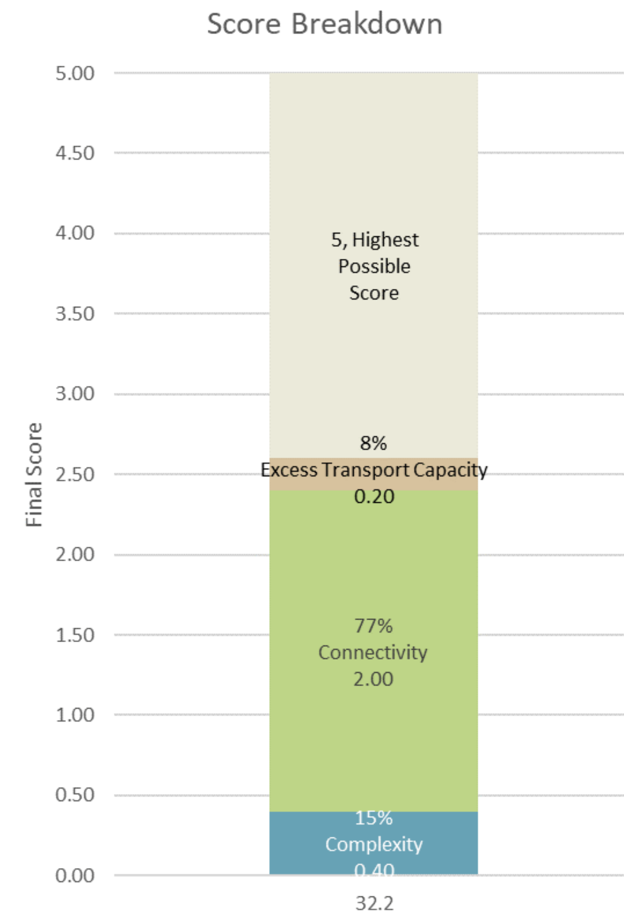
About 600 feet downstream of the falls, the channel goes through a long, straight reach with thick canary grass on the right bank. This area shows up as aggradation on the change analysis; it is unclear if this apparent aggradation is real or a result of this vegetation growth (box 2). Immediately downstream, the bar is building on the left bank and inside of the meander bend, with associated erosion on the right bank (box 3). This is a common geomorphic process in meander bends, but it could be exacerbated by the aggradation on the right bank and may be the beginning of a new meander bend. Further downstream, another meander bend is forming with bar building on the right bank and erosion on the left bank. A disconnected side channel near this erosional bend also shows downcutting, possibly indicating that there could be channel downcutting (box 4). After this meander bend, deposition on the left bank is forcing a minor channel avulsion to the right where erosion and downcutting are evident (box 5).

Finally, at the downstream end of this project area and just upstream of the Highway 12 bridge, the channel has gone through several major avulsions. There are some minor areas of deposition on the floodplain in this area, but these avulsions are primarily driven by erosion in several locations. Based on field observations and the 2018 aerial imagery, several large channel-spanning log jams in the channel here may be forcing this geomorphic change (box 5).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 32.2 receives the majority of its prioritization score in the Connectivity metric. PA 32.2 ranks in the top 25% of all project areas for Connectivity and ranks among the top project areas for the Channel Aggradation analysis result and near average for the Encroachment Removal metric. The high rank for the Channel Aggradation analysis result is mostly due to low-lying areas immediately surrounding the active 2-year floodplain. This indicates that this channel is likely slightly incised, as would be expected for the reach immediately downstream of the Tucannon Falls, and a large amount of the total available floodplain can be connected at the 2-year event through channel aggradation. The primary restoration strategy for this reach should be gravel augmentation in conjunction with the addition of instream wood to store and retain the sediment and cause channel aggradation. PA 32.2 receives a low score in Excess Transport Capacity, indicating that instream wood should easily trap and maintain sediment. The disconnected area in this reach, indicated by the average ranking in the Encroachment Removal analysis result, exists mostly in side channel areas that would be reconnected with channel aggradation. This is why the Total Floodplain Potential analysis result is lower than the combined Encroachment Removal and Channel Aggradation analysis results.

PA 32.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 32.2 receives a low score in the Complexity metric, indicating that it ranks below average in the 10th to 40th percentile. This range has been identified as having poor enough complexity that a high level of restoration would be needed to reach a good level of complexity. However, the above identified restoration strategies can be used to also increase the total amount of complexity in the reach. Several side channel opportunities exist throughout the reach that can be connected at a perennial event with pilot channel cuts and the addition of strategic placement of instream wood. Placing instream wood to store sediment and promote geomorphic change, along with pilot channel cuts and gravel augmentation to access more the of the floodplain, should be the primary restoration strategies in the reach.

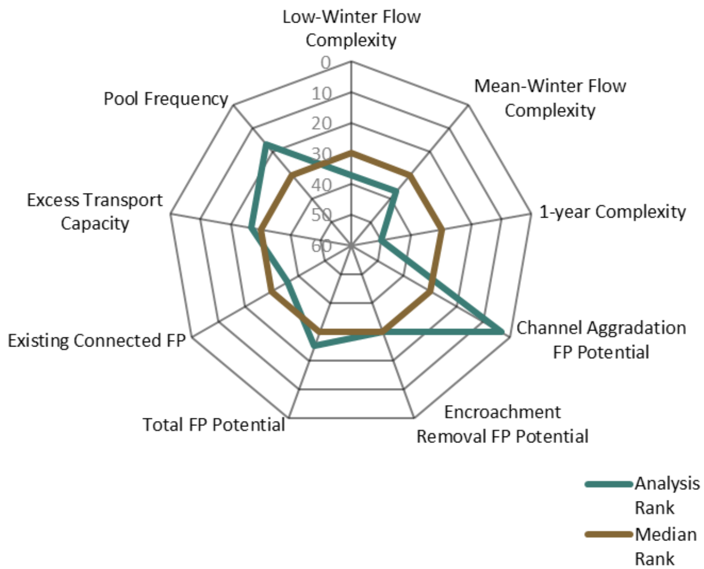
Finally, the Pool Frequency analysis result indicates that this project area ranks relatively high for number of pools per valley mile. The identified restoration strategies of adding instream wood and gravel augmentation should assist in maintaining and increasing the number of pools in this reach.

Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)
- Modify or remove obstructions

PA 32.2 Analysis Results Summary

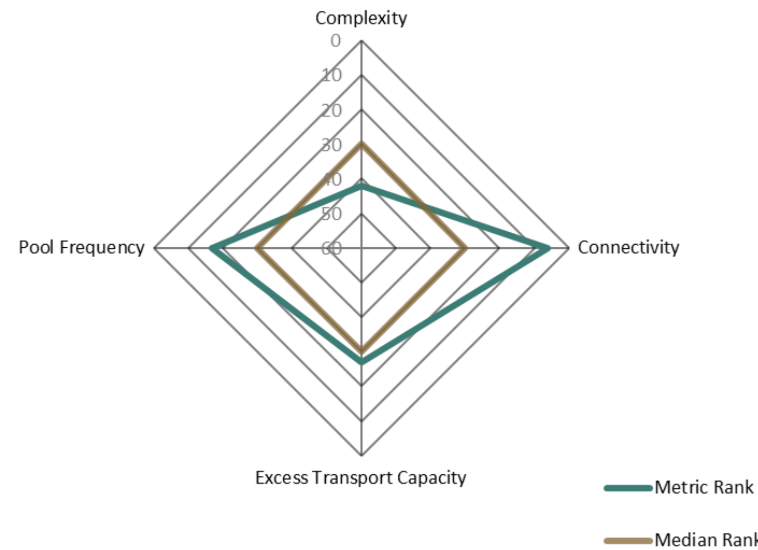
Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

PA 32.2 Prioritization Scoring Summary

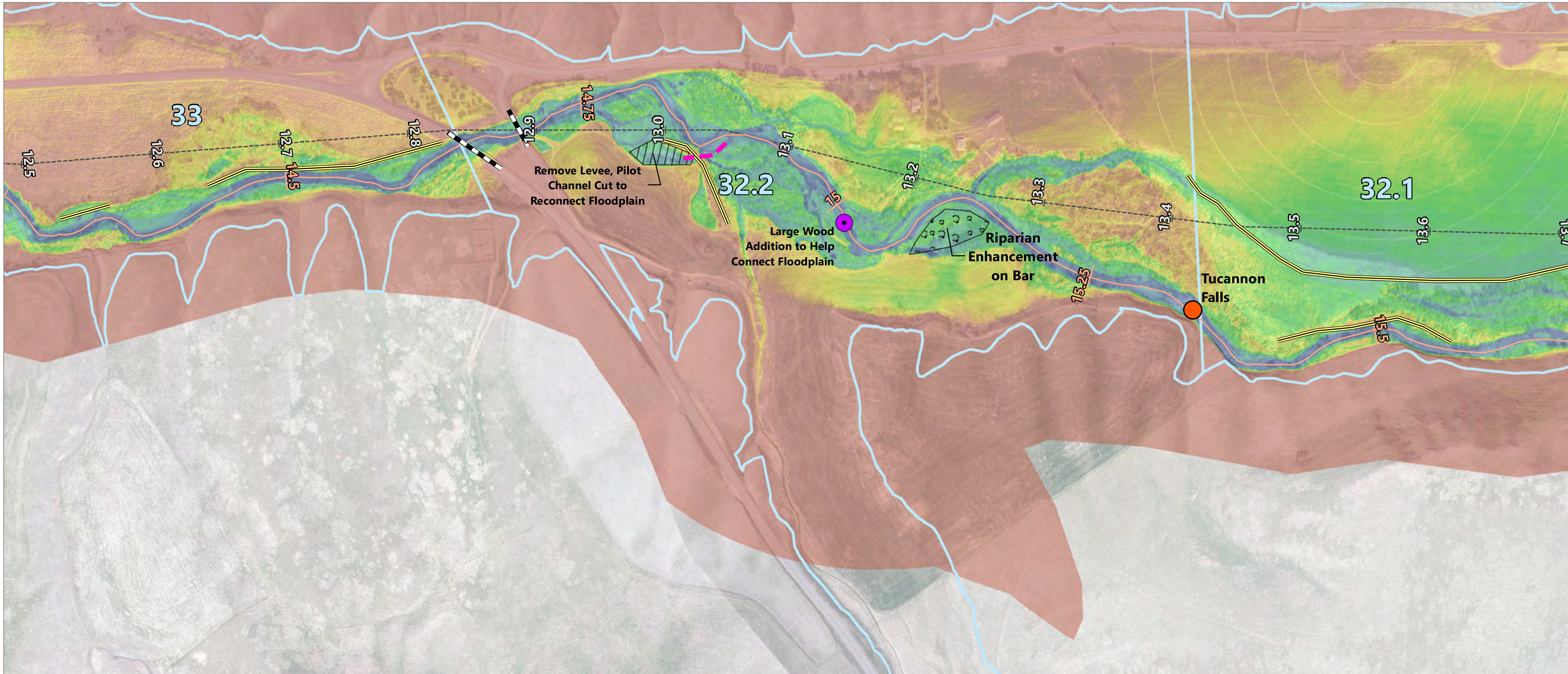
Scoring Metric Ranks

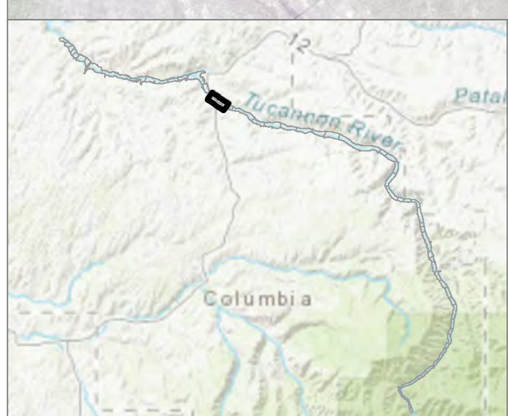


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 32.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.125	37	40%	Complexity	0.149	42	60% to 90%	4 of 5	1	40%	2.6	17	1	Untreated	9	1
Mean-Winter Flow Complexity	0.180	37	40%													
1-year Complexity	0.138	50	20%													
Channel Aggradation FP Potential	0.394	3	40%	Connectivity	0.276	6	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.084	30	40%													
Total FP Potential	0.422	25	20%													
Existing Connected FP	0.578	36	0%													
Excess Transport Capacity	0.03	27	100%	Excess Transport Capacity	1.000	27	30% to 52%	3 of 4	1	20%						
Pool Frequency	15.84	17	100%	Pool Frequency	0.407	17	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Riparian Enhancement
- Placemark

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 14.65
RIVER MILE END: 15.34
VALLEY MILE START: 12.84
VALLEY MILE END: 13.42

0 500
Feet

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ANCHOR QEA

Project Area 32.2
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 34.1 Description

Project Area 34.1 begins at VM 10.58 and extends upstream to a bridge crossing for the Territorial Road at VM 11.71. The 2017 RM length is 1.14 miles. The 2011 prioritization separated PA 34 into two geomorphically distinct sections (PA 34.1 and PA 34.2) for analysis. Due to lack of landowner access, no field observations were conducted in this reach in 2011 or 2018.

From the relative elevation map, the upstream end of PA 34.1 appears to be confined between a close right bank levee and the valley wall.

The confluence with Pataha Creek, which is a major tributary of the Tucannon River, is near the downstream end of this reach. From the relative elevation map, this area appears to be much more complex, with a relatively large amount of floodplain.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows three notable areas of geomorphic change in PA 34.1. Near the middle of the reach, there is significant aggradation of the right bank but none of it is in the actual channel; it is possible that these higher elevation locations are not a result of natural geomorphic processes and could be manmade (box 1).

Just upstream of the confluence of Pataha Creek, the channel is forming two alternating meander bends, with erosion occurring

Project Area 34.1
No site photograph available.

Project Area 34.1 Reach Characteristics

VM Start (mi)	10.55
VM Length (mi)	1.17
Valley Slope	0.62%
RM Start (mi)	12.28
RM Length (mi)	1.14
Average Channel Slope	0.63%
Sinuosity	0.98
Connected FP (ac/VM)	23.44
Encroachment Removal (ac/VM)	7.18
Channel Aggradation (ac/VM)	6.24
Total FP Potential (ac/VM)	19.09
Encroaching Feature Length (ft)	4,184.52
Connected FP Rank	11

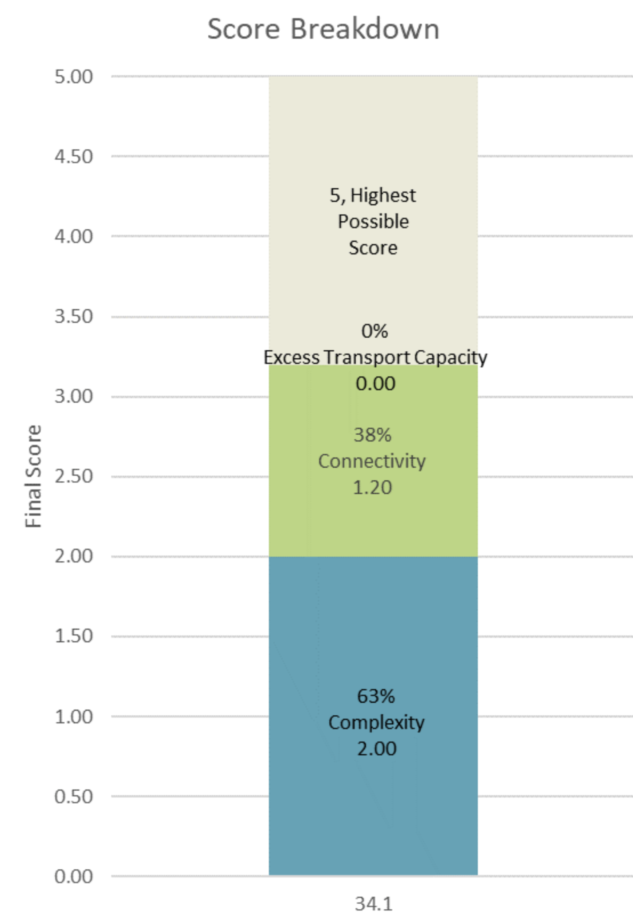
on the outside of the bends and bar building occurring on the inside. The second meander bend is working towards the Pataha Creek channel and has the potential to avulse and occupy that channel should the erosion on the outside right bank continue. There may already be some flow between the two channels at this point given that there are some signs of erosion between them (box 2).

Finally, at the very downstream end of the reach, between the bridge and the confluence of Pataha Creek, there is a large depositional area with aggradation both in the channel and in the floodplain. This is likely additional material that has been transported by Pataha Creek, and the bridge may be causing a backwater effect that is reducing sediment transport capacity in this area. This section of the reach appears to have been more complex at one time, based on evidence of several large meander scars with sediment aggradation, but the 2017 aerial imagery shows the channel as relatively straight (box 3).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 34.1 receives a high score in the Complexity prioritization metric, ranking in the 40th to 60th percentile, which is a range that has been identified for this assessment as having the most potential for restoration. This reach also has a high score for floodplain connectivity potential, ranking above average in the 50th to 75th percentile range and, although this is not the highest

PA 34.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

score, floodplain connectivity should still be targeted for restoration. Finally, the Excess Transport Capacity metric ranks around average for PA 34.1, and receives no prioritization score.

The low-winter flow complexity analysis result is well below average and is driven by the fact that the complex area near the confluence of Pataha Creek is not connected at this flow. At the mean-winter flow, multiple side channels in this area are activated including a side channel that connects to Pataha Creek before the confluence. Some additional complexity is achieved in this area and downstream at the 1-year flow but the complexity score does not increase significantly. At all flows, the upstream half of the reach is relatively uncomplex except for a few mid-channel bars at the 1-year flow. In the upstream half of the reach, restoration techniques should include developing instream wood and structure to promote in-channel bars, small side channels, and pools. For the downstream half of the reach, restoration techniques should focus on activating the high-flow channels to perennial flow through making strategic side channel cuts and adding instream wood to promote geomorphic change into the floodplain.

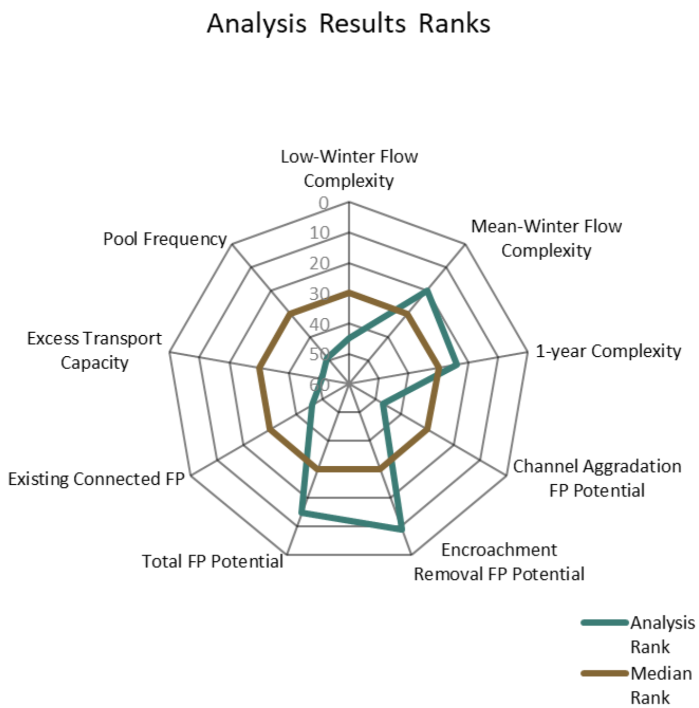
The floodplain connectivity potential score is driven almost entirely by a large amount of low-lying floodplain on the left bank floodplain, and appears to be in a field with no pivot irrigation infrastructure. Taking advantage of this area would require removing the levee that protects this field, and because this area is currently an agricultural field, heavy riparian zone enhancement should occur before attempting to connect this area. There are a few other pockets of floodplain potential that could be connected through floodplain encroachment removal on the right bank near the upstream end of the reach. While these areas are relatively small, the river through this reach currently has very little floodplain and connecting these areas through encroachment removal and adding instream wood could benefit both the complexity and connectivity in the upper part of the project area.

Finally, the Pool Frequency metric in this reach scores very low. The identified restoration strategies of adding instream structure and wood should help to promote geomorphic change towards more in-channel complexity and conditions where pools are more likely to form in the future.

Summary of Restoration Opportunities Identified

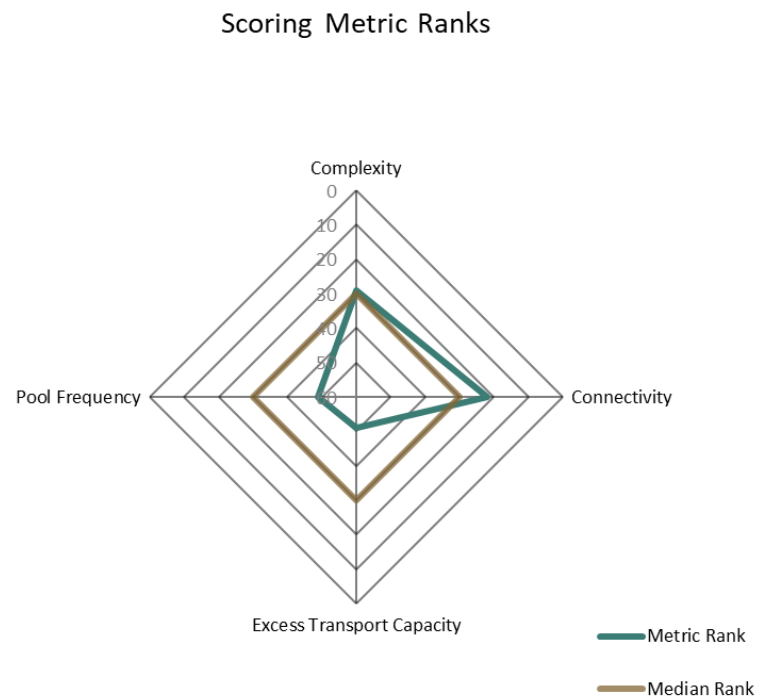
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 34.1 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

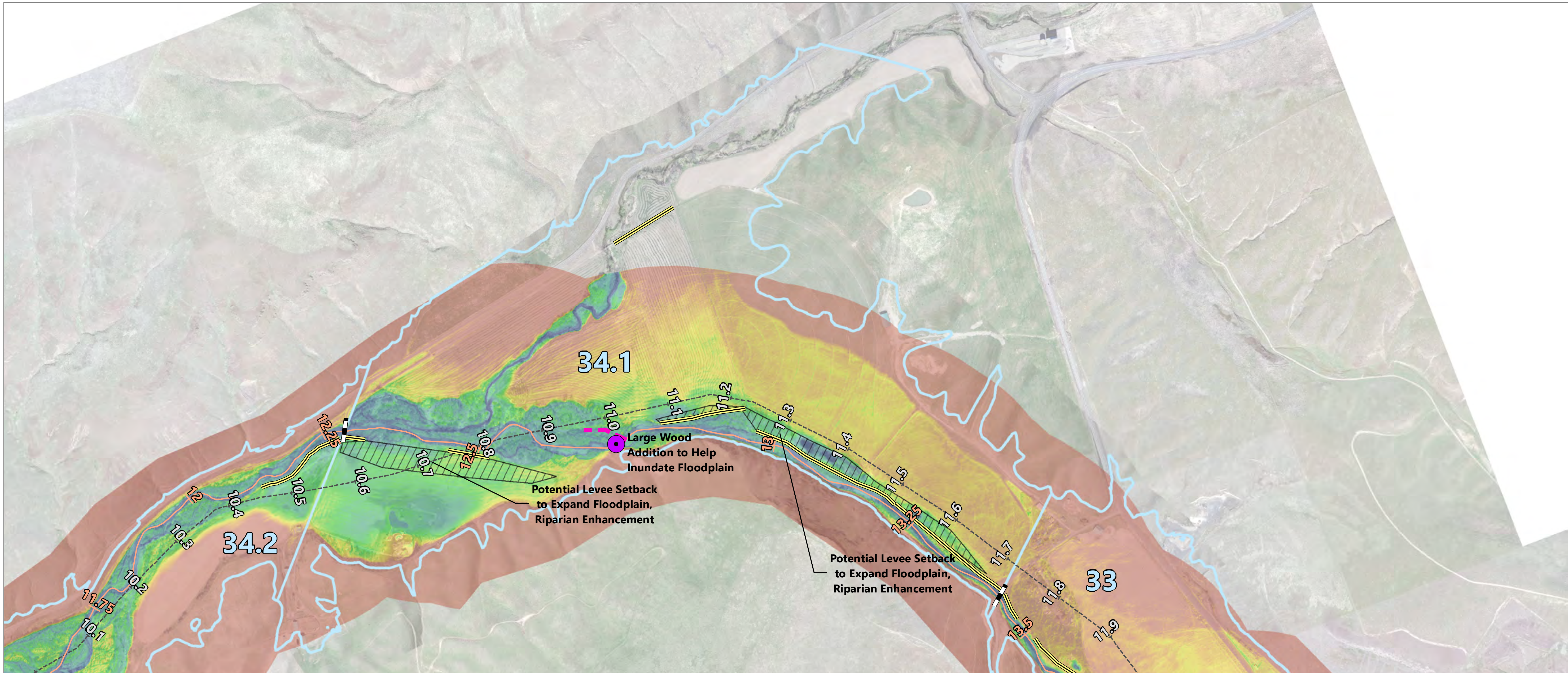
PA 34.1 Prioritization Scoring Summary



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 34.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.098	45	40%	Complexity	0.235	29	40% to 60%	3 of 5	5	40%	3.2	11	1	Untreated	8	1
Mean-Winter Flow Complexity	0.310	20	40%													
1-year Complexity	0.360	24	20%													
Channel Aggradation FP Potential	0.147	47	40%	Connectivity	0.216	22	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.169	9	40%													
Total FP Potential	0.449	15	20%													
Existing Connected FP	0.551	46	0%													
Excess Transport Capacity	-0.14	51	100%	Excess Transport Capacity	0.000	51	52% to 100%	4 of 4	0	20%						
Pool Frequency	5.25	49	100%	Pool Frequency	0.135	49	60% to 90%	4 of 5	1	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 12.28
RIVER MILE END: 13.43
VALLEY MILE START: 10.55
VALLEY MILE END: 11.71

0 500
Feet

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ANCHOR QEA

Project Area 34.1
Conceptual Restoration Opportunities

Project Area 41 Description

Project Area 41 begins at VM 2.85 and extends upstream to VM 3.16. The 2017 RM length is 0.35 mile. Field observations for PA 41 were conducted on October 10, 2018, when flow at the Starbuck gage was approximately 115 cfs.

PA 41 is relatively short compared to the other project areas but has complex flow for the majority of the reach. At the upstream end of PA 41, a large log jam has created complex flow with multiple side channels through the forested riparian area. Large trees have fallen into the flow paths in multiple locations, causing deep scour pools. However, it is unclear if this wood will remain in the reach after higher flows, and this reach may require additional hard points or stabilization.

At VM 3, a large gravel bar appears to have been recently manipulated in the floodplain for access and this has pushed the channel into the trees on the left bank.

Downstream of this complex area, the channel goes through a short section of single-thread flow, with a forested riparian area on the left bank but an exposed area on the right bank. This section of the reach still has a large amount of gravel and fine material, and any addition of large woody material would likely result in geomorphic change. At the time of the site visit, this section of the reach did not have much large woody material. This section ends with a steep eroding left bank bordering an irrigated field.

Project Area 41
Looking downstream from PA 40 to the log jam and avulsion at the beginning of PA 41.

Project Area 41 Reach Characteristics

VM Start (mi)	2.85
VM Length (mi)	0.31
Valley Slope	0.73%
RM Start (mi)	3.68
RM Length (mi)	0.35
Average Channel Slope	0.64%
Sinuosity	1.14
Connected FP (ac/VM)	37.40
Encroachment Removal (ac/VM)	7.08
Channel Aggradation (ac/VM)	20.44
Total FP Potential (ac/VM)	37.01
Encroaching Feature Length (ft)	759.10
Connected FP Rank	1

Immediately downstream of this eroding left bank, the channel flows through the riparian forested floodplain, and the reach becomes very complex again, with multiple flow paths, instream wood, and evident scour pools in gravel material. At the downstream end of the project area, the channel enters an exposed area of the floodplain with little riparian cover.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows that PA 41 has had significant deposition across almost the entire reach. At the upstream end, a series of natural log and debris jams have triggered a channel avulsion through the forested right bank floodplain where complex multi-channel flow has formed. This area is associated with a large amount of deposition in the former main channel as well as the left bank floodplain (box 1).

This deposition in the main channel continues to the next highlighted area of change, where several log jams have caused erosion towards the left bank that appears to be threatening some pivot infrastructure (box 2). The pattern of deposition in the main channel and floodplain continue for the remainder of the reach.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 41 receives equal scores in the Connectivity and Complexity metrics, which make up the entire prioritization score. Both prioritization metrics received moderate scores. For Connectivity, this indicates that PA 41 ranks near the top in the 60th to 90th percentile of all project areas, which is a range that has been identified as only needing a slight boost to reach a high level of complexity. For Connectivity, this indicates that PA 41 ranks above average in the 50th to 75th percentile of all project areas.

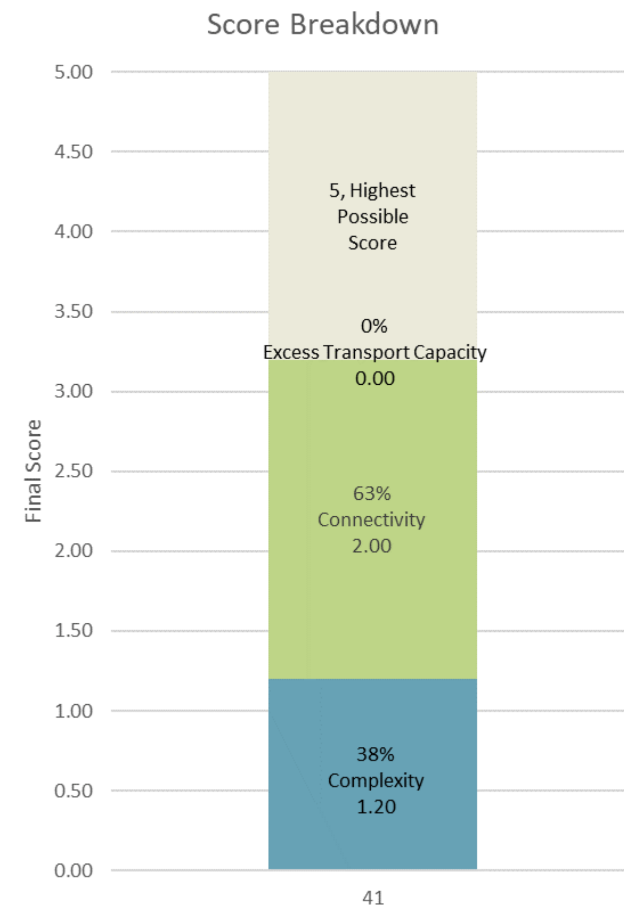
PA 41 ranks highly in all three flows for the Complexity analysis results. However, while the project area ranks near the top in low-winter flow complexity, the mean-winter flow complexity is slightly lower, and the 1-year flow complexity is only slightly above average. This indicates that many of the islands and side channels are being washed out during the higher flow events. A primary restoration strategy should be to add instream wood to ensure that complex flow channels are maintained during higher flow events. Because PA 41 currently has a large amount of natural log jams, it may be possible to stabilize these log jams via large rock or piles.

The connectivity potential in this reach is driven by both the Channel Aggradation analysis result and the Encroachment Removal analysis result, both of which rank PA 41 slightly above average. Total Floodplain Potential is greater than the sum of the two alone, indicating more floodplain can be gain when both potential reconnection methods are targeted. However, the majority of the potential floodplain is outside of the levee and in the bordering fields. Reconnection to the floodplain may be difficult and would require extensive revegetation efforts with riparian species. The remainder of the potential area exists in small patches in the forested floodplain and can be reconnected with channel bed aggradation. Because this reach was noted to be extremely depositional in nature in the geomorphic change analysis, gravel augmentation is probably not necessary, and restoration strategies should focus on adding instream wood and structure to store and maintain the sediment already available. PA 41 receives no score in the Excess Transport Capacity metric, indicating that any added gravel material will be easily stored and maintained with the addition of instream wood.

While gravel augmentation is not currently necessary, it may be possible that this reach is part of a larger gravel augmentation plan for several reaches in the area, in which case the extra material will likely only serve to add some slight complexity and connectivity. Should this reach ever reverse its trend of being a depositional reach, gravel augmentation would likely be necessary along with the addition of instream wood to achieve the desired results.

Finally, PA 41 ranks very highly in the Pool Frequency metric, indicating a high amount of pools per valley mile. The restoration strategy of adding instream structure and wood should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

PA 41 Score Breakdown

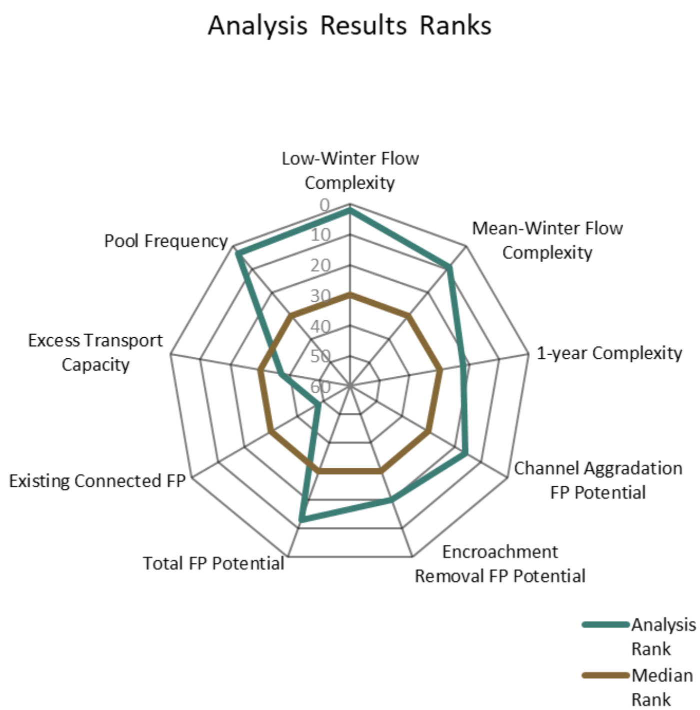


This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

Summary of Restoration Opportunities Identified

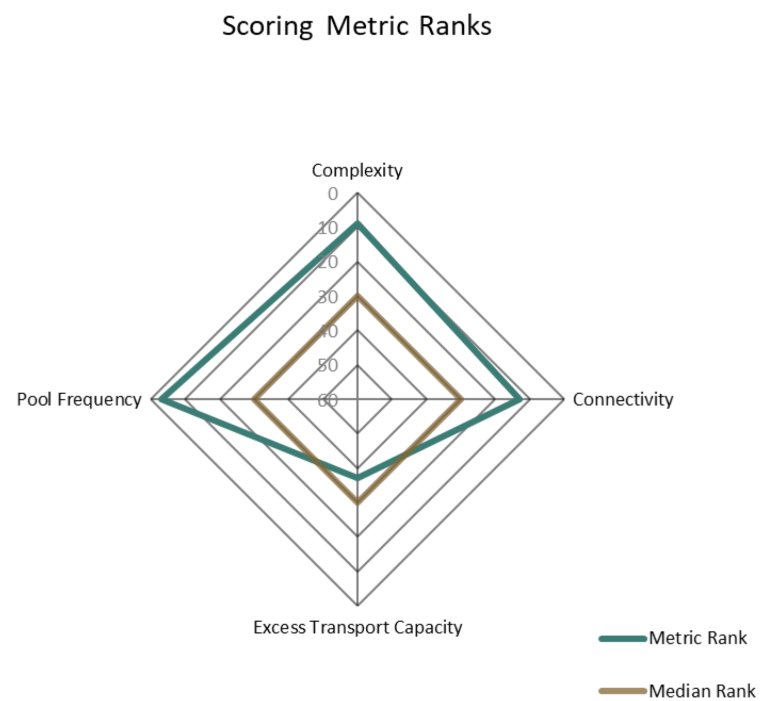
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 41 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

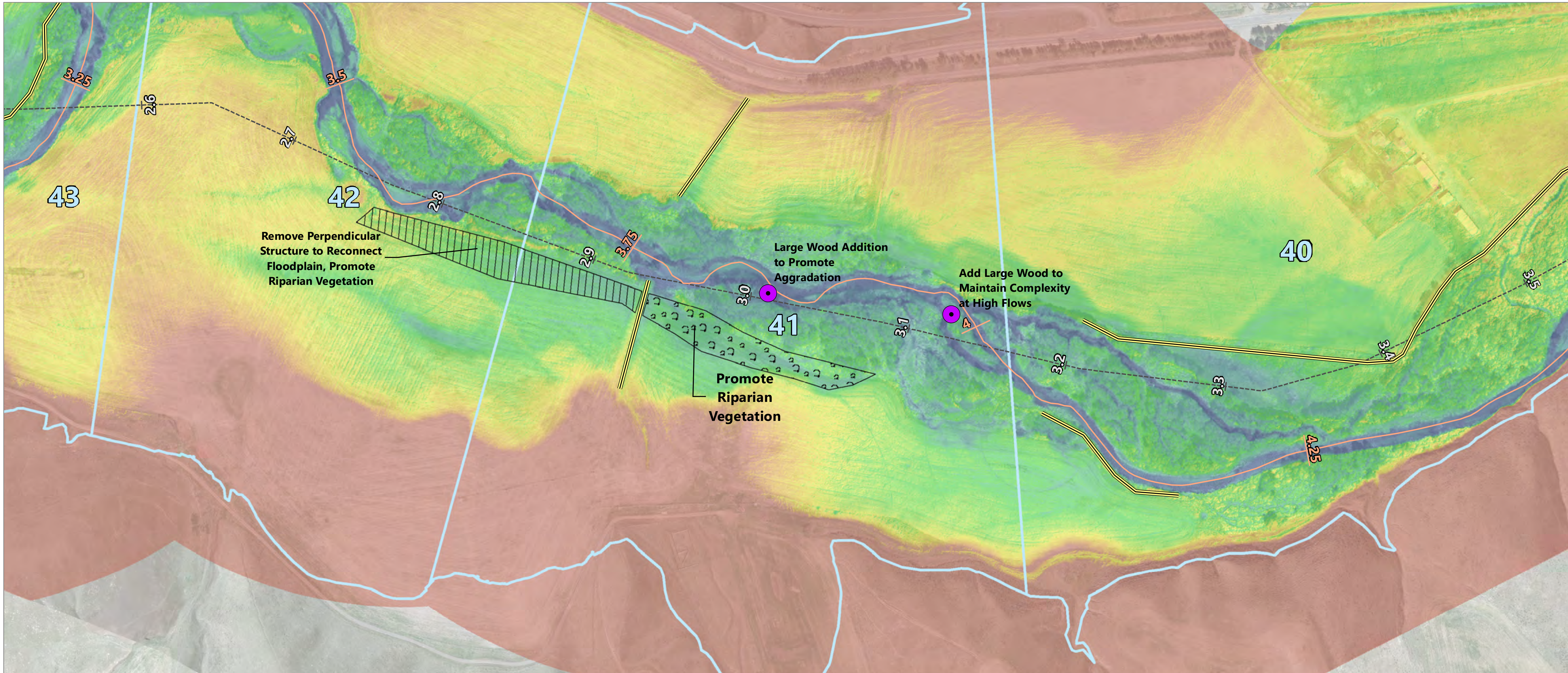
PA 41 Scoring Metric Ranks

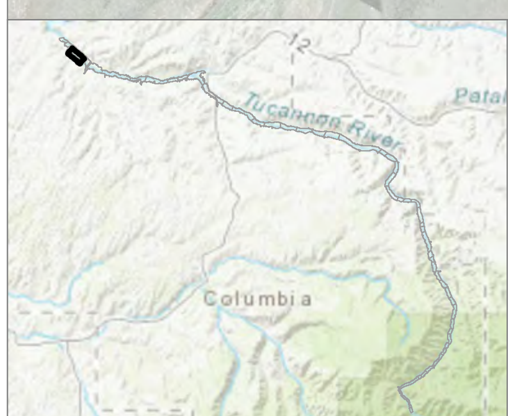


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 41 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.415	2	40%	**Complexity**	0.423	9	10% to 40%	2 of 5	3	40%	3.2	12	1	Untreated	9	1
Mean-Winter Flow Complexity	0.454	9	40%													
1-year Complexity	0.377	22	20%													
Channel Aggradation FP Potential	0.275	16	40%	**Connectivity**	0.247	13	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.095	20	40%													
Total FP Potential	0.497	13	20%													
Existing Connected FP	0.503	48	0%													
Excess Transport Capacity	-0.05	37	100%	**Excess Transport Capacity**	0.000	37	52% to 100%	4 of 4	0	20%						
Pool Frequency	31.21	3	100%	**Pool Frequency**	0.801	3	1% to 10%	1 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 3.68
RIVER MILE END: 4.03
VALLEY MILE START: 2.85
VALLEY MILE END: 3.16

0 500
Feet

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ANCHOR QEA

Project Area 41
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 44 Description

Project Area 44 begins at VM 2.01 at the Powers Road bridge and extends upstream to VM 2.32. The 2017 RM length is 0.43 mile. Field observations for this reach were conducted on October 10, 2018, when flow at the Starbuck gage was approximately 115 cfs.

PA 44 is mostly a single-thread uniform channel, which meanders across the accessible floodplain. At the upstream end of the reach, the left bank is heavily forested while the right bank runs along a cultivated field. From the mid-reach to the downstream end, the channel bends through the forested area so that the left bank runs along an exposed field and the right bank is heavily forested. In the downstream section, irrigation infrastructure is very close to the eroding left bank; this should be addressed before the problem requires emergency actions.

The area in both forested sections of the floodplain is relatively low, with multiple flow path options that could be candidates for split flows or side channels to direct flow away from eroding outside banks. One large log jam on the right bank, near where the channel switches to the other side of the floodplain, is causing some bank erosion. Otherwise, instream wood and channel complexity in this reach are very low but the reach has the potential to achieve both of these with more connection and interaction with the already forested portions of the floodplain.

Project Area 44
PA 44 mid-reach, looking downstream at erosion into a field on the left bank on the outside of a meander bend.

Project Area 44 Reach Characteristics

VM Start (mi)	2.01
VM Length (mi)	0.31
Valley Slope	0.75%
RM Start (mi)	2.49
RM Length (mi)	0.43
Average Channel Slope	0.55%
Sinuosity	1.39
Connected FP (ac/VM)	21.15
Encroachment Removal (ac/VM)	1.08
Channel Aggradation (ac/VM)	28.50
Total FP Potential (ac/VM)	44.65
Encroaching Feature Length (ft)	178.24
Connected FP Rank	13

Geomorphic Changes

Analysis of the change between the 2010 and 2017 LiDAR for PA 44 shows that the reach is geomorphically active but, because it is also a relatively short reach, only three significant locations are highlighted here. The first area of significant geomorphic change begins at the upstream boundary of the project area, where a large meander bend protrudes into the right bank field. This meander bend is migrating outward as the inside bar is building and erosion can be seen on the outside of the bend. Just downstream, a second meander is forming with bar building and erosion seen on the opposite banks (box 1).

The second area of significant geomorphic change is further downstream at another bend in the river bordered by a steep bank to the agricultural field. Significant erosion appears to be working through the steep bank to the field (box 2).

At the downstream end of this project area, just upstream of the Powers Road bridge, a large log jam appears to be contributing to significant erosion on both sides of the channel. Deposition has occurred immediately downstream of this log jam, possibly as a direct result of this erosion and also considering that the bridge likely creates a low-energy backwater effect at higher flows (box 3).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 44 receives most of its prioritization score from the Connectivity metric and is ranked in the top 25% of all project areas for this metric. This high rank is driven mostly by the Channel Aggradation analysis result. This potential is located almost entirely on the right bank in a large, low-lying area inside of the river bend. Raising the bed elevation through the reach would help to access this area more frequently and should be the target of restoration in this reach. This project area is near the downstream end of the basin and should be able to receive easily transportable material from upstream reaches. Additionally, this project area receives a low score in the Excess Transport Capacity metric, indicating that the shear stress for this reach is near normal levels for the slope of the reach and will store sediment given instream wood and structure. The primary restoration strategy in this reach should be to add wood structures to the main channel and floodplain to trap and store sediment with the objective of raising the channel bed elevation.

Additionally, several high-flow channels are located in this floodplain and accessing them could provide an opportunity to inundate a portion of this floodplain. Cutting pilot channels into the floodplain, along with the placement of wood structure in channel, will help to inundate this area and should be included as part of the restoration strategy for this reach.

This project also directly borders an agricultural field on the left bank with little to no riparian area. Pushing flow into the right bank floodplain will take some of the flow out of this exposed area, but enhancing the riparian area should also be considered as a restoration strategy for this reach.

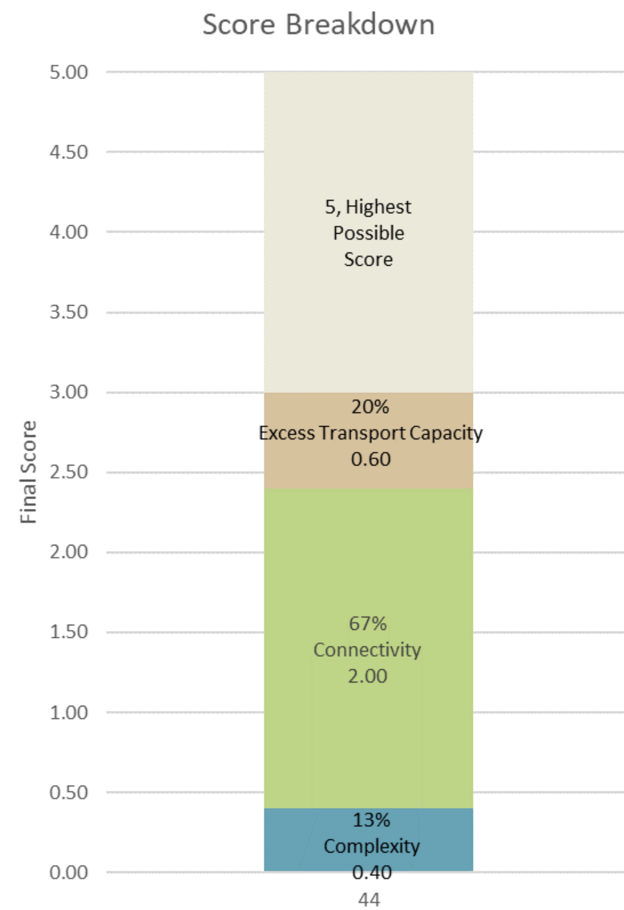
This project area ranks below average in the Complexity metric for all three flows, indicating that a high level of complexity would be difficult to achieve through restoration. However, the identified restoration strategies will also add to complexity if pilot channels are cut to an elevation so that they receive flow on a regular basis. Cutting perennial pilot channels, along with the addition of instream wood and structure, should be a secondary restoration strategy for this reach.

Finally, the Pool Frequency metric in this reach ranks very highly, indicating a large amount of pools per river mile. The restoration strategies of adding instream wood and cutting pilot channels should promote more geomorphic change and complexity that will maintain existing pools and form new ones so that the pool frequency in this reach remains high.

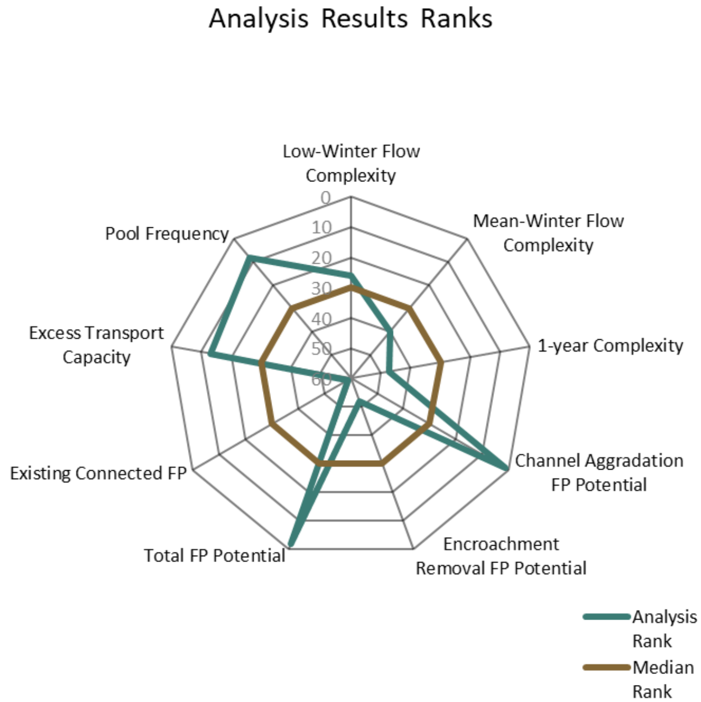
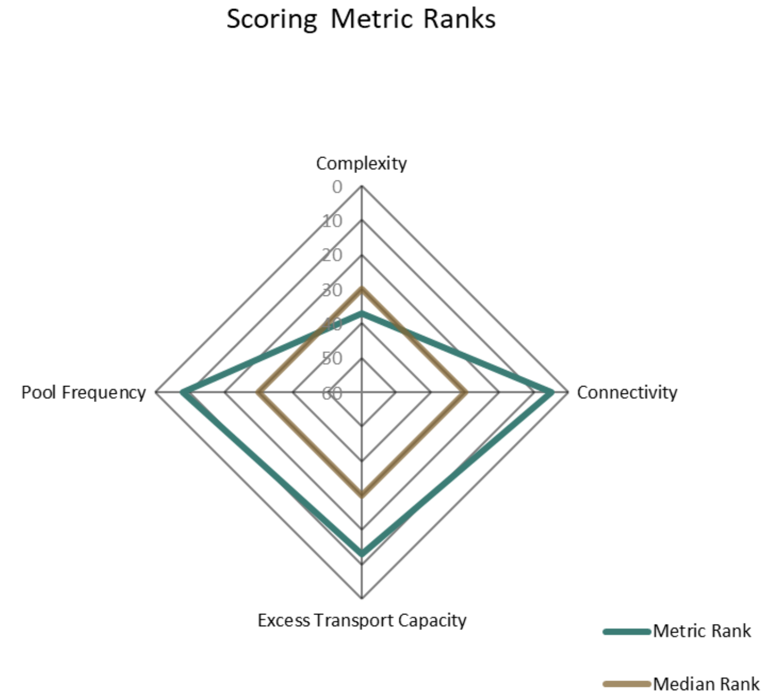
Summary of Restoration Opportunities Identified

- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement
- Modify or remove obstructions

PA 44 Score Breakdown

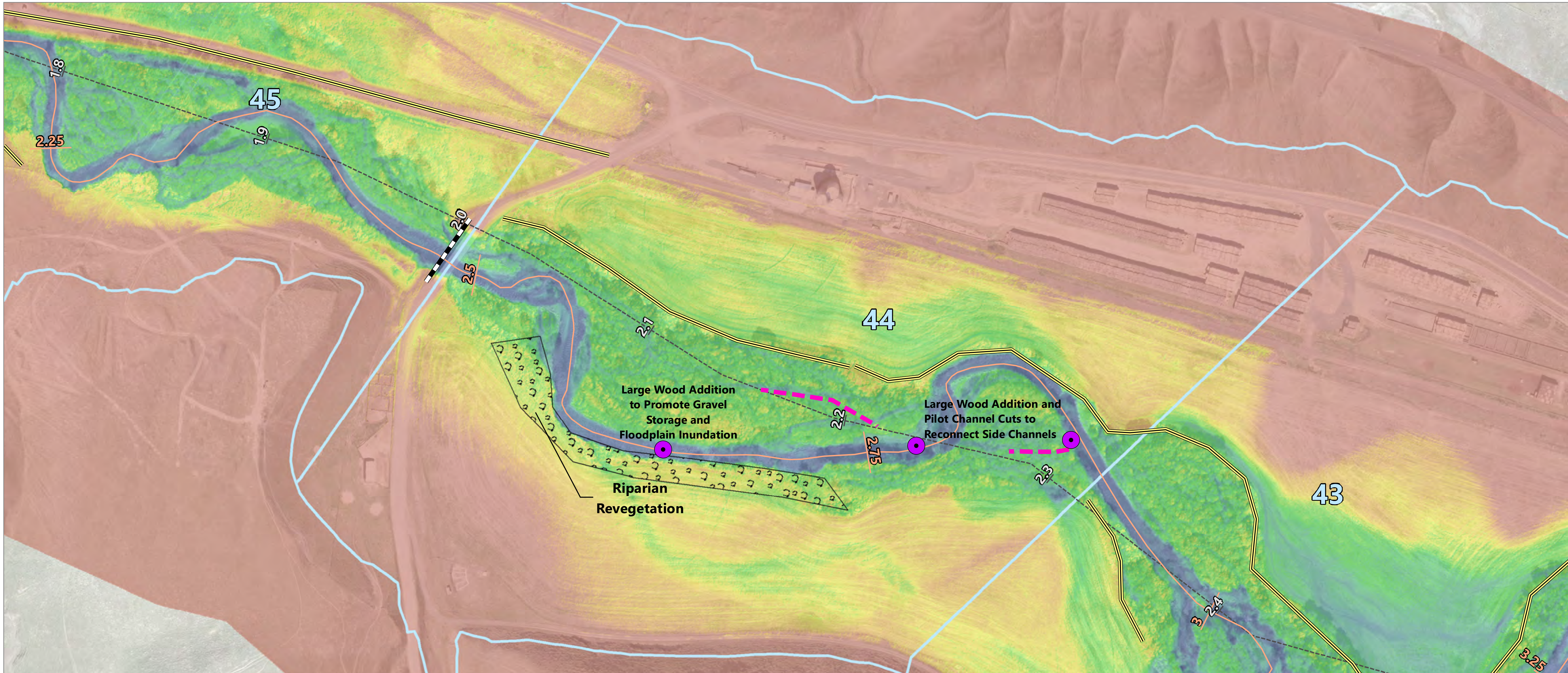


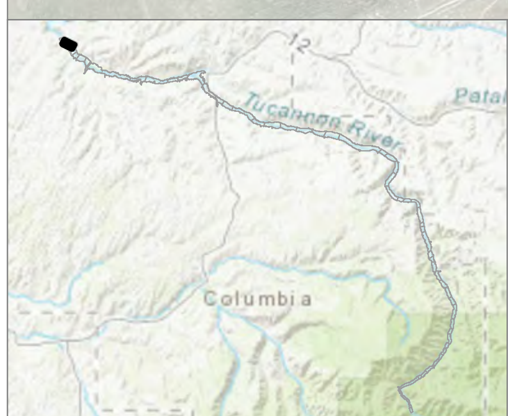
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 44 Analysis Results Summary	PA 44 Prioritization Scoring Summary
	
This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.	This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 44 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.182	26	40%	Complexity	0.169	37	60% to 90%	4 of 5	1	40%	3.0	17	1	Untreated	12	1
Mean-Winter Flow Complexity	0.159	40	40%													
1-year Complexity	0.161	47	20%													
Channel Aggradation FP Potential	0.433	1	40%	Connectivity	0.316	5	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.016	52	40%													
Total FP Potential	0.679	2	20%													
Existing Connected FP	0.321	59	0%													
Excess Transport Capacity	0.16	13	100%	Excess Transport Capacity	3.000	13	10% to 30%	2 of 4	3	20%						
Pool Frequency	23.17	8	100%	Pool Frequency	0.595	8	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 2.49
RIVER MILE END: 2.92
VALLEY MILE START: 2.01
VALLEY MILE END: 2.32

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Feet

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ANCHOR QEA

Project Area 44
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

APPENDIX J.2
TIER 2: UNTREATED PROJECT AREAS

Project Area 3.1 Description

Project Area 3.1 begins at VM 42.73 and extends upstream to the bridge crossing at Tucannon Road at VM 43.10. The 2017 RM length is 0.37 mile. Field observations for PA 3.1 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

For this assessment update, PA 3 as defined in the 2011 prioritization was separated into two project areas (PA 3.1 and PA 3.2) for distinct analysis because only PA 3.2 was treated. The downstream boundary of PA 3.1 marks the beginning of the restoration work that took place in PA 3.2.

Based on the relative elevation map and aerial imagery, this reach appears to be mostly straight with several significant side channel opportunities. The channel through PA 3 is characterized as a single-thread channel containing both plane-bed and forced pool-riffle sections. Local steep rapids are present; in these sections, the thalweg is typically deep with high velocities. In the 2011 assessment, one rock weir and multiple rock and rootwad restoration features were identified in the project area. Other than rock armor along the Cow Camp bridge abutments and an approximately 350-foot riprap bank downstream of the bridge, no other significant infrastructure was identified in the channel. Only a few side channels were observed that appeared to provide minimal habitat benefit.

Project Area 3.1
Plane-bed, straight, and uniform section of river with little instream complexity. View is from the bridge upstream of PA 3.1 and looking downstream.

Project Area 3.1 Reach Characteristics

VM Start (mi)	42.73
VM Length (mi)	0.37
Valley Slope	1.59%
RM Start (mi)	48.23
RM Length (mi)	0.37
Average Channel Slope	1.55%
Sinuosity	1.01
Connected FP (ac/VM)	6.54
Encroachment Removal (ac/VM)	1.73
Channel Aggradation (ac/VM)	2.24
Total FP Potential (ac/VM)	5.02
Encroaching Feature Length (ft)	356.27
Connected FP Rank	59

The availability and quality of instream habitat was limited by lack of complexity and hydraulic conditions that prevented the retention of sufficient volumes of LWD and sediment. The spatial distribution of existing LWD was limited. Large log jams and sediment deposits were present but sporadic; the log jams that were observed were typically associated with local areas of high temporary sediment storage, split flow, and side channels. However, the majority of the project area is made up of long, straight, plane-bed stretches that lack any adequate cover or hydraulic complexity.

Throughout a majority of the project area, the channel is moderately entrenched between the bedrock valley wall and remnant alluvial fan and hillslope deposits, resulting in a relatively high floodplain surface. Thus, much of the valley floor is not within the low floodplain.

The influence of the riprap to floodplain connectivity does not appear to be significant, although the armoring likely prevents channel migration and transfers energy downstream along the left bank. A relatively low former channel position was located in the western portion of the floodplain. Flowing water was observed through the channel, although it was unclear if it was supplied by hyporheic exchange or a groundwater spring. No fish use was observed within this feature.

The 2011 assessment noted that the riparian zone was in a moderately healthy condition, with local areas that had been degraded by infrastructure, fire, and development. Riparian trees were mixed deciduous and conifer, dominated by ponderosa pine, alder, and dogwood. The banks upstream of the Little Tucannon River were dominated by alder saplings, grasses and other emergent vegetation, buttercup, and other invasive species.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows very little significant geomorphic change has occurred over the past 7 years. Near the upstream end of the reach, some deposition has occurred in the channel forming a mid-channel bar. There is some minor erosion on the opposite bank associated with this bar (box 1).

The only other significant change in this reach is a meander bar forming on the right bank near the downstream end of the channel. No erosion is evident on the opposite bank, and this is likely just a depositional area (box 2).

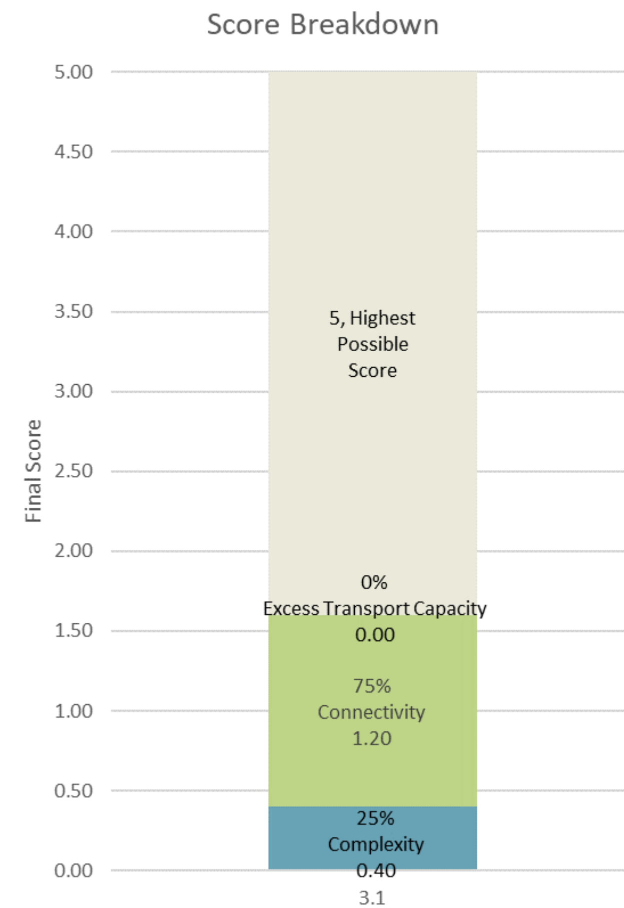
The few geomorphic changes in this reach could indicate that there is not enough instream wood and gravel material, or the reach is highly incised and resistant to change.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 3.1 receives the majority of its prioritization score from the Connectivity metric. PA 3.1 ranks within the 50th to 75th percentile of all project areas for Complexity and ranks near average in the Channel Aggradation analysis result and well above average in the Encroachment Removal analysis result. This high rank in the Encroachment Removal analysis result is driven almost entirely by a large, low-lying area on the left bank floodplain that appears to be an old channel location or side channel location. This area is disconnected at the upstream end either by a high bank or channel incision. A primary restoration strategy for this reach should be to connect this area through pilot channel cuts and the addition of instream wood. The channel aggradation potential is mostly driven by areas directly surrounding the active 2-year floodplain. Channel aggradation should be targeted through a restoration strategy of gravel augmentation along with the addition of instream wood to store sediment. Raising the channel bed will also likely help reconnect the low-lying area by increasing flows through pilot channel cuts. PA 3.1 receives no score for Excess Transport Capacity and any instream wood or structure added should be able to store and maintain sediment material from gravel augmentation.

PA 3.1 receives a low score in Complexity, indicating that it falls within the 10th to 40th percentile of all project areas for this

PA 3.1 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

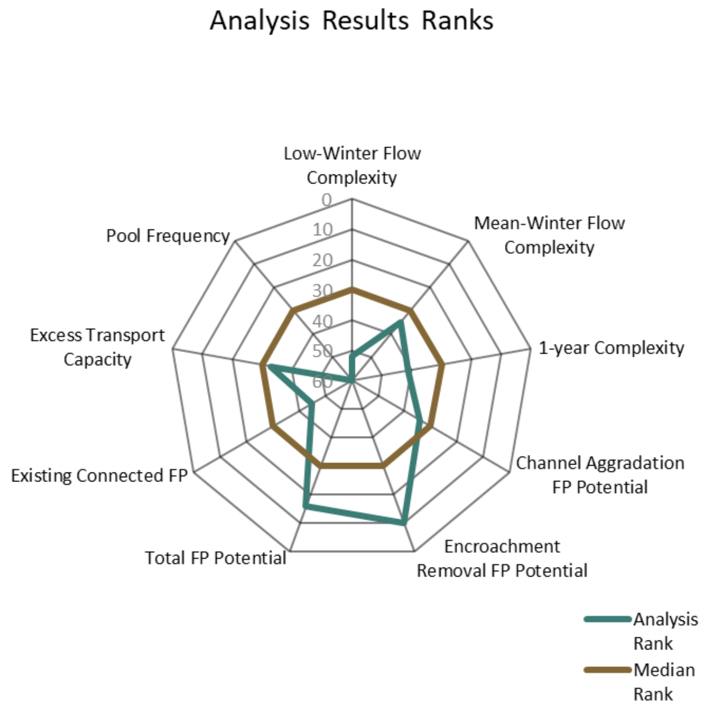
metric, and all three Complexity analysis results rank below average; the low-winter flow complexity result is particularly low as several side channels are connected at the mean-winter and 1-year flow events but not at the low-winter flow event. Restoration strategies for complexity should focus initially on reconnecting these side channels. This can be accomplished through the addition of instream wood and pilot channel cuts in the areas of the side channels. A gravel augmentation strategy may also help to raise the water surface elevation and reconnect some of these channels. Reconnecting the former channel should provide opportunities to increase complexity as well.

Finally, PA 3.1 ranks very low among project areas in the Pool Frequency metric. Adding instream wood and gravel augmentation will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target increasing pool frequency in the reach.

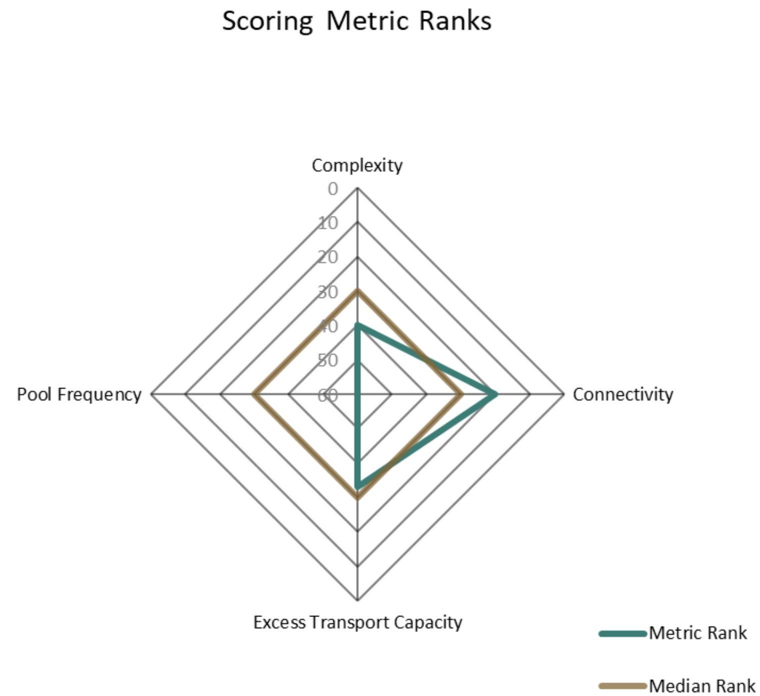
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 3.1 Analysis Results Ranks



PA 3.1 Scoring Metric Ranks

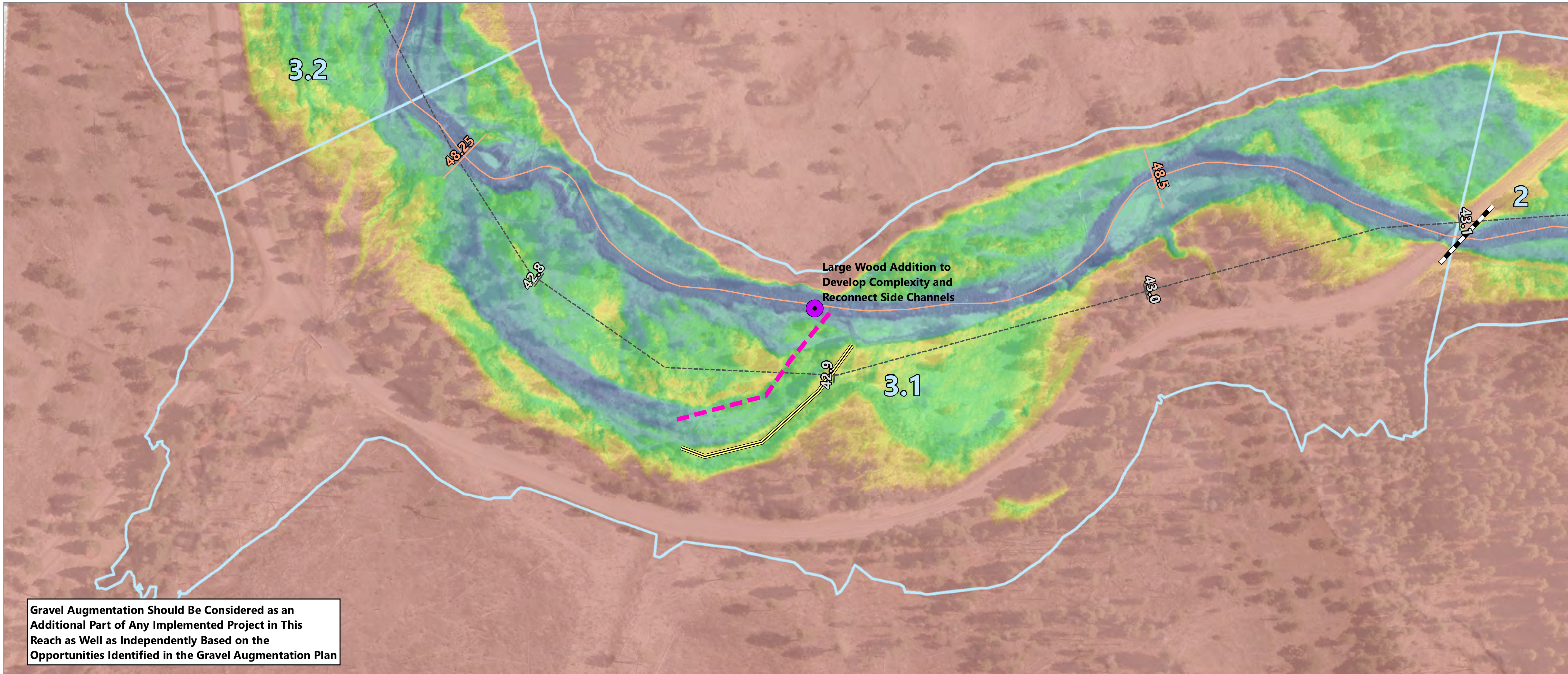


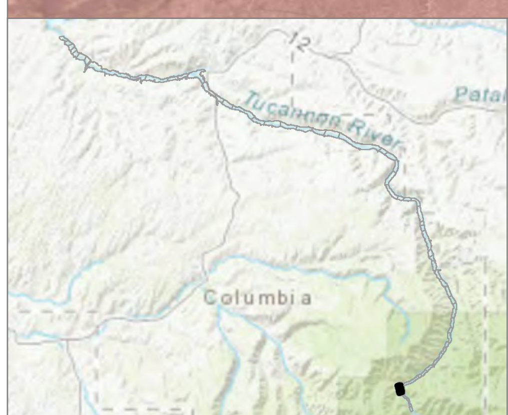
This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 3.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.093	52	40%	Complexity	0.152	40	60% to 90%	4 of 5	1	40%	1.6	36	2	Untreated	23	2
Mean-Winter Flow Complexity	0.182	35	40%													
1-year Complexity	0.211	41	20%													
Channel Aggradation FP Potential	0.194	34	40%	Connectivity	0.224	20	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.149	10	40%													
Total FP Potential	0.435	16	20%													
Existing Connected FP	0.565	45	0%													
Excess Transport Capacity	-0.01	33	100%	Excess Transport Capacity	0.000	33	52% to 100%	4 of 4	0	20%						
Pool Frequency	0.00	60	100%	Pool Frequency	0.000	60	90% to 100%	5 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 48.23
RIVER MILE END: 48.6
VALLEY MILE START: 42.73
VALLEY MILE END: 43.1

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Feet

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Project Area 3.1
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 16 Description

Project Area 16 begins at VM 31.05 at a bridge crossing for the Tucannon Road near McGovern Lane and extends upstream to VM 32.29. The 2017 RM length is 1.39 miles. Field observations for PA 16 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

In 2011, the channel through PA 16 was characterized as a single-thread, plane-bed channel with occasional pools forced by engineered structures and resistant banks. The channel was located through a highly developed residential area and was significantly affected by several levees, armored banks, and rock and LWD structures. These structures were providing limited habitat benefits and preventing channel migration and floodplain connectivity. In addition, portions of the left bank were confined against resistant alluvial fan deposits. Some banks within the project area were actively eroding and migrating. Remnant levee or spoil piles were observed on the right bank at approximately RM 35.9 and from about RM 35.7 to the mouth of Tumalum Creek. Large right bank levees with LWD and rock structures at the toe were observed from RM 35.45 to just downstream of RM 35.2. Large left bank levees were observed from approximately RM 35.2 to 35.1. Both banks from RM 35.1 to 34.9 were sporadically armored with large angular rock and riprap. Larger J-hook structures at the upstream end of the project area to approximately RM 36.2

Project Area 16
Photograph taken from the 2011 prioritization showing bank erosion adjacent to a private infrastructure, looking across at the right bank.

Project Area 16 Reach Characteristics

VM Start (mi)	31.05
VM Length (mi)	1.24
Valley Slope	1.24%
RM Start (mi)	34.97
RM Length (mi)	1.39
Average Channel Slope	1.09%
Sinuosity	1.12
Connected FP (ac/VM)	9.30
Encroachment Removal (ac/VM)	4.36
Channel Aggradation (ac/VM)	5.16
Total FP Potential (ac/VM)	10.43
Encroaching Feature Length (ft)	5,172.54
Connected FP Rank	52

likely have had an influence on the channel grade. Very few off-channel areas were observed except the mouth of Tumalum Creek and a short side channel at approximately RM 35.25 that appeared to be maintained for water diversion. Instream habitat was limited by a lack of complexity and hydraulic conditions due to confinement. The confined condition of the channel likely has resulted in high velocities during seasonal high flows and flooding that prevents the retention of sufficient volumes of LWD for cover and refuge, or sediment for spawning areas. Few pools were observed except at man-made structures, many of which were fast-moving along outer banks. Preferred juvenile rearing areas were very limited due to the absence of side channels. Much of the channel had little overhanging vegetation.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several notable locations of geomorphic change in PA 16, although they are relatively minor and isolated. The first location of geomorphic change in this reach is at the outlet of Tumalum Creek where there is a depositional area typical of the alluvial fan of a tributary. While this area does not directly influence the Tucannon River mainstem channel, it appears to have raised the right bank floodplain and may be more influential in the future (box 1). Downstream of Tumalum Creek, the next notable change is not a natural geomorphic change but a location where the road bordering the river has been raised significantly (box 2).

Near the downstream end of the reach are the two most notable geomorphic changes for this reach. Both areas are located were there has been significant bank erosion, first on the right bank and then on the left bank. The upstream area is also associated with bar building on the left bank and may have been caused by a log jam on an island near the left bank (boxes 3 and 4).

Geomorphic Characteristics and Restoration Strategies

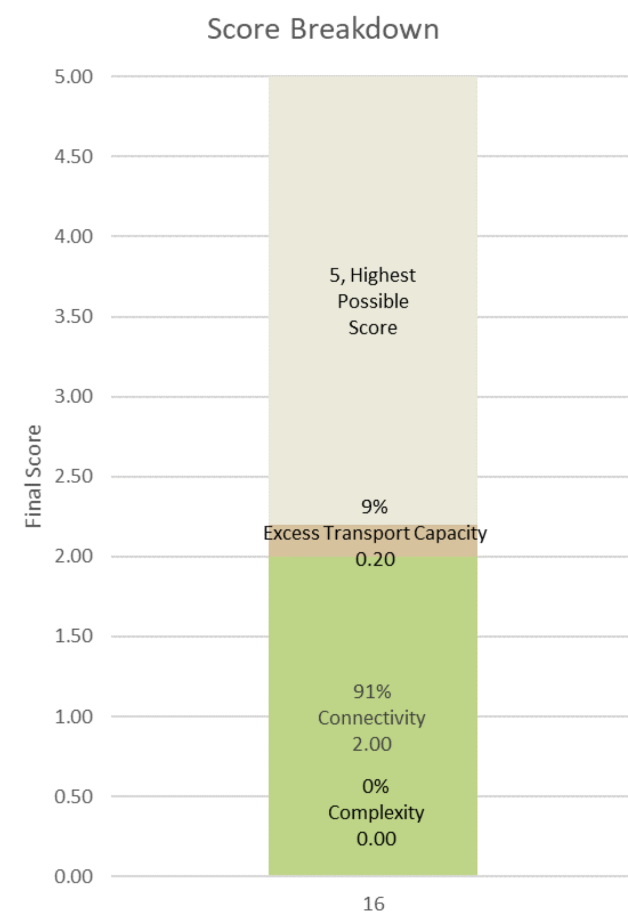
As shown in the following graphs and table, PA 16 received the highest possible score in the Connectivity metric, ranking in the top 25% of all project areas. There appears to be significant opportunity for both channel aggradation and encroachment removal techniques in several locations throughout the reach based on the rankings in the analysis results. In most places, some sort of levee or encroachment removal will be necessary to reconnect the floodplain, but there are also several locations where raising the water surface elevation through gravel augmentation could reconnect isolated floodplain. Gravel augmentation and levee and encroachment removal should be considered primary restoration strategies for this reach, along with the addition of instream wood to promote geomorphic changes and channel dynamics.

PA 16 also received a moderate score for excess transport capacity, ranking in the 70th to 90th percentile of all project areas for that metric, indicating there is excess transport capacity in this reach. The moderate score indicates that this reach probably transports gravel sediment easily as would be expected of a mostly confined and straight reach. In order for gravel augmentation to be successful in activating abandoned floodplain, in-channel and floodplain structure should be added to promote sediment storage near the middle part of the reach. A large amount of wood and structure should also be added to the upstream portion of the reach to promote channel dynamics and geomorphic change, which could release sediment stored in the floodplain and restart the natural sediment transport processes in the reach.

The valley through this reach is occupied by mostly residential land use, and the riparian vegetation is very poor based on the aerial imagery and notes from the 2011 assessment. Any restoration activity in this reach should be accompanied by heavy riparian zone enhancement in any areas where other planned restoration strategies are going to be implemented.

Finally, pool frequency in the project area scores well below average, indicating a low amount of pools per river mile. The identified restoration strategies of gravel augmentation and adding instream wood should promote the natural processes that will encourage pools to form more frequently and be sustained with changing geomorphic conditions.

PA 16 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

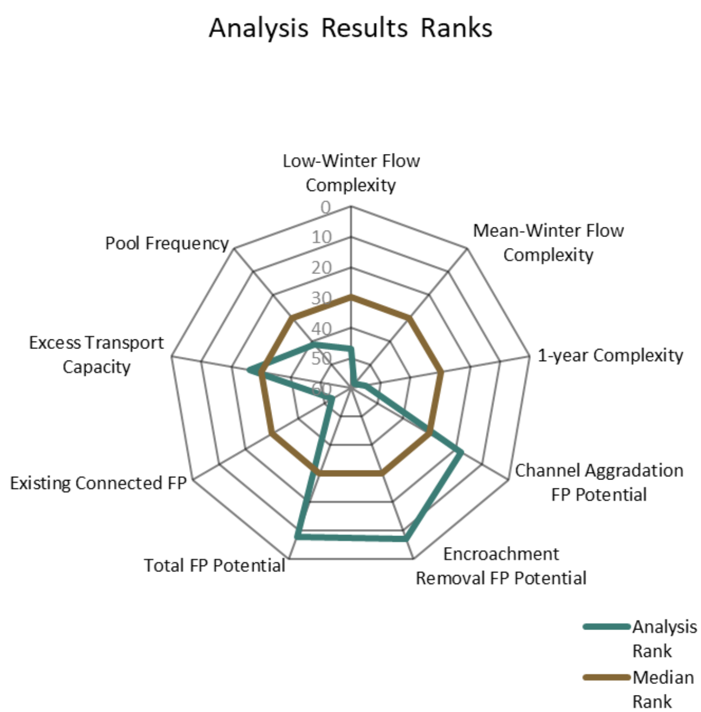
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian Zone Enhancement

Long-Term Opportunities in this Project Area

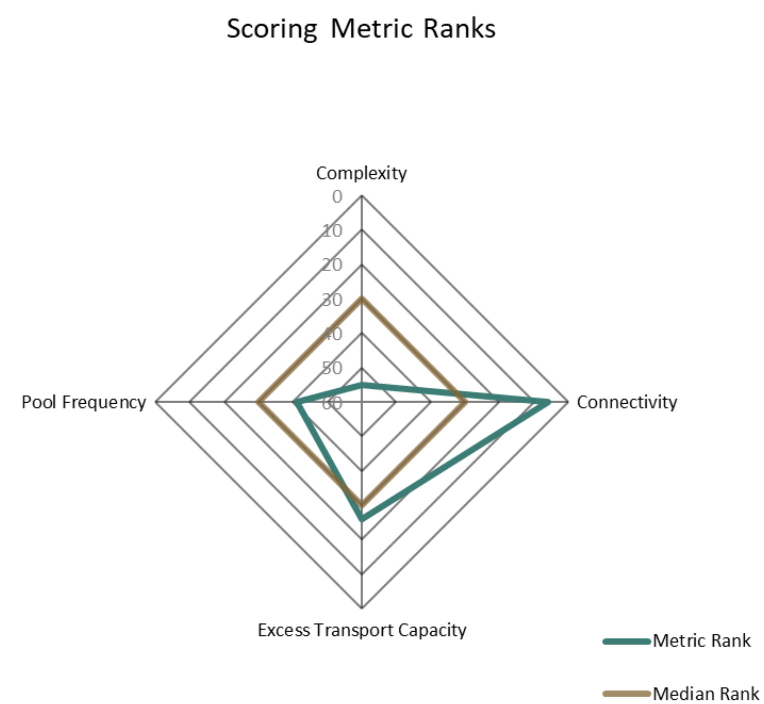
- Set back road against left valley wall for more floodplain connection and channel migration area.

PA 16 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

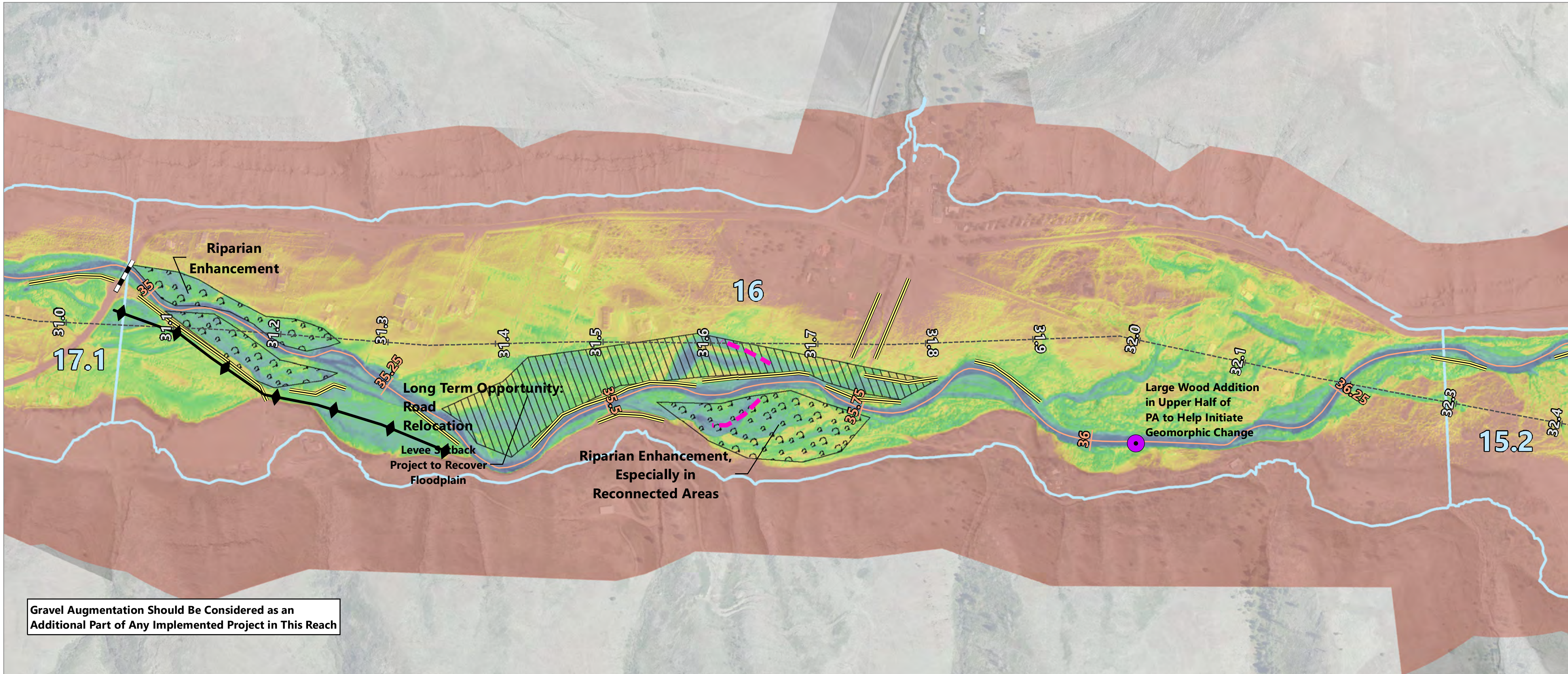
PA 16 Prioritization Scoring Summary

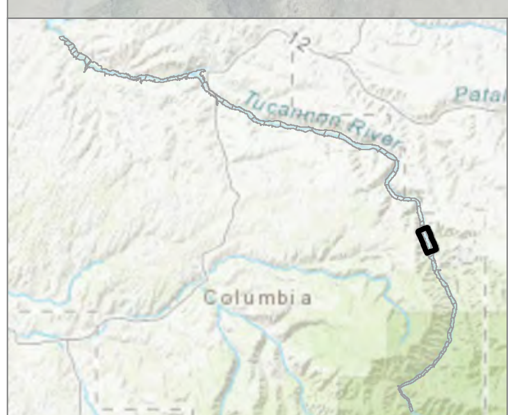


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 16 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.097	47	40%	Complexity	0.094	55	90% to 100%	5 of 5	0	40%	2.2	26	2	Untreated	19	2
Mean-Winter Flow Complexity	0.094	58	40%													
1-year Complexity	0.092	55	20%													
Channel Aggradation FP Potential	0.262	18	40%	Connectivity	0.299	6	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.221	7	40%													
Total FP Potential	0.529	8	20%													
Existing Connected FP	0.471	53	0%													
Excess Transport Capacity	0.06	26	100%	Excess Transport Capacity	1.000	26	30% to 52%	3 of 4	1	20%						
Pool Frequency	7.90	41	100%	Pool Frequency	0.203	41	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Long Term: Relocate Road
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 34.97
RIVER MILE END: 36.36
VALLEY MILE START: 31.05
VALLEY MILE END: 32.29

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Feet

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ANCHOR QEA

Project Area 16
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

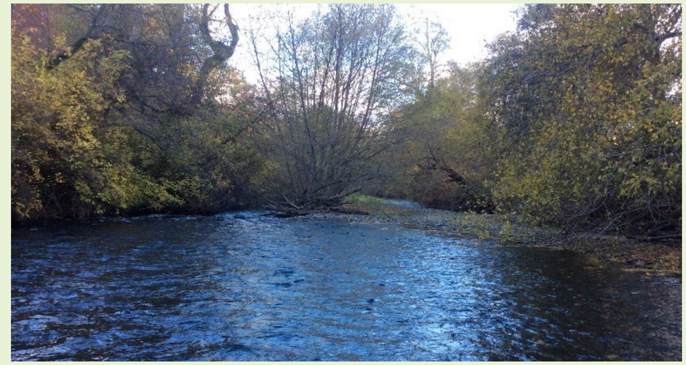
Project Area 19 Description

Project Area 19 begins at VM 28.31 at a bridge crossing for the Tucannon Road and extends upstream to VM 28.78. The 2017 RM length is 0.56 mile. Field observations for PA 19 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

It should be noted that PA 18.1 (just upstream of PA 19) was treated with a large amount of wood shortly before these data were collected, which could have had a significant effect on the geomorphic characteristics of this reach not reflected in the data.

The river through PA 19 is characterized as a single-thread, plane-bed channel. The channel is wide and shallow with little complexity. The 2011 assessment noted that a rock-armored levee was located along the right bank, and other large boulders and riprap were observed along the left bank upstream of the bridge. The bridge abutments were lined with corrugated steel sheeting. The bridge span and low chord elevation created a narrow opening beneath the bridge. This was likely constricting the river during high flows and creating high velocities through the bridge opening and on the downstream side. The bridge appeared to be old and in disrepair. No available off-channel areas other than a minor flow split near RM 32.0 were observed in this project area.

Project Area 19
Looking downstream at a split flow around a vegetated island with good riparian cover.



Project Area 19 Reach Characteristics

VM Start (mi)	28.31
VM Length (mi)	0.47
Valley Slope	1.07%
RM Start (mi)	31.90
RM Length (mi)	0.56
Average Channel Slope	0.89%
Sinuosity	1.20
Connected FP (ac/VM)	16.03
Encroachment Removal (ac/VM)	0.53
Channel Aggradation (ac/VM)	4.96
Total FP Potential (ac/VM)	5.05
Encroaching Feature Length (ft)	723.55
Connected FP Rank	23

Instream habitat was characterized by a wide, shallow channel with a lack of pools, off-channel areas, cover, and hydraulic refuge. Only small LWD and some undercut root masses provided cover in the channel. During high flows, the bridge crossing and the area downstream likely contained very high velocities that may be detrimental to fish, particularly juveniles.

Geomorphic Changes

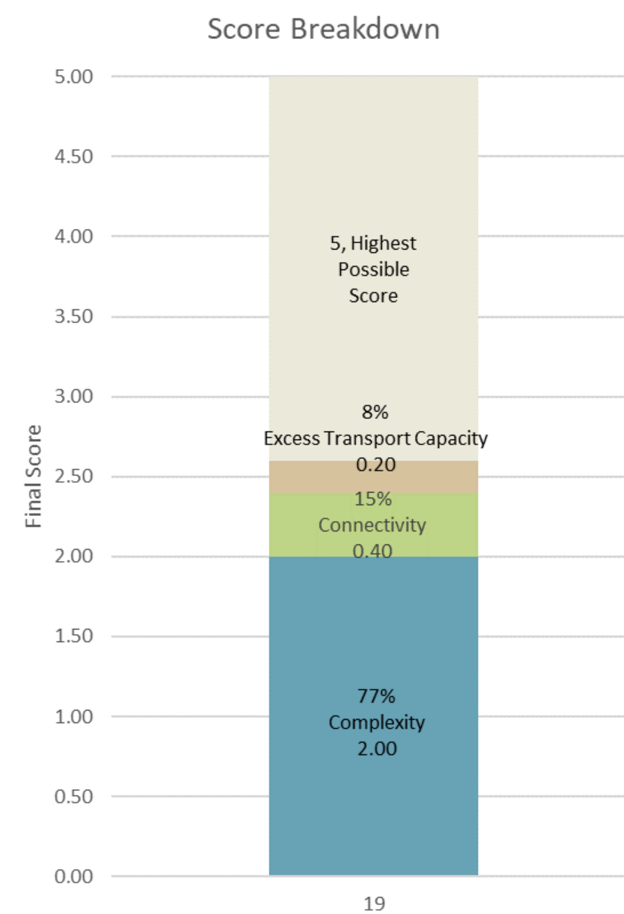
Analysis of the difference between the 2010 and 2017 LiDAR data shows only two locations of relatively minor geomorphic change in PA 19. Near the upstream end of the reach, there appears to be the very beginnings of two meander bends forming. Aggregation appears on the inside of the bend during bar building and some erosion is occurring on the outside of the bend on the second meander bend, although this meander appears to be running along the left bank valley wall and is unlikely to progress any further (box 1).

After running along the valley wall for approximately 800 feet, the channel appears to contain a log jam that spans the channel and is causing aggregation and erosion on the left bank, forming a pool and alcove that were noted during field observations (box 2).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 19 received its only score in the complexity metric. This project area falls in the

PA 19 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

bottom 25% of floodplain connectivity potential and near average for transport capacity. PA 19 scores in the 40th to 60th percentile for complexity (which is the range in which reaches have the most potential for complexity without being too confined to allow realistic projects to be completed). This complexity score is driven by all three flows falling near average for project areas in this assessment. Existing side channels are distributed evenly throughout the reach, with each high-flow event adding some small amount of complexity in generally the same locations.

There are a limited number of floodplain connectivity locations where the inundated area for the 5-year flood event is larger than the inundated area for the 2-year flood event, and there are almost no locations for encroachment removal, which is why the floodplain connection potential score is so low. However, by looking at these areas as well as the relative elevation maps, the low-lying areas and high-flow channels that could be activated become apparent, with several existing high-flow channels near the middle of the reach and another cluster near the bottom of this reach.

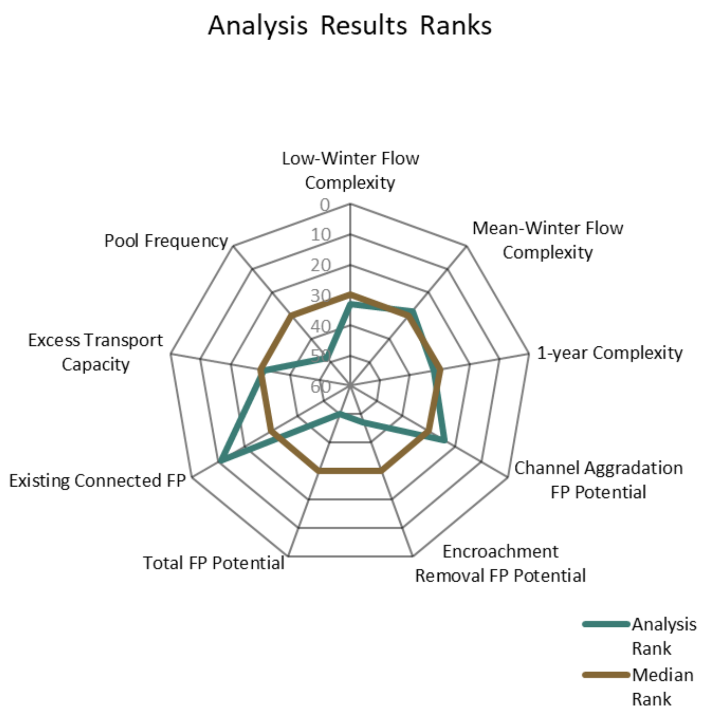
To increase complexity in this reach, restoration strategies should target getting perennial flow into these higher flow channels as well as increasing channel complexity in locations where there is little low-lying floodplain available. The primary restoration strategy should be adding instream wood structure to promote floodplain geomorphic change for in-channel complexity. Some side channels may also need to be initially connected with pilot channels to jumpstart geomorphic change.

Finally, PA 19 ranks very low among project areas in the Pool Frequency metric. Adding instream wood will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target increasing pool frequency in the reach.

Summary of Restoration Opportunities Identified

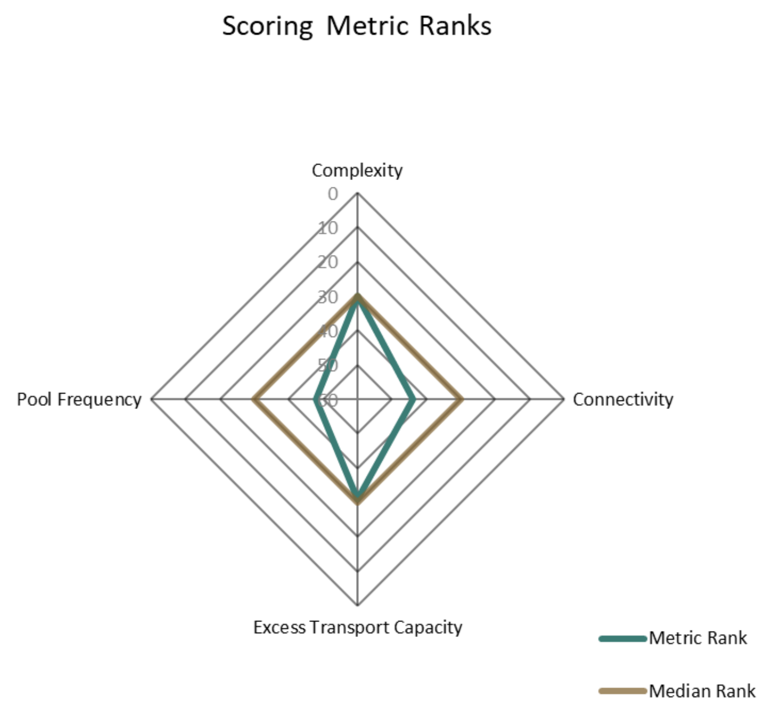
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 19 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

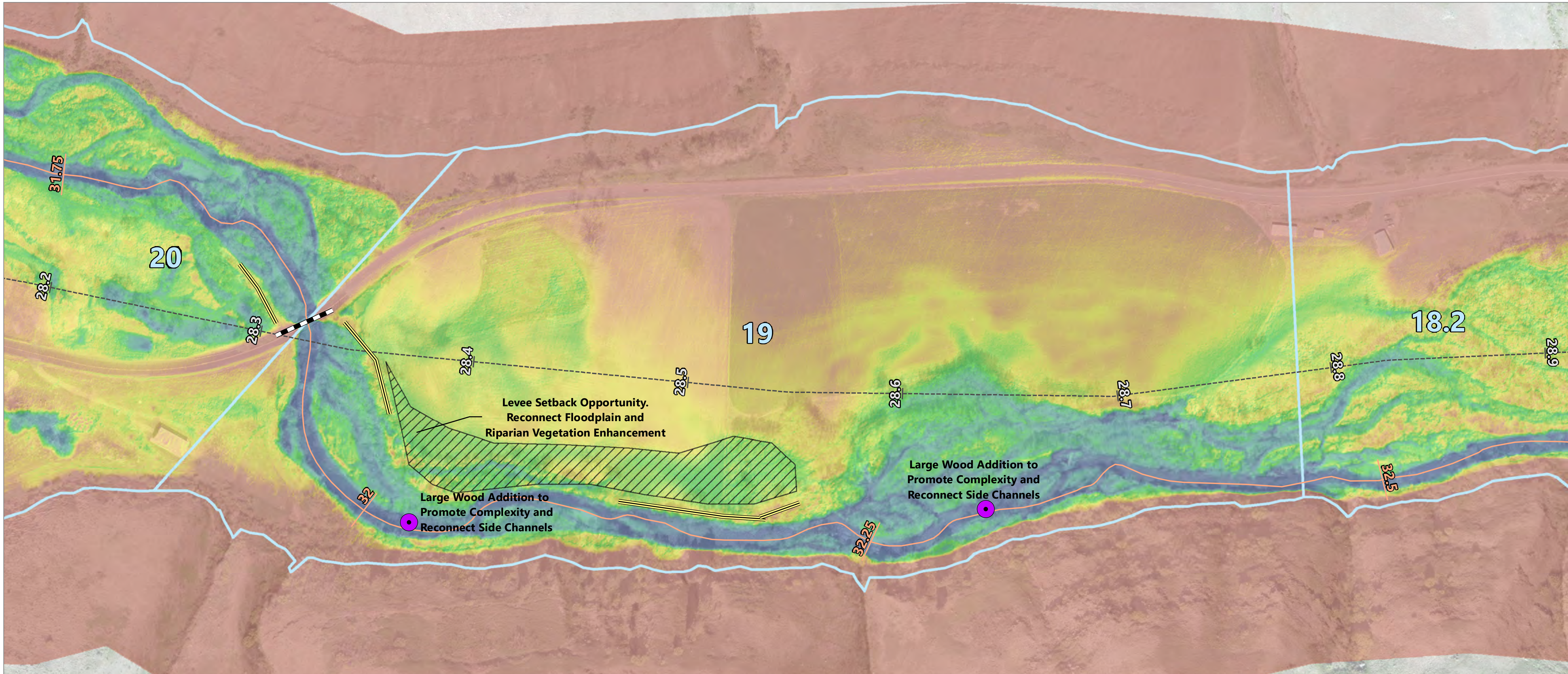
PA 19 Scoring Metric Ranks

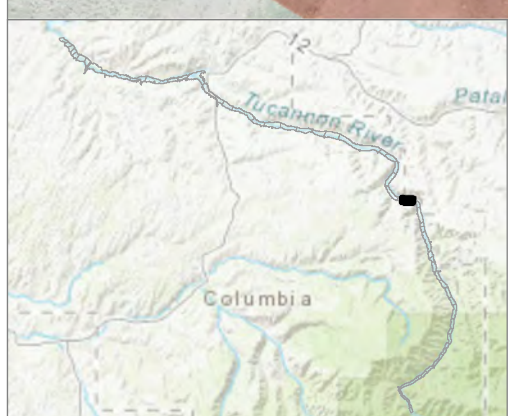


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 19 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.143	33	40%	Complexity	0.227	30	40% to 60%	3 of 5	5	40%	2.6	19	2	Untreated	13	2
Mean-Winter Flow Complexity	0.266	28	40%													
1-year Complexity	0.314	32	20%													
Channel Aggradation FP Potential	0.235	24	40%	Connectivity	0.152	44	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.025	47	40%													
Total FP Potential	0.240	50	20%													
Existing Connected FP	0.760	11	0%													
Excess Transport Capacity	0.02	31	100%	Excess Transport Capacity	1.000	31	30% to 52%	3 of 4	1	20%						
Pool Frequency	5.35	48	100%	Pool Frequency	0.137	48	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 31.9
RIVER MILE END: 32.46
VALLEY MILE START: 28.31
VALLEY MILE END: 28.78

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ANCHOR QEA

Project Area 19
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 28.1 Description

Project Area 28.1 begins at VM 19.42 and extends upstream to VM 20.21. The 2017 RM length is 0.87 mile. Field observations for PA 17.1 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

For this assessment update, PA 28 as defined in the 2011 prioritization was separated into three project areas (PA 28.1, PA 28.2, and PA 28.3. In 2016, the lower sections of this project area (PA 28.2 and PA 28.3) were the subject of a restoration project, while PA 28.1 has remained untreated. PA 28.2 and PA 28.3 represent distinct parts of the restoration project and were therefore separated for distinct analysis.

The channel through PA 28 contains primarily a dynamic, multiple-thread channel with forced pools, riffles, and rapid sections. The 2011 assessment noted that, for the majority of this reach, the channel was actively migrating and aggrading. Several recently recruited trees and newly formed side channels were observed throughout this area, along with a high volume of temporary sediment storage in the form of gravel point bars and islands. Deep pools were observed at rootwad logs, larger log jams, and along the outside of meander bends. One engineered log jam was observed that contained a very large pool and ample cover that many fish were utilizing. This section of the project area did not contain any significant bank

Project Area 28.1
Photograph taken from the 2011 prioritization showing forced pools and riffles near the upstream end of the reach.

Project Area 28.1 Reach Characteristics

VM Start (mi)	19.42
VM Length (mi)	0.79
Valley Slope	1.00%
RM Start (mi)	22.08
RM Length (mi)	0.87
Average Channel Slope	0.88%
Sinuosity	1.09
Connected FP (ac/VM)	24.87
Encroachment Removal (ac/VM)	5.30
Channel Aggradation (ac/VM)	7.44
Total FP Potential (ac/VM)	15.32
Encroaching Feature Length (ft)	2,799.68
Connected FP Rank	8

armoring, but some remnant spoil piles or pushup levees were present in the floodplain. However, these did not appear to significantly impair channel migration or floodplain connectivity.

Instream habitat conditions were generally good in the dynamic portions of the project area where the channel is in a recovery state. Channel migration had recruited a significant amount of LWD in several areas and there were many side channels with various hydraulic conditions. Ample deep holding pools were present at LWD and along eroding bends. The riffles formed between the pools and the sediment deposits in the lee of LWD and on point bars provided good spawning areas. The many alcoves and side channels observed are preferred habitat for juvenile fish.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows many geomorphic changes throughout the reach, with minor pockets of deposition occurring frequently in the channel and floodplain. Three areas are highlighted for this narrative, but areas of deposition occur almost constantly in this reach.

At the upstream end, deposition in the channel has caused some minor erosion on the left bank and multiple split flow channels have formed (box 1). Shortly downstream, another split flow has formed with deposition on the resulting island and erosion in both of the channels (box 2).

Finally, an area of erosion and deposition on alternate banks occurs for several hundred feet. Meander bends are forming as the channel avulses into the location of erosion in this area (box 3).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 28.1 receives its prioritization score from moderate scores in the Connectivity and Complexity metrics. The complexity score indicates it falls above average in the 60th to 90th percentile of project areas. This range has been identified as needing only a small boost from restoration work to achieve a high level of complexity.

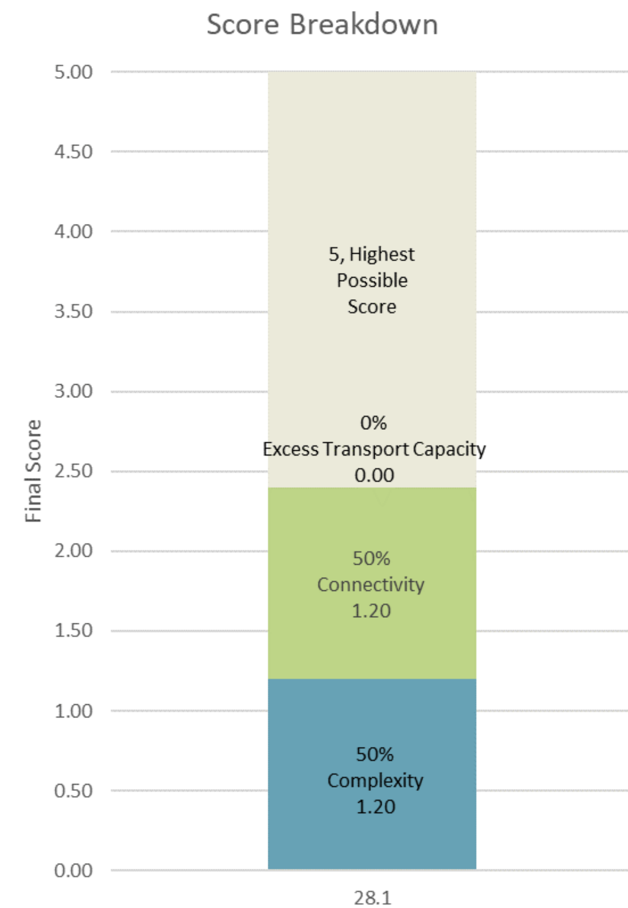
The analysis results for Complexity remain relatively constant across all three flows, indicating that side channels are connected at lower flows and are stable at higher flows. Based on the relative elevation map, there are several low-flow paths in a large, connected area of the upstream right bank floodplain. Several more pockets of channel connection opportunities exist in pockets throughout the reach. The upstream area may be a good candidate for a levee setback because several levee remnants may need to be removed in this area. In general, the restoration strategy should be to reconnect side channels through pilot channel cuts and blockage removal as well as the addition of instream wood to promote geomorphic change. Gravel augmentation should also be considered as an additional restoration strategy to promote dynamic changes and raise the bed elevation for easier access to pilot cut side channels.

The floodplain connection score is driven mostly by a higher than average encroachment removal score. The field on the right bank at the upstream end of the floodplain has been disconnected through the road and road levee and presents a large opportunity for floodplain reconnection through removal or breaching of the levee. Removing or breaching this levee should be considered the primary restoration opportunity for this reach. This opportunity should be pursued in tandem with adding LWD and pilot channel cuts in order to increase complexity at lower flows and increase floodplain inundation in this area.

Summary of Restoration Opportunities Identified

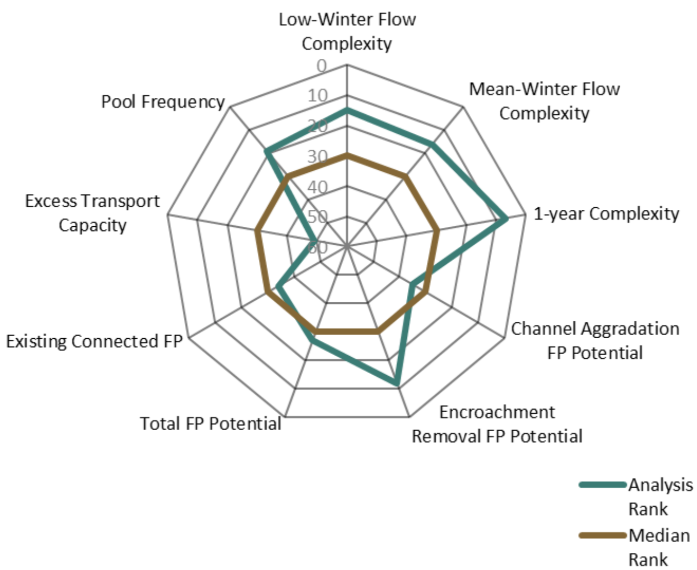
- Address encroaching features
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)
- Gravel augmentation

PA 28.1 Score Breakdown

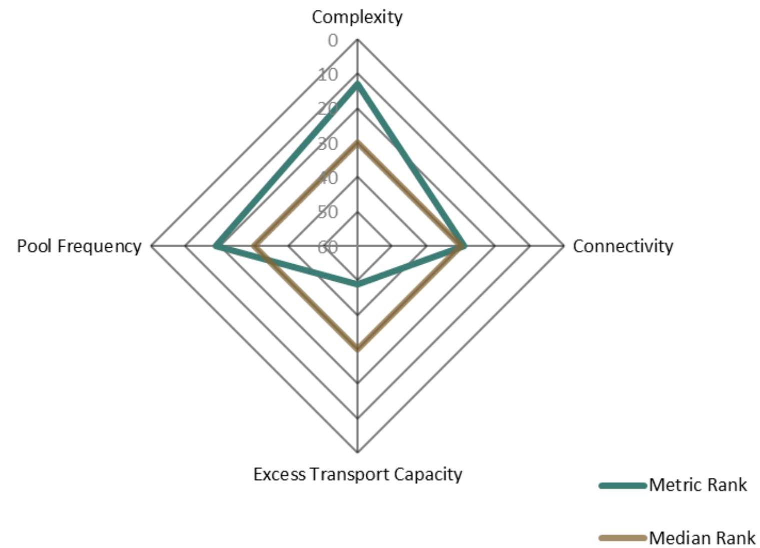


This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 28.1 Analysis Results Ranks



PA 28.1 Scoring Metric Ranks

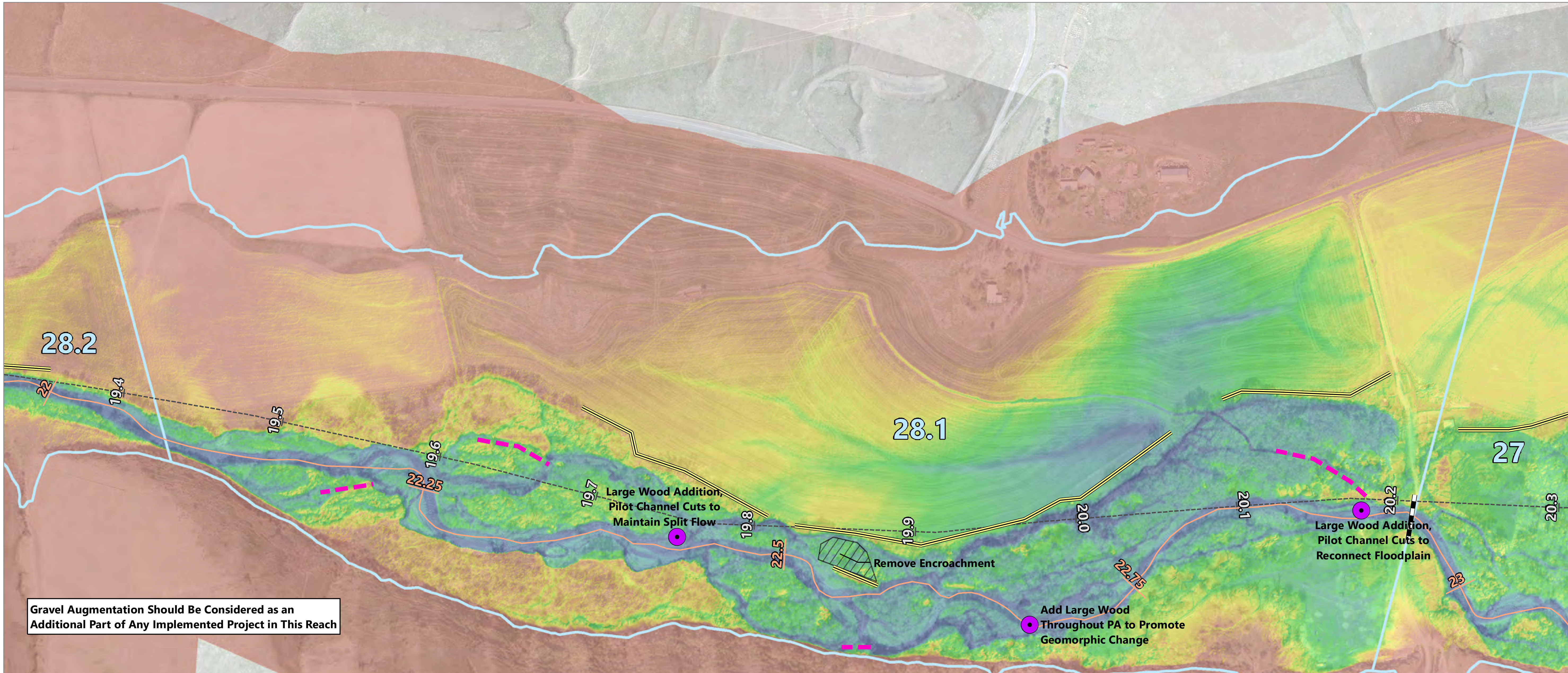


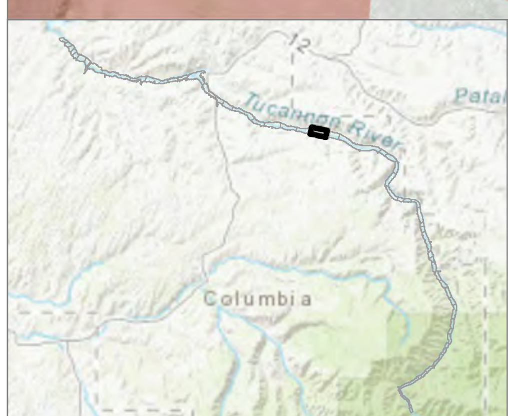
This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 28.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.262	15	40%	**Complexity**	0.371	13	10% to 40%	2 of 5	3	40%	2.4	21	2	Untreated	14	2
Mean-Winter Flow Complexity	0.345	16	40%													
1-year Complexity	0.640	7	20%													
Channel Aggradation FP Potential	0.185	35	40%	**Connectivity**	0.203	29	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.132	12	40%													
Total FP Potential	0.381	27	20%													
Existing Connected FP	0.619	34	0%													
Excess Transport Capacity	-0.13	49	100%	**Excess Transport Capacity**	0.000	49	52% to 100%	4 of 4	0	20%						
Pool Frequency	14.98	19	100%	**Pool Frequency**	0.385	19	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet
High : 15
Low : -0

NOTES:
1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 22.08
RIVER MILE END: 22.95
VALLEY MILE START: 19.42
VALLEY MILE END: 20.21

0 500
Feet

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ANCHOR QEA

Project Area 28.1
Conceptual Restoration Opportunities

Project Area 31 Description

Project Area 31 begins at VM 14.11 and extends upstream to VM 15.54. The 2017 RM length is 1.49 miles. Field observations for PA 31 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

The river through PA 31 is primarily characterized by a low-sinuosity, single-thread, plane-bed channel, with local areas of split flow, LWD, or bedrock-forced pools, and depositional areas. The 2011 assessment noted that the project area was highly influenced in places by bedrock outcrops along the left bank and in the channel bed. Bedrock maintained the grade of the channel and controlled the left bank along the valley wall. Pools were found throughout the project area and were associated with bedrock, armored banks, and locally recruited LWD. In the upper extent of the project area, the channel was highly confined between the valley wall (along the left bank) and levees and revetments along the right bank. Minimal bedrock was exposed along the channel bed in this confined segment.

Downstream, the 2011 assessment noted that the channel widened and deposition was occurring with an unvegetated gravel bar developing in the channel. In this area, an active side channel was located along the right bank. In the lower segment of the project area, bedrock controlled the channel grade.

Project Area 31
Photograph taken from the 2011 prioritization showing the plane-bed channel with a bedrock bank, looking downstream.

Project Area 31 Reach Characteristics

VM Start (mi)	14.11
VM Length (mi)	1.44
Valley Slope	0.75%
RM Start (mi)	16.13
RM Length (mi)	1.49
Average Channel Slope	0.71%
Sinuosity	1.04
Connected FP (ac/VM)	13.78
Encroachment Removal (ac/VM)	2.64
Channel Aggradation (ac/VM)	3.54
Total FP Potential (ac/VM)	9.10
Encroaching Feature Length (ft)	4,359.76
Connected FP Rank	28

Grazing in the channel was noted. There was a small falls (identified as DeRuwe Falls) with a large, deep pool at the bottom. Downstream of the falls, the channel was moderately to highly confined between the valley wall on the left bank and rock levees along the right bank, with deposition in the less confined areas.

Throughout PA 31, the channel was moderately to highly confined with some areas of floodplain connectivity. The bedrock valley wall limited floodplain development along the left bank and the right bank was mostly confined by rock levees and revetments to limit flooding and channel migration into the adjacent agricultural fields. The channel was incised through much of the project area, with overbank flooding in areas that were less confined.

The riparian zone was in generally poor to moderate health. Overall, the riparian corridor was relatively narrow and flanked by fields and pastures along the right bank. Riparian trees were predominantly mature alders with few cottonwoods with moderate density. The riparian vegetation provided shading along the channel margins. Stands of riparian trees were lacking in places along the left bank where the river is adjacent to the valley wall, which is composed of bedrock along much of the project area. Understory consisted of sparse coverage of invasive species.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several locations of minor geomorphic change over the project area since the previous assessment. The upstream end of the reach is highly confined by a levee on the right bank and the valley wall on the left bank, and as expected no geomorphic change was observed in this reach.

Immediately downstream of the highly confined portion of this project area, a pattern of minor deposition and erosion on opposite and alternating banks is evident. This pattern is typical of meander bends beginning to form (box 1).

A short distance downstream of here, a log jam and mid-channel bar have caused a small side channel where significant erosion has occurred in the left bank floodplain. Deposition is seen shortly downstream of here and is likely the sediment sourced from the upstream erosion (box 2).

Finally, near the downstream end of the reach, some erosion has occurred on the right bank of the channel, and shortly downstream sediment has deposited on the right bank floodplain (box 3).

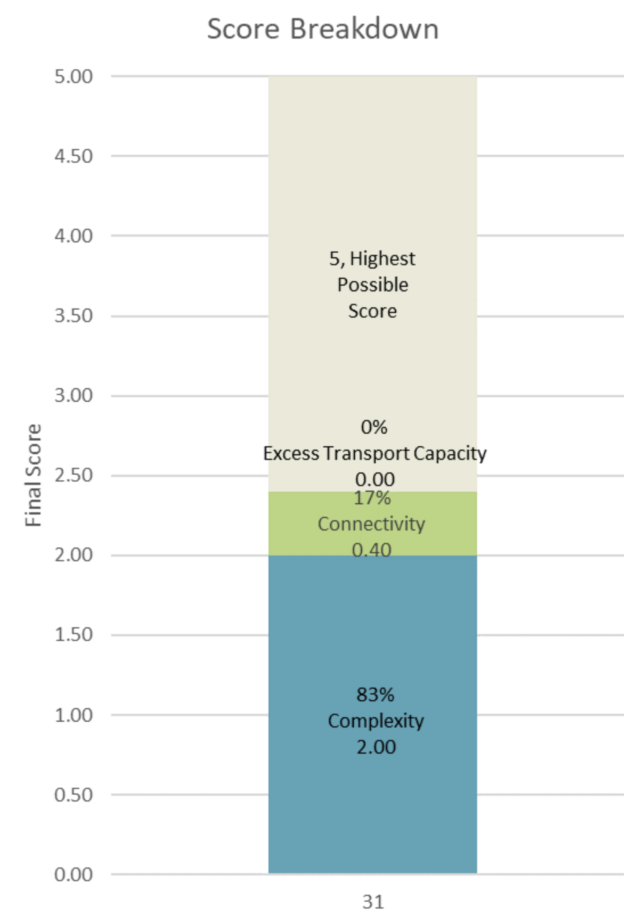
Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 31 receives a low score in the Connectivity metric, and the highest possible score in the Complexity metric, which account for the entire prioritization scores. The high Complexity score indicates that this project area ranks just above average in the 40th to 60th percentile, which is a range that has been identified as having a high amount of potential for restoring channel complexity at the lower flows. The low Connectivity score indicates that this project area also ranks below average in the 25th to 50th percentile range for connectivity potential.

The Connectivity score is driven mostly by the Encroachment Removal analysis result, which ranks PA 31 above average. This potential area is located almost entirely in a large, low-lying field on the right bank mid-reach that does not appear to be supported by irrigation pivot infrastructure. This field is disconnected by a large levee and there are several residential structures nearby so reconnecting this area might be difficult. The Complexity score in this reach is driven mostly by several side channels and mid-channel bars in this same area, where the floodplain is a bit wider than the rest of the reach.

In general, this reach is relatively confined, especially at the upstream end. The downstream end has more connected floodplain and will likely be the area where gains for complexity

PA 31 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

are realized. Restoration strategies for this reach should be to add instream wood and structure along with gravel augmentation to promote geomorphic change in the lower portion of this reach. The upper portion of the reach should also be treated with instream wood, but the complexity gain in this reach will mostly be from in-channel bars, pools, and riffles.

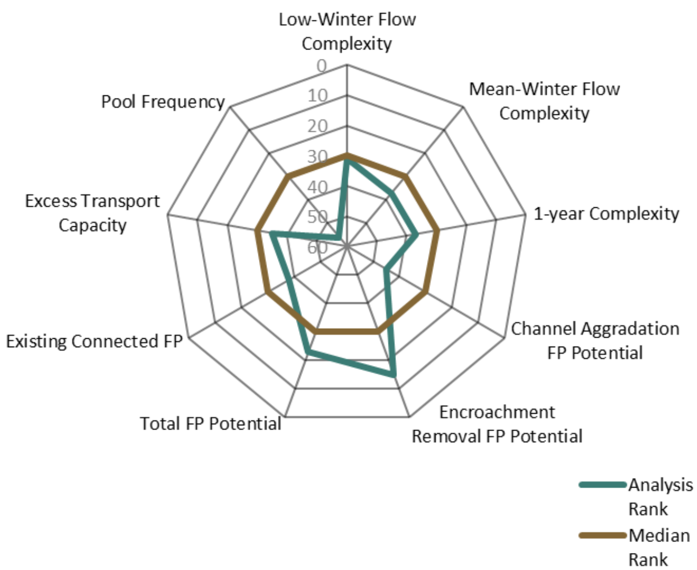
Should the opportunity arise to remove or set back the levee in this reach, it would greatly benefit the connectivity and complexity of this project area. Adding instream wood and gravel augmentation would remain the primary restoration strategies after the levee has been removed.

Finally, PA 31 scores very poorly in pool frequency, likely due to the confined nature of this reach. The identified restoration strategies of widening the floodplain, adding instream wood, and providing gravel augmentation should allow more complexity to form and create the conditions that will allow pools to form more regularly through natural geomorphic processes.

Summary of Restoration Opportunities Identified

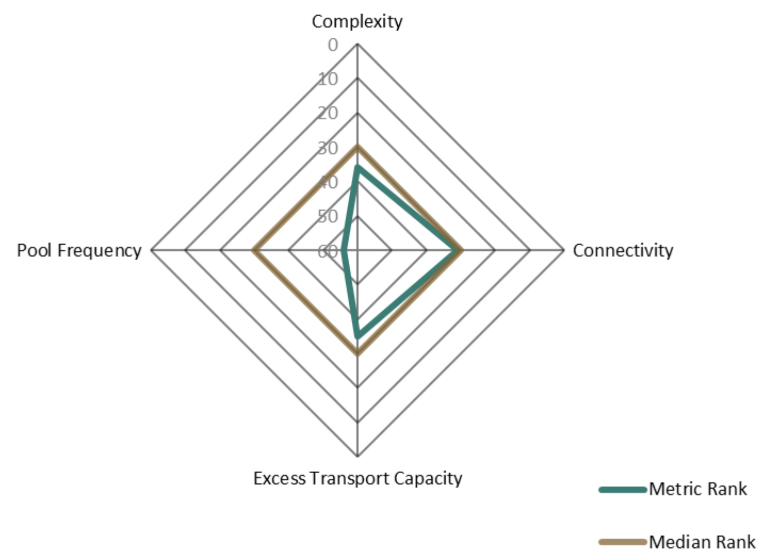
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

PA 31 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

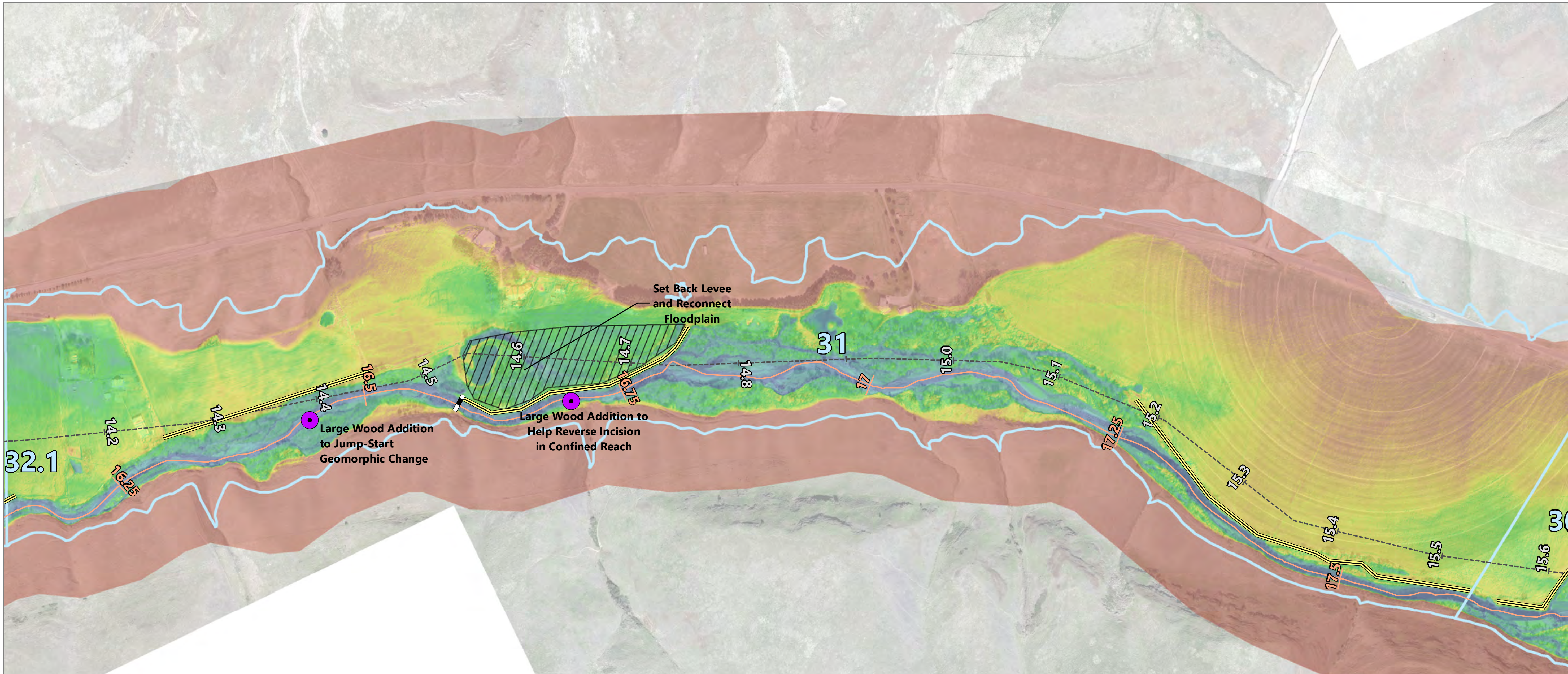
PA 31 Scoring Metric Ranks

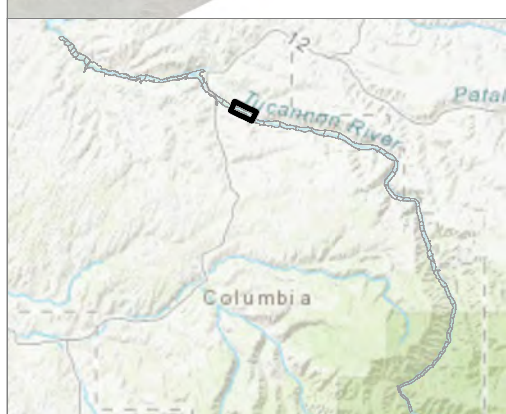


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 31 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.146	31	40%	Complexity	0.173	36	40% to 60%	3 of 5	5	40%	2.4	22	2	Untreated	15	2
Mean-Winter Flow Complexity	0.177	37	40%													
1-year Complexity	0.218	37	20%													
Channel Aggradation FP Potential	0.155	45	40%	Connectivity	0.188	31	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.115	15	40%													
Total FP Potential	0.398	23	20%													
Existing Connected FP	0.602	38	0%													
Excess Transport Capacity	-0.03	35	100%	Excess Transport Capacity	0.000	35	52% to 100%	4 of 4	0	20%						
Pool Frequency	3.35	56	100%	Pool Frequency	0.086	56	90% to 100%	5 of 5	0	0%						





LEGEND:
- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet
High : 15
Low : -0

NOTES:
1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 16.13
RIVER MILE END: 17.62
VALLEY MILE START: 14.11
VALLEY MILE END: 15.54

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Feet

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ANCHOR QEA

Project Area 31
Conceptual Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 34.2 Description

PA 34.2 begins at VM 9.92, just upstream of a large lateral levee on PA 35, and extends to a bridge for a private road at VM 10.58. The 2017 RM length is 0.78 mile. Field observations for PA 34.2 were conducted on November 1, 2018, when flow at the Starbuck gage was approximately 100 cfs.

From the upstream end of the reach to approximately VM 10.41, the reach is characterized by the valley wall and road riprap on the right bank and a large levee on the left bank. This section contains instream wood and channel complexity due to several log jams and side channel opportunities, but a significant portion of the floodplain is disconnected by the levee.

Downstream of VM 10.41, the levee becomes less well defined, and remnants of an old levee are partially protecting floodplain. Several long side channels appear to be connected by groundwater and high flow. At VM 10.1, a large split flow has one flow path going through the riparian forested area and another eroding into loose fine sediment material in the banks.

Throughout this area, the right bank has a large, forested riparian area with mature vegetation. The entire reach has patches of mature forested riparian area in the floodplain but also meanders through long exposed sections with very little cover. The mid-channel section is mostly exposed with little established vegetation.

Project Area 34.2
Instream wood from an upstream avulsion is forcing water towards the right bank where the channel is migrating into the floodplain with sparse vegetation.

Project Area 34.2 Reach Characteristics

VM Start (mi)	9.92
VM Length (mi)	0.63
Valley Slope	0.83%
RM Start (mi)	11.50
RM Length (mi)	0.78
Average Channel Slope	0.64%
Sinuosity	1.25
Connected FP (ac/VM)	27.92
Encroachment Removal (ac/VM)	5.85
Channel Aggradation (ac/VM)	8.15
Total FP Potential (ac/VM)	17.21
Encroaching Feature Length (ft)	779.80
Connected FP Rank	5

In general, wood loading was high throughout most of this reach during the site visit, but most pieces were not yet entrenched and could be easily mobilized during subsequent flood events.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several major geomorphic changes evident in the change analysis. At the upstream end of the reach, a massive reach of deposition and degradation in the main channel has continued from the upstream PA 34.1. This is just downstream of the confluence with Pataha Creek, and this sediment is likely input from that major tributary. This has caused erosion and channel avulsion towards the left bank, which is also evident in the change analysis (box 1). In this same area, it is clear from the LiDAR that the levee along the left bank in this reach has been built up and improved within the past 7 years.

Just downstream of here is a large depositional area on the right bank floodplain, which is likely still influenced by the sediment input from Pataha Creek, as well as some more minor deposition on the left bank floodplain and some erosion towards the left bank in the main channel (box 2).

Further downstream, the channel is avulsing towards the left bank, with erosion evident there, and deposition on the opposite right bank bar. More deposition is evident on the left bank floodplain in this area likely due to high-flow events depositing material here (box 3).

Closer to the downstream end of the reach, the river has formed a long split flow, which includes an avulsion through a large, forested area of the left bank floodplain. The main channel has further avulsed as it erodes into the right bank in this split flow. A large log jam is evident at the head of the island formed here as well as another at the downstream end of the former main channel, and likely both log jams helped trigger this geomorphic change (box 4).

Finally, at the very downstream end of the reach, the channel has avulsed towards the right bank floodplain, with erosion evident there, and deposition on the opposite right bank (box 5).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 34.2 receives the majority of its prioritization score in the Complexity metric. PA 34.2 received a moderate score in Complexity, indicating that it ranked in the 60th to 90th percentile for project areas, a range which has been identified as needing only a small boost from restoration work to achieve a high level of complexity. The analysis results show complexity is relatively high for all three flows, ranking well above average, although a slight dip at the 1-year complexity indicates that some of the side channels and split flows may be washed out or inundated and may be unstable at the higher flow. Looking at the GIS layers for islands and complexity, it appears that this complexity is distributed evenly across the reach and is concentrated in many of the areas noted has having geomorphic change in the above analysis. The primary restoration strategy for this reach should be to add instream wood structure to ensure flow paths at the mean-winter and low-winter flows are maintained or replaced after higher flow events. Several low-lying areas also present an opportunity for additional side channels to be connected at all flows. A strategic pilot channel cut, along with coordinated placement of instream wood to promote geomorphic change into the areas and establish perennial side channels and split flows, should be considered as part of the primary restoration strategy to boost complexity across all three flows.

PA 34.2 also receives a low score in the Connectivity metric, indicating that it ranks in the 25th to 50th percentile of all project areas. This low score is driven mostly by the Encroachment Removal analysis result, which ranks PA 34.2 well above average. The opportunity for encroachment removal exists almost entirely at the upstream end of the project area. A large portion of the floodplain that appears to be outside of the agricultural fields nearby, based on the 2018 aerial imagery, is disconnected by a levee that extends from the road and bridge at the upstream end of this project area. It should be noted that this levee has been built up since 2011, as noted in the LiDAR change analysis above. Reconnection of this area

PA 34.2 Score Breakdown

This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

through levee removal and setback should be considered a primary restoration strategy for this reach, in addition to the strategies of pilot channel cuts and instream wood placement.

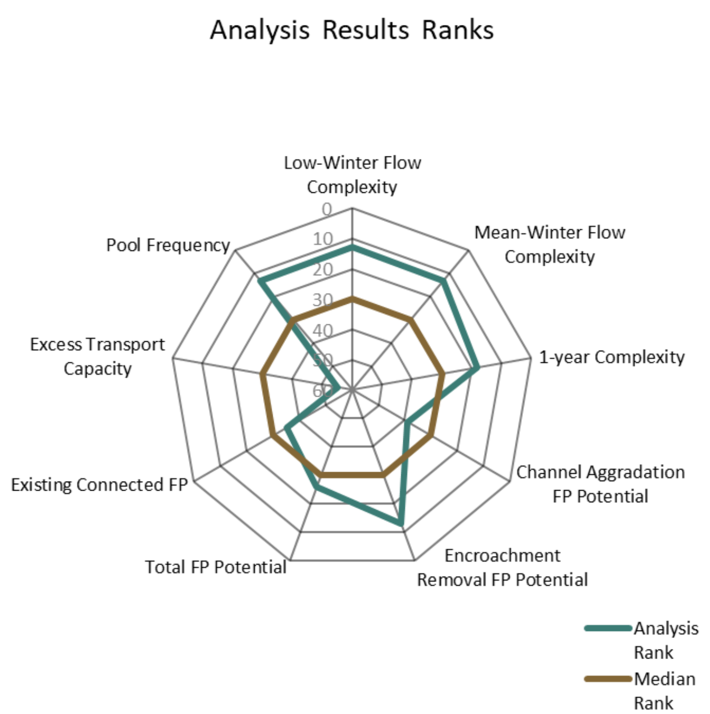
This reach receives no score in the Excess Transport Capacity metric, indicating it is a depositional reach, which is consistent with a reach just downstream of a major tributary with large sediment input. Some consideration should be given to the fact that this reach needs to process the sediment input from Pataha Creek and should be factored into restoration design. Gravel augmentation is almost certainly not necessary in this reach.

Finally, PA 34.2 ranks well above average in the Pool Frequency metric, indicating a high amount of pools per river mile. The identified restoration strategy of adding instream structure and wood should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

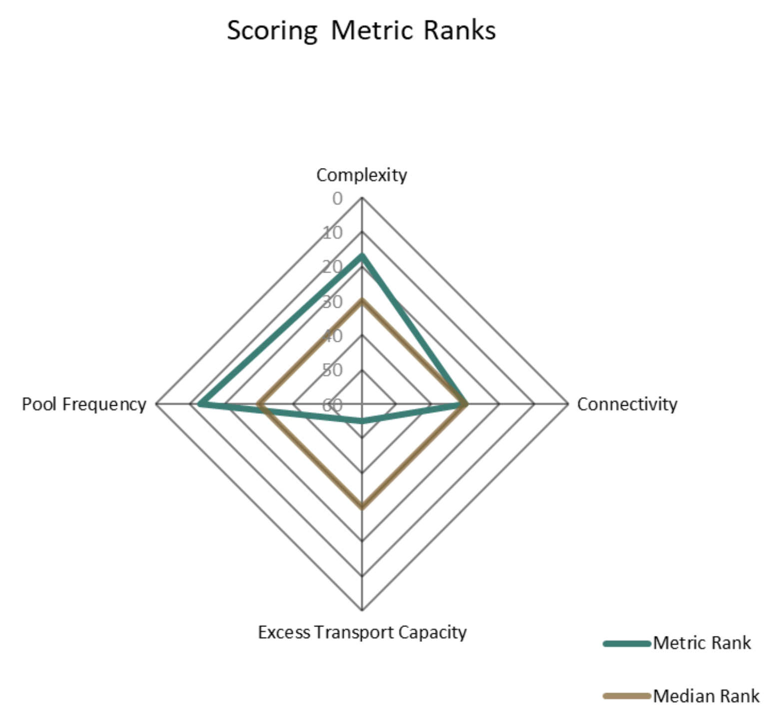
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Modify or remove obstructions

PA 34.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

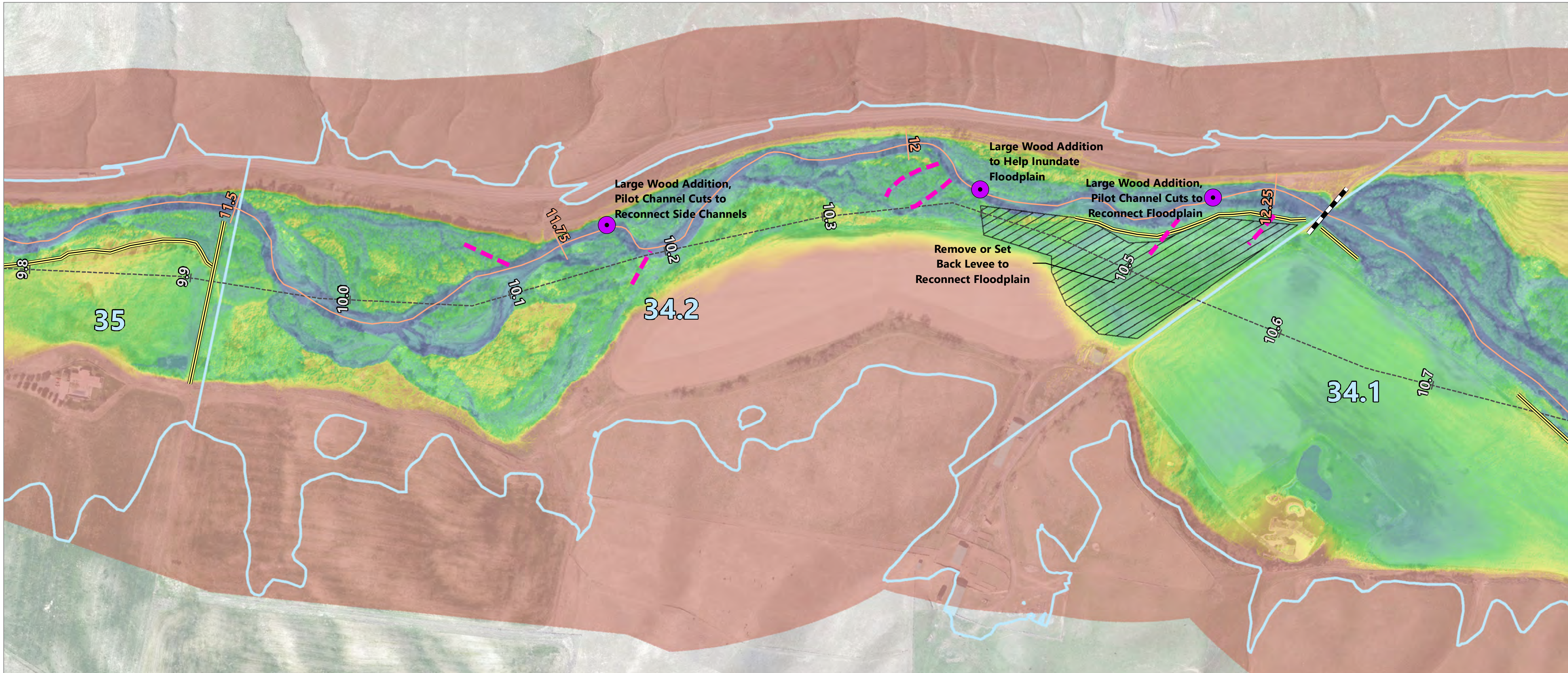
PA 34.2 Scoring Metric Ranks



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 34.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.266	13	40%	Complexity	0.351	17	10% to 40%	2 of 5	3	40%	2.4	23	2	Untreated	16	2
Mean-Winter Flow Complexity	0.408	13	40%													
1-year Complexity	0.408	18	20%													
Channel Aggradation FP Potential	0.181	39	40%	Connectivity	0.200	30	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.130	13	40%													
Total FP Potential	0.381	26	20%													
Existing Connected FP	0.619	35	0%													
Excess Transport Capacity	-0.19	55	100%	Excess Transport Capacity	0.000	55	52% to 100%	4 of 4	0	20%						
Pool Frequency	17.91	13	100%	Pool Frequency	0.460	13	10% to 40%	2 of 5	3	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 11.5
RIVER MILE END: 12.28
VALLEY MILE START: 9.92
VALLEY MILE END: 10.55

0 500
Feet

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ANCHOR QEA

Project Area 34.2
Conceptual Restoration Opportunities

Project Area 35 Description

Project Area 35 begins at VM 9.30 and extends upstream to VM 9.92 just upstream of a large lateral levee. The 2017 RM length is 0.66 mile. Field observations for this reach were conducted on November 1, 2018, when flow at the Starbuck gage was approximately 100 cfs.

This reach is characterized by a long, parallel levee that runs along the left bank for the entire reach, beginning with the lateral levee at the upstream end. On the right bank, the channel is bordered closely by the road, confining the floodplain to only a few channel widths for the entire reach.

Behind the levee are several fields that, based on site observations, appear to be relatively low and accessible without pivot or irrigation infrastructure. Pockets of floodplain with some mature riparian vegetation exist on alternating banks as the river meanders within the levee's limits.

A small amount of instream wood was noted during field observations, possibly from upstream avulsions, but the channel in general seems to be straight and uniform without much instream complexity. Mid-way through the reach there is a bridge for River Ranch Lane.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows a relatively large amount of significant geomorphic

Project Area 35
The reach is confined by a levee on the left bank in PA 35. The instream wood seen in the distance has fallen in from the old levee.

Project Area 35 Reach Characteristics

VM Start (mi)	9.27
VM Length (mi)	0.65
Valley Slope	0.52%
RM Start (mi)	10.81
RM Length (mi)	0.69
Average Channel Slope	0.49%
Sinuosity	1.05
Connected FP (ac/VM)	13.30
Encroachment Removal (ac/VM)	10.20
Channel Aggradation (ac/VM)	5.85
Total FP Potential (ac/VM)	40.21
Encroaching Feature Length (ft)	3,980.57
Connected FP Rank	32

change for PA 35, despite being a relatively confined reach. There are four areas of major geomorphic change noted in this reach. The first area occurs at VM 9.8 where a depositional area is evident on the right bank floodplain and associated erosion on the left bank, allowing the channel to migrate almost a full channel width (box 1). A few hundred feet downstream, deposition in the main channel has caused a channel migration towards the left bank where another channel-wide erosional area is evident, before the channel runs along the riprap bank for the old railway (box 2).

Just downstream of the River Ranch Lane bridge that bisects this project area, the beginnings of several meander bends are evident, with alternating erosion on the outside and bar building on the inside of each bend. A large log jam noted just downstream during field observations is likely helping to promote this process (box 3).

Finally, at VM 9.45 a channel avulsion has occurred with gravel deposition in the former main channel on the right and a large erosional area on the left bank where the channel currently runs. Field observations noted that the floodplain alluvial material appears to be gravel-sized and small cobble-sized and would be a good source of transportable material (box 4).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 35 receives most of its prioritization score from the Connectivity metric and is ranked in the top 25% of all project areas for this metric. This high ranking is driven almost entirely by the Encroachment Removal analysis result as well as the Total Floodplain Potential analysis result, both of which rank PA 35 near the top of all project areas. This encroachment removal potential is located entirely on the left bank floodplain for the entire reach of the project. The left bank floodplain is currently occupied by two agricultural fields, separated by River Ranch Lane and protected by a levee for the length of the river. A large portion of both fields would be almost entirely within the 5-year floodplain without the levee, and neither field appears to be supported by existing irrigation infrastructure (which would disqualify this area as part of this prioritization). The downstream field has a large portion already low enough to be connected at the 2-year event and appears to be connected via spring or tributary flow at the downstream end, going into PA 36.

The primary restoration strategy for this reach should be to reconnect this area via a combination of levee removal, pilot channel cuts, and strategic instream wood placement to promote geomorphic change. The downstream low-lying area is distant enough from the active channel that levee removal alone is unlikely to reconnect the floodplain, so pilot channel cuts will likely be necessary to jumpstart reconnection of the floodplain in this area.

Because this area is currently occupied by agricultural fields, a restoration strategy of riparian zone enhancement should also be considered to promote riparian species growth in the area connected through restoration.

The upstream field has less area that is low enough to be connected at the 2-year event, so removal of this levee does not gain as much benefit. However, much of the field is within the 5-year floodplain, and a restoration strategy that targeted both levee removal and channel aggradation could eventually see benefit at the 2-year event, as shown by the high ranking for Total Floodplain Potential. Additionally, this reach scores below average in the Excess Transport Capacity metric, indicating that added gravel material is likely to be easily stored and maintained in this reach, forcing geomorphic change. Gravel augmentation along with levee removal in this project area would be necessary to achieve connection to the floodplain in the upper reach of the project area.

Another reason to consider the gravel augmentation restoration strategy is to promote complexity throughout the reach. PA 35 receives a low score for the Complexity metric, indicating that it ranks in the 10th to 40th percentile of all project areas, and complexity in this reach may be difficult to achieve. Complexity ranks well below average in all three flows for this project area, and the little complexity that does exist consists of a few in-channel split flows. However, gravel augmentation, along with adding instream wood structure, could greatly improve the

PA 35 Score Breakdown

This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

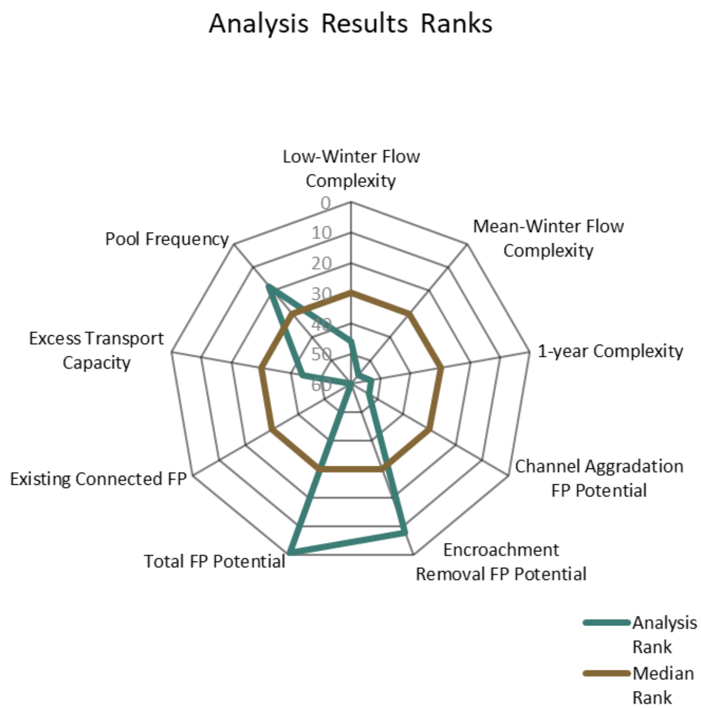
complexity in the reach. These restoration strategies are already identified for reconnecting the floodplain in the lower and upper reaches of the project area, and they should also be employed with the intent of increasing complexity. In addition, pilot channel cuts targeted for the low-winter and mean-winter flow events should also be considered in the floodplain between the levee and the river to activate complexity in this area.

Finally, the Pool Frequency metric in this reach scores slightly above average. The identified restoration strategies of adding instream structure and wood, along with gravel augmentation, should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

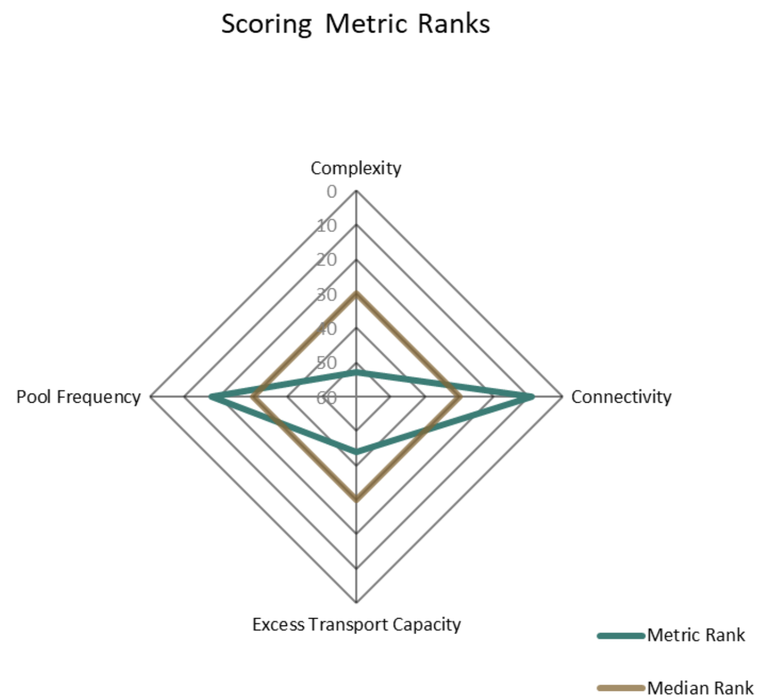
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 35 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

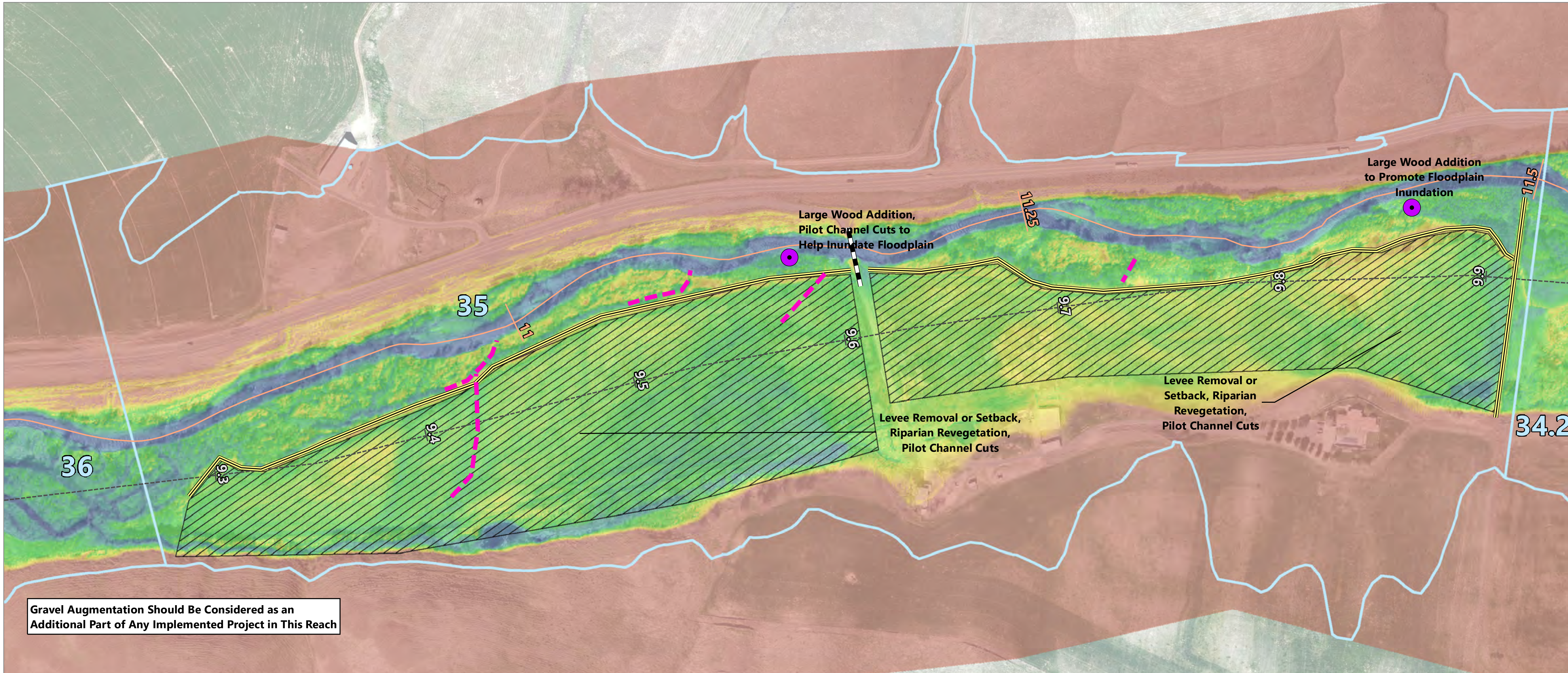
PA 35 Prioritization Scoring Summary

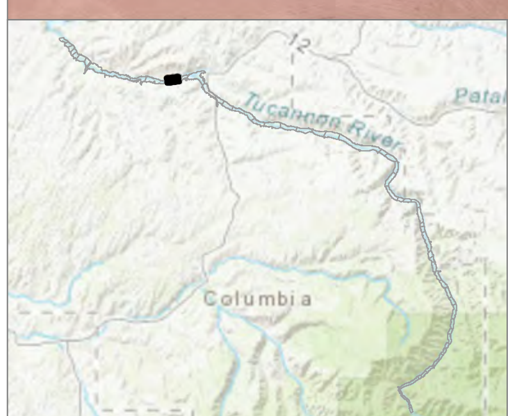


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 35 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.098	46	40%	Complexity	0.100	53	60% to 90%	4 of 5	1	40%	2.4	24	2	Untreated	17	2
Mean-Winter Flow Complexity	0.098	56	40%													
1-year Complexity	0.111	53	20%													
Channel Aggradation FP Potential	0.109	53	40%	Connectivity	0.270	9	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.191	8	40%													
Total FP Potential	0.751	1	20%													
Existing Connected FP	0.249	60	0%													
Excess Transport Capacity	-0.09	44	100%	Excess Transport Capacity	0.000	44	52% to 100%	4 of 4	0	20%						
Pool Frequency	15.24	18	100%	Pool Frequency	0.391	18	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 10.81
RIVER MILE END: 11.5
VALLEY MILE START: 9.27
VALLEY MILE END: 9.92

0 500
Feet

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ANCHOR QEA

Project Area 35
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 36 Description

Project Area 36 begins at VM 7.83 at the beginning of the Tucannon RV Park levee and extends to VM 9.30. The 2017 RM length is 1.73 miles. Field observations for this reach were conducted on November 30, 2018, when flow at the Starbuck gage was approximately 110 cfs. On August 14, 2019, another field observation was conducted per the landowner's request to look at several locations where recent avulsions were causing erosion near fields on the left bank and the railroad prism on the right bank.

The upstream end of PA 36 is uniform, straight, and mostly plane-bed with small sections of split flows and side channels. Some floodplain opportunity is available, and a tributary flows in from upstream behind the PA 35 left bank levee, creating a wetland area with established large vegetation.

Through the middle portion of the reach, the channel becomes more confined and disconnected from the floodplain as it runs along the valley wall on the left bank with high disconnected floodplain on the right bank. A steady flow through reed canary grass enters on the right bank. It is unclear whether this is a groundwater spring, irrigation runoff from the other side of the road, or a tributary from the other side of the valley. In any case, high fish use was observed in this location.

At VM 8.5, a large debris jam has caused an avulsion toward the right bank through the forested floodplain. The channel

Project Area 36
Natural wood material in the river downstream of a large avulsion through the floodplain trees. This section of riparian habitat has thick undergrowth but very few mature trees.

Project Area 36 Reach Characteristics

VM Start (mi)	7.83
VM Length (mi)	1.44
Valley Slope	0.68%
RM Start (mi)	9.11
RM Length (mi)	1.70
Average Channel Slope	0.57%
Sinuosity	1.18
Connected FP (ac/VM)	33.79
Encroachment Removal (ac/VM)	2.14
Channel Aggradation (ac/VM)	19.14
Total FP Potential (ac/VM)	19.59
Encroaching Feature Length (ft)	2,207.60
Connected FP Rank	3

through here is extremely complex with multiple jams and split flows. As of 2019, the abandoned channel was disconnected at the top but reconnected through a small side channel and groundwater seepage; this area is overgrown with the invasive false indigo, which is highly prevalent throughout this reach. As expected of a recent avulsion, the channel through this section has a high amount of instream wood, often forcing deep pools.

Near the end of this complex section, the river currently runs along the riprapped embankment for the old railway and is likely one of the areas of concern for the landowner. The channel becomes uniform and straight for a short distance before entering another complex reach around VM 8, where a meander scar on either bank has good, young cottonwood growth but is lacking in mature vegetation and cover. The right bank abandoned channel shows signs of heavy beaver activity.

This complexity continues to the end of the project area, where the right bank floodplain begins to be impacted by a levee and high bank for an RV park.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows a particularly large amount of geomorphic change, and active geomorphic change was noted during field observations in 2018 and 2019 Some of the larger scale processes and more major change locations are highlighted here, but because this reach is so active there are many other locations that could be noted.

One observation not highlighted in the data sets is that aggregation appears to be occurring in the floodplain and in some channel locations from the upstream end of the reach to the first location of geomorphic change. This could indicate that flood flows are depositing material on the floodplain through this reach. The first location of geomorphic change is a clear bar building and associated erosion bend into the right bank field (box 1).

Near the middle of the reach, a major channel avulsion has occurred. A large sediment deposit occurred at a log jam in the channel and the river avulsed and downcut into the forested right bank floodplain. In the abandoned main channel downstream of this sediment deposit and erosion, additional erosion and downcutting has occurred, and field observations confirmed that this location was flowing with surface water from side channels through the forest floodplain. More erosion and downcutting has occurred downstream in both the main channel and side channel where several large log jams are located in the main channel (box 2).

Just downstream of this avulsion, the channel has caused major erosion first on the left and then the right bank. The first erosional bend is working its way into an agricultural field and the second is running along the armored bank for the old railway line. Several large log jams are present in this section and it is possible this change was initiated by these log jams (box 3). Just downstream of this area is another large erosional area on the right bank, also associated with several natural channel-spanning log jams (box 4).

Further downstream is a major erosional area on the left bank, and the river has subsequently moved back closer to its old location, leaving a large meander scar filled with cottonwoods. The abandoned channel location has filled in to some degree with sediment, and a large beaver complex was noted here during field observations. Just downstream of this area is another large erosional area on the right bank, but this flow path has been blocked by LWD and moved back into the former channel location, leaving a deep backwater in the erosional scar. It is interesting that sinuosity increased in this location through increased erosional meander bends and then subsequently straightened out again, abandoning the meanders. Depending on the timing of the two events, it is possible that the river was responding to a large amount of sediment supply released by the upstream channel avulsion (box 5).

At the downstream end of this project area, several more channel migrations are forming bars and erosional bends, but these are less extreme than those just upstream. Additionally, there are several large depositional areas in this location on both the left and right floodplains (box 6).

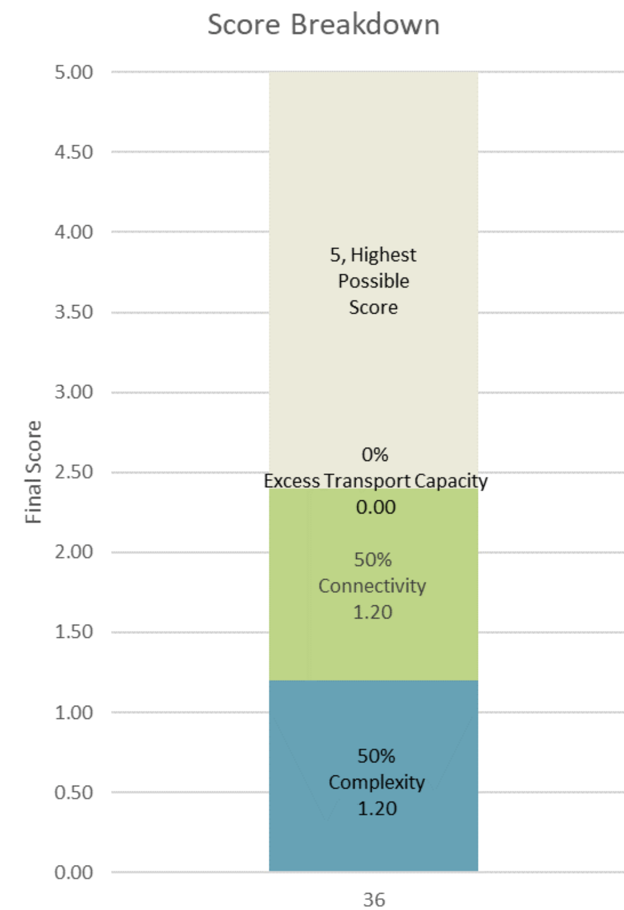
Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 36 has a moderate score for both complexity and floodplain connectivity potential but no score for excess transport capacity, which was below the assessment average. This reach has several large depositional areas, so the lack of excess transport capacity indicates that it is already acting as a depositional reach.

This project area falls in the 50th to 75th percentile for floodplain connectivity potential, but this score is primarily driven by channel aggradation potential, which scores much higher than the encroachment removal potential or both combined. It appears the potential area to be gained via channel aggradation is spread across the project area, and much of it exists in the areas between high-flow channels where the floodplain is already connected at the 2-year event. However, there are several significant areas that are connected at the 5-year event and could be connected at the 2-year event given channel aggradation or another method of raising the water surface elevation. At the upstream end, there are two fields with no pivot irrigation infrastructure that could potentially be connected. At VM 8.36 there is a large area of potential floodplain connection that includes some unused but non-vegetated land and a portion of a field with no pivot irrigation infrastructure. Some of this area is low enough that it could also be connected at the 2-year event by removing the encroachments that are disconnecting it, but these areas are patchy and not as large as the channel aggradation potential area. Channel aggradation should be a primary restoration objective in this reach, and because this reach already seems to be depositional, gravel augmentation is likely not necessary at the time of this assessment. However, a restoration strategy for this reach should be to add wood structure to trap and store sediment to potentially trigger aggradation on the bed of the channel. There are already several observed log jams in this project area, so securing these against being washed away in high-flow events could be a part of this strategy.

PA 36 falls in the 60th to 90th percentile for complexity, a range that still shows moderate complexity but does not place it in the top 10% of project areas, an objective that could be achieved with relatively little effort. Because the complexity in this project area already falls close to the 90th percentile mark, which no longer receives any points for prioritization, there appears to be good complexity across the whole reach. All three flows score at or above the assessment average, but the highest score for complexity is the 1-year flow. This increase is driven in large part by the connection of several side channels at the very upstream end of the project area; connecting these year-round would be an easy way to increase overall complexity. Adding wood structure and opening or lowering high-flow channels should be the restoration strategy employed for increasing complexity. It should be noted that

PA 36 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

any increase in connected floodplain will also likely result in increased complexity for this reach.

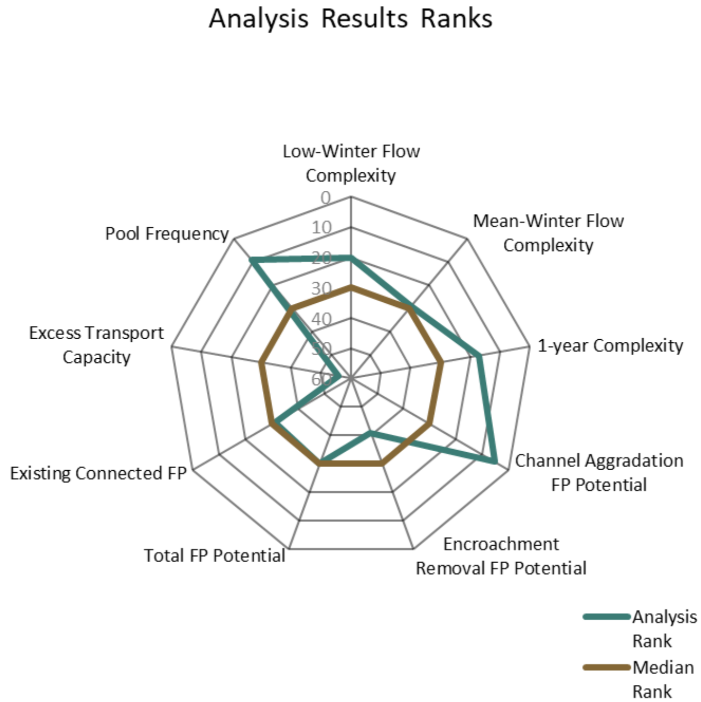
Riparian zone enhancement and plantings will be an essential part of any set of restoration strategies used in this project area. Much of the potential floodplain and side channels exist in large, open agricultural fields. Initiating riparian vegetation growth in these areas should be done along with or even prior to any of the above restoration strategies.

Finally, PA 36 ranks well above average in the Pool Frequency metric, indicating a high amount of pools per river mile. The restoration strategy of adding instream structure and wood should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

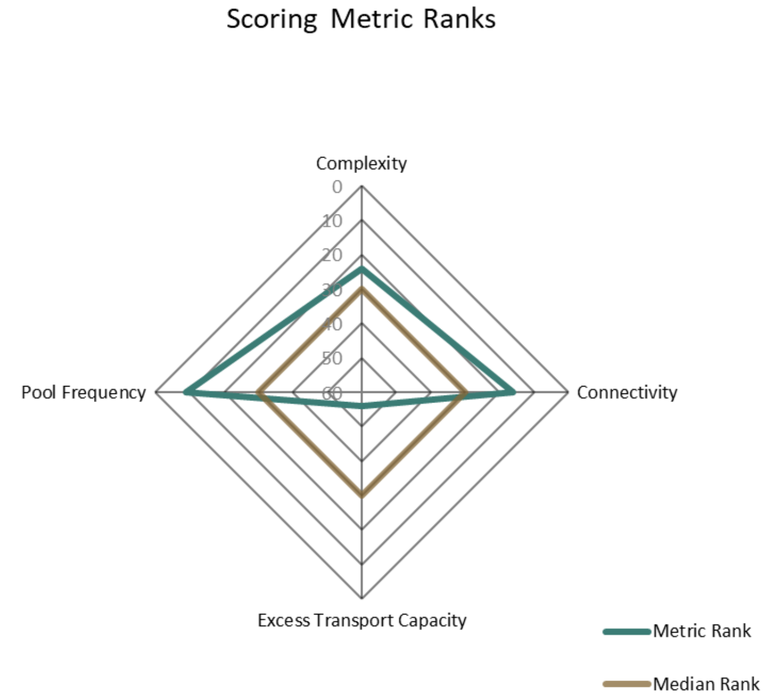
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 36 Analysis Results Summary



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

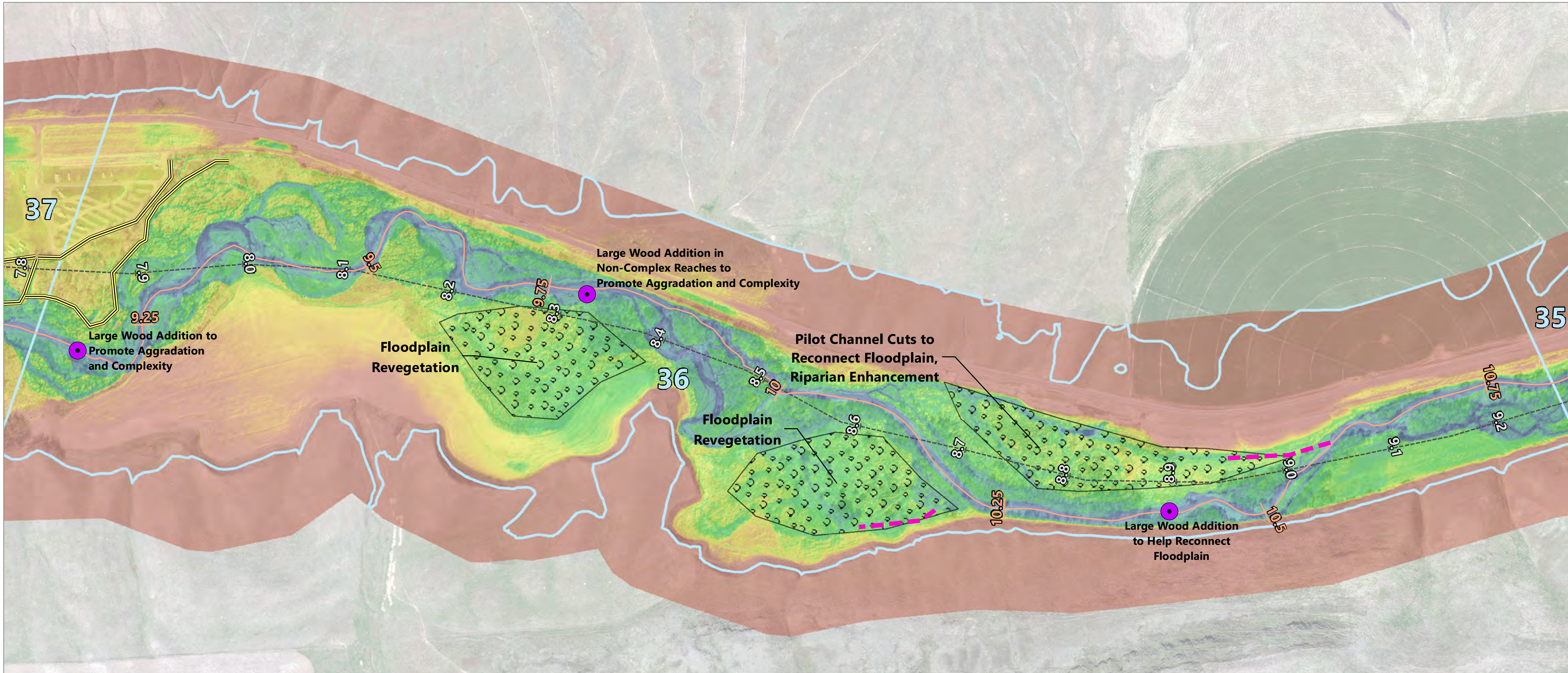
PA 36 Prioritization Scoring Summary

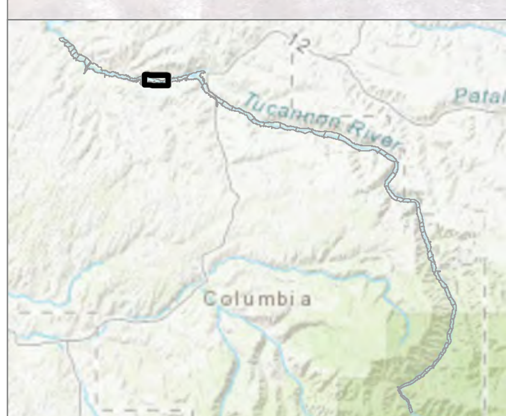


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 36 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.229	20	40%	Complexity	0.278	24	10% to 40%	2 of 5	3	40%	2.4	25	2	Untreated	18	2
Mean-Winter Flow Complexity	0.256	29	40%													
1-year Complexity	0.421	17	20%													
Channel Aggradation FP Potential	0.359	5	40%	Connectivity	0.233	16	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.040	41	40%													
Total FP Potential	0.367	30	20%													
Existing Connected FP	0.633	31	0%													
Excess Transport Capacity	-0.20	56	100%	Excess Transport Capacity	0.000	56	52% to 100%	4 of 4	0	20%						
Pool Frequency	20.76	9	100%	Pool Frequency	0.533	9	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 9.11
RIVER MILE END: 10.81
VALLEY MILE START: 7.83
VALLEY MILE END: 9.27

0 500
Feet

Publish Date: 2021/01/25, 3:54 PM | User: mgieschen
Filepath: \\orcas\gis\Jobs\TucannonRiver_1006\Maps\Conceptual Maps\Tucannon Untreated Project Areas_mg.mxd

ANCHOR QEA

Project Area 36
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 38 Description

Project Area 38 begins at the lateral Starbuck levee at VM 4.09 and extends upstream to VM 6.86. The 2017 RM length is 2.97 miles. Field observations for PA 38 were conducted October 9, 2018, when flow at the Starbuck gage was approximately 105 cfs.

PA 38 is one of the longest project areas and is largely a straight and uniform channel with very little instream wood and channel complexity. The left bank is confined by the valley wall for the entirety of the reach and does not stray more than one or two channel widths from the base of the wall. On the right bank, the channel is confined either by a high bank or levee and is often armored.

At the upstream end at VM 6.76, a rock berm extends into the active channel to divert water into a ditch for irrigation. This irrigation ditch runs for a long distance on the high right bank to approximately VM 6.11, where it begins to spill back into the river. There is potential to utilize this irrigation ditch as side channel habitat but much of it runs through reed canary grass with very little other vegetative cover.

At VM 5.48, Tucannon Dam presents a potential fish migration impediment, and at VM 5.22 a bridge for a private road crosses the river. Upstream of the bridge, pocket floodplain areas and high-flow path exist on the inside of the small meander bends between the levee and the valley wall. There are mature

Project Area 38
Looking upstream near the upstream end of the reach at a straight, plane-bed channel with fringe floodplain pockets behind levees (left) and high banks (right).

Project Area 38 Reach Characteristics

VM Start (mi)	4.09
VM Length (mi)	2.77
Valley Slope	0.56%
RM Start (mi)	5.04
RM Length (mi)	2.97
Average Channel Slope	0.51%
Sinuosity	1.07
Connected FP (ac/VM)	13.29
Encroachment Removal (ac/VM)	1.59
Channel Aggradation (ac/VM)	6.56
Total FP Potential (ac/VM)	8.83
Encroaching Feature Length (ft)	15,772.97
Connected FP Rank	33

deciduous trees in this area but they are often dead, and a large amount of dry rotting logs were observed on the floodplain.

Downstream of the bridge, a slightly larger amount of floodplain is available with good riparian cover and mature deciduous trees. However, this reach is still highly confined by the levee high bank and valley wall.

Bed material throughout this reach is mostly larger and resistant to sediment transport with little gravel material. It is likely that this straight and confined reach acts as a transport reach, moving most gravel material out in any flood event.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows very few instances of significant geomorphic change have occurred in PA 38 since the previous assessment, especially considering PA 38 is one of the longest reaches in the assessment area. This is likely due to the fact the PA 38 is highly confined between the valley wall on the left bank and levees on the right bank, as well as through natural incision.

At VM 6.4 towards the upstream end of the reach, a minor avulsion has occurred towards the right bank with associated erosional area. Based on the 2018 aerial imagery, there appears to be a log jam forcing some of this change (box 1).

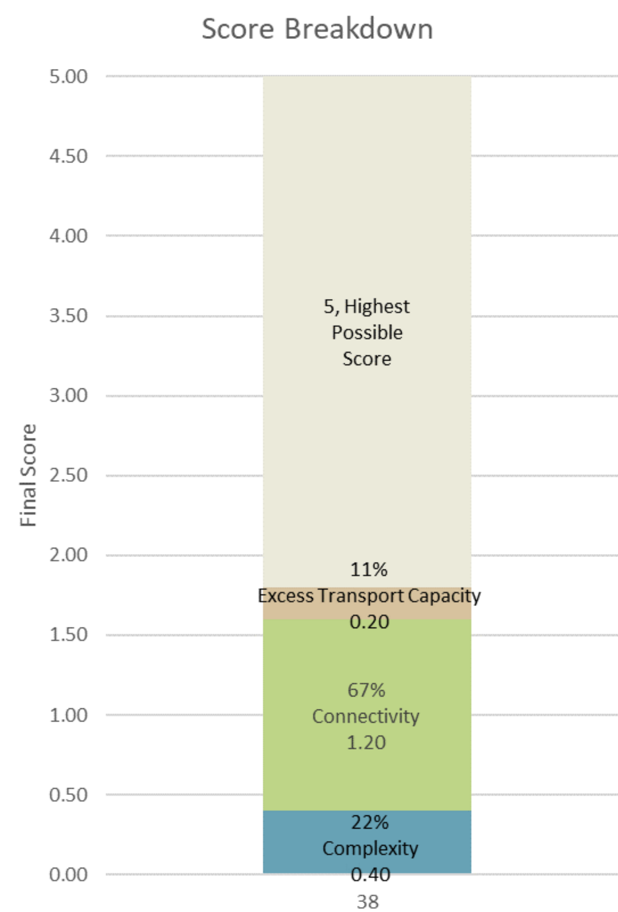
The next area highlighted for discussion at VM 5.6 is a very similar avulsion and erosional area towards the right bank as well (box 2). Between these two highlighted areas, the entire channel appears to be almost entirely erosional. This area occurs almost entirely where the active channel is the same for 2017 and 2011, which could indicate that it is a false reading based on the differences in ability of the 2017 LiDAR to detect channel bathymetry compared to the 2011 LiDAR, as discussed in the Geomorphic Assessment (Anchor QEA 2019). However, as it is consistent over such a long reach, it may be possible that this is a real indicator of incision occurring in this reach, especially considering the confined nature of PA 38.

Finally, the most significant area of geomorphic change occurs near the very downstream end of the reach at VM 4.5. Here the channel is forming several meander bends, with consecutive and alternative erosion on one bank and depositional bars forming on the other. At the downstream end of this pattern, the channel has formed a mid-channel bar with evident deposition. It is unclear what precipitated these changes as no significant log jams are evident in the 2018 aerial imagery, and this section of PA 38 was not walked for this assessment (box 3).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 38 receives the majority of its prioritization score from the Connectivity metric. PA 38 received a moderate score in Connectivity, indicating that it is above average and ranks in the 50th to 75th percentile of project areas. PA 38 ranks very highly in the Channel Aggradation analysis result and near average for the Encroachment Removal analysis result, and both should be considered as potential for floodplain connection. The channel aggradation potential is driven mostly by a large area of what appears to be currently used as pasture between the Tucannon Dam and the bridge near the middle of this reach. Additional areas for reconnection via channel aggradation exist in small pockets behind the levee along the reach. Several of these areas could also be reconnected through removal of the high bank or old levee that is disconnecting them at the 2-year event, so either levee removal or aggradation would be possible. There are several similar pockets of floodplain that exist on the outside of the levee that would need to be reconnected through pilot channel cuts or removal of the levee or encroachment. The primary restoration strategies for the reconnection of these areas to the 2-year floodplain should be gravel augmentation to raise the bed elevation, addition of instream wood to store and maintain the sediment in the reach, and strategic pilot channel cuts or removal of entire sections of levee.

PA 38 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 38 receives a low score in the Excess Transport Capacity metric, indicating that it could have slightly more transport capacity than would be expected of a reach with this average slope. Instream wood placement should be relatively aggressive and dense to ensure that sediment material from gravel augmentation is not washed away.

PA 38 receives a low score in the Complexity metric, indicating it ranks below average in the 10th to 40th percentile of all project areas. Across the three flows evaluated for complexity in the analysis results, PA 38 ranks particularly low for low-winter flow complexity, almost the worst in the assessment area. It appears that several flow paths in the floodplain, that are still between the levee and the river, are activated at the mean-winter and 1-year flow events. In general, although complexity is poor throughout this reach with the exception of a few pockets at the mean-winter and 1-year flows, reconnecting the floodplain should open up many more opportunities for the river to form complex flow. The addition of instream wood and gravel augmentation will also promote in-channel complexity. Pilot channel cuts are already identified as opportunities to reconnect floodplain at the 2-year event, but additional pilot channel cuts should be considered that target reconnecting flow paths at the low-flow event as well as completely disconnected flow paths to promote complexity across the board.

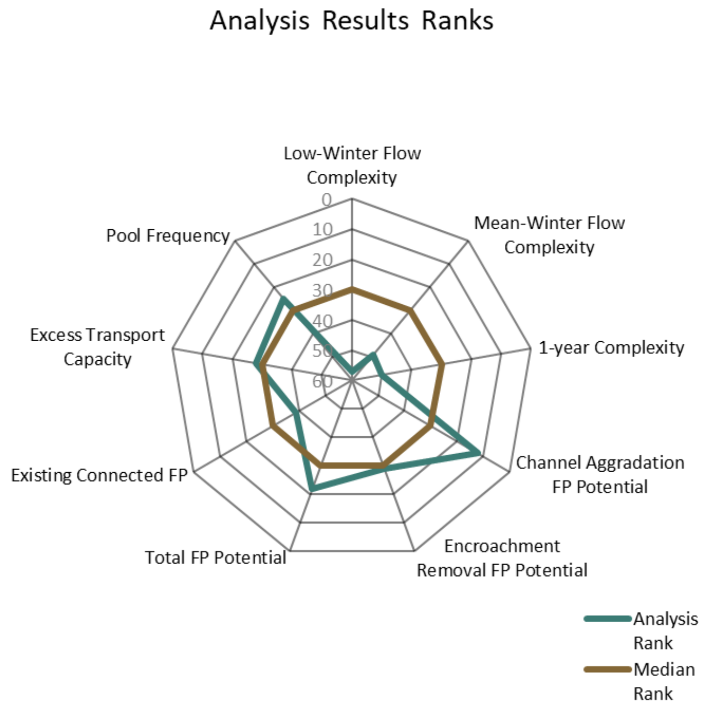
PA 38 ranks near average among project areas in the Pool Frequency metric. Adding instream wood and gravel augmentation will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target maintaining and increasing pool frequency in the reach.

Finally, it should be noted that the Tucannon Dam plays a large role in the geomorphic processes that occur in this reach. Until the dam is removed, it may not be possible to achieve self-sustaining channel aggradation downstream of the dam even after some gravel augmentation. If the dam is not removed, it is possible continuous gravel augmentation will be necessary to promote geomorphic change in this area. If the dam is removed, it should be noted that the effective slope and gradient of this reach will increase drastically, and transport capacity will be much higher. Removal of the dam should be associated with drastic measures of floodplain reconnection to reverse the incision seen upstream and promote a more sinuous and longer channel length to effectively decrease the slope of the channel in this reach.

Summary of Restoration Opportunities Identified

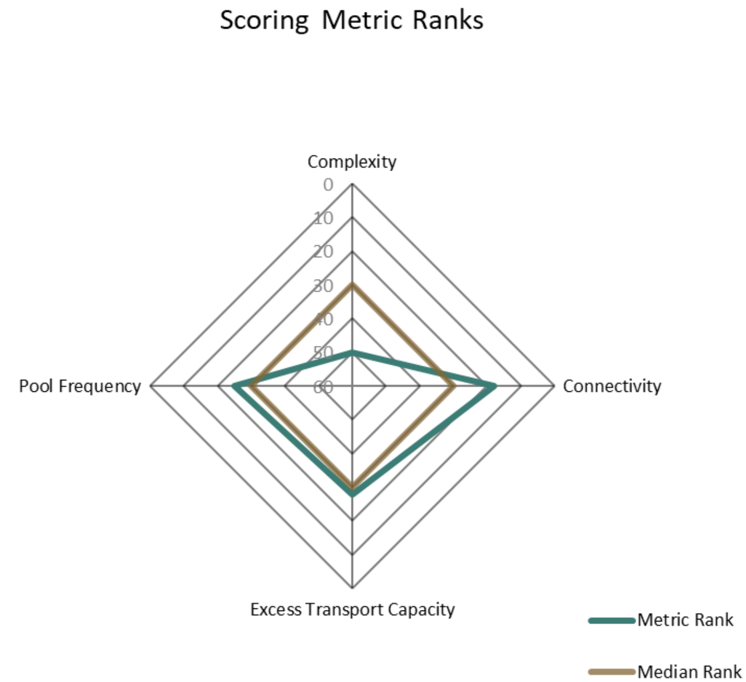
- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement
- Modify or remove obstructions

PA 38 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

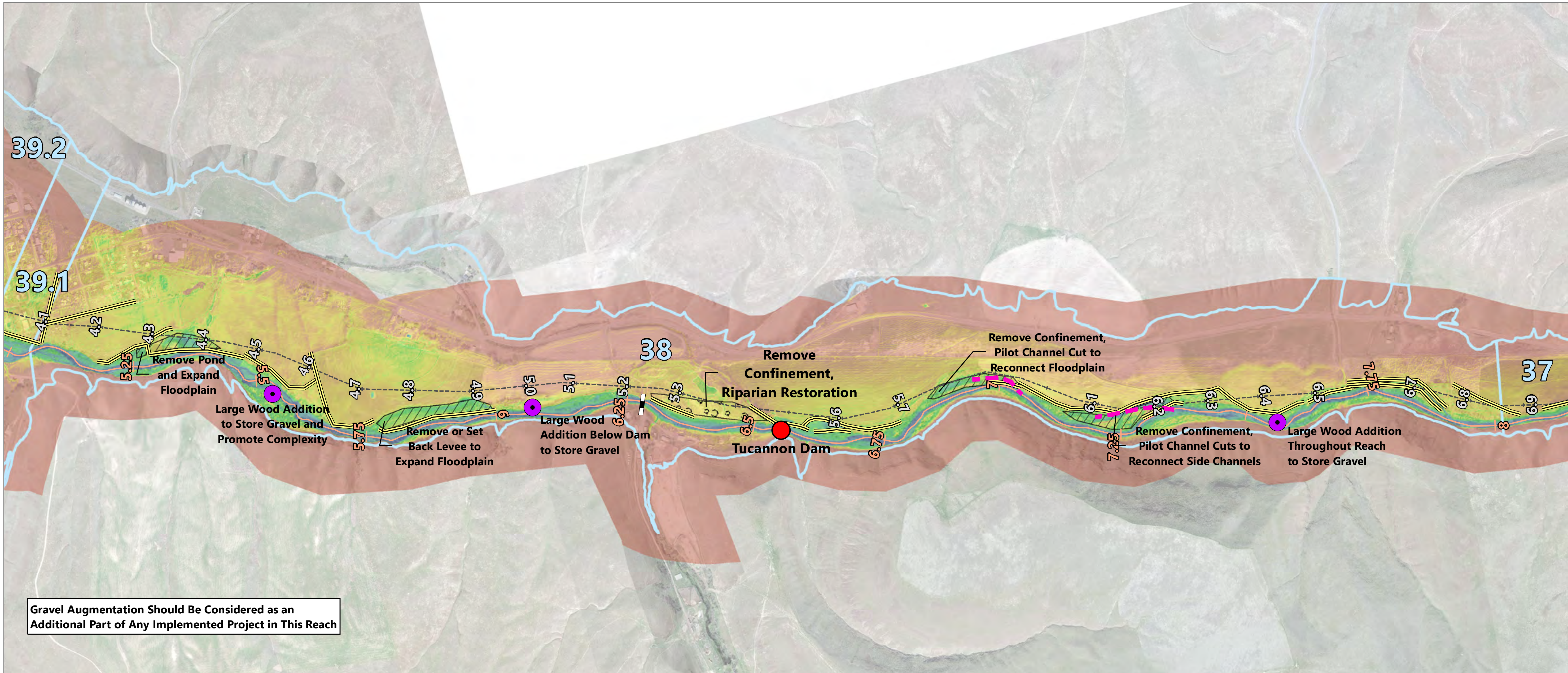
PA 38 Scoring Metric Ranks

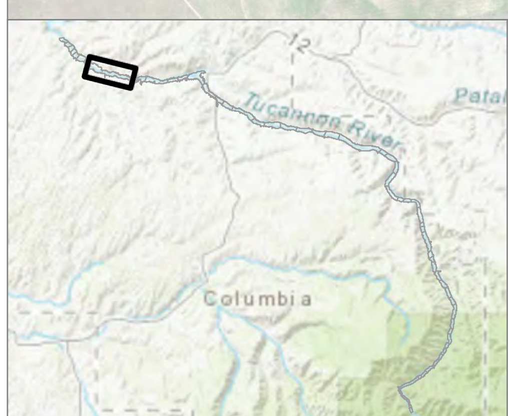


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 38 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.084	57	40%	Complexity	0.112	50	60% to 90%	4 of 5	1	40%	1.8	34	2	Untreated	21	2
Mean-Winter Flow Complexity	0.126	49	40%													
1-year Complexity	0.138	50	20%													
Channel Aggradation FP Potential	0.296	12	40%	Connectivity	0.227	18	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.072	29	40%													
Total FP Potential	0.399	22	20%													
Existing Connected FP	0.601	39	0%													
Excess Transport Capacity	0.05	28	100%	Excess Transport Capacity	1.000	28	30% to 52%	3 of 4	1	20%						
Pool Frequency	12.45	25	100%	Pool Frequency	0.320	25	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Riparian Enhancement
- Current Infrastructure in River Corridor

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 5.04
RIVER MILE END: 8.01
VALLEY MILE START: 4.09
VALLEY MILE END: 6.86

0 500
Feet

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ANCHOR QEA

Project Area 38
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 39.1 Description

Project Area 39.1 begins at VM 4.00 and extends upstream to VM 4.09 and is entirely behind the Starbuck levee. The 2017 RM length is 0.1 mile. Field observations for PA 39.1 were not conducted in 2018 as part of this assessment update. PA 39.1 represents a unique case among the project areas of this assessment. This project area was split before the last assessment, with the idea of isolating a section for a possible project that was never completed. PA 39 is such a short reach that many of the data-driven statistics for this reach may be slightly skewed and so the following analysis has been completed with that in mind.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows one significant change that occurs over the length of PA 39.1. The channel is eroding a significant amount of the left bank, and has moved more than a channel width into the floodplain since the 2011 assessment, along with deposition on the right bank. This erosion is extremely close to a bend in Kellogg Creek, which currently enters the Tucannon River further downstream in PA 39.2. Should this avulsion cut off Kellogg Creek in this location, there would be a significant elevation change that could possibly cause a headcut up Kellogg Creek (box 1).

Project Area 39.1
No site photograph available.

Project Area 39.1 Reach Characteristics

VM Start (mi)	4.00
VM Length (mi)	0.09
Valley Slope	0.26%
RM Start (mi)	4.94
RM Length (mi)	0.10
Average Channel Slope	0.21%
Sinuosity	1.15
Connected FP (ac/VM)	20.80
Encroachment Removal (ac/VM)	0.03
Channel Aggradation (ac/VM)	3.80
Total FP Potential (ac/VM)	3.83
Encroaching Feature Length (ft)	831.64
Connected FP Rank	15

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 39.1 receives the majority of its prioritization score from the Complexity and Excess Transport Capacity metrics. However, due to the extremely short length of this reach, and the fact that it contains only one modeled cross section, these scores are partially artificial. There is complexity potential in PA 39.1, short as it is, and the restoration strategy for the reach should be to add instream structure to stabilize the left bank, and promote split flow through the small wooded area on the right bank.

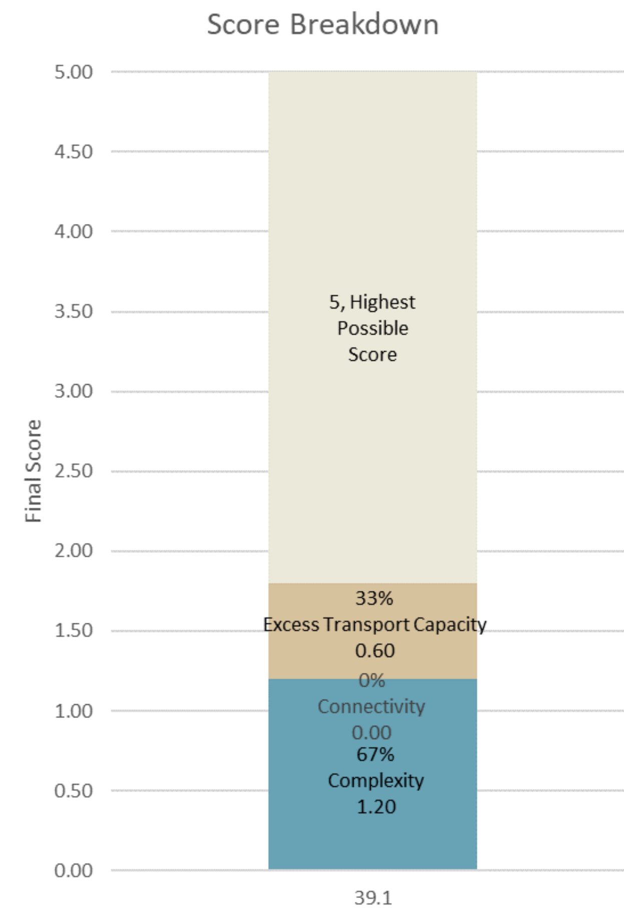
The Pool Frequency metric scores highly but again is deceiving due to the length of the reach. Adding instream wood will help to promote channel complexity and maintain several pools throughout the reach.

In general, restoration in this reach should be folded into either PA 38 or PA 39.2, which score as Tier 2 and Tier 3 untreated reaches, respectively.

Summary of Restoration Opportunities Identified

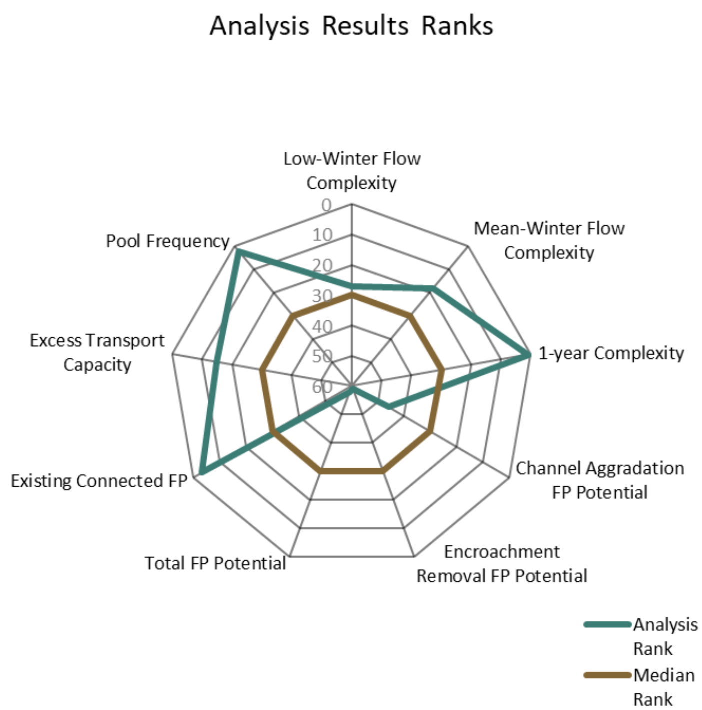
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 39.1 Score Breakdown



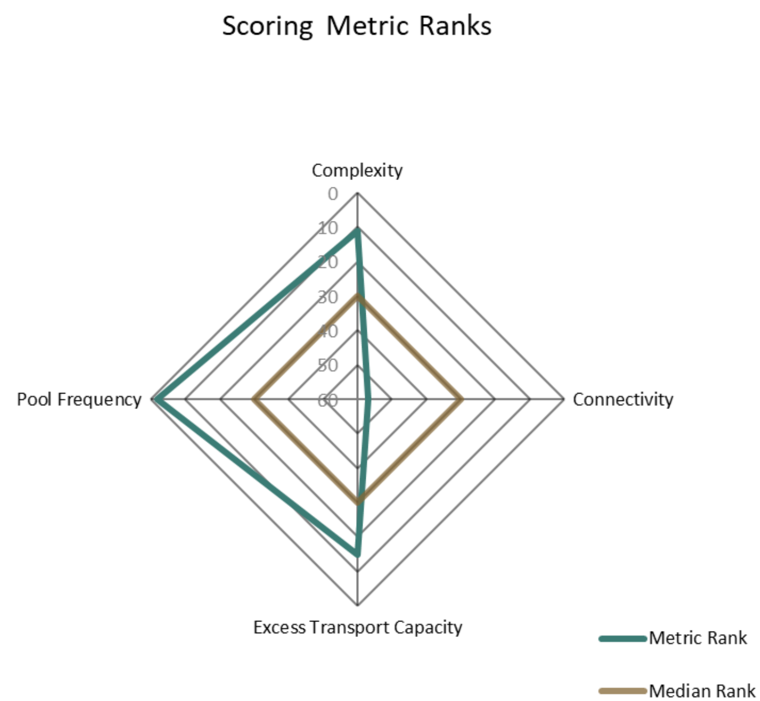
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 39.1 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

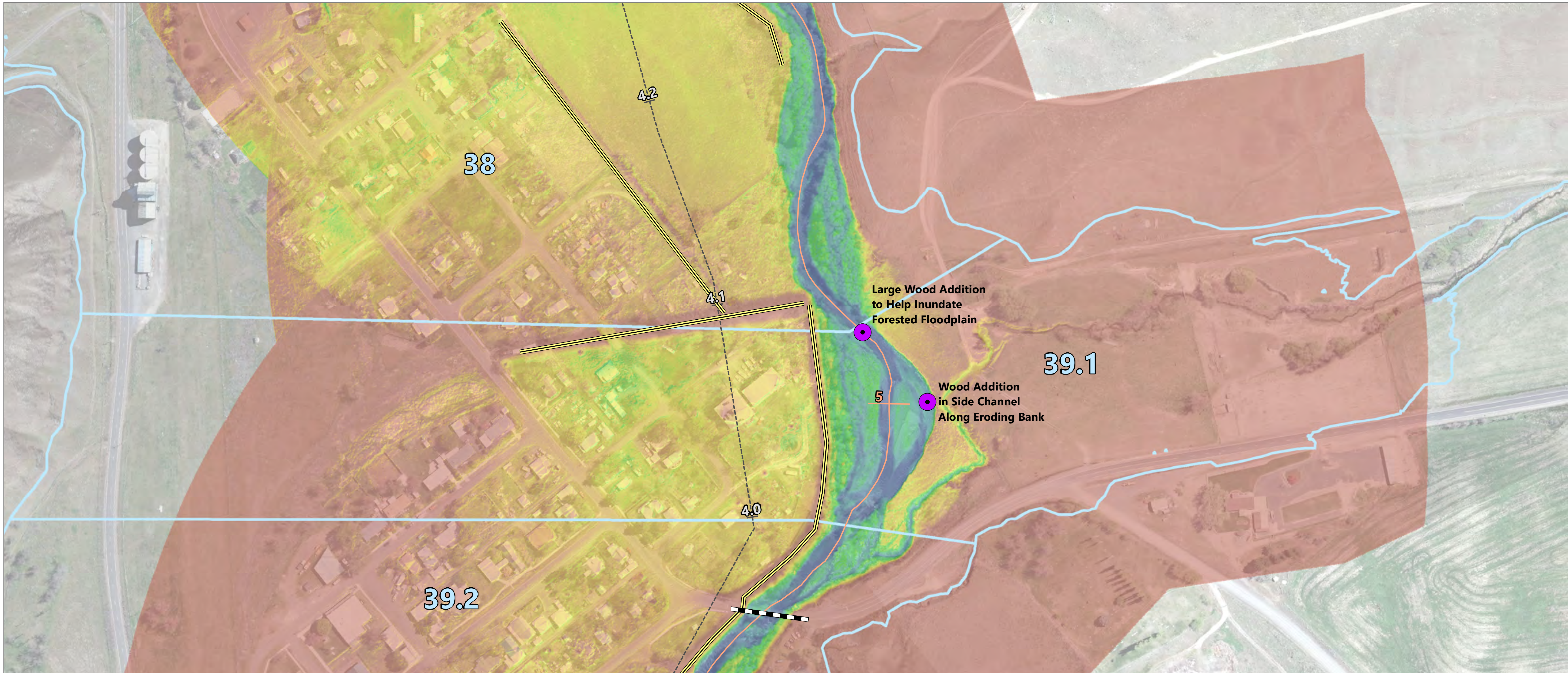
PA 39.1 Scoring Metric Ranks

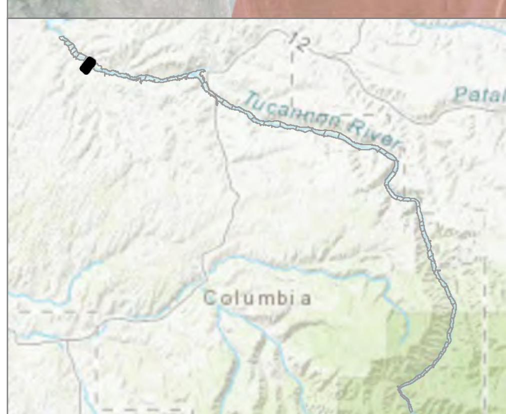


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 39.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.166	27	40%	Complexity	0.381	11	10% to 40%	2 of 5	3	40%	1.8	35	2	Untreated	22	2
Mean-Winter Flow Complexity	0.340	18	40%													
1-year Complexity	0.892	1	20%													
Channel Aggradation FP Potential	0.154	46	40%	Connectivity	0.093	57	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.001	59	40%													
Total FP Potential	0.156	58	20%													
Existing Connected FP	0.844	3	0%													
Excess Transport Capacity	0.14	15	100%	Excess Transport Capacity	3.000	15	10% to 30%	2 of 4	3	20%						
Pool Frequency	38.51	2	100%	Pool Frequency	0.989	2	1% to 10%	1 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 4.94
RIVER MILE END: 5.04
VALLEY MILE START: 4
VALLEY MILE END: 4.09

0 500
Feet

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Filepath: \\orcas\gis\Jobs\TucannonRiver_1006\Maps\Conceptual Maps\Tucannon Untreated Project Areas_mg.mxd

ANCHOR QEA

Project Area 39.1
Conceptual Restoration Opportunities

Project Area 42 Description

Project Area 42 begins at VM 2.60 and extends upstream to VM 2.85. The 2017 RM length is 0.33 mile. Field observations for PA 42 were conducted on October 10, 2018, when flow at the Starbuck gage was approximately 115 cfs.

PA 42 is a very short reach that is bounded by cultivated fields for the majority of the reach and is heavily influenced by these neighboring agricultural fields. The upstream end has small pockets of riparian floodplain with trees on the right bank. At VM 2.75, an irrigation pipe supplying a pivot close to the left bank crosses the river on a metal truss. On the right bank in this same location, a vegetated pocket of floodplain has some side channel opportunities that are currently disconnected. At the very downstream end, the floodplain is low and disconnected from the channel at this flow by a gravel berm, with very little vegetation.

The bed material throughout this reach includes plenty of transportable gravel material, indicating that adding some instream wood could easily increase the channel complexity. However, very little instream wood was observed in this reach and channel complexity was relatively poor, especially compared to PA 41 upstream and PA 43 downstream.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows many significant locations of geomorphic change in

Project Area 42
Looking downstream at an irrigation pipe crossing. The channel has complex planforms but little instream wood and poor riparian cover.

Project Area 42 Reach Characteristics

VM Start (mi)	2.60
VM Length (mi)	0.26
Valley Slope	0.78%
RM Start (mi)	3.35
RM Length (mi)	0.33
Average Channel Slope	0.59%
Sinuosity	1.29
Connected FP (ac/VM)	27.44
Encroachment Removal (ac/VM)	3.01
Channel Aggradation (ac/VM)	5.50
Total FP Potential (ac/VM)	19.71
Encroaching Feature Length (ft)	0.00
Connected FP Rank	6

this short reach. At the very upstream end, significant bank erosion is occurring on the outer edge of a meander bend, with associated bar building deposition on the inside of the bend (box 1).

Immediately downstream, deposition in the main channel has caused significant erosion on the left bank where the channel appears to be threatening some pivot infrastructure (box 2).

Near the midpoint of the reach, the channel has made a significant avulsion into the right bank floodplain with deposition in the main channel and erosion in the right bank floodplain. It is not immediately clear from the aerial imagery or field observation what has caused this avulsion (box 3). Another long avulsion has occurred just downstream of here, again with deposition in the main channel and this time erosion towards the left bank (box 4). The combination of these two changes has effectively straightened the channel significantly throughout this reach.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 42 receives the majority of its prioritization score from the Complexity metric. PA 42 ranks near the top in the 60th to 90th percentile of all project areas for Complexity, which is a range that has been identified as only needing a slight boost to reach a high level of complexity. Similarly to the upstream PA 41, PA 42 ranks highly in all three flows for the Complexity analysis results. However, while PA 42 ranks near the top in low-winter flow complexity, the mean-winter flow complexity is significantly lower, and the 1-year flow complexity is around average. This indicates that many of the islands and side channels are being washed out during the higher flow events. A primary restoration strategy should be to add instream wood to ensure that complex flow channels are maintained during higher flow events. There are several additional low-flow paths, evident in the relative elevation map, that are not being connected at any of the three flows. Reconnecting these for perennial flow through a combination of instream wood placement and pilot channel cuts should be primary restoration strategies for this reach to boost complexity across all three flows.

If geomorphic response to the addition of instream wood does not occur, it may be possible that gravel augmentation is necessary to jumpstart geomorphic change and should be considered as a secondary restoration strategy. PA 42 received no score in the Excess Transport Capacity metric, indicating that any added gravel material will be easily stored and maintained with the addition of instream wood.

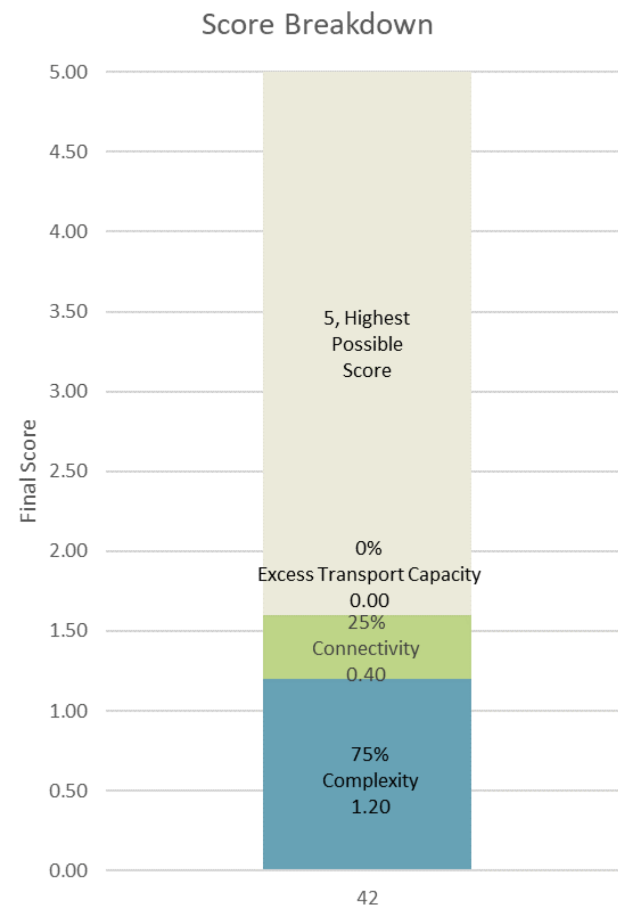
PA 42 ranks below average in the 25th to 50th percentile for Connectivity. Both the Channel Aggradation and Encroachment Removal analysis results score well below average, but the Total Floodplain Potential analysis result scores above average, indicating that both potential reconnection methods will be necessary to achieve results. However, the majority of this potential floodplain is outside of the levee and in the bordering fields. Reconnection to the floodplain may be difficult and would require extensive revegetation efforts with riparian species. Given that both channel aggradation and encroachment removal would be required to access this area, they should only be considered as a secondary restoration priority after boosting the complexity with the addition of instream wood, pilot cuts, and gravel augmentation.

Finally, PA 42 ranks very highly in the Pool Frequency metric, indicating a high amount of pools per river mile. The identified restoration strategies of adding instream structure and wood should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

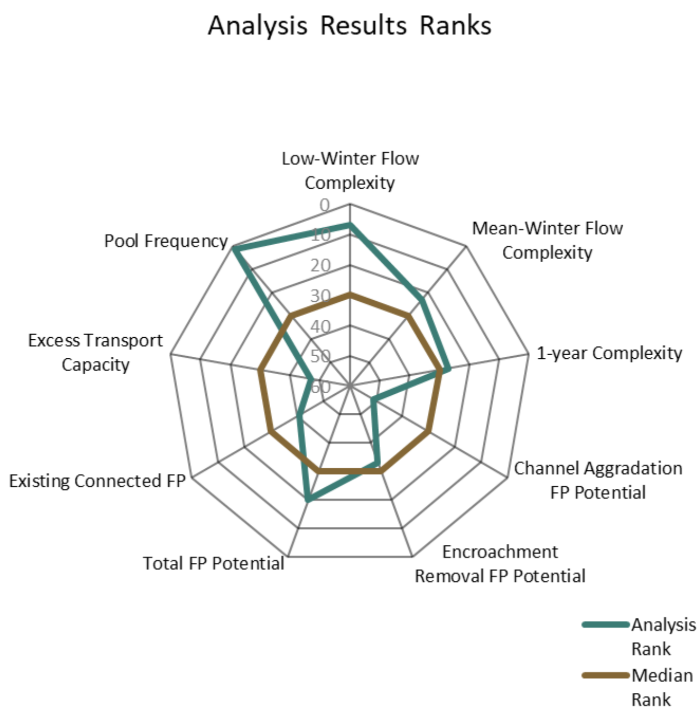
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 42 Score Breakdown



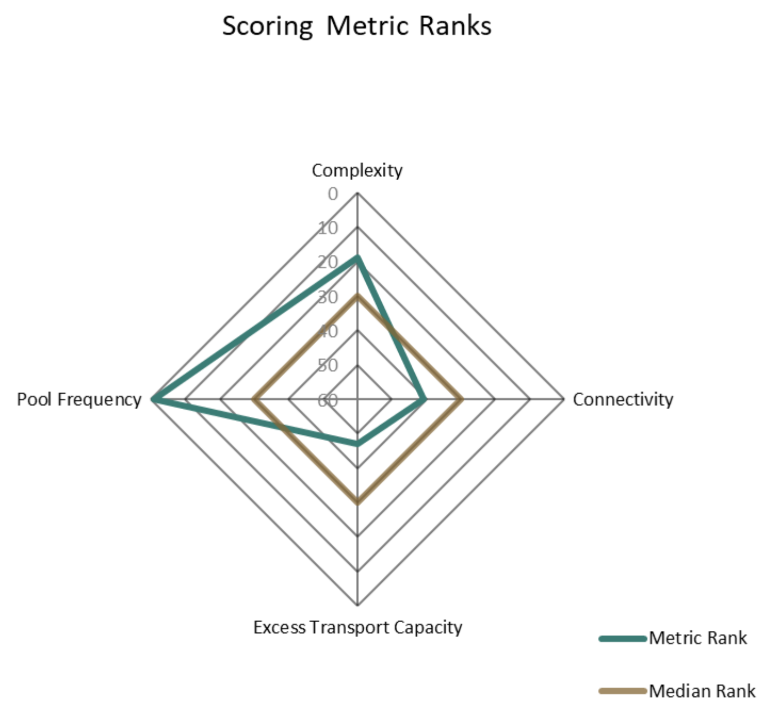
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 42 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

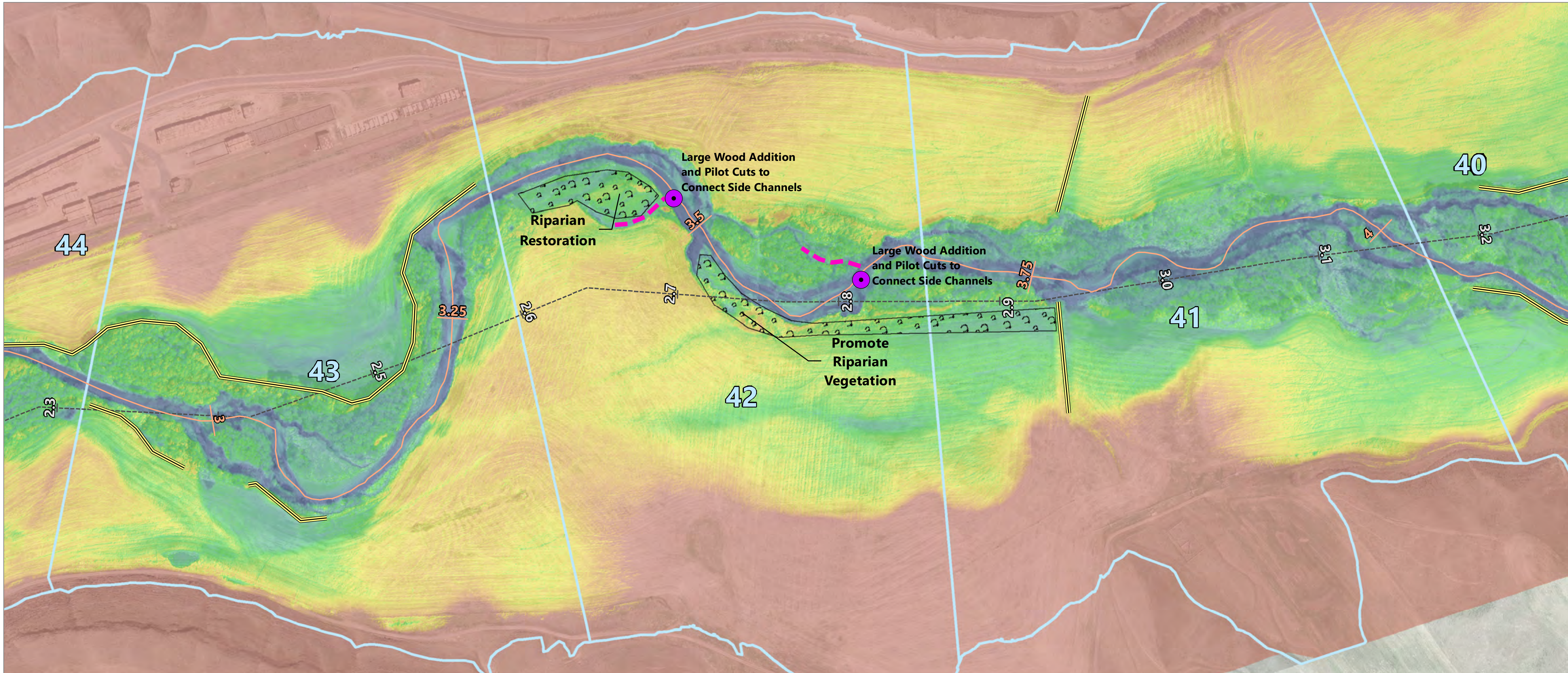
PA 42 Scoring Metric Ranks

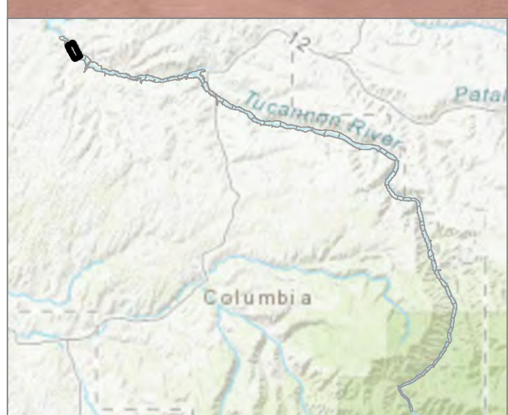


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 42 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.320	7	40%	Complexity	0.313	19	10% to 40%	2 of 5	3	40%	1.6	39	2	Untreated	24	2
Mean-Winter Flow Complexity	0.293	23	40%													
1-year Complexity	0.341	27	20%													
Channel Aggradation FP Potential	0.117	51	40%	Connectivity	0.156	41	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.064	33	40%													
Total FP Potential	0.418	20	20%													
Existing Connected FP	0.582	41	0%													
Excess Transport Capacity	-0.12	47	100%	Excess Transport Capacity	0.000	47	52% to 100%	4 of 4	0	20%						
Pool Frequency	38.95	1	100%	Pool Frequency	1.000	1	1% to 10%	1 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 3.35
RIVER MILE END: 3.68
VALLEY MILE START: 2.6
VALLEY MILE END: 2.85

0 500
Feet

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Filepath: \\orcas\gis\Jobs\TucannonRiver_1006\Maps\Conceptual Maps\Tucannon Untreated Project Areas_mg.mxd

ANCHOR QEA

Project Area 42
Conceptual Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 43 Description

Project Area 43 begins at VM 2.32 and extends upstream to VM 2.60. The 2017 RM length is 0.43 mile. Field observations for PA 43 were conducted on October 10, 2018, when flow at the Starbuck gage was approximately 115 cfs.

At the upstream end of the reach, the channel is flowing directly into the right bank levee, which is protecting a very low cultivated field. Several trees have fallen in at this location and the landowner reports water flooding this area regularly. This field is protected by an inconsistent levee already behind a buffer of vegetation on the right bank. Throughout this area on the left bank, the channel borders exposed agricultural fields with little to no riparian vegetation.

Just downstream and still behind the levee, the channel becomes extremely complex, beginning with a channel-spanning log jam at VM 2.56. Multiple low-flow paths travel through the trees. A large amount of woody material and abundant transportable material have caused dynamic geomorphic conditions and channel planforms.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows significant geomorphic changes occurring throughout the reach. At the very upstream end, significant bank erosion is occurring on the outer edge of a meander bend, with associated bar building deposition on the inside of

Project Area 43
Looking downstream at a recent avulsion area with multiple areas of channel-spanning woody material. This section of PA 43 was extremely complex at the time of the site visit.

Project Area 43 Reach Characteristics

VM Start (mi)	2.32
VM Length (mi)	0.28
Valley Slope	0.79%
RM Start (mi)	2.92
RM Length (mi)	0.43
Average Channel Slope	0.51%
Sinuosity	1.52
Connected FP (ac/VM)	34.58
Encroachment Removal (ac/VM)	22.40
Channel Aggradation (ac/VM)	33.06
Total FP Potential (ac/VM)	63.40
Encroaching Feature Length (ft)	300.57
Connected FP Rank	2

the bend. This area was pointed out to Anchor QEA field staff as a location of concern by the landowner (box 1).

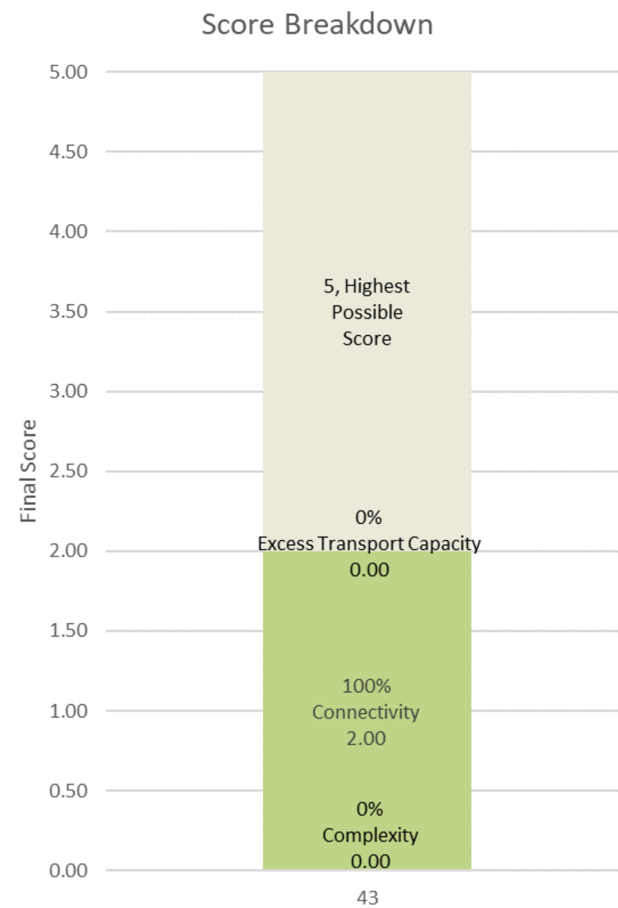
Shortly downstream of here and occupying the majority of the remainder of the reach, a large debris and log jam has caused significant geomorphic changes. The changes begin with sediment deposition over a large right bank bar. Further downstream, the debris jam has caused a channel avulsion and split flow through the forested floodplain creating multiple complex flow channels, which are apparent as erosional areas in the change analysis (box 2).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 43 receives its entire score in the Complexity metric. This project area has the highest possible score and ranks in the top tier of project areas in the 75th to 100th percentile range. This high score is driven almost entirely by the Encroachment Removal analysis result, which ranks PA 43 near the top of project areas in the assessment, while Channel Aggradation potential ranks near the bottom, although the Total Floodplain Potential analysis result indicates there may be some benefit to targeting both.

This potential area is located entirely in the bordering agricultural fields behind established levees and may not be accessible for restoration efforts. Should these areas become available for restoration activities, the primary restoration

PA 43 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

strategy should be to remove or breach the levees disconnecting these areas and add instream wood to promote geomorphic change into these areas. Pilot channel cuts could be considered as an additional restoration strategy to potentially access this area more quickly and add some immediate benefit to complexity. It should be noted that because these areas are currently agricultural fields, riparian vegetation enhancement will be a necessary restoration strategy in this reach to ensure a well-vegetated floodplain.

PA 43 receives no score in the Complexity metric because this project area ranks among the highest in the 90th to 100th percentile of all project areas for Complexity. While this range has been identified as complex enough to no longer require restoration, the addition of instream wood and the expansion of the floodplain will likely help create even more complexity in this reach.

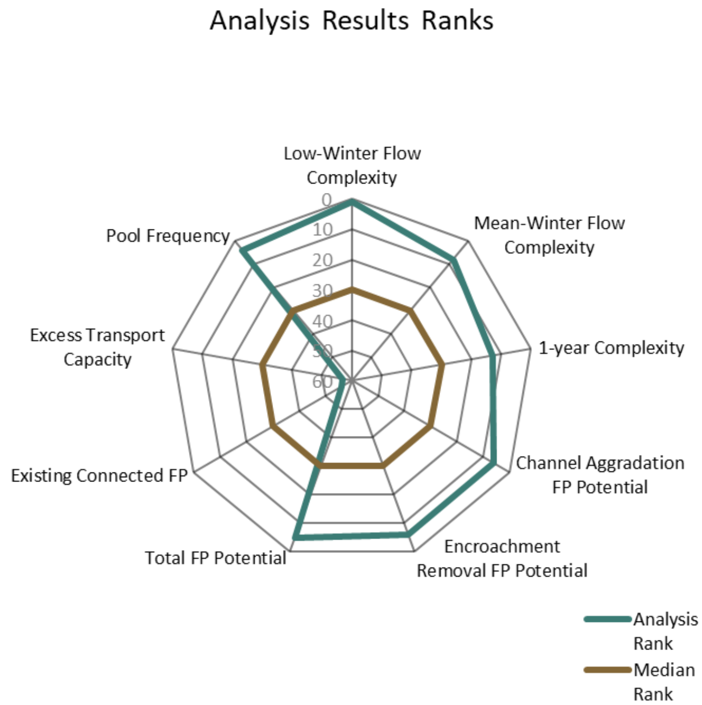
PA 43 also receives no score in Excess Transport Capacity, indicating it should trap and store sediment easily. While gravel augmentation is not currently necessary, it may be possible that this reach is part of a larger gravel augmentation plan for several reaches in the area, in which case the extra material will likely only serve to add some slight complexity and connectivity.

Finally, PA 43 ranks very highly in the Pool Frequency metric, indicating a high amount of pools per river mile. The restoration strategy of adding instream structure and wood should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

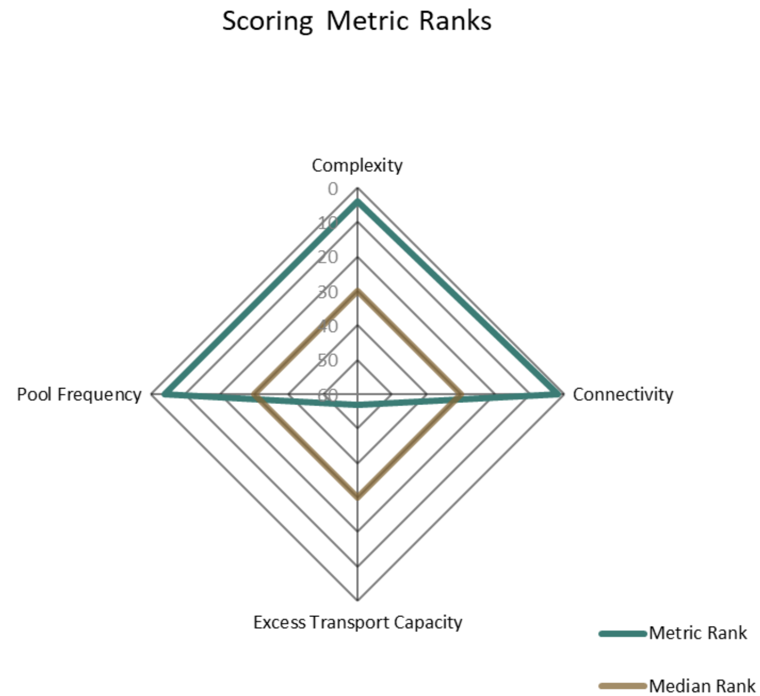
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)

PA 43 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

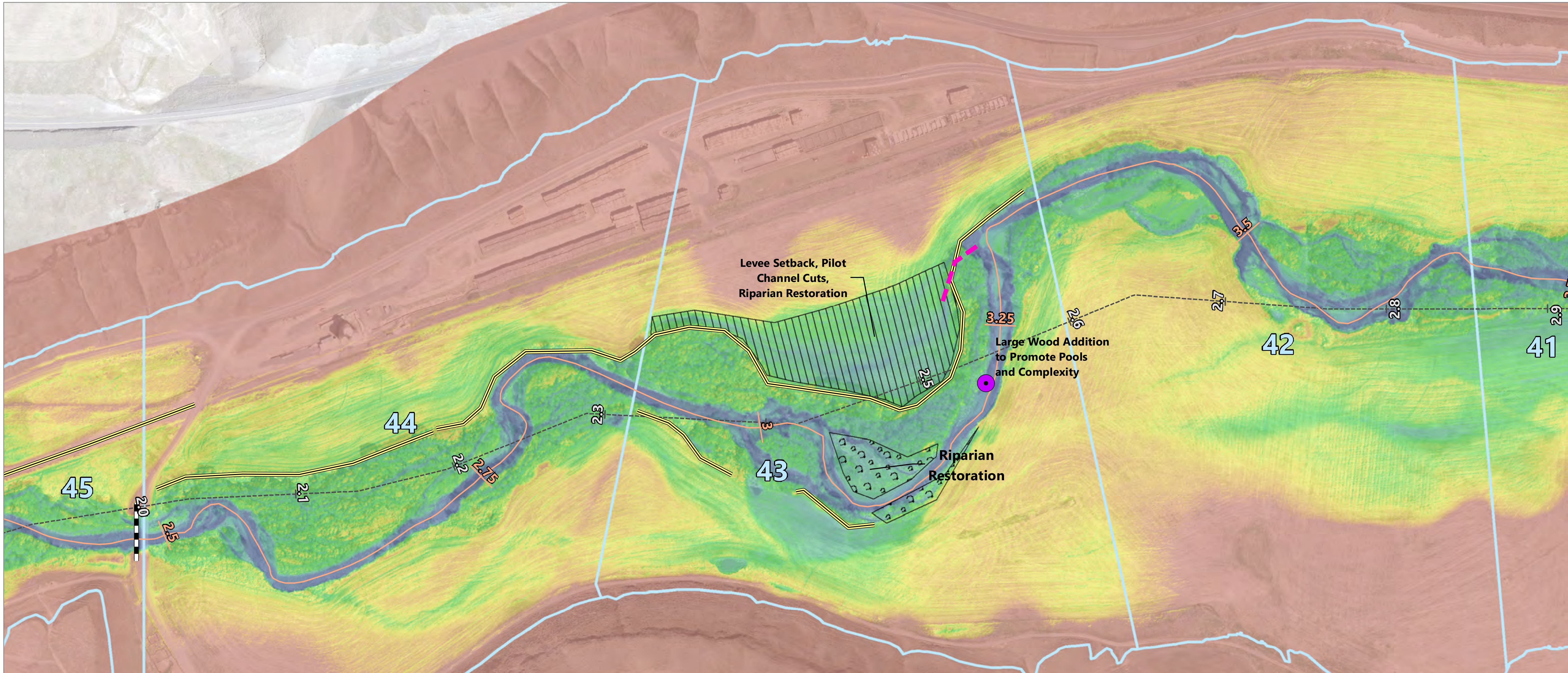
PA 43 Scoring Metric Ranks

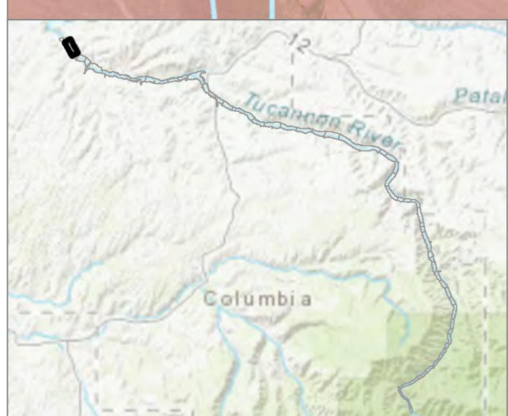


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 43 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.449	1	40%	Complexity	0.468	4	1% to 10%	1 of 5	0	40%	2.0	30	2	Untreated	20	2
Mean-Winter Flow Complexity	0.473	8	40%													
1-year Complexity	0.495	13	20%													
Channel Aggradation FP Potential	0.337	6	40%	Connectivity	0.356	2	1% to 25%	1 of 4	5	40%						
Encroachment Removal FP Potential	0.229	6	40%													
Total FP Potential	0.647	5	20%													
Existing Connected FP	0.353	56	0%													
Excess Transport Capacity	-0.21	57	100%	Excess Transport Capacity	0.000	57	52% to 100%	4 of 4	0	20%						
Pool Frequency	30.32	4	100%	Pool Frequency	0.778	4	1% to 10%	1 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 2.92
RIVER MILE END: 3.35
VALLEY MILE START: 2.32
VALLEY MILE END: 2.6

0 500
Feet

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ANCHOR QEA

Project Area 43
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

APPENDIX J.2
TIER 3: UNTREATED PROJECT AREAS

Project Area 1.2 Description

Project Area 1.2 begins at VM 43.66 and extends upstream to VM 44.02. The 2017 RM length is 0.39 mile. Field observations for PA 1.2 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

For this assessment update, PA 1 as defined in the 2011 prioritization was separated into two project areas (PA 1.1 and PA 1.2) for distinct analysis. In 2014, PA 1.1 was the subject of a restoration project, while PA 1.2 has remained untreated.

The channel through PA 1.2 is characterized as a single-thread, plane-bed channel with local rapid sections. This project area is located in a relatively steep, narrow section of the valley. In the 2011 assessment, several minor side channels were observed during site reconnaissance, although many of these features are likely dry during the low-flow period.

The quality of instream habitat was limited by the lack of hydraulic and bedform complexity in the channel. Very few key logs were observed, so pools and instream cover were generally limited to the locations of man-made structures and small side channels. Overall, woody debris retention and temporary sediment storage was low.

In 2011, floodplain connectivity appeared to be unaffected by infrastructure, although remnant alluvial fan and hillslope

Project Area 1.2
Looking upstream at the end of the side channel that marks the delineation between PA 1.1 and PA 1.2. PA 1.2 has more sections that are single-thread, plane-bed channels as shown here.

Project Area 1.2 Reach Characteristics

VM Start (mi)	43.66
VM Length (mi)	0.36
Valley Slope	1.62%
RM Start (mi)	49.24
RM Length (mi)	0.39
Average Channel Slope	1.47%
Sinuosity	1.09
Connected FP (ac/VM)	6.29
Encroachment Removal (ac/VM)	1.09
Channel Aggradation (ac/VM)	1.13
Total FP Potential (ac/VM)	3.46
Encroaching Feature Length (ft)	493.83
Connected FP Rank	60

deposits have created moderately high surfaces that restrict the area of the low floodplain throughout much of the project area. Small sections of remnant levees and sections of riprap were located in a few places; however, the influence of these features to natural processes appeared to be minor.

The riparian zone was generally in a moderately healthy condition, with local areas that had been degraded by recreational use, development, and fire.

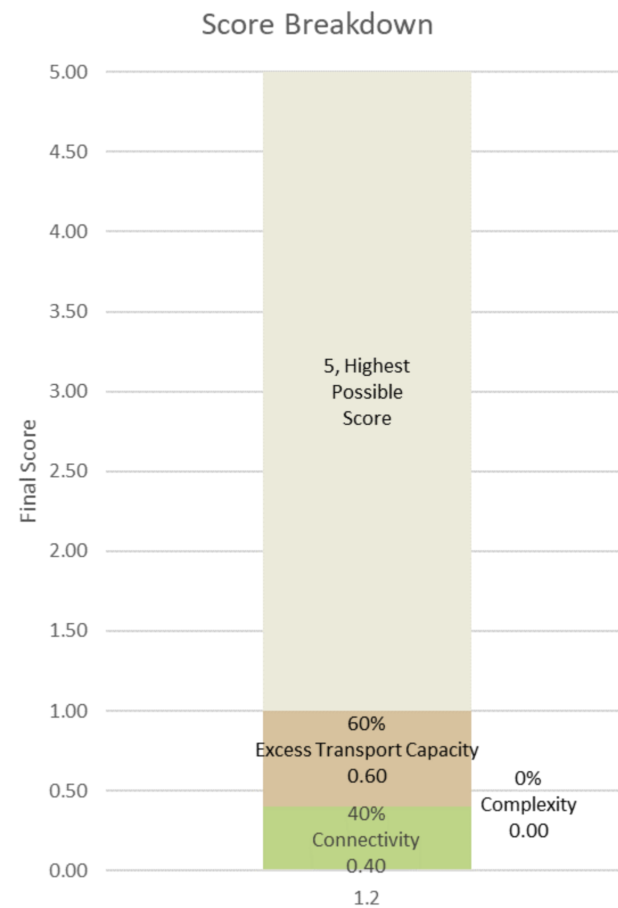
Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows very little geomorphic change has occurred in PA 1.2 since 2011. The only notable location of change is a small area of deposition on a right bank bar near the upstream end of the project area (box 1). Some minor areas of deposition and erosion occur periodically throughout the reach but are not worth noting.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 1.2 receives a low score in the Connectivity metric and a moderate score in the Excess Transport Capacity metric, which combine to make the entire prioritization score for PA 1.2. The low Connectivity score indicates that PA 1.2 ranks below average in the 25th to 50th percentile for project areas in the assessment. This

PA 1.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

Connectivity score is driven almost entirely by encroachment removal potential, which is located in several disconnected side channels on the left bank floodplain of the reach. The primary restoration strategy for this reach should be to reconnect these disconnected side channels through pilot channel cuts and the addition of instream wood to promote geomorphic change into these areas.

This project area scores near the bottom in the 10th percentile for the Complexity metric, a range which has been identified as typically having complexity that is too poor to target in restoration efforts. However, this analysis does not account for the fact that reconnecting the disconnected floodplain would greatly improve the opportunities for improving complexity. Pilot channel cuts for floodplain reconnection are a primary restoration strategy, and targeting a lower flow for reconnection, along with the addition of instream wood to promote geomorphic change throughout the reach, should greatly increase the complexity throughout this reach with minimal added effort.

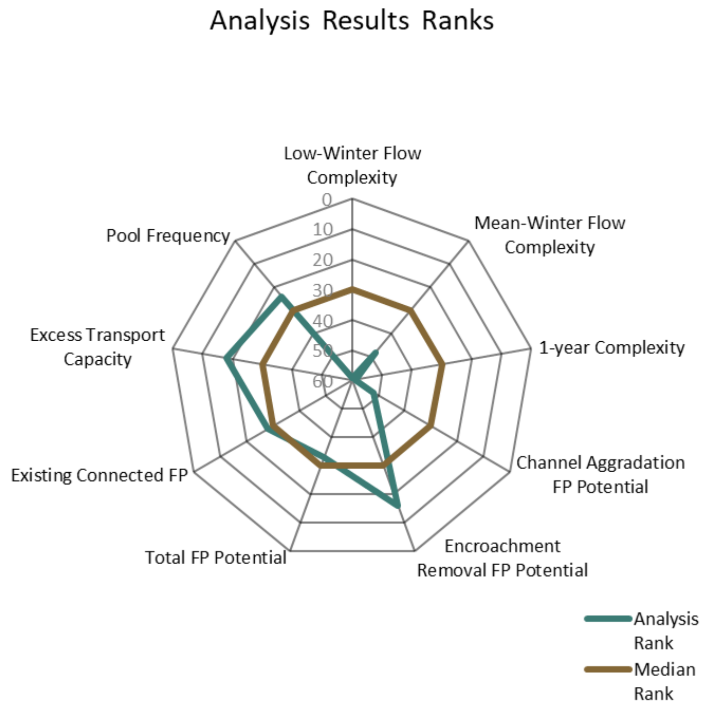
PA 1.1 has had little change since 2011 and appears to be resistant to geomorphic change, which is likely due to large bed sediment size and a lack of transportable material. Gravel augmentation should also be considered as a primary restoration strategy for this reach, to help promote geomorphic change into the disconnected floodplain areas and improve in-channel complexity. However, this reach receives a moderate score in the Excess Transport Capacity metric, indicating that added sediment could be quickly flushed out of the system without adequate instream wood to store and retain the sediment. The addition of instream wood should be dense and aggressive in this reach to induce the most geomorphic change from gravel augmentation. Opening the floodplain should also decrease this excess amount of transport capacity.

Finally, PA 1.2 ranks above average in the Pool Frequency metric, indicating a higher amount of pools per river mile. The restoration strategy of adding instream wood and gravel augmentation should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

Summary of Restoration Opportunities Identified

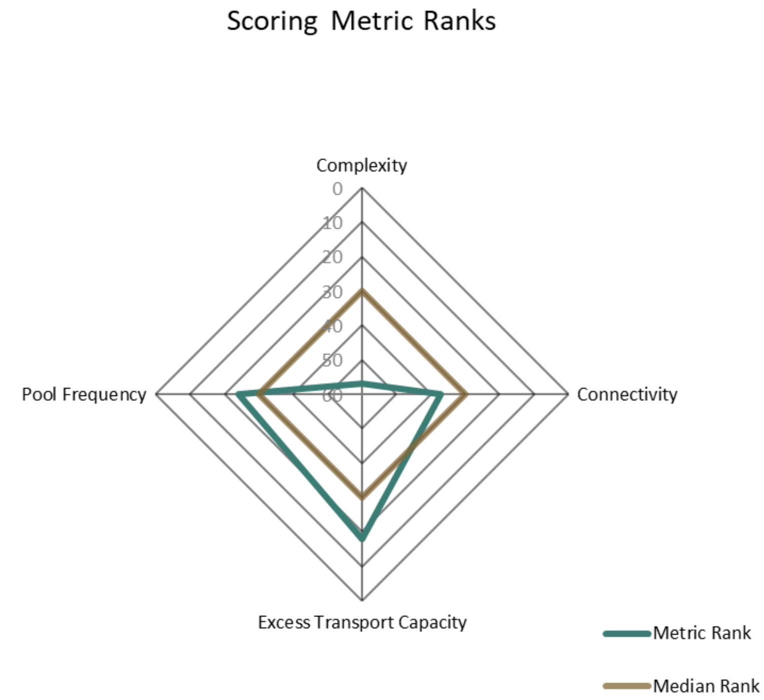
- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)

PA 1.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

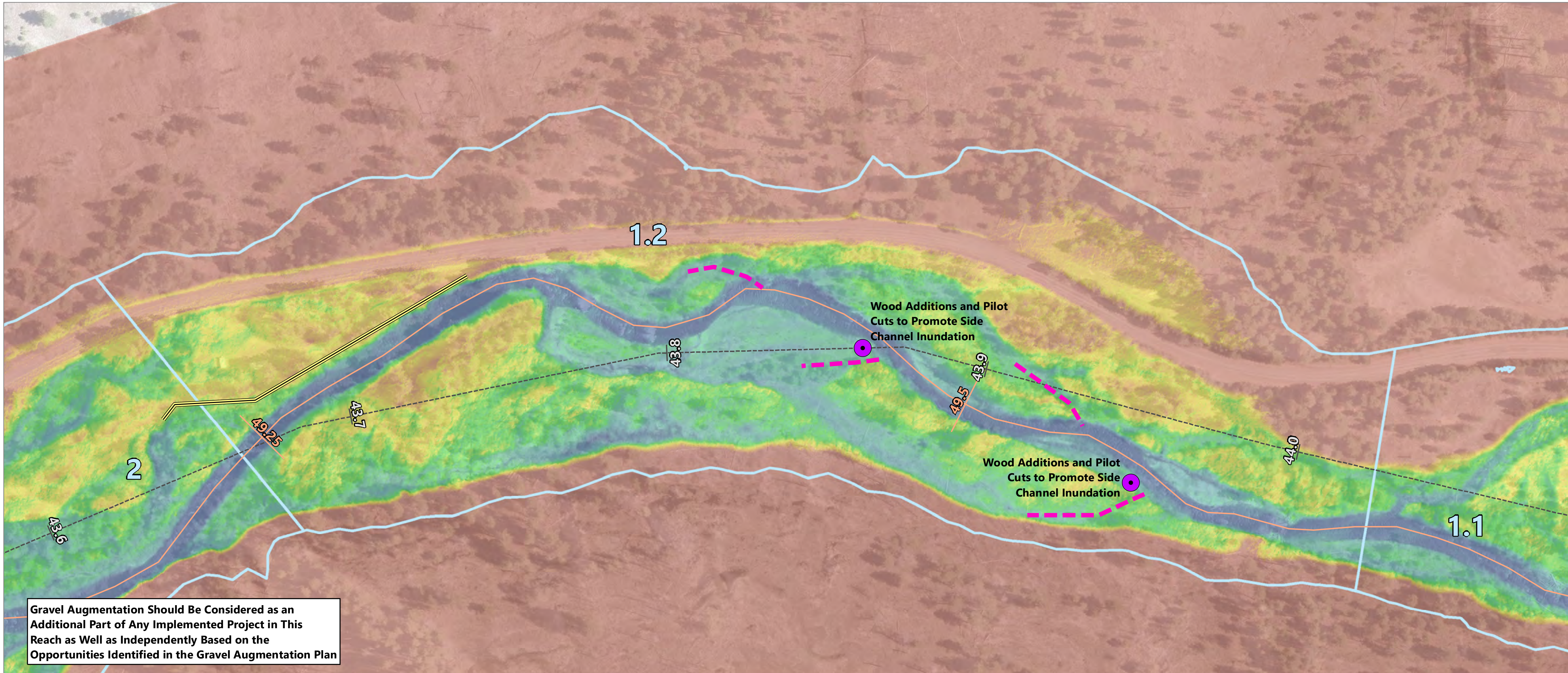
PA 1.2 Scoring Metric Ranks



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 1.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.071	59	40%	Complexity	0.093	57	90% to 100%	5 of 5	0	40%	1.0	49	3	Untreated	29	3
Mean-Winter Flow Complexity	0.126	48	40%													
1-year Complexity	0.071	59	20%													
Channel Aggradation FP Potential	0.116	52	40%	Connectivity	0.162	37	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.112	16	40%													
Total FP Potential	0.354	33	20%													
Existing Connected FP	0.646	28	0%													
Excess Transport Capacity	0.13	18	100%	Excess Transport Capacity	3.000	18	10% to 30%	2 of 4	3	20%						
Pool Frequency	12.75	24	100%	Pool Frequency	0.327	24	10% to 40%	2 of 5	3	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Side Channel

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 49.24
RIVER MILE END: 49.63
VALLEY MILE START: 43.66
VALLEY MILE END: 44.02

0 500
Feet

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ANCHOR QEA

Project Area 1.2
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 4 Description

Project Area 4 begins at VM 41.23 and extends upstream to VM 41.44. The 2017 RM length is 0.24 mile. Field observations for PA 4 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

The river and floodplain in PA 4 are highly confined between a levee and the road grade, which has resulted in a single-thread, high-velocity channel with large armor substrate and angular riprap banks. The levee on the right bank currently serves as an access road to the upstream side of the Camp Wooten facilities, including Donnie Lake.

The 2011 assessment noted that the quality of instream habitat in this project area was limited by the lack of hydraulic and bedform complexity in the channel. Although a few trees were observed in the channel, the high-velocity conditions likely prevent any retention of mobile debris or sediment deposition, and these trees were likely to be transported downstream during the next high-flow event.

Floodplain connectivity was greatly limited by the right bank road levee, which confined the channel to the left side of the valley and cut off a majority of the floodplain to the right. A large amount of low floodplain area and low-lying channel paths existed within the cutoff portion of the floodplain. One of these channels originated on the downstream side of the levee

Project Area 4
Looking upstream at PA 4 from the top of PA 5. The channel is straight, uniform, and tightly confined by the right bank levee.

Project Area 4 Reach Characteristics

VM Start (mi)	41.23
VM Length (mi)	0.21
Valley Slope	1.48%
RM Start (mi)	46.55
RM Length (mi)	0.24
Average Channel Slope	1.30%
Sinuosity	1.11
Connected FP (ac/VM)	11.00
Encroachment Removal (ac/VM)	0.92
Channel Aggradation (ac/VM)	1.70
Total FP Potential (ac/VM)	3.06
Encroaching Feature Length (ft)	1,340.82
Connected FP Rank	42

and flowed through the camp on the southeast side of the valley. During the 2011 assessment, the channel was dry at the upstream end and became wetted where a tributary meets the main valley; this tributary may be spring-fed, although it was unclear if the flow is perennial due to the unusually wet conditions at the time of observation.

The riparian zone was generally in a moderately healthy condition, where it had not been cleared or disturbed for development of the Camp Wooten site and for other recreational use. Riparian trees were predominantly immature deciduous trees, with very few mature or coniferous trees in the area. The riparian zone narrowed to approximately 5 to 10 feet wide and vegetation was limited with little overhang. In the overall project area, species were moderately diverse.

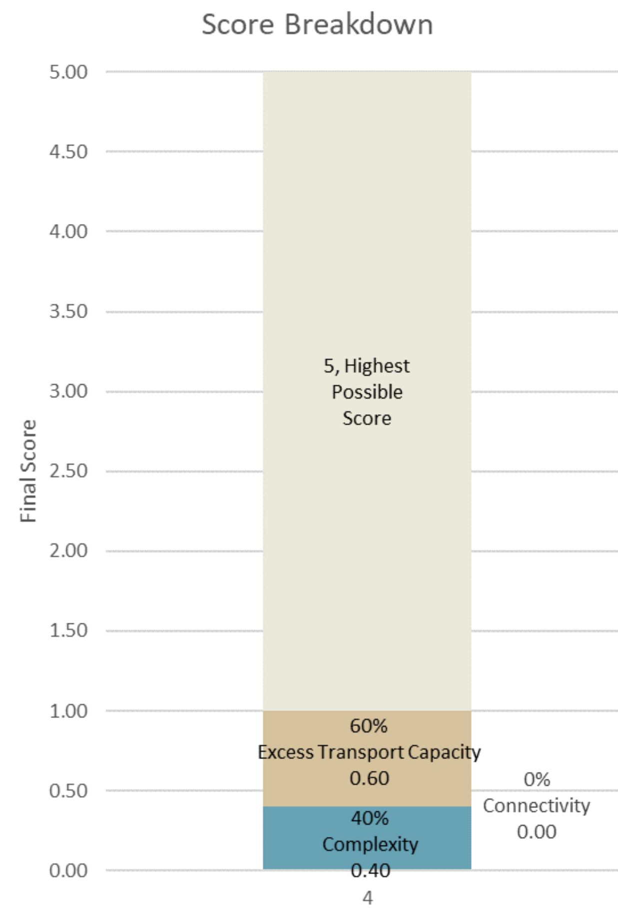
Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows very little geomorphic change over the entire reach. This reach is highly confined and leveed making geomorphic change difficult. The only notable change occurs near the upstream end of the reach, where deposition has occurred on a right bank bar (box 1).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 4 receives the majority of its score from the highest possible score in the

PA 4 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

Excess Transport Capacity metric. PA 4 also receives a low score in the Complexity metric, which indicates that the reach ranks low among project areas in the 10th to 40th percentile. This range has been identified as having a small amount of existing complexity but would likely require a large restoration effort to achieve higher levels. This is especially true of PA 4, which is highly confined by the valley wall on the left bank and a levee on the right bank. The analysis results show that the actual complexity values are nearly constant across all three flows, although this appears as a decrease in rank in the following graphs because most project areas increase from the low to winter flows. Some small amount of instream complexity may be gained with the addition of instream wood and should be the primary restoration strategy for this reach.

It is unlikely that the levee in this reach will be removed or set back in the foreseeable future due to the infrastructure behind it. However, should the opportunity ever become available, the reach would see the most possible benefit from setting back or removing this levee, and providing more riparian area for the channel to establish complexity and connectivity. If the levee were removed or set back, restoration strategies should be to aggressively add instream wood and promote channel aggradation through gravel augmentation.

On the right bank near the upstream end of the project area and on the river side of the levee, the small spring channel noted in the 2011 field assessment presents some opportunity for connection. Improving the floodplain connection and side channels in this area to capture the spring as an off-channel cold water input should also be considered as a restoration strategy in this reach.

PA 4 is tied for the worst ranking in the Pool Frequency metric, with no pools found with this assessment. Pools are transient and this may not always be the case, but the highly confined and uniform nature of this reach makes the lack of pools an expected condition. Until the levee is removed or set back, it is unlikely this reach will ever have decent pool frequency. However, some pools may be promoted through the addition of instream wood in the main channel.

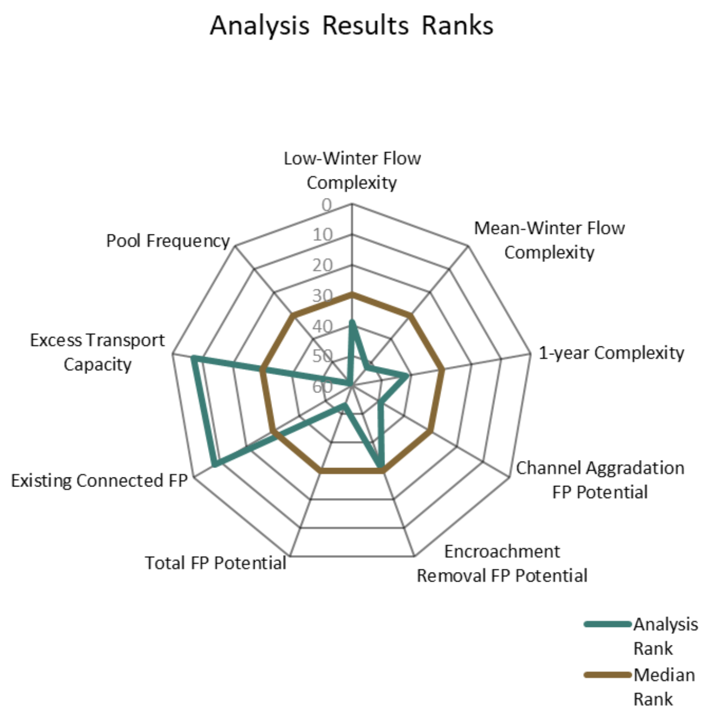
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)

Long-Term Opportunities in this Project Area

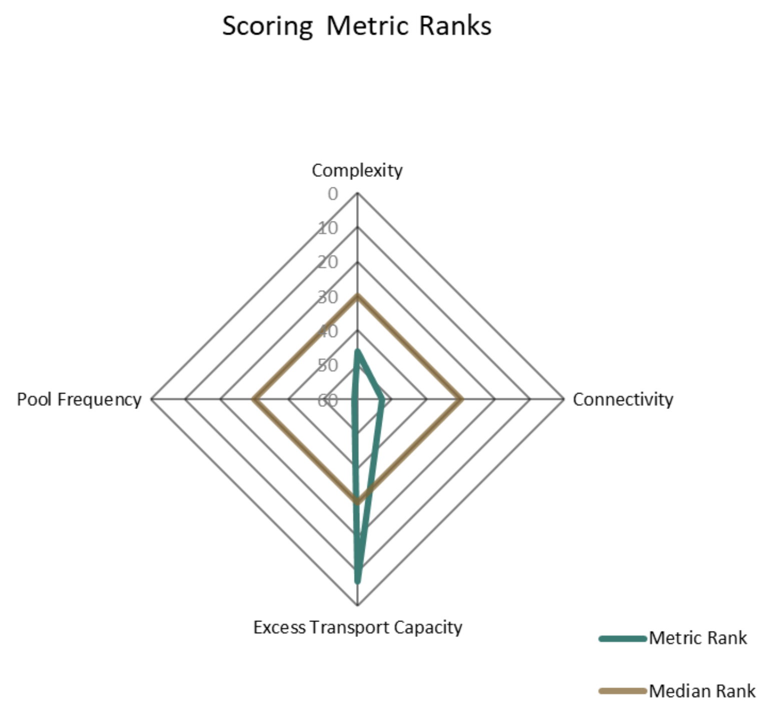
- Set back Camp Wooten road to expand floodplain.
- Relocate bridge to Camp Wooten to confined reach and remove the bridge downstream.

PA 4 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

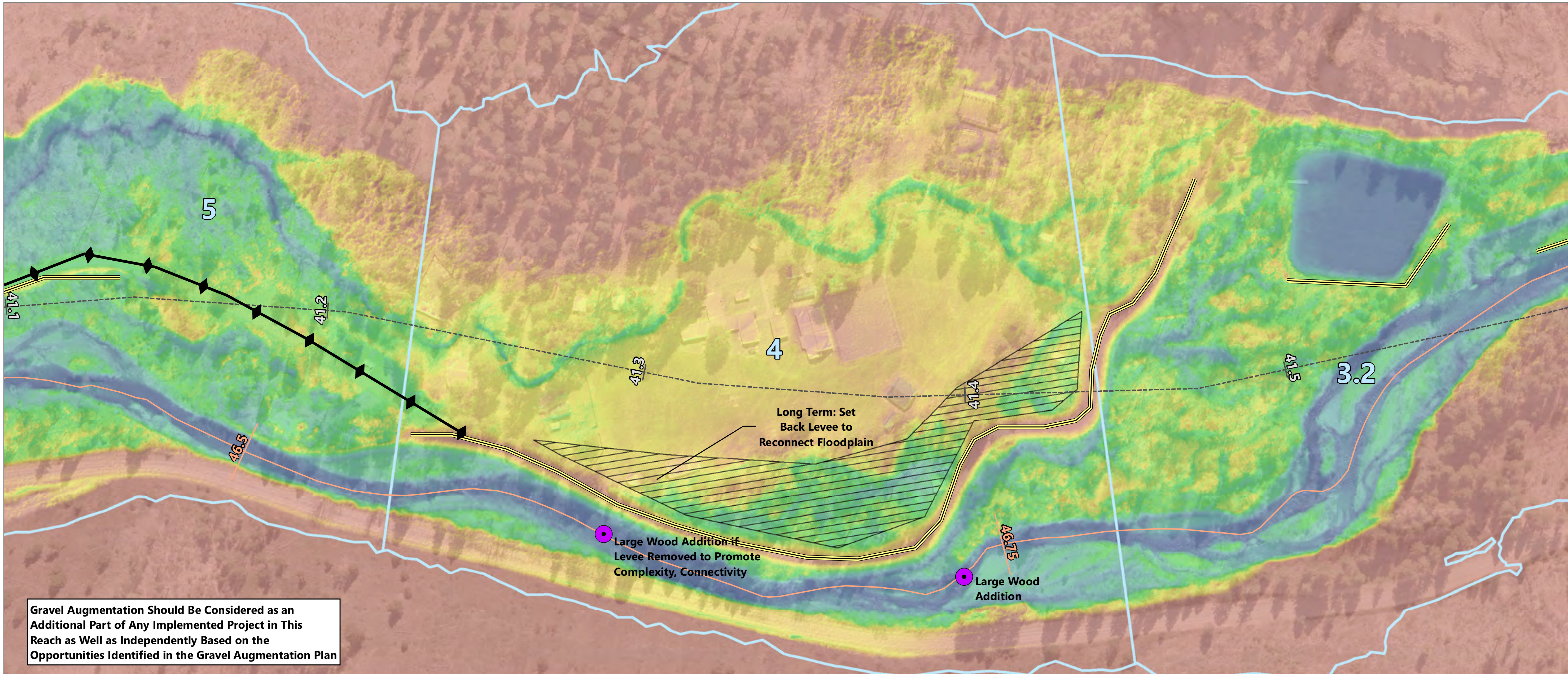
PA 4 Scoring Metric Ranks

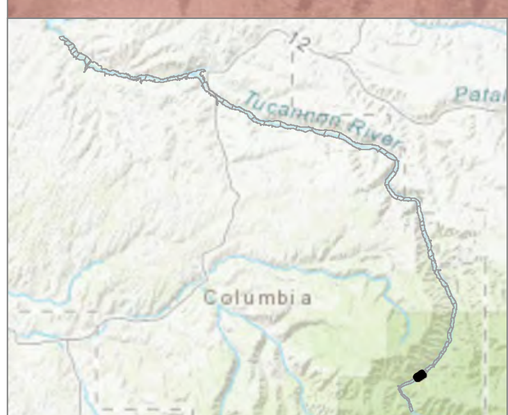


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 4 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.124	39	40%	Complexity	0.135	46	60% to 90%	4 of 5	1	40%	1.0	50	3	Untreated	30	3
Mean-Winter Flow Complexity	0.114	52	40%													
1-year Complexity	0.201	42	20%													
Channel Aggradation FP Potential	0.121	49	40%	Connectivity	0.118	53	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.065	31	40%													
Total FP Potential	0.218	53	20%													
Existing Connected FP	0.782	8	0%													
Excess Transport Capacity	0.22	7	100%	Excess Transport Capacity	3.000	7	10% to 30%	2 of 4	3	20%						
Pool Frequency	0.00	59	100%	Pool Frequency	0.000	59	90% to 100%	5 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential
- Long Term: Relocate Road

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 46.55
RIVER MILE END: 46.79
VALLEY MILE START: 41.23
VALLEY MILE END: 41.44

0 500
Feet

Publish Date: 2021/01/25, 3:43 PM | User: mgieschen
Filepath: \\orcas\gis\Jobs\TucannonRiver_1006\Maps\Conceptual Maps\Tucannon Untreated Project Areas_mg.mxd

ANCHOR QEA

Project Area 4
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 7 Description

Project Area 7 begins at VM 39.74 and extends upstream to VM 40.16. The 2017 RM length is 0.45 mile. Field observations for PA 7 were conducted on October 11, 2018, when flow at the Starbuck gage was approximately 100 cfs.

PA 7 is just upstream of Curl Lake, which is part of the Tucannon Hatchery program infrastructure. The upper part of the reach is closely confined on the left bank by Tucannon Road, which is often protected with large riprap. On the right bank, the upper part of the reach is confined by the valley wall and a high bank upland area, which may possibly be an abandoned floodplain terrace but is now 6 to 10 feet above the channel with some low areas only 4 feet above the channel. Riparian vegetation on this terrace and through much of the floodplain is dominated by conifers and upland vegetation. At the downstream end of this terrace, a low area along the wall is filled with large cut logs and other woody debris. This area may be inundated during high flows but does not likely receive any flow.

At approximately VM 39.83, a large diversion structure spans the main channel to supply water to Curl Lake downstream. A large log jam has been built on the right bank opposite the diversion structure, possibly to create additional head for the diversion as well as provide some marginal habitat. Downstream, several more large log jam structures were observed in the last quarter mile of PA 7, built as part of the

Project Area 7
Looking downstream at PA 7, which is a straight, confined channel largely disconnected from the riparian area with upland vegetation, but with some instream wood and geomorphic planforms.

Project Area 7 Reach Characteristics

VM Start (mi)	39.74
VM Length (mi)	0.42
Valley Slope	1.51%
RM Start (mi)	44.90
RM Length (mi)	0.45
Average Channel Slope	1.38%
Sinuosity	1.07
Connected FP (ac/VM)	9.03
Encroachment Removal (ac/VM)	1.12
Channel Aggradation (ac/VM)	1.11
Total FP Potential (ac/VM)	3.50
Encroaching Feature Length (ft)	1,061.49
Connected FP Rank	53

restoration project done on PA 8. These structures are interacting with flow and providing habitat, with some better channel complexity but with limited deep pools.

Near the same location of this diversion structure, the channel moves away from the road on the left bank and a large, low-lying area is partially leveed off in a pocket upstream of Curl Lake. It appears that there has been some floodplain manipulation in this area and it is possible that this area may have served some purpose for the operation of Curl Lake. However, at the time of the site visit, this area had good riparian vegetation growth and seemed to be a good opportunity for floodplain reconnection.

Throughout the whole reach, bed material is relatively large, with few patches of more easily transportable gravel material. In addition to the engineered log jams near the downstream end of the project area, some instream wood was observed. However, given the lack of gravel material and the low amount of instream wood, this is not enough to cause significant geomorphic complexity or planform variation in a reach that is for the most part extremely confined and disconnected from the floodplain.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows very little change has occurred in PA 7 since the previous assessment. PA 7 is highly confined by levees and the valley wall, which makes geomorphic change difficult. The one location highlighted for discussion occurs near the middle of the reach. A log jam has caused mid-channel deposition forming a bar and split flow, along with erosion on the left bank, where field observations noted a steep bank and deep pool (box 1).

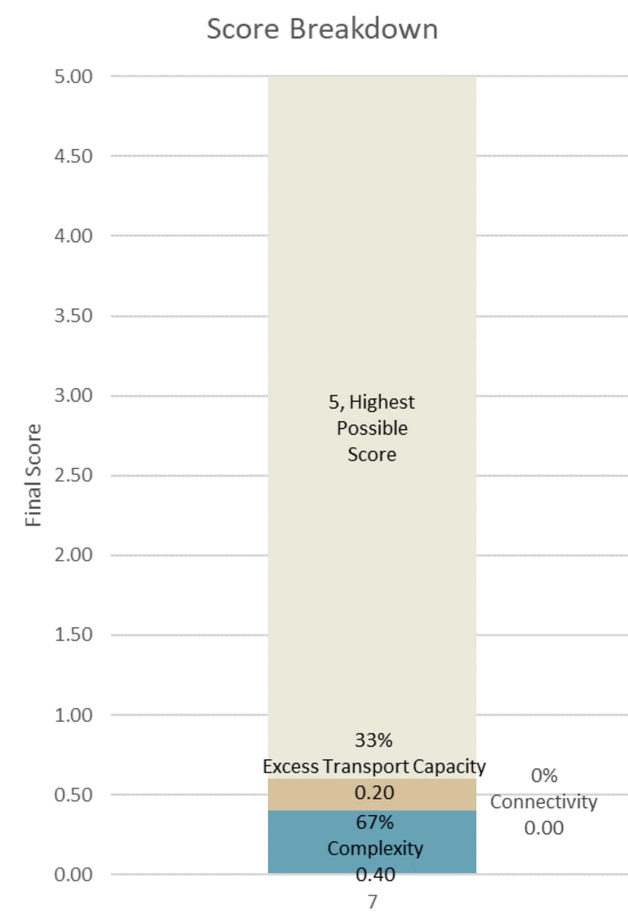
Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 7 receives the majority of its score from a moderate score in the Excess Transport Capacity metric. PA 4 also receives a low score in the Complexity metric, which indicates that the reach ranks low among project areas in the 10th to 40th percentile. This range has been identified as having some small existing complexity but would likely require a large restoration effort to achieve higher levels. This is especially true of PA 7, which is highly confined by the valley wall on the right bank and the road and high bank on the left bank. The analysis results show that the actual complexity values are nearly constant across all three flows with a slightly higher rank in the mean-winter flow than both the 1-year and low-winter flow complexity analysis results. At the upstream end of the reach, very little opportunity for complexity exists, but several lower flow paths are evident on the relative elevation map near mid-reach on the right bank and at the downstream end on the left bank. However, between these two areas, the infrastructure for the intake for Curl Lake ties the river to its current location. The primary restoration strategy for this reach, as it is now, should be to add instream wood to promote channel complexity and create pilot channel cuts where possible.

Gravel augmentation should also be considered in this reach to promote more in-channel complexity and geomorphic responses to the addition of instream wood, although the intake for Curl Lake may make this more difficult. Because this reach receives a moderate score in the Excess Transport Capacity metric, a large amount of instream wood should be added to ensure gravel material is not washed out of the reach immediately.

This reach is highly confined by the road and levee on the left bank, and the relative elevation map shows there is a large amount of low-lying floodplain on the opposite side of this infrastructure. It is unlikely that this road and levee will be removed at any point in the foreseeable future, so until then the identified restoration strategies noted earlier should be the primary focus for this reach. However, should the opportunity arise to set the road back against the valley wall and remove the levee, these opportunities would provide the most possible benefit to the reach by allowing more connectivity and room for complexity. If the road and levee were moved, the restoration strategies should be to aggressively add instream wood and promote channel aggradation through gravel augmentation. Expanding the floodplain and reversing incision

PA 7 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

would drastically reduce the excess amount of transport capacity in this reach.

Finally, PA 7 ranks around average in the Pool Frequency metric, indicating a moderate amount of pools per river mile. The identified restoration strategy of adding instream wood and gravel augmentation should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be promoted with the natural processes of the reach.

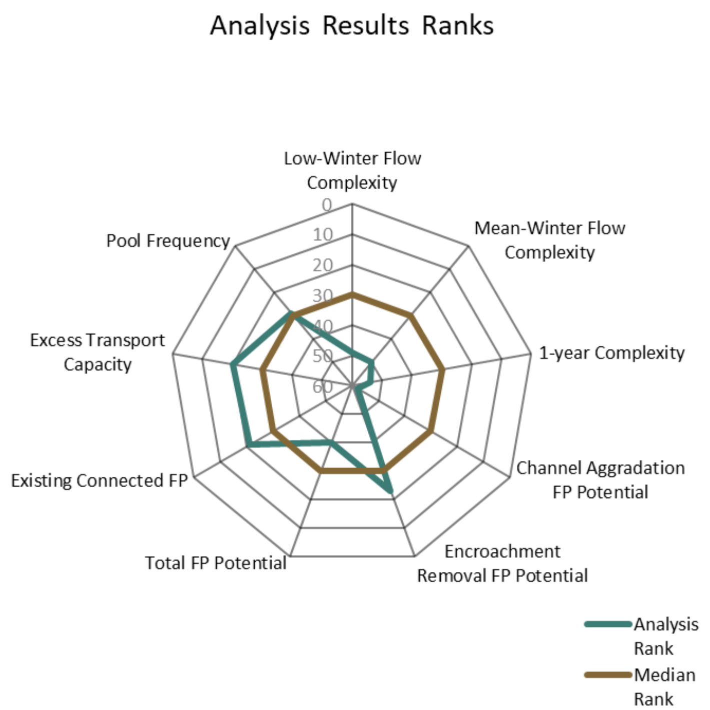
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Modify or remove obstructions

Long-Term Opportunities in this Project Area

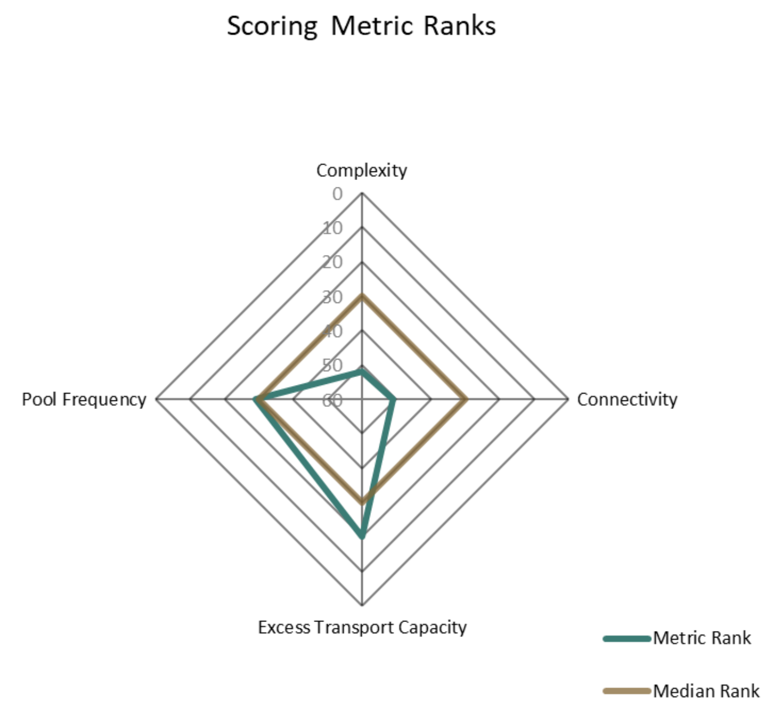
- Set back road against left valley wall for more floodplain connection and channel migration area.

PA 7 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

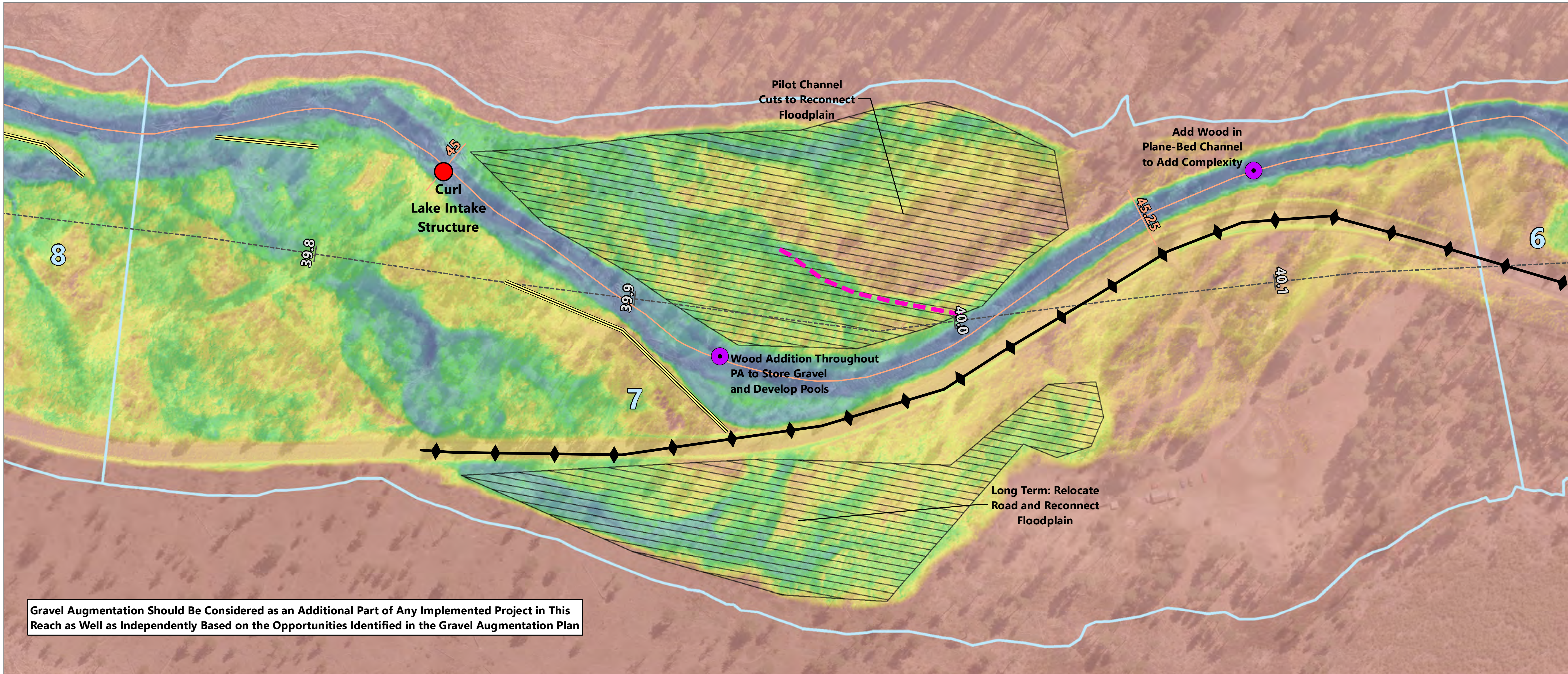
PA 7 Scoring Metric Ranks

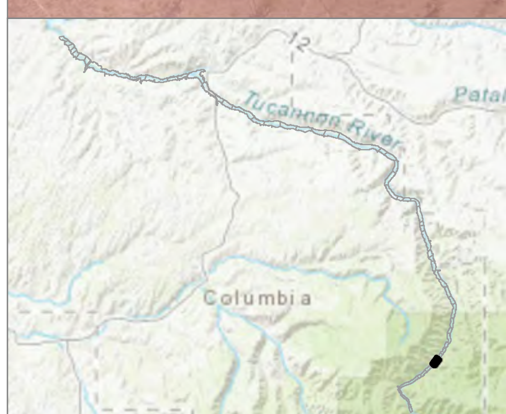


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 7 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.095	49	40%	Complexity	0.104	52	60% to 90%	4 of 5	1	40%	0.6	55	3	Untreated	34	3
Mean-Winter Flow Complexity	0.119	50	40%													
1-year Complexity	0.095	54	20%													
Channel Aggradation FP Potential	0.088	58	40%	Connectivity	0.127	51	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.090	23	40%													
Total FP Potential	0.279	40	20%													
Existing Connected FP	0.721	21	0%													
Excess Transport Capacity	0.11	20	100%	Excess Transport Capacity	1.000	20	30% to 52%	3 of 4	1	20%						
Pool Frequency	11.10	29	100%	Pool Frequency	0.285	29	40% to 60%	3 of 5	5	0%						





LEGEND:
- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Long Term: Relocate Road
- Current Infrastructure in River Corridor

Relative Elevation in Feet
High : 15
Low : -0

NOTES:
1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 44.9
RIVER MILE END: 45.35
VALLEY MILE START: 39.74
VALLEY MILE END: 40.16

0 500
Feet

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ANCHOR QEA

Project Area 7
Conceptual Restoration Opportunities
Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 12 Description

Project Area 12 begins at the Hatchery Dam at VM 35.48 and extends upstream to VM 36.00. The 2017 RM length is 0.65 mile. Field observations for PA 12 were conducted on October 31, 2018, when flow at the Starbuck gage was approximately 95 cfs.

Channel conditions for PA 12 are very similar to the conditions of the reach in 2011. The channel through PA 12 is relatively complex with many flow pathways through a relatively wide corridor; natural processes are occurring that are aiding in recovery through this area. No major infrastructure was observed within the channel, although the Hatchery Dam at the downstream end of the project area is a significant grade control. Several side channels were observed, a majority of which are initiated by LWD. An anabranching channel pattern is located mid-reach, where a significant side channel has cut through the floodplain along the left valley floor. This channel runs below a power line adjacent to the road through a grassy area. Another major side channel was conveying at least a third of the total discharge at the time of observation.

Several side channels are head cutting through the right bank floodplain and it is apparent that the entire floodplain has a large amount of groundwater flow. Some of these channels were hidden beneath deep canary reed grass, preventing other riparian vegetation from establishing.

Project Area 12
Looking downstream. The channel has highly complex flow, high wood loading, and floodplain inundation, but with little riparian vegetation.

Project Area 12 Reach Characteristics

VM Start (mi)	35.48
VM Length (mi)	0.52
Valley Slope	1.66%
RM Start (mi)	40.08
RM Length (mi)	0.65
Average Channel Slope	1.41%
Sinuosity	1.25
Connected FP (ac/VM)	18.24
Encroachment Removal (ac/VM)	1.01
Channel Aggradation (ac/VM)	5.58
Total FP Potential (ac/VM)	6.83
Encroaching Feature Length (ft)	1,675.76
Connected FP Rank	20

Instream habitat in PA 12 is currently limited but recovering. The project area contains a moderate amount of LWD that provides some amount of cover and initiates channel and hydraulic complexity. The reach is still in the process of recovering from the 2005 School Fire, but moderate vegetation growth has been established on many previously bare gravel bars and floodplain areas.

Bed material throughout the reach contains a large amount of fine material and gravel and is likely a direct result of the dam providing a grade control location at the downstream end of the reach.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows many significant changes have occurred in PA 12 since the last assessment. At the upstream end of the reach, deposition has occurred in a side channel and there no longer appears to be flow in this channel (box 1).

Several hundred feet from the upstream end of the reach, a large amount of deposition has occurred in the main channel, and the main flow path has shifted into the left bank floodplain, although the former main channel still has significant flow and this split continues for the remainder of the reach (box 2).

Complex multi-threaded flow extends from the right bank floodplain channel and there is some evidence of new channels forming with associated erosion in this location. Field observations noted several deep and dynamic channels through this area (box 3).

Further downstream in the main channel, where all but the main split flow has merged together, a log jam on the left bank has triggered some deposition and erosion on the opposite bank (box 4).

Just upstream of the confluence of the two main channels, a large log jam has caused significant erosion on the left bank and a large amount of deposition on the right bank. This deposition appears to be partially blocking a side channel through this area (box 5). At the actual confluence of the two main channels, deposition has caused several split flows and associated erosion (box 6).

Immediately downstream of here, a large amount of erosion has occurred on the alternating left and right bank and is associated with some deposition on the left bank as meander bends begin to form in this reach (box 7).

Finally, at the downstream end of the reach, a small drop has formed over a log jam with deep erosion here and large amounts of deposition on the right bank floodplain (box 8).

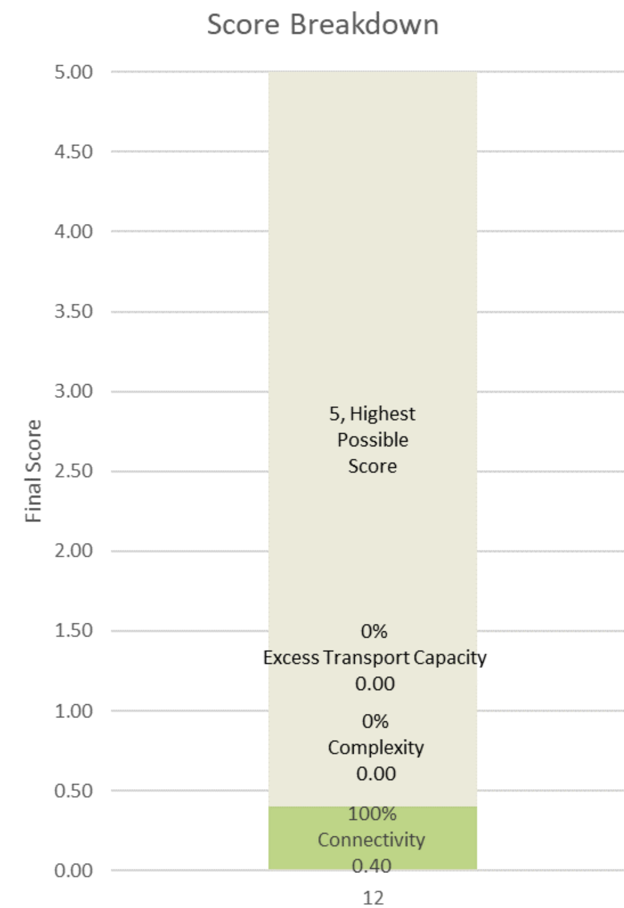
Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 12 receives its entire prioritization score from a low score in the Connectivity metric. This score indicates that PA 12 ranks below average in the 25th to 50th percentile of project areas for Connectivity. Most of this score is driven by the Channel Aggradation analysis result, which ranks PA 12 slightly above average. However, based on the GIS layer for connectivity, this potential area exists mostly in the areas immediately around the existing connected 2-year floodplain. In reality, PA 12 is already well connected. Because this project area is upstream of the Hatchery Dam, it holds the grade and creates a large depositional zone in this area. Potentially some more of this area could be accessed through the restoration strategy of adding instream wood to allow the dynamic channels to continue, but gravel augmentation is likely not necessary in this reach. PA 12 ranks highly in Complexity in the 90th to 99th percentile, indicating that this reach likely has little additional complexity potential to be gained.

Because the riparian vegetation is still in recovery from the 2005 fire, riparian vegetation enhancement should be the primary restoration strategy for this reach.

It is unlikely that the dam at the downstream end of this reach will be removed in the foreseeable future. However, should the

PA 12 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

opportunity arise, drastic measures in this reach will need to be taken to prevent the loss of complexity.

Finally, the pool frequency in this reach scores below average, which does not reflect the conditions observed during field visits. However, pools are a transitory outcome of complexity and the frequency, size, and location may vary from year to year. Maintaining the high sediment load, as well as adding some instream wood either naturally through recruitment or artificially through restoration, should continue to create the conditions that will promote complexity and form pools.

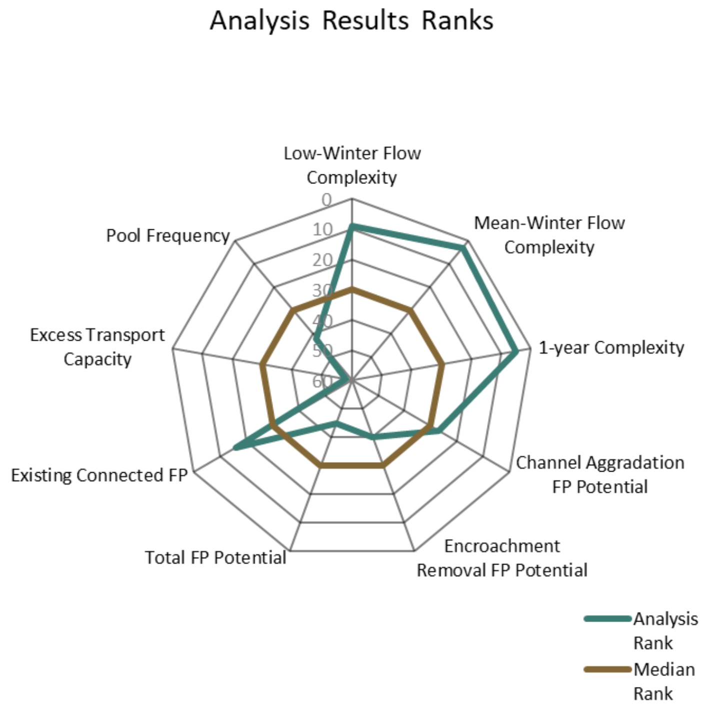
Summary of Restoration Opportunities Identified

- Add instream structure (LWD)
- Riparian zone enhancement
- Modify or remove obstructions

Long-Term Opportunities in this Project Area

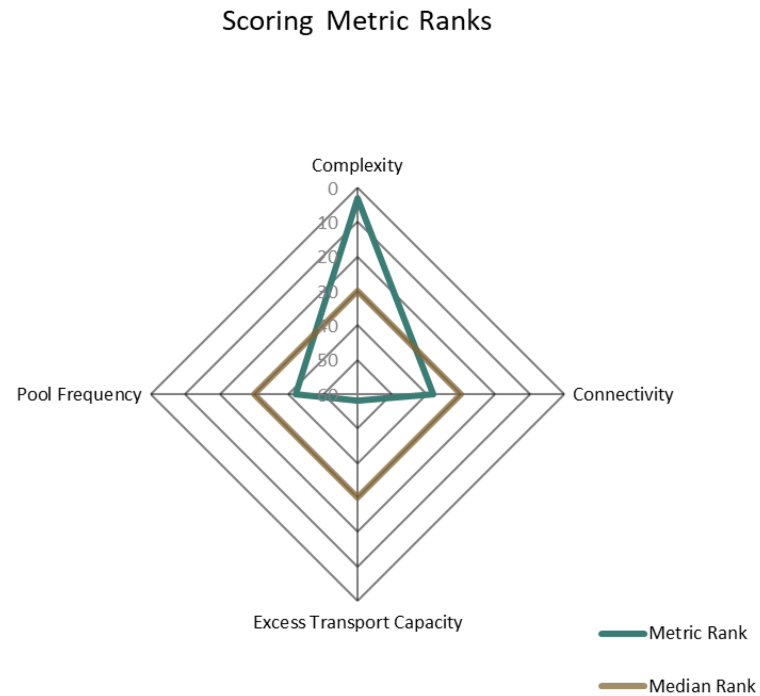
- Reconfigure Deer Lake to reconnect floodplain and consider decommissioning and removing if ever feasible.

PA 12 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

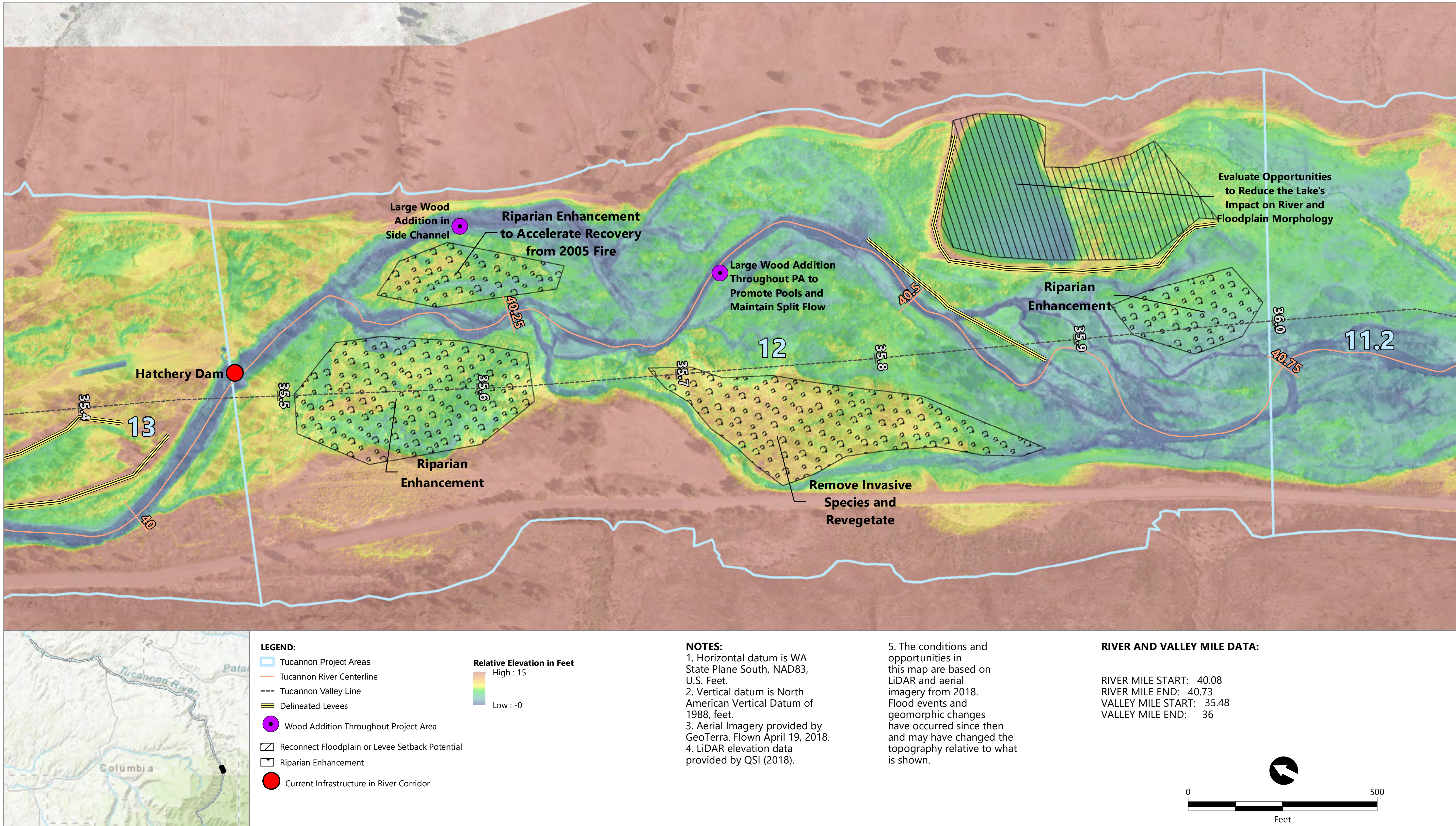
PA 12 Scoring Metric Ranks



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 12 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.305	9	40%	Complexity	0.484	3	1% to 10%	1 of 5	0	40%	0.4	60	3	Untreated	37	3
Mean-Winter Flow Complexity	0.562	3	40%													
1-year Complexity	0.685	5	20%													
Channel Aggradation FP Potential	0.223	27	40%	Connectivity	0.160	38	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.040	40	40%													
Total FP Potential	0.272	45	20%													
Existing Connected FP	0.728	16	0%													
Excess Transport Capacity	-0.29	58	100%	Excess Transport Capacity	0.000	58	52% to 100%	4 of 4	0	20%						
Pool Frequency	7.68	42	100%	Pool Frequency	0.197	42	60% to 90%	4 of 5	1	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential
- Riparian Enhancement
- Current Infrastructure in River Corridor

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 40.08
RIVER MILE END: 40.73
VALLEY MILE START: 35.48
VALLEY MILE END: 36

0 500
Feet

Publish Date: 2021/01/25, 3:45 PM | User: mgieschen
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ANCHOR QEA

Project Area 12
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 13 Description

Project Area 13 begins at the Rainbow Lake Road bridge at VM 34.81 and extends upstream to the Hatchery Dam at VM 35.48. The 2017 RM length is 0.77 mile. Field observations for PA 13 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization. A restoration project has been planned for PA 13 to add wood structure and widen the floodplain, and the following description become outdated after the restoration project is completed.

The channel through PA 13 is characterized as a single-thread, plane-bed channel with forced pool-riffle and local rapid sections. The channel is typically straight, wide, and contains little complexity in much of the project area. Large levees confine the channel along the right bank and are typically heavily armored with large, angular boulders. The Hatchery Dam at the upstream end of the project area controls the channel grade. The 2011 assessment noted that the dam had an approximately 3-foot drop in water surface elevation with a deep plunge pool on the downstream side. No significant side channels or off-channel areas were observed in the project area at the time of field reconnaissance.

The quality and availability of instream habitat was restricted by the lack of channel and hydraulic complexity. The straight and confined channel has resulted in hydraulic conditions that

Project Area 13
Photograph taken from the 2011 prioritization showing the main channel just upstream of the large levee on the right bank, looking downstream.

Project Area 13 Reach Characteristics

VM Start (mi)	34.81
VM Length (mi)	0.67
Valley Slope	1.46%
RM Start (mi)	39.32
RM Length (mi)	0.77
Average Channel Slope	1.26%
Sinuosity	1.15
Connected FP (ac/VM)	7.45
Encroachment Removal (ac/VM)	0.16
Channel Aggradation (ac/VM)	0.79
Total FP Potential (ac/VM)	1.14
Encroaching Feature Length (ft)	4,990.88
Connected FP Rank	58

create high velocities and high transport capacity. These conditions do not support the retention of LWD and bedload, and, therefore, lack hydraulic complexity. A few downed logs and one log jam provided pools and cover in the actively eroding area, but overall very few adequate pools for adult fish holding were available. The lack of side channels (except some apparent high-flow channels) limited the quantity of habitat for rearing juveniles.

In 2011, floodplain connectivity in this project area was affected by the presence of infrastructure, and little low-lying floodplain was present. Although there was not a high quantity of disconnected floodplain, likely because of local channel incision, the levees prevented channel migration and the development of gravel bars and low-lying emergent floodplain, which exacerbated the limited floodplain connectivity. Rainbow Lake, the public camping areas, and the access road to these areas are located atop a terrace and not within the low-lying floodplain.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows very little geomorphic change in PA 13 since the previous assessment. PA 13 is highly confined by levees and the valley wall, which makes geomorphic change difficult. The one location highlighted for discussion occurs near the middle of the reach. A log jam has triggered significant right bank erosion and left bank deposition and the river appears to be trending towards cutting two sharp turns in the channel (box 1).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 13 receives its entire prioritization score from a moderate score in the Excess Transport Capacity metric. Both the Complexity and Connectivity metrics rank PA 13 so low that only a large amount of restoration effort could add complexity and connectivity.

The primary restoration strategy for PA 13 would be to remove the confinement on the left and right banks to create more floodplain opportunity. This restoration effort would require a massive amount of earthwork and movement of material, because benching would be required in much of the floodplain to make it accessible. This restoration effort should also include a large amount of instream wood to begin to promote geomorphic change in the newly created floodplain. Gravel augmentation will likely also be necessary to create some channel aggradation and reverse the effects of incision. It is possible gravel augmentation will have to occur regularly below the dam because the dam likely hampers most natural sediment transport. Restoration efforts of this magnitude should have the effect of widening the floodplain and reducing the excess transport capacity in this reach. It should be noted that a restoration effort to reduce confinement in this reach has begun at the time of this report.

Pool frequency in PA 13 is well below average, as would be expected in a reach that is starved of sediment supply and severely confined. The identified restoration strategies of widening the floodplain, adding instream wood, and providing gravel augmentation, should greatly benefit the natural processes of complexity and connectivity that will promote pool formation in this reach.

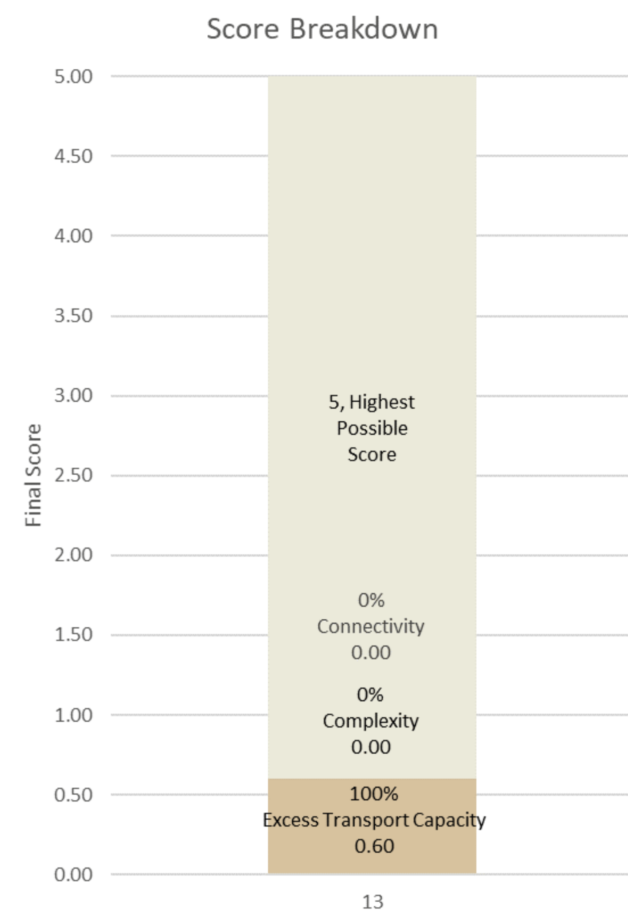
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)
- Modify or remove obstructions

Long-Term Opportunities in this Project Area

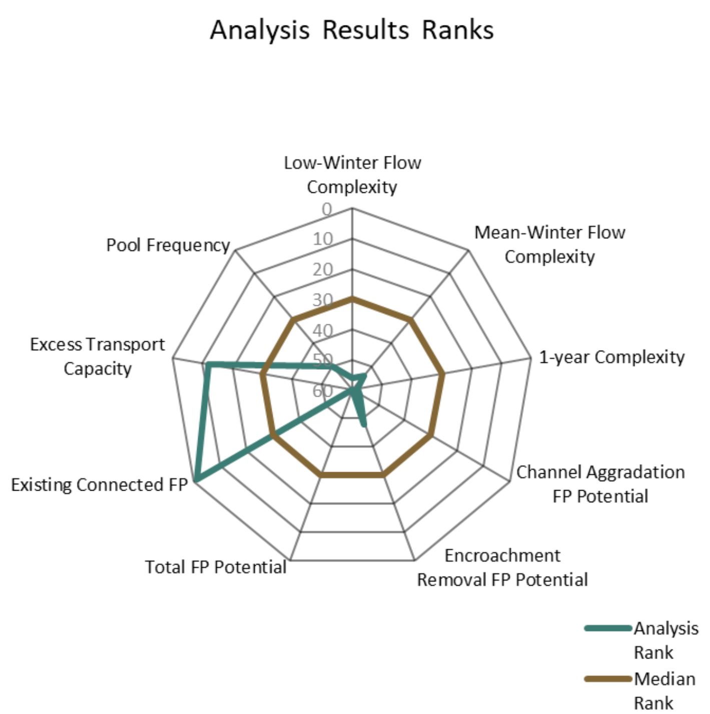
- Reconfigure Rainbow Lake to reconnect floodplain and consider decommissioning and removing if ever feasible.

PA 13 Score Breakdown



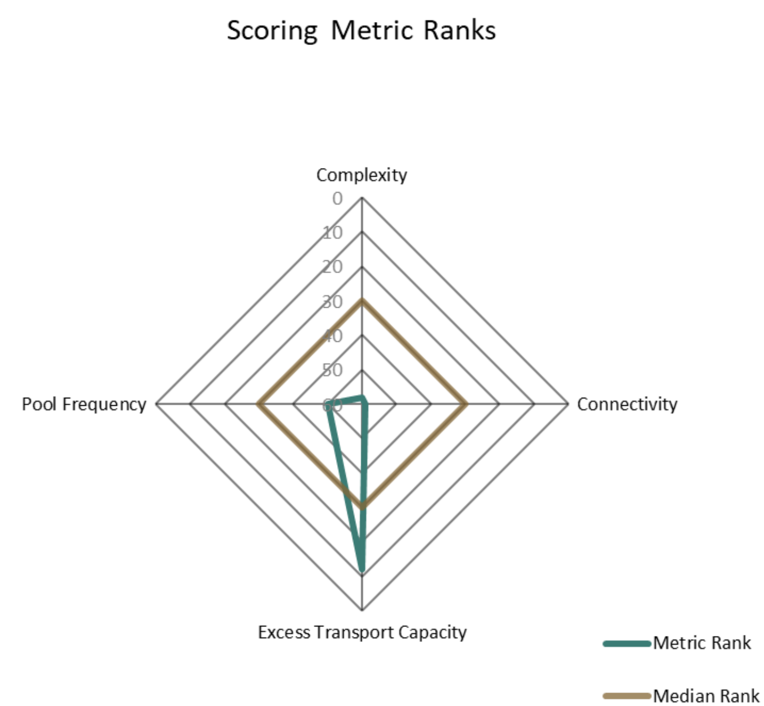
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 13 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

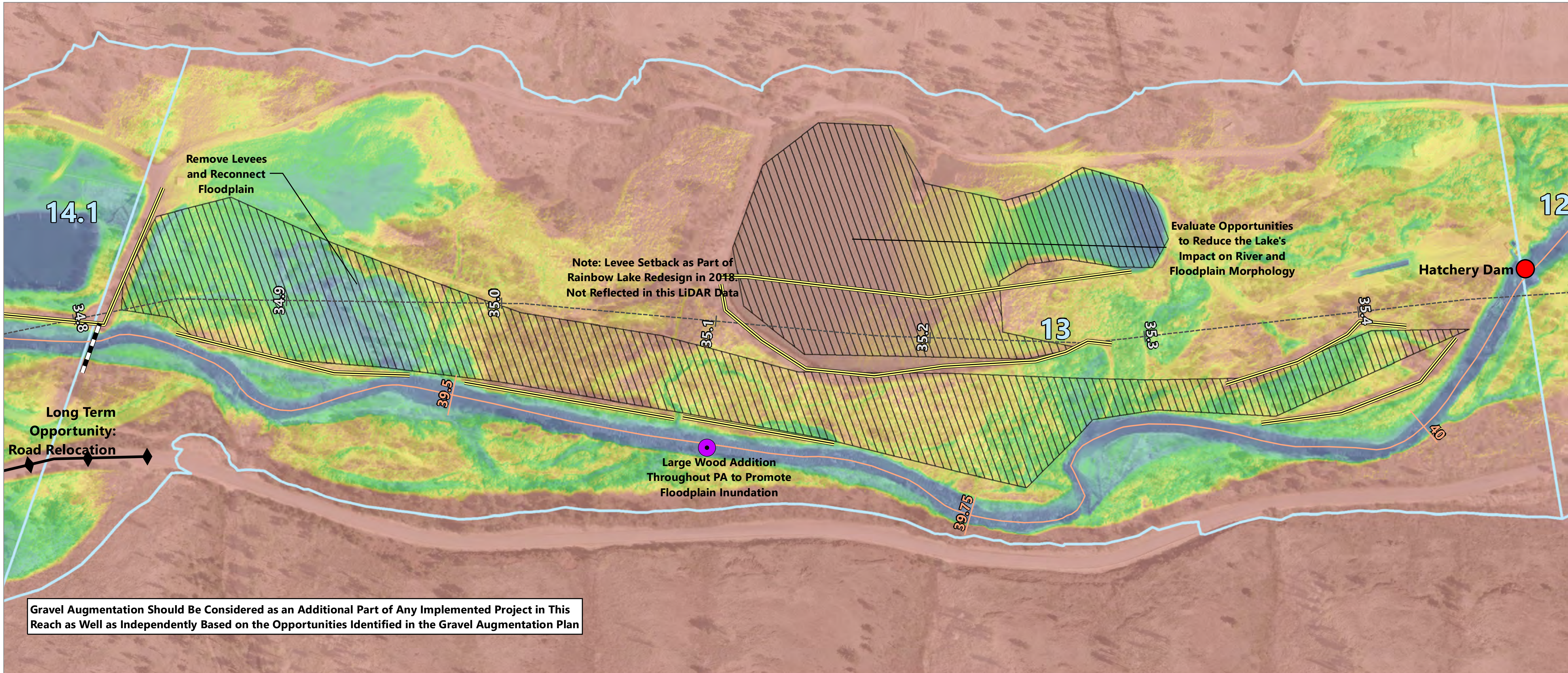
PA 13 Scoring Metric Ranks

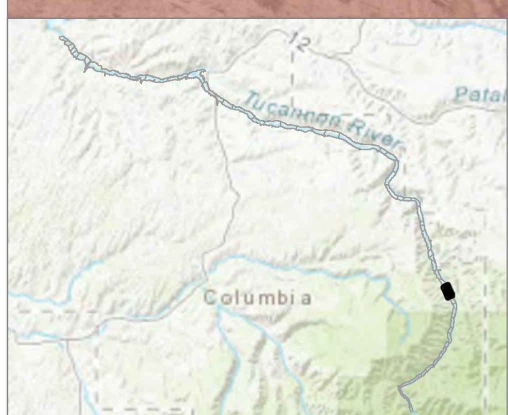


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 13 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.088	56	40%	**Complexity**	0.091	58	90% to 100%	5 of 5	0	40%	0.6	56	3	Untreated	35	3
Mean-Winter Flow Complexity	0.102	54	40%													
1-year Complexity	0.075	58	20%													
Channel Aggradation FP Potential	0.091	57	40%	**Connectivity**	0.071	59	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.019	48	40%													
Total FP Potential	0.133	60	20%													
Existing Connected FP	0.867	1	0%													
Excess Transport Capacity	0.16	12	100%	**Excess Transport Capacity**	3.000	12	10% to 30%	2 of 4	3	20%						
Pool Frequency	5.23	50	100%	**Pool Frequency**	0.134	50	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential
- Long Term: Relocate Road
- Current Infrastructure in River Corridor

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 39.32
RIVER MILE END: 40.08
VALLEY MILE START: 34.81
VALLEY MILE END: 35.48

0 500
Feet

Publish Date: 2021/01/25, 3:45 PM | User: mgieschen
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ANCHOR QEA

Project Area 13
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 17.1 Description

Project Area 17.1 begins at VM 30.71 and extends upstream to the bridge crossing at Tucannon Road at VM 31.05. The 2017 RM length is 0.34 mile. Field observations for PA 17.1 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

The channel through PA 17.1 is characterized as a single-thread, plane-bed channel with local deep, rapid sections that contain little hydraulic complexity. Resistant fine-grained material is located along much of the left bank. The 2011 assessment noted bank armoring in the upstream portion of the project area on both the left and right banks. From this section to the downstream end the channel is incised and disconnected from the floodplain. Riparian planting projects undertaken here have been largely unsuccessful, likely due to channel incision and lowering of the water table.

Instream habitat was limited by lack of complexity and high-velocity conditions through the incised portion of the project area. Very little LWD was observed. The straight, confined, and incised conditions found throughout much of the project area likely result in high velocities during seasonal high flows and floods, which prevent the retention of sufficient volumes of LWD that would provide cover, refuge, or sediment deposition

Project Area 17.1
Looking downstream on plane-bed uniform channel in PA 17.1.

Project Area 17.1 Reach Characteristics

VM Start (mi)	30.71
VM Length (mi)	0.34
Valley Slope	1.01%
RM Start (mi)	34.62
RM Length (mi)	0.34
Average Channel Slope	0.99%
Sinuosity	1.01
Connected FP (ac/VM)	14.44
Encroachment Removal (ac/VM)	1.17
Channel Aggradation (ac/VM)	7.14
Total FP Potential (ac/VM)	8.98
Encroaching Feature Length (ft)	1,189.71
Connected FP Rank	26

for spawning areas. Few side channels were available to provide preferred rearing habitat for juveniles.

In 2011, floodplain connectivity in this project area was poor to moderate. There was little low-lying floodplain on the left bank of the river due to natural alluvial fan deposits. Much of the right floodplain was composed of remnant alluvial fan and hillslope deposits that were reworked during the 1996/1997 flooding. These surfaces were covered in cobble and supported little vegetation. Some remnant spoils and armor material were observed on the floodplain, which limited the channel from naturally migrating and expanding into the low areas of the floodplain. Terraces were also present that appear to provide some level of erosion resistance. Dry channels were observed that likely convey floodwaters during high-flow events. Channels observed in the floodplain were largely dry.

The 2011 assessment noted that the riparian zone adjacent to the channel was generally in a moderately healthy condition, with some local areas that had been degraded by development, historic flooding, or poor hyporheic connection with the channel. The riparian zone was generally in poor health and contained few mature trees, sparse vegetation coverage, and an overall narrow riparian corridor. The upstream end of the reach contained the poorest conditions; the floodplain vegetation appeared to have a poor hyporheic connection with the channel and little to no soil development. Riparian trees were mostly immature deciduous species.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows almost no significant geomorphic change has occurred in PA 17.1. Some erosion is apparent in the channel but could be the result of the difference in LiDAR technology for sensing the channel bottom, as discussed in the Geomorphic Assessment. PA 17.1 is highly confined, which prevents most geomorphic change other than incision, so the apparent channel downcutting could be real.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 17.1 receives most of its prioritization score from the Connectivity metric. PA 17.1 receives a moderate score in Connectivity, indicating that it falls in the 50th to 75th percentile of project areas for floodplain connectivity potential. Several former channels or side channels have created isolated opportunities in the floodplain that could be connected most effectively by channel aggradation. PA 17.1 ranks very highly in the Channel Aggradation analysis result. The primary restoration target for PA 17.1 should be to raise the bed elevation and reverse the trend of incision in the reach. Gravel augmentation should be considered the primary restoration strategy for this reach in order to accomplish this. However, PA 17.1 also receives a moderate score in the Excess Transport Capacity metric, indicating that material will likely be transported quickly through the reach. Therefore, an equally important restoration strategy will be to heavily add instream wood to store and maintain any added sediment in the reach. Pilot channel cuts should also be pursued to quickly allow flows into these low-lying areas as a secondary restoration strategy.

PA 17.1 receives no score in the Complexity metric and ranks very poorly in all three flows of the Complexity analysis results, meaning PA 17.1 ranks in the bottom 10% of all project areas for complexity. This range of complexity has been identified as being too poor to warrant restoration effort. Despite this, the restoration strategies of adding instream wood, gravel augmentation, and pilot channel cuts should also help to increase complexity. Achieving greater floodplain connectivity and reversing incision in this reach should also provide more room for complex channel features to form.

It should be noted that, because most of the floodplain in this reach is disconnected, the riparian vegetation is relatively poor. Therefore, a restoration strategy of riparian vegetation enhancement should be strongly considered as part of the restoration plan for this reach.

Finally, PA 17.1 ranks very low among project areas in the Pool Frequency metric. Adding instream wood and gravel augmentation will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target increasing pool frequency in the reach.

PA 17.1 Score Breakdown

This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

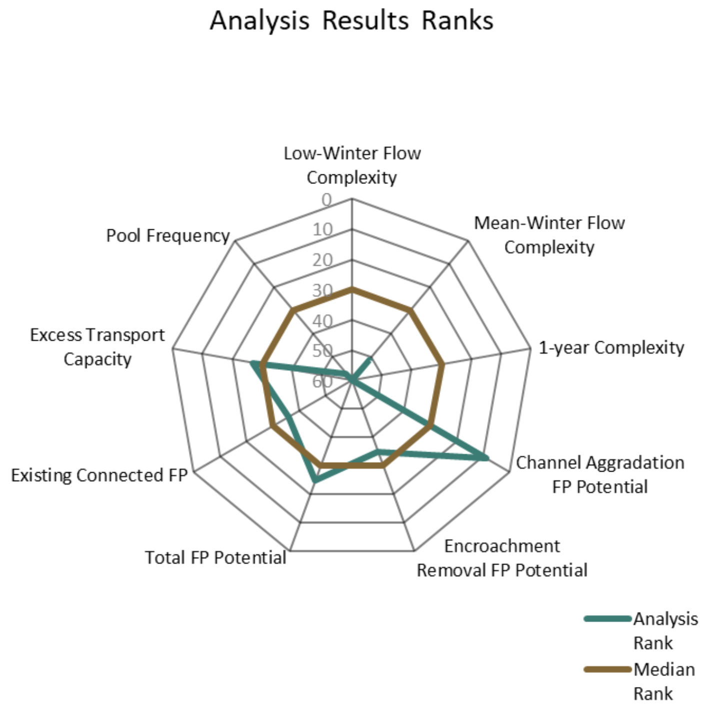
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

Long-Term Opportunities in this Project Area

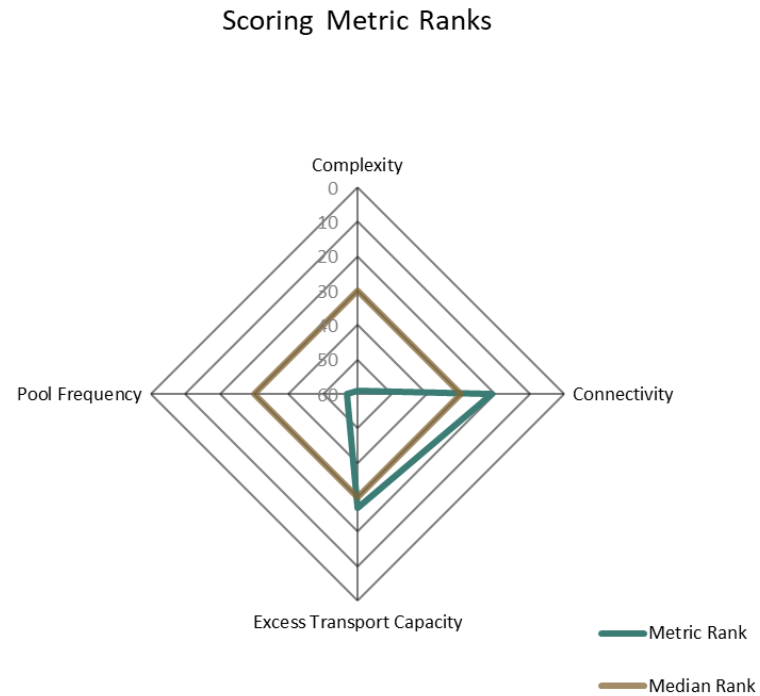
- Set back road against left valley wall for more floodplain connection and channel migration area.

PA 17.1 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

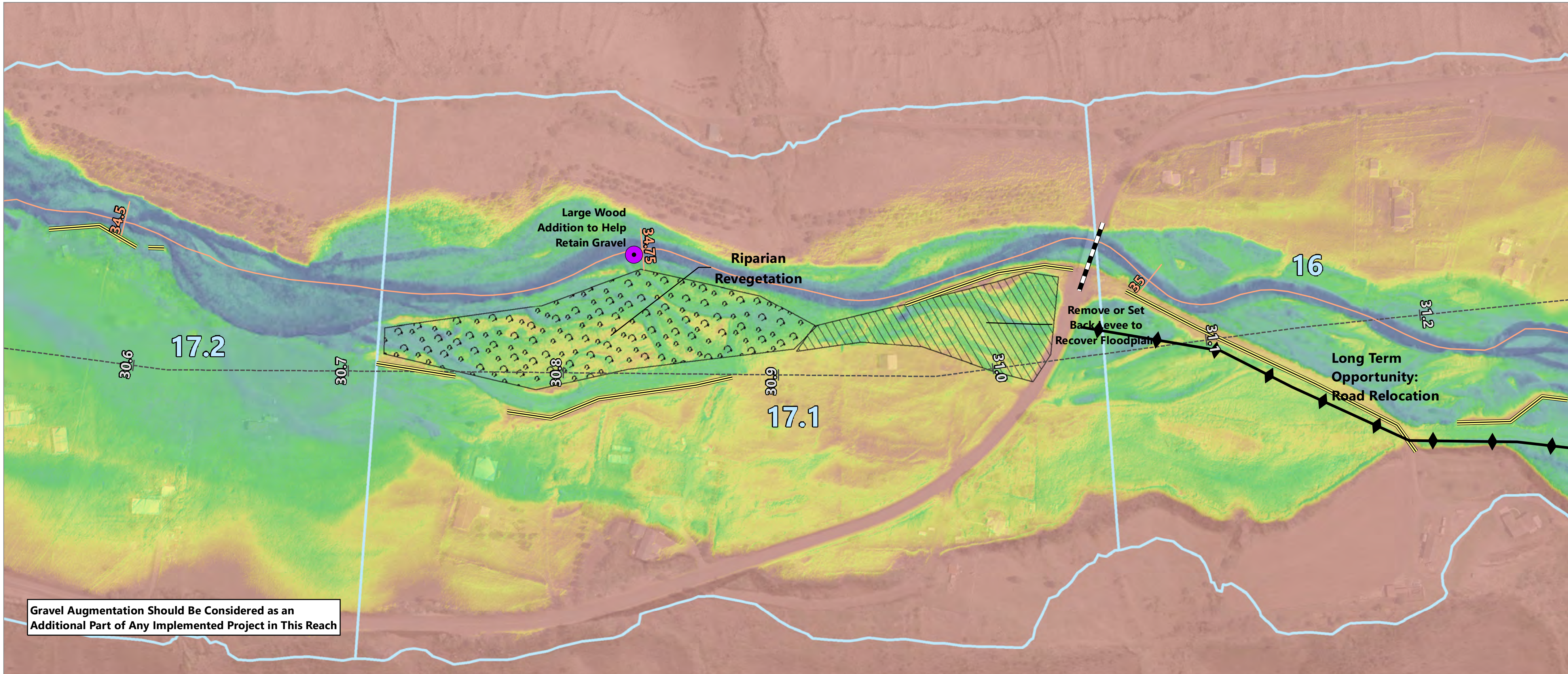
PA 17.1 Scoring Metric Ranks

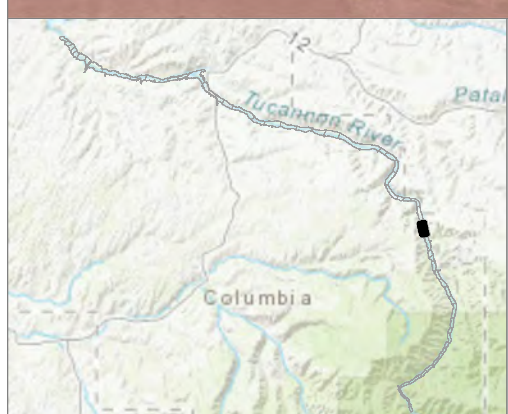


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 17.1 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.067	60	40%	Complexity	0.086	59	90% to 100%	5 of 5	0	40%	1.4	40	3	Untreated	25	3
Mean-Winter Flow Complexity	0.115	51	40%													
1-year Complexity	0.067	60	20%													
Channel Aggradation FP Potential	0.305	9	40%	Connectivity	0.219	21	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.050	35	40%													
Total FP Potential	0.383	25	20%													
Existing Connected FP	0.617	36	0%													
Excess Transport Capacity	0.06	27	100%	Excess Transport Capacity	1.000	27	30% to 52%	3 of 4	1	20%						
Pool Frequency	2.91	57	100%	Pool Frequency	0.075	57	90% to 100%	5 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential
- Long Term: Relocate Road
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 34.62
RIVER MILE END: 34.97
VALLEY MILE START: 30.71
VALLEY MILE END: 31.05

0 500
Feet

Publish Date: 2021/01/25, 3:47 PM | User: mgieschen
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ANCHOR QEA

Project Area 17.1
Conceptual Restoration Opportunities

Project Area 17.2 Description

Project Area 17.2 begins at VM 30.45 and extends upstream to VM 30.71. The 2017 RM length is 0.31 mile. Field observations for PA 17.2 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

The channel through PA 17.2 is characterized as a single-thread, plane-bed channel with local deep, rapid sections that contain little hydraulic complexity. Resistant fine-grained material is located along much of the left bank. The channel is wide and plane-bed with some deeper areas adjacent to the resistant bank. The 2011 assessment noted a few minor side channels that were wetted at the time of field observation.

In 2011, floodplain connectivity in this project area was poor to moderate. There was little low-lying floodplain on the left bank of the river due to natural alluvial fan deposits. Much of the right floodplain was composed of remnant alluvial fan and hillslope deposits that were reworked during the 1996/1997 flooding. These surfaces were covered in cobble and supported little vegetation. Some remnant spoils and armor material were observed on the floodplain, which limited the channel from naturally migrating and expanding into the low areas of the floodplain. Channels observed in the floodplain were largely dry; some standing water was observed in the right floodplain.

Project Area 17.2
Photograph taken from the 2011 prioritization showing a plane-bed section of the channel that flows along the base of a high terrace (right bank).

Project Area 17.2 Reach Characteristics

VM Start (mi)	30.45
VM Length (mi)	0.27
Valley Slope	1.31%
RM Start (mi)	34.32
RM Length (mi)	0.31
Average Channel Slope	1.06%
Sinuosity	1.15
Connected FP (ac/VM)	24.72
Encroachment Removal (ac/VM)	3.06
Channel Aggradation (ac/VM)	9.99
Total FP Potential (ac/VM)	14.23
Encroaching Feature Length (ft)	268.70
Connected FP Rank	9

The 2011 assessment noted that the riparian zone adjacent to the channel was generally in a moderately healthy condition, with some local areas that had been degraded by development, historic flooding, or poor hyporheic connection with the channel.

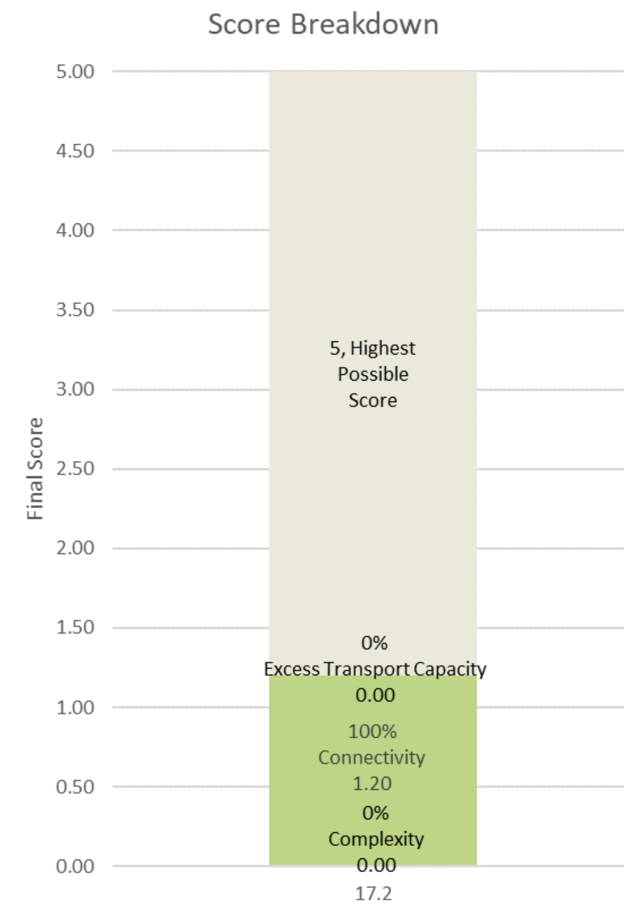
Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows a large amount of deposition has occurred for almost the entire PA 17.2 reach. While PA 17.2 is a short reach, the extent of this depositional area is unique in the geomorphic change analysis for this basin. At the upstream end, deposition in the main channel has caused only minor split flows and avulsions (box 1). At the downstream end, several large split flows and side channels have formed as a result of the deposition and channel aggradation in the main channel (box 2). It should be noted that the complexity seen as a result of the deposition in this reach is the representative of the desired outcome of the channel aggradation and gravel augmentation restoration strategies discussed in other parts of this assessment.

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 17.2 receives its entire prioritization score from a moderate score in the Connectivity metric, which is above average in the 50th to 75th percentile. This score is primarily driven by the Channel

PA 17.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

Aggradation analysis result, which ranks above average, although the Encroachment Removal analysis result ranks around average as well. The potential area for connection by channel aggradation is located at the upper end of the project area on the left bank, in what is currently occupied by residential lawns and property. Similarly, a narrow, low-lying area is disconnected on the left bank near the middle of the reach. Connecting these two areas through pilot channel cuts and high bank or encroachment removal, along with the addition of instream wood, should be the primary restoration strategy for this reach, although this may be difficult given the residential nature of the area, and full reconnection is unlikely.

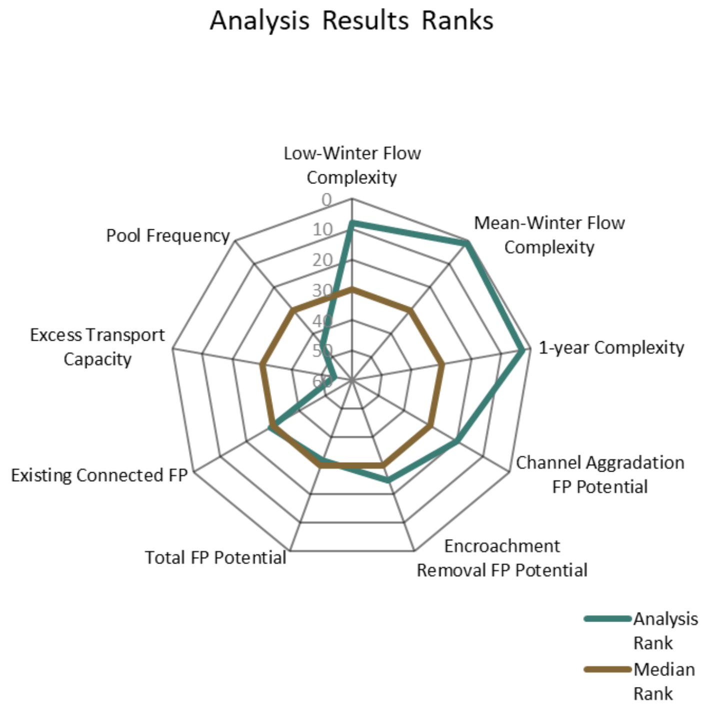
PA 17.2 ranks highly in the Complexity metric and falls in the 90th to 99th percentile, a range which has been identified as needing no further restoration for complexity. This is likely due in large part to the depositional nature of the reach. The riparian buffer in this reach is thin in many places, although the beginnings of riparian enhancement restoration effort are evident on the right bank. A primary restoration strategy should also be to improve the riparian vegetation on both banks to provide a thicker riparian buffer.

Finally, the pool frequency in this reach scores below average, which might reflect the fact that the deposition in this reach has occurred recently. Maintaining the high sediment load, as well as adding some instream wood either naturally through recruitment or artificially through restoration, should continue to create the conditions that will promote complexity and form pools.

Summary of Restoration Opportunities Identified

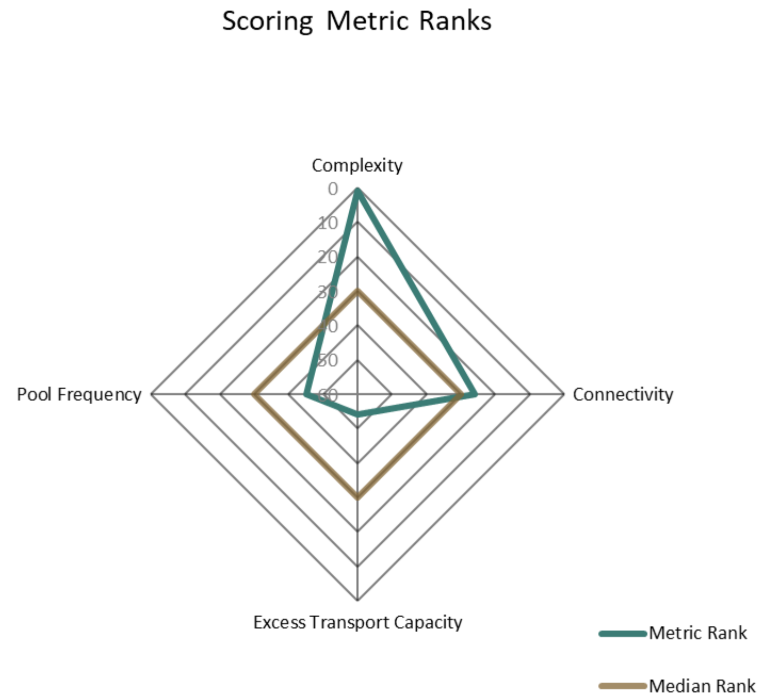
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 17.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

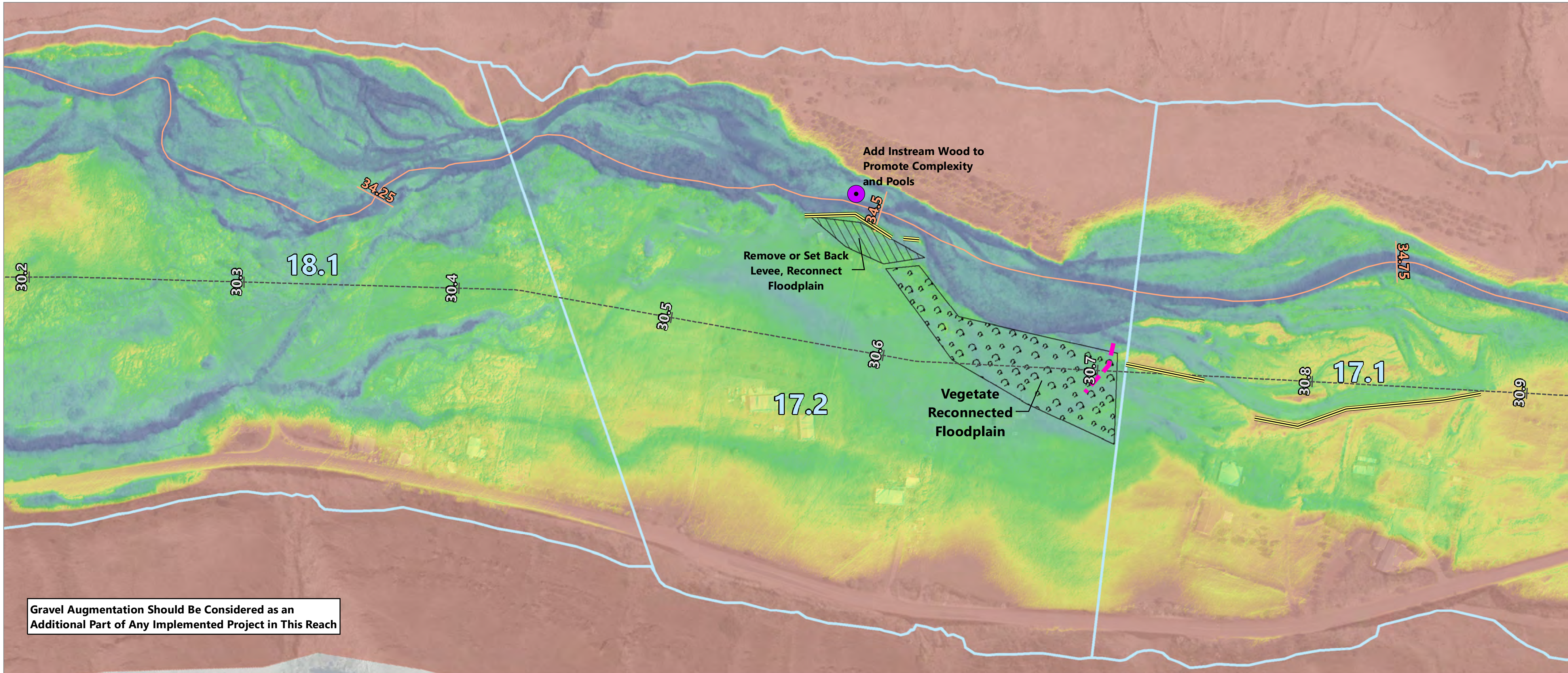
PA 17.2 Scoring Metric Ranks

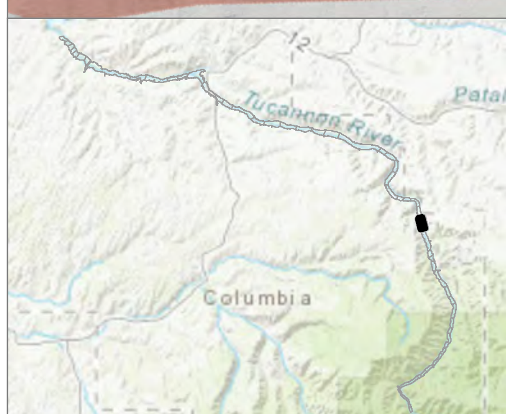


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 17.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.309	8	40%	Complexity	0.630	1	1% to 10%	1 of 5	0	40%	1.2	47	3	Untreated	27	3
Mean-Winter Flow Complexity	0.882	1	40%													
1-year Complexity	0.769	3	20%													
Channel Aggradation FP Potential	0.256	20	40%	Connectivity	0.207	26	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.079	25	40%													
Total FP Potential	0.365	32	20%													
Existing Connected FP	0.635	29	0%													
Excess Transport Capacity	-0.17	54	100%	Excess Transport Capacity	0.000	54	52% to 100%	4 of 4	0	20%						
Pool Frequency	6.53	45	100%	Pool Frequency	0.168	45	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 34.32
RIVER MILE END: 34.62
VALLEY MILE START: 30.45
VALLEY MILE END: 30.71

0 — 500
Feet

Publish Date: 2021/01/25, 3:47 PM | User: mgieschen
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ANCHOR QEA

Project Area 17.2
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 21 Description

Project Area 21 begins at the bridge crossing of Tucannon Road at VM 26.85 and extends upstream to VM 27.91. The 2017 RM length is 1.05 miles. Field observations for PA 21 were conducted on October 29, 2018, when flow at the Starbuck gage was approximately 110 cfs.

PA 21 is largely characterized by moderate confinement with several levee sections and high banks on the left bank and the valley wall on the right bank. This moderate confinement does allow more floodplain than typically seen behind levees on the Tucannon River, and there are large pockets of mature deciduous riparian vegetation on the left and right banks.

For the first upstream 1,500 feet of the channel, the left bank does not have a well-defined levee, but several high spots suggest older levee remnants still disconnecting a large, low area and several side channel opportunities. Near the downstream end of this section, a large debris jam has forced flow onto the limited floodplain and caused decent channel complexity. There are large side channels in this area disconnected by levee remnants.

At VM 27.44, an access road and irrigation pump on the left bank bisects a significant side channel that is already disconnected by an old levee. Downstream from this access road, the left bank levee becomes much more well defined with large riprap.

Project Area 21
Looking downstream towards the location of a major avulsion. The former channel is a plane-bed gravel bar with little vegetation. The flow now goes through a confined steep section as shown on the right side of the photograph.

Project Area 21 Reach Characteristics

VM Start (mi)	26.85
VM Length (mi)	1.06
Valley Slope	1.00%
RM Start (mi)	30.41
RM Length (mi)	1.05
Average Channel Slope	1.03%
Sinuosity	0.99
Connected FP (ac/VM)	8.73
Encroachment Removal (ac/VM)	0.45
Channel Aggradation (ac/VM)	2.00
Total FP Potential (ac/VM)	2.83
Encroaching Feature Length (ft)	2,908.22
Connected FP Rank	55

At VM 27.3, the defined levee ends and a large avulsion has occurred towards the right bank. The main flow now is funneled into a narrow channel between a high spot on the left bank and the valley wall on the right. The abandoned channel was dry with no vegetation at the time of the site visit but appears to receive regular higher flows. Downstream of this abandoned channel, several flow paths split off from the main abandoned flow path and meander through forested floodplain for several hundred feet.

Downstream, the channel again becomes more confined and is generally a straight, plane-bed, and uniform channel. Several rock weirs were noted throughout this reach, each with large, deep scour pools.

Bed material in this reach is relatively large with mostly cobbles and small boulders; some patches of gravel deposits were observed but not in any significant amounts. Instream wood was lacking with only one notable large log jam at the top of the reach. Due to the confined nature of this reach, it is likely that it serves as a transport reach for both sediment and wood, although the healthy riparian area could provide a good source for future wood recruitment.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several minor geomorphic changes in PA 21 have occurred since the last assessment. Near the middle of the reach, a log jam has triggered a meander bend to be cut off although the former main channel still has some flow. A depositional bar has formed on the right bank in this area as well (box 1).

Further downstream, a major channel avulsion has occurred and the main channel has had massive deposition. During the field investigation, this area was an open gravel bar and all flow had been forced into a narrow channel on the right bank floodplain where some erosion was evident (box 2).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 21 receives the highest possible score in the Excess Transport Capacity metric, and a low score in the Complexity metric, both of which combine to make up the entire prioritization score. The low Complexity score indicates that this project area falls below average in the 10th to 40th percentile, which is a range that has been identified as having some small existing complexity but would likely require a large restoration effort to achieve higher levels.

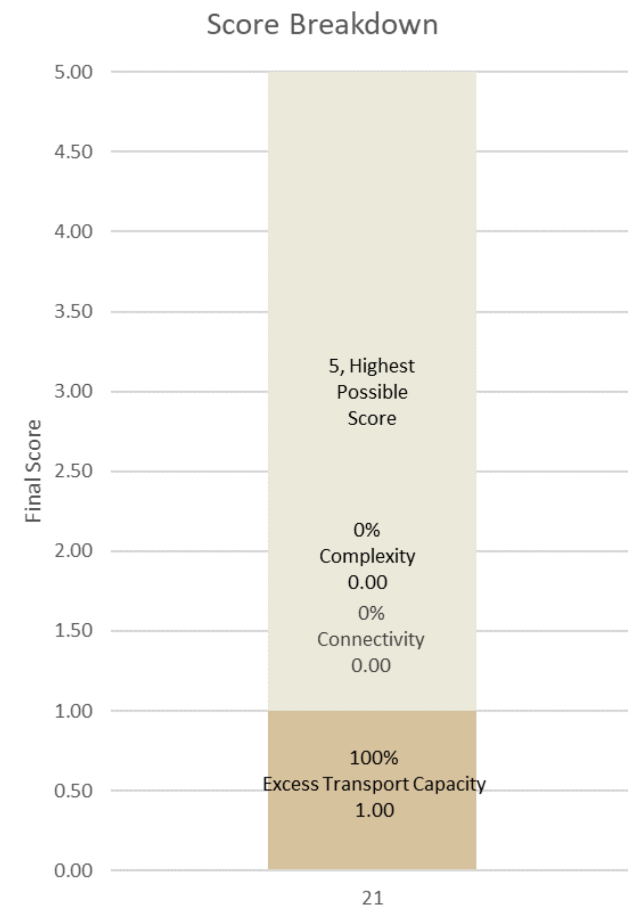
PA 21 is highly confined and leveed for most of the reach between the valley wall on the right bank and the levees on the left bank. The high Excess Transport Capacity score reflects this fact and addressing this should be a primary restoration target. Fortunately, many of these levees appear to be good opportunities for setback levee locations because there is some riparian area behind many of them. Widening the floodplain through removal and setback of levees and floodplain benching should increase complexity and connectivity in this reach. After addressing the confinement, the restoration focus should be on adding instream wood and gravel augmentation to promote in-channel complexity as well as more split flows and side channels in the newly available floodplain. A combination of levee setbacks, adding instream wood, and gravel augmentation should be the primary restoration strategies for this reach.

PA 21 scores very poorly in pool frequency, likely due to the confined nature and lack of geomorphic change in this reach. The identified restoration strategies of widening the floodplain, adding instream wood, and providing gravel augmentation should allow more complexity to form and create the conditions that will allow pools to form more regularly through natural geomorphic processes.

Summary of Restoration Opportunities Identified

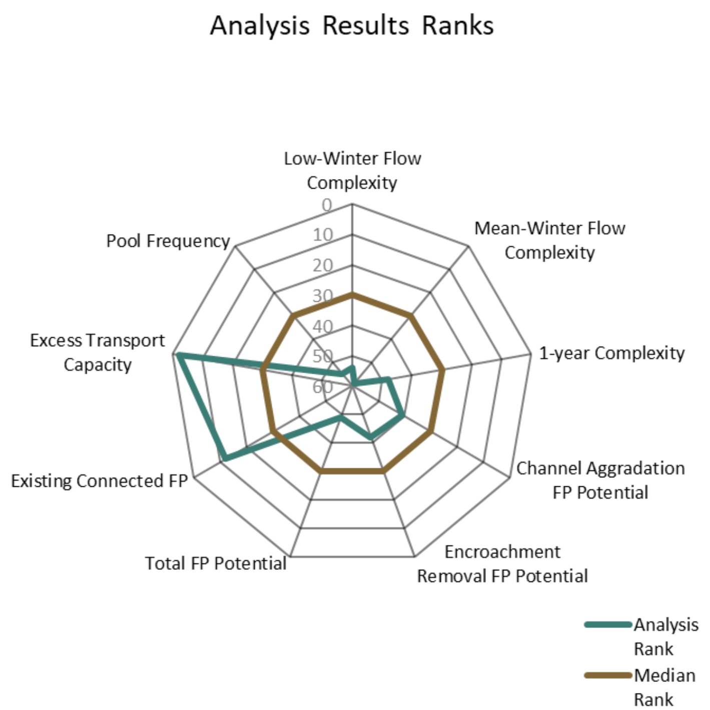
- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)

PA 21 Score Breakdown



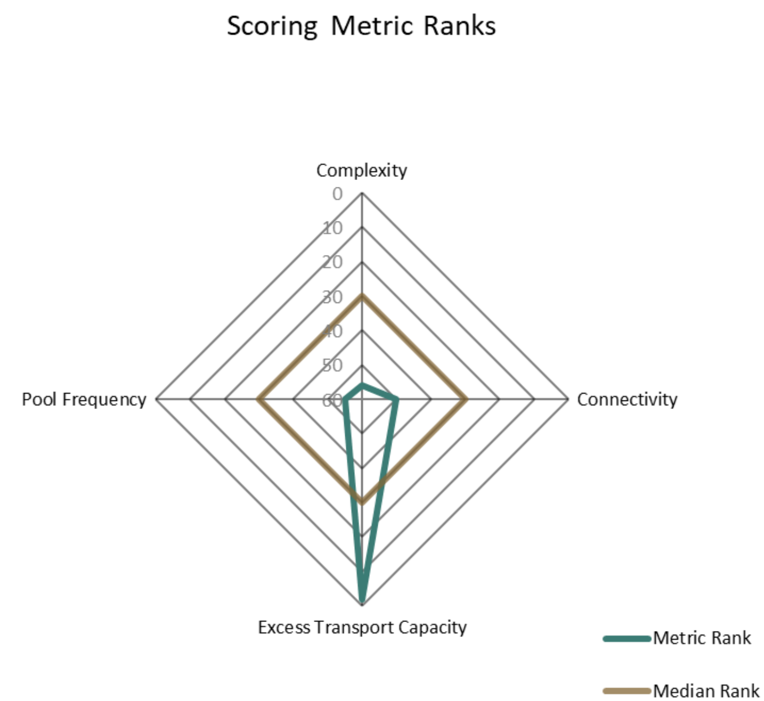
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 21 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

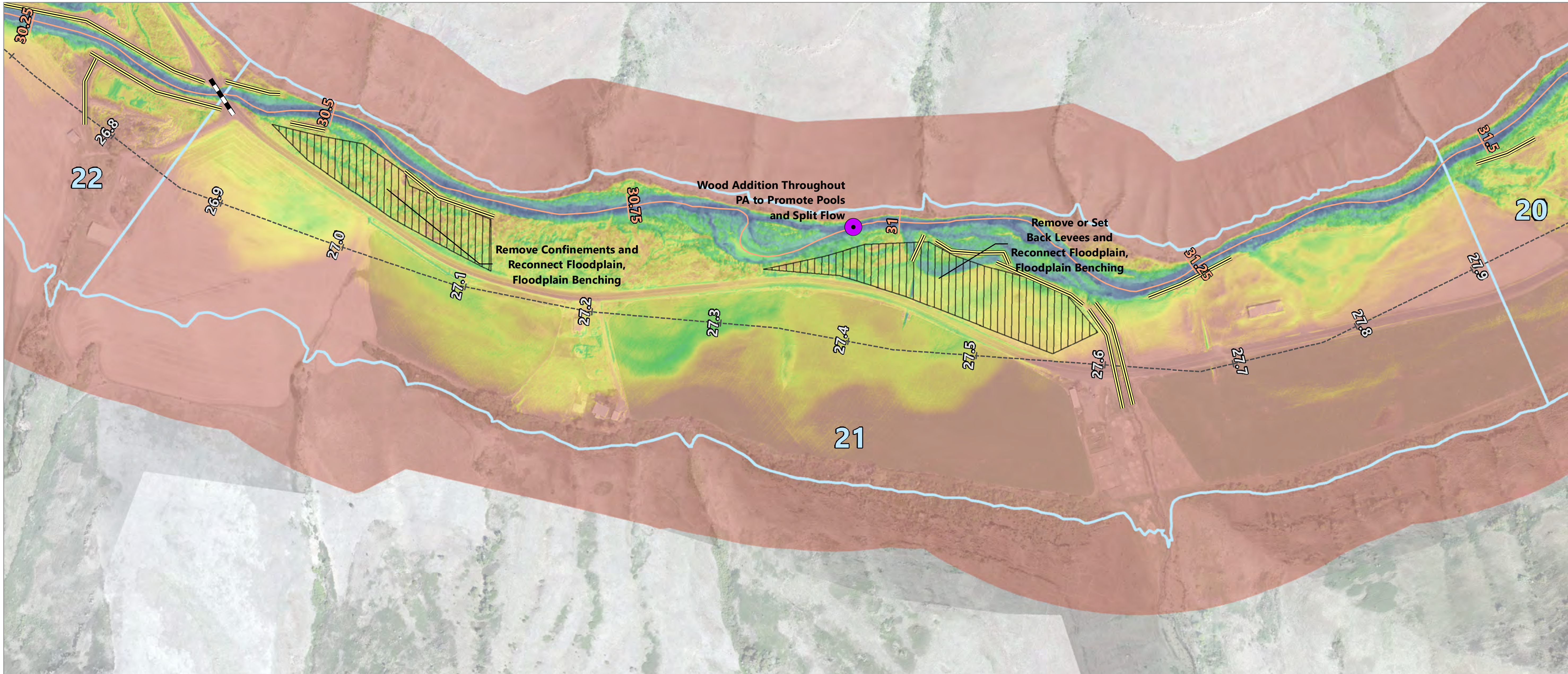
PA 21 Scoring Metric Ranks

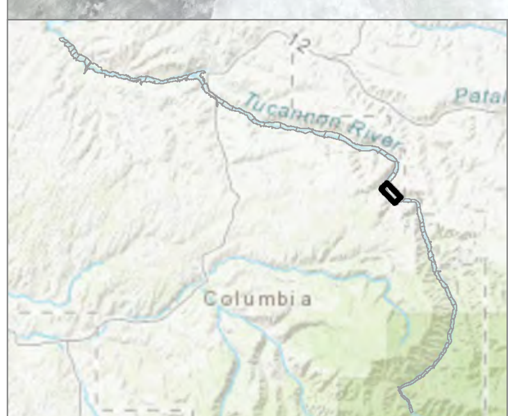


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 21 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.089	54	40%	Complexity	0.094	56	90% to 100%	5 of 5	0	40%	1.0	51	3	Untreated	31	3
Mean-Winter Flow Complexity	0.075	59	40%													
1-year Complexity	0.140	48	20%													
Channel Aggradation FP Potential	0.173	41	40%	Connectivity	0.134	50	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.039	42	40%													
Total FP Potential	0.245	49	20%													
Existing Connected FP	0.755	12	0%													
Excess Transport Capacity	0.32	2	100%	Excess Transport Capacity	5.000	2	1% to 10%	1 of 4	5	20%						
Pool Frequency	3.80	55	100%	Pool Frequency	0.098	55	90% to 100%	5 of 5	0	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 30.41
RIVER MILE END: 31.46
VALLEY MILE START: 26.85
VALLEY MILE END: 27.91

0 500
Feet

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ANCHOR QEA

Project Area 21
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 30 Description

Project Area 30 begins at VM 15.54 and extends upstream to the Brines Road bridge crossing at VM 16.37. The 2017 RM length is 1.01 miles. Field observations for PA 30 were conducted on October 10, 2018, when flow at the Starbuck gage was approximately 115 cfs.

PA 30 is a unique reach on the Tucannon River. At the time of the site visit, the channel width throughout the reach was 2 or 3 times wider than channel widths for nearby reaches. There is a large amount of gravel material in this reach with a moderate amount of instream wood. However, there is almost no riparian vegetation established throughout the reach, and large gravel bars are exposed to full sun. These gravel bars form multiple side channels and any piece of wood is forcing split flows; however, the split flows have almost no cover and are likely extremely transient.

At the upstream end of the project area, some sections have good mature riparian vegetation on the right bank, but it appears this portion of the river has had cattle grazing and very few young trees or undergrowth are present. There are several side channel opportunities in the wooded area that could be reconnected to move flow out of the large exposed gravel bar area.

Just downstream of this wooded right bank, the channel enters an approximately half-mile reach that has almost no riparian

Project Area 30
Looking downstream. The channel has complex flow but exposed gravel bars with little vegetation or instream wood structure, making the current conditions geomorphically unstable.

Project Area 30 Reach Characteristics

VM Start (mi)	15.54
VM Length (mi)	0.83
Valley Slope	0.99%
RM Start (mi)	17.62
RM Length (mi)	1.01
Average Channel Slope	0.82%
Sinuosity	1.22
Connected FP (ac/VM)	18.70
Encroachment Removal (ac/VM)	2.05
Channel Aggradation (ac/VM)	8.06
Total FP Potential (ac/VM)	9.05
Encroaching Feature Length (ft)	2,213.87
Connected FP Rank	18

vegetation and is eroding into loess banks in several locations. It should be noted that this site was visited by Anchor QEA staff again in April of 2019, and significant erosion has occurred in several of these meander bends. Very little of the complexity apparent at the low flow was visible during a higher flow.

Near the downstream end of the reach at VM 15.8, a large rock berm extrudes into the active channel to push water into an irrigation channel on the right bank. Just downstream of here, a large log jam is forcing erosion into the left bank before the irrigation ditch returns to the river.

In general, this reach has decent instream wood, but with few riparian trees to hold it in place, much of this wood will likely be flushed downstream within the next few high flows. Bed material is a good mix of gravels, cobbles, and boulders, and geomorphic pools and planforms seem to form relatively easily. The apparent complexity of this reach appears to be transient in nature, though, and the very poor riparian vegetation makes this likely poor juvenile salmonid habitat despite the complexity.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows geomorphic changes in PA 30 that occur on a large scale and occupy large portions of the reach. PA 30 has been noted to have very large riparian vegetation in the lower portion of the reach, which likely contributes to the scale in which geomorphic changes are occurring in this reach.

In the upstream end where both banks still have some riparian vegetation, a large log jam in the middle of the channel has caused split flows and side channels with associated deposition behind the log jam and erosion in the main channel (box 1).

The primary change pattern in the reach occurs for the entire downstream section of PA 30, where little mature woody vegetation on the banks has made the channel highly susceptible to erosion. Large areas of erosion into alternating banks are forming five distinct meander bends as the channel erodes into the banks over approximately 2,000 feet of channel length. Large areas of the bank have eroded, and it is likely this process will continue given that there is little vegetation to hold banks and resist erosion (box 2).

Geomorphic Characteristics and Restoration Strategies

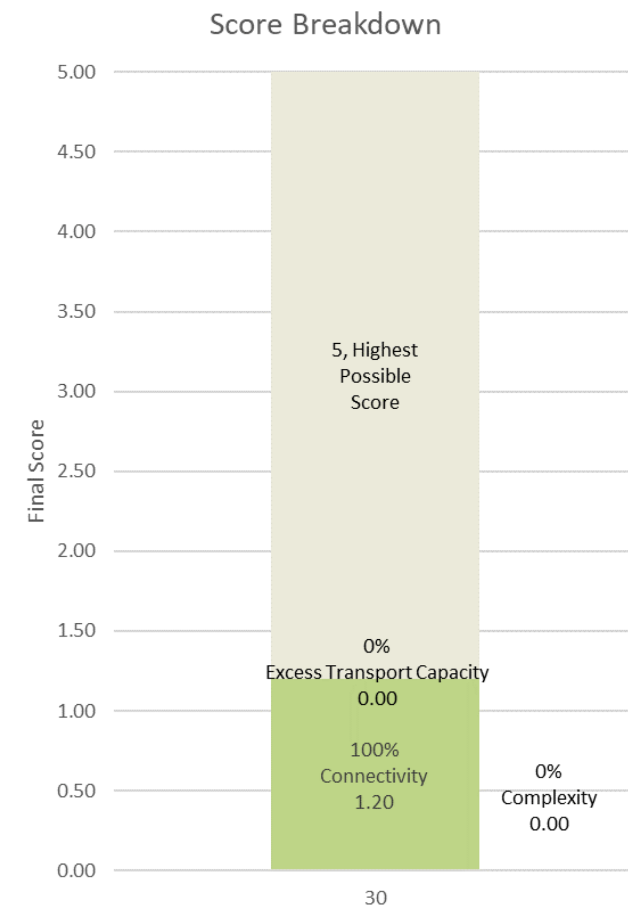
As shown in the following graphs and table, PA 30 receives its entire prioritization score from a moderate score in the Connectivity metric, which indicates that PA 30 ranks above average in the 50th to 75th percentile for floodplain connectivity potential. This ranking is almost entirely driven by an above average rank in the Channel Aggradation analysis result. Much of this area exists as expansion of the boundaries of the existing 2-year floodplain as well as several channels in the right bank floodplain that appear to be disconnected even at the 2-year event.

PA 30 scores no points in the Complexity metric because it ranks at the top of the assessment in the 90th to 99th percentile range. While this range receives no score because it has been identified as likely needing no further complexity from restoration work, PA 30 is a special case. The complexity in this reach is driven by large gravel islands completely bare of vegetation. This type of complexity is extremely transient and does not provide the same habitat benefits that complexity through a healthy riparian area does. For example, major channel changes occurred between the LiDAR flight in fall 2017 and the aerial imagery in spring 2018. Given the instability of the reach, it is likely that significant changes like this happen with yearly flows.

The primary restoration strategies for this reach should be to add instream wood and cut pilot channels to connect the channel identified as providing potential connectivity. These strategies will add connected floodplain and should be targeted for perennial flow to increase complexity. Because most of these areas are in the portion of the reach with a somewhat intact riparian zone, this should provide a stable habitat and beneficial boost to complexity.

For the downstream portion of the reach, the primary restoration strategy should be to aggressively add instream structure and

PA 30 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

wood to stabilize gravel bars, along with intense riparian vegetation plantings on the floodplain and on the bars if possible. This should help to stabilize the complex flow paths and hopefully provided better habitat through these areas as well.

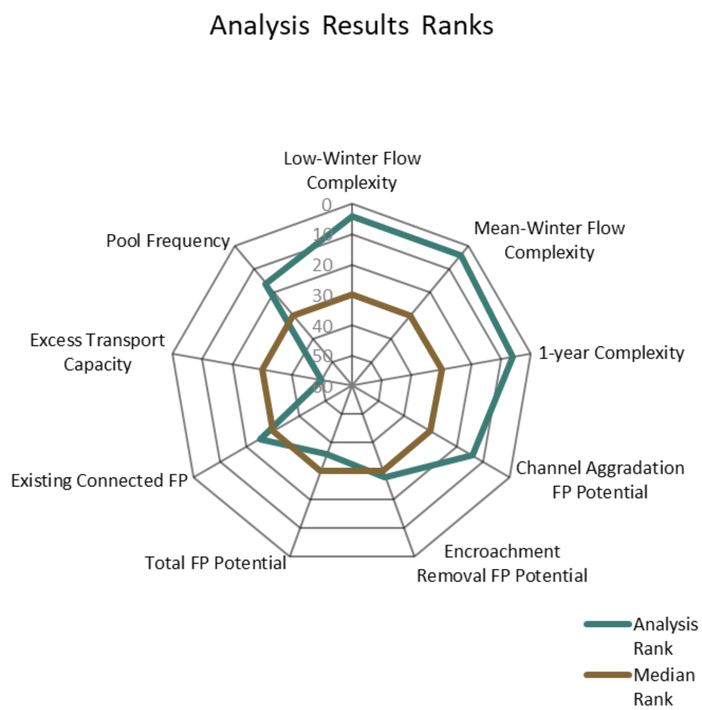
Because this reach could benefit from channel aggradation, gravel augmentation should be considered after this reach has been treated with the above restoration strategies to promote more stable complexity that can trap and store some of the incoming sediment.

Finally, PA 30 ranks well above average in the Pool Frequency metric, indicating a high amount of pools per river mile. However, due to the lack of riparian vegetation, these pools may not actually be providing good habitat. The restoration strategies of adding instream structure and wood, along with riparian zone enhancement, should promote conditions where pools are likely to be maintained and provide better habitat benefit with shade, cover, and complexity.

Summary of Restoration Opportunities Identified

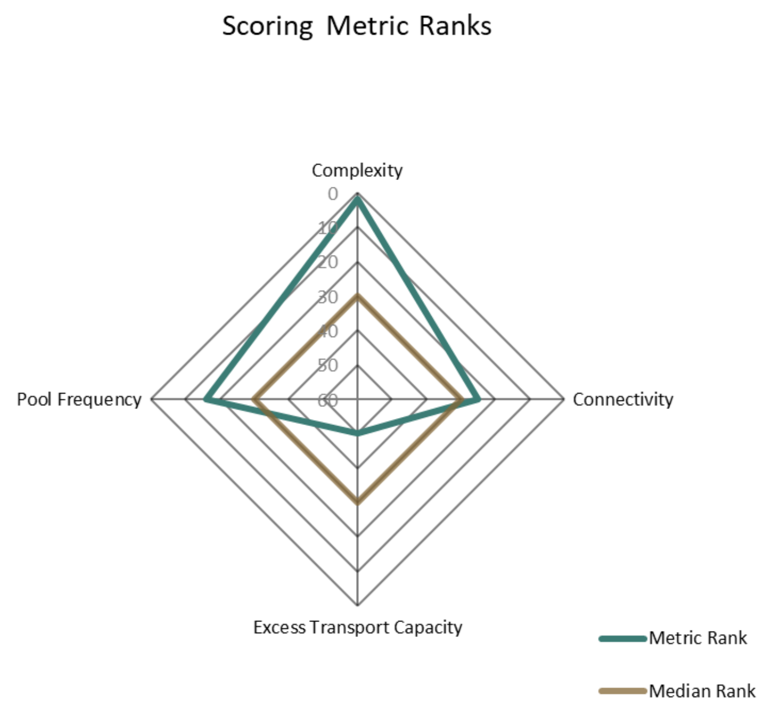
- Reconnect side channels and disconnected habitats
- Add instream structure (LWD)
- Riparian zone enhancement

PA 30 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

PA 30 Scoring Metric Ranks

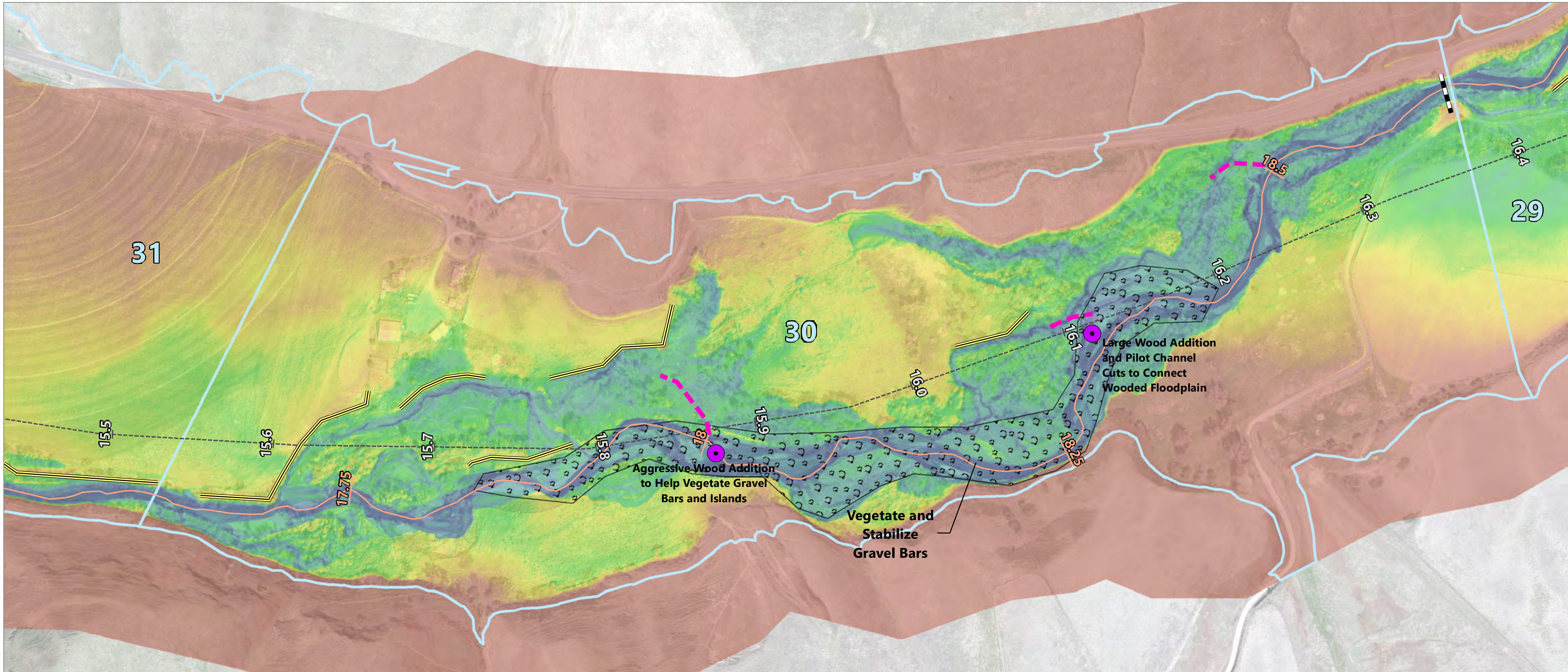


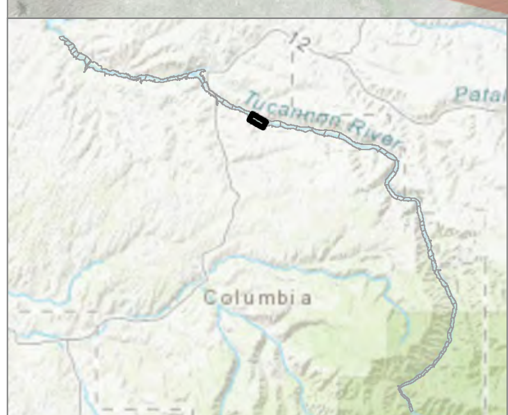
This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PROJECT AREA 30 TIER 3: UNTREATED

PA 30 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.369	4	40%	Complexity	0.500	2	1% to 10%	1 of 5	0	40%	1.2	48	3	Untreated	28	3
Mean-Winter Flow Complexity	0.559	4	40%													
1-year Complexity	0.645	6	20%													
Channel Aggradation FP Potential	0.290	14	40%	Connectivity	0.211	25	25% to 50%	2 of 4	3	40%						
Encroachment Removal FP Potential	0.074	28	40%													
Total FP Potential	0.326	36	20%													
Existing Connected FP	0.674	25	0%													
Excess Transport Capacity	-0.13	50	100%	Excess Transport Capacity	0.000	50	52% to 100%	4 of 4	0	20%						
Pool Frequency	15.88	16	100%	Pool Frequency	0.408	16	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 17.62
RIVER MILE END: 18.63
VALLEY MILE START: 15.54
VALLEY MILE END: 16.37

0 500
Feet

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ANCHOR QEA

Project Area 30
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 33 Description

Project Area 33 begins at the Territorial Road bridge at VM 14.11 and extends upstream to the Highway 12 bridge at VM 15.54. The 2017 RM length is 1.49 miles. Field observations for PA 33 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

Within PA 33, the river is largely confined and incised within a relatively straight, single-thread channel. The 2011 assessment noted that some portions of the channel had cut down to expose historical compacted alluvium along the banks and LWD had been unburied. The channel was primarily a transport reach with a low volume of temporary sediment storage and low volume of wood material. In the upper project, occasional bedrock outcrops were located in the channel bed, which forced local pools and rapids and likely contributed to holding the channel grade. A majority of the upper reach was confined by riprap and unarmored levees. A significant bedrock sill was located along the left bank and in the channel. The bedrock sill area contained split flow, a large log jam, and active migration of the channel into the right floodplain (which was a field at the time of the 2011 assessment). The lower portion of the project reach was primarily a plane-bed channel with local forced pools where the channel was located along the toe of the bedrock valley wall, and sporadic LWD pools. The right bank contained

Project Area 33
Photograph taken from 2011 prioritization showing a bedrock sill (left) and plane-bed channel conditions.

Project Area 33 Reach Characteristics

VM Start (mi)	11.71
VM Length (mi)	1.12
Valley Slope	0.72%
RM Start (mi)	13.43
RM Length (mi)	1.22
Average Channel Slope	0.66%
Sinuosity	1.09
Connected FP (ac/VM)	7.76
Encroachment Removal (ac/VM)	0.11
Channel Aggradation (ac/VM)	1.71
Total FP Potential (ac/VM)	1.87
Encroaching Feature Length (ft)	3,629.84
Connected FP Rank	57

sporadic riprap, and an armored and unarmored access road prism at a decommissioned pump and ditch site.

In 2011, instream habitat conditions were generally characterized by a lack of LWD and cover, low hydraulic complexity, and poor bedload sediment distribution. The existing bedrock pools were likely providing good adult holding habitat, but the overall quantity of pools was low. In general, there was a low amount of potential spawning area. No significant side channels or off-channel areas for high-flow refuge or juvenile rearing areas were observed.

The riparian zone was in generally poor health. The riparian corridor was very narrow and not well connected to the water table. Riparian trees were predominantly mature alders and cottonwoods. In some exposed sections of the channel, regenerating locusts or other invasive plants were dominant. Shade was poor to moderate. Understory vegetation was dominated by invasive groundcover including several thick patches of poison hemlock.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows several locations of significant geomorphic change in this project area. PA 33 also shows long stretches of erosion in locations where the channel has not moved. These have not been highlighted because it is possible that these are false indicators based on the differences in ability of the 2017 LiDAR to detect bathymetry compared to the 2010 LiDAR. However, PA 33 is a straight and confined reach where incision and downcutting would be expected, so it is not impossible that some of this is real change.

The first notable location of change comes at the upstream end of the project area, where the channel has migrated slightly into the right bank floodplain, and then more drastically towards the left bank, where it now runs against the valley wall (box 1).

Immediately downstream, the channel has formed a split flow and erosion is evident in the side channel and main channel. Past the bend, more erosion is evident on the right bank along with some deposition on the left bank bar (box 2).

Finally, near the downstream end of the reach, the channel has again migrated toward the left bank and is now completely up against the valley wall (box 3).

Geomorphic Characteristics and Restoration Strategies

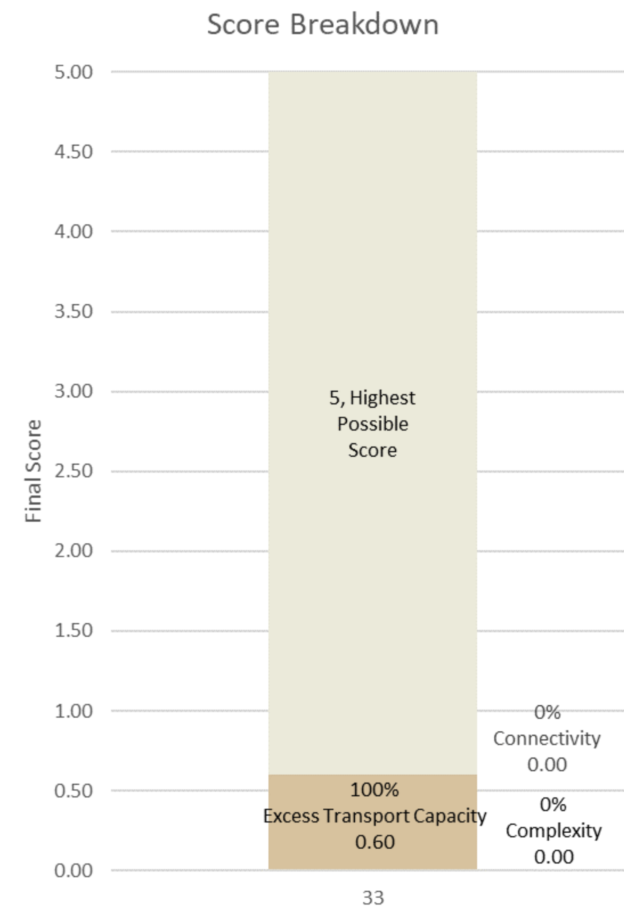
As shown in the following graphs and table, PA 33 receives a moderate score in the Excess Transport Capacity metric, which makes up the entirety of its prioritization score. PA 33 is highly confined and ranks in the bottom 10% and bottom 25% for Complexity and Connectivity, respectively. The moderate Excess Transport Capacity score is likely due to this confinement, which appears to be due to mostly incision because no well-defined levees are evident on the relative elevation map. The primary restoration target for this reach should be to reverse some of this incision through channel aggradation and adding a large amount of instream wood to trap and store sediment in the main channel. However, floodplain reconnection may be difficult to achieve through channel aggradation and floodplain benching may provide more immediate habitat gains in the short term, although this would likely require a large amount of effort.

Pool frequency in PA 33 is slightly above average despite what would be expected in a reach that is starved of sediment supply and severely confined. The identified restoration strategies of widening the floodplain, adding instream wood, and providing gravel augmentation should greatly benefit the natural processes of complexity and connectivity that will maintain pool formation in this reach.

Summary of Restoration Opportunities Identified

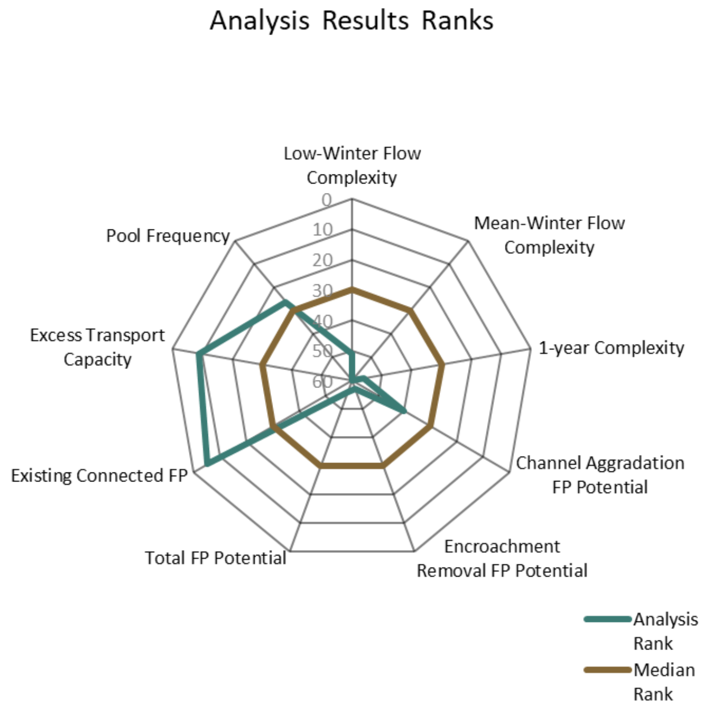
- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

PA 33 Score Breakdown



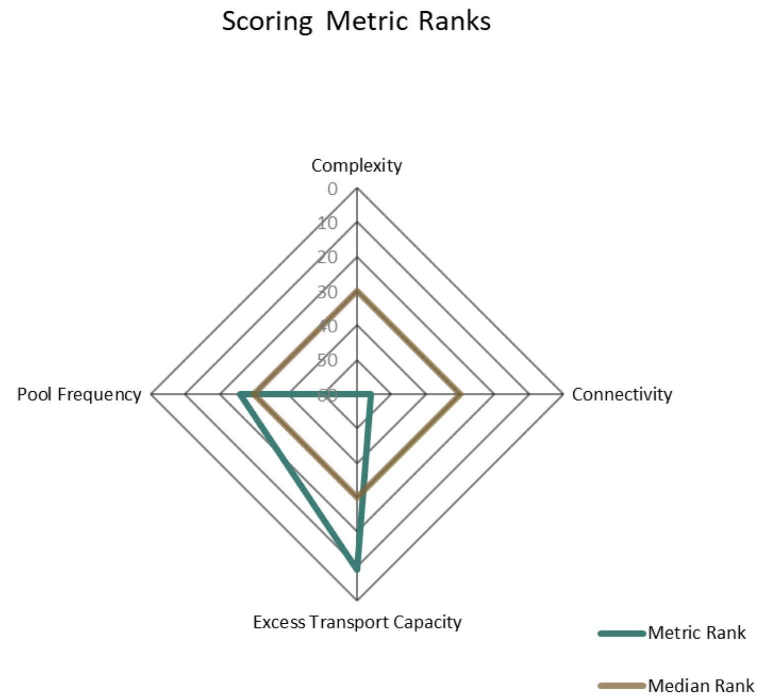
This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

PA 33 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

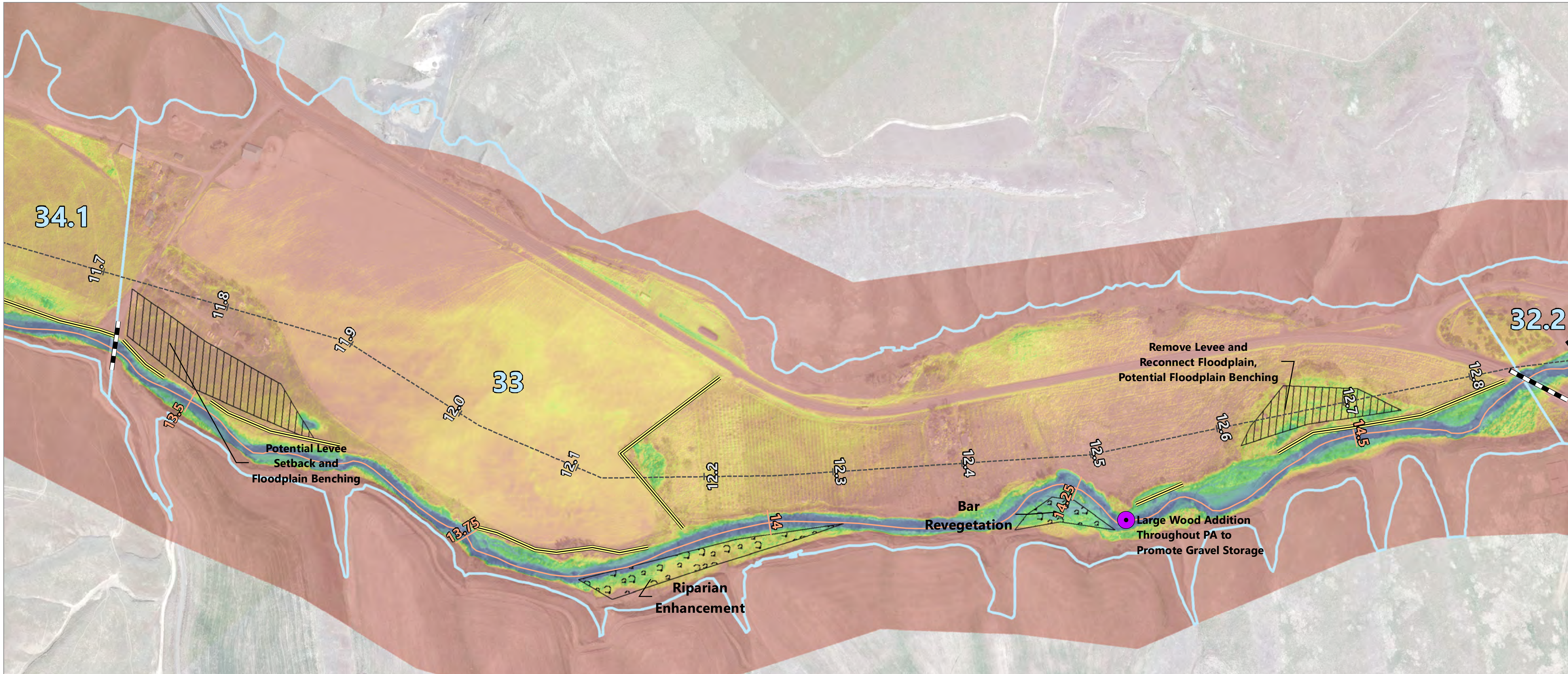
PA 33 Scoring Metric Ranks

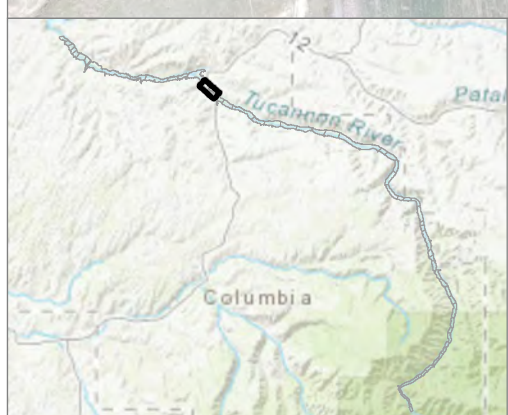


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 33 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.094	51	40%	Complexity	0.084	60	90% to 100%	5 of 5	0	40%	0.6	58	3	Untreated	36	3
Mean-Winter Flow Complexity	0.075	60	40%													
1-year Complexity	0.085	56	20%													
Channel Aggradation FP Potential	0.177	40	40%	Connectivity	0.114	56	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.011	57	40%													
Total FP Potential	0.194	56	20%													
Existing Connected FP	0.806	5	0%													
Excess Transport Capacity	0.18	9	100%	Excess Transport Capacity	3.000	9	10% to 30%	2 of 4	3	20%						
Pool Frequency	12.28	26	100%	Pool Frequency	0.315	26	40% to 60%	3 of 5	5	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential
- Riparian Enhancement

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 13.43
RIVER MILE END: 14.65
VALLEY MILE START: 11.71
VALLEY MILE END: 12.84

0 500
Feet

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ANCHOR QEA

Project Area 33
Conceptual Restoration Opportunities

Project Area 37 Description

Project Area 37 begins at VM 6.86 and extends upstream to VM 7.83. The 2017 RM length is 1.10 miles. Field observations for the upper portion of PA 37 were conducted on November 30, 2018, when flow at the Starbuck gage was approximately 110 cfs.

PA 37 is mostly defined by extreme channel confinement and disconnection from the surrounding floodplain. At the time of the site visit, the reach contained a minimal amount of large woody material and almost no geomorphic forced pools or plan forms.

The Smith Hollow Road bridge crosses the river mid-reach at VM 7.21, and a U.S. Geological Survey gage is located shortly downstream of the bridge. The channel confinement continues downstream, with only a thin strip of riparian vegetation and large riprap observed on both banks.

PA 37 likely functions as a pure transport reach with almost no gravel side sediment observed in the bed material and very little instream wood. The few pools observed in this reach were forced by large angular rock or the bridge abutments.

Geomorphic Changes

Analysis of the difference between the 2010 and 2017 LiDAR data shows only two minor locations of notable geomorphic change in PA 37. PA 37 also shows long stretches of erosion in

Project Area 37
Looking upstream. The reach is a straight, uniform channel that is highly confined by levees and high banks.

Project Area 37 Reach Characteristics

VM Start (mi)	6.86
VM Length (mi)	0.97
Valley Slope	0.58%
RM Start (mi)	8.01
RM Length (mi)	1.10
Average Channel Slope	0.50%
Sinuosity	1.13
Connected FP (ac/VM)	10.85
Encroachment Removal (ac/VM)	0.18
Channel Aggradation (ac/VM)	2.55
Total FP Potential (ac/VM)	3.11
Encroaching Feature Length (ft)	4,656.68
Connected FP Rank	43

locations where the channel has not moved. These have not been highlighted because it is possible that these are false indicators based on the differences in ability of the 2017 LiDAR to detect bathymetry compared to the 2010 LiDAR. However, PA 37 is a straight and confined reach where incision and downcutting would be expected, so it is not impossible that some of this is real change.

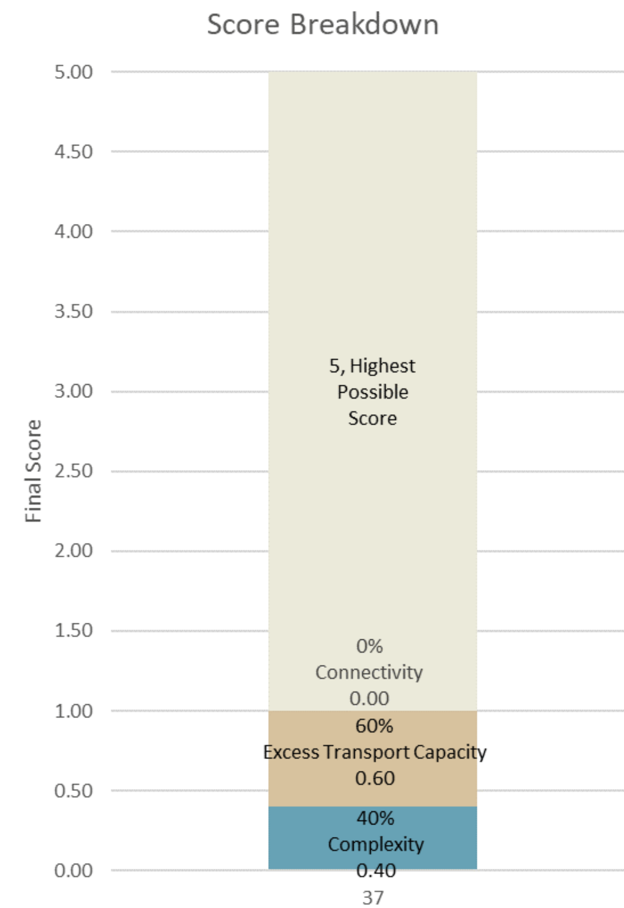
At the upstream end of the reach, a large amount of deposition has occurred on the left and right bank floodplains, followed by a small erosional area on the left bank. It is possible the noted deposition on the right bank may not be natural because it coincides closely with the levee in that location (box 1).

Immediately downstream, a long stretch of deposition has occurred in the main channel and on the left bank floodplain and pushed the channel towards the left bank further downstream. Erosion is evident on both the left and right banks in this location (box 2).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 37 receives a moderate score in the Excess Transport Capacity metric and a low score in the Complexity metric, which combine to account for the entire prioritization score for this project area. The low Complexity score indicates that this project area falls below average in the 10th to 40th percentile, which is a range that has

PA 37 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

been identified as having some small existing complexity but would likely require a large restoration effort to achieve higher levels. Almost all of the existing complexity comes from the upstream end of this reach where some mid-channel bars and small side channels have formed.

The primary restoration strategy for this reach should be to add instream wood and structure to promote in-channel complexity and better habitat conditions. There are several small side channel connection opportunities in the immediate floodplain evident on the relative elevation map that could be connected via the addition of instream wood and pilot channel cuts. Gravel augmentation could also be considered a restoration strategy that would allow more pools and in-channel complexity to form. However, it will be difficult to retain sediment in this reach because of the higher-than-average score in the Excess Transport Capacity metric, so wood loading should be aggressive if gravel augmentation is considered.

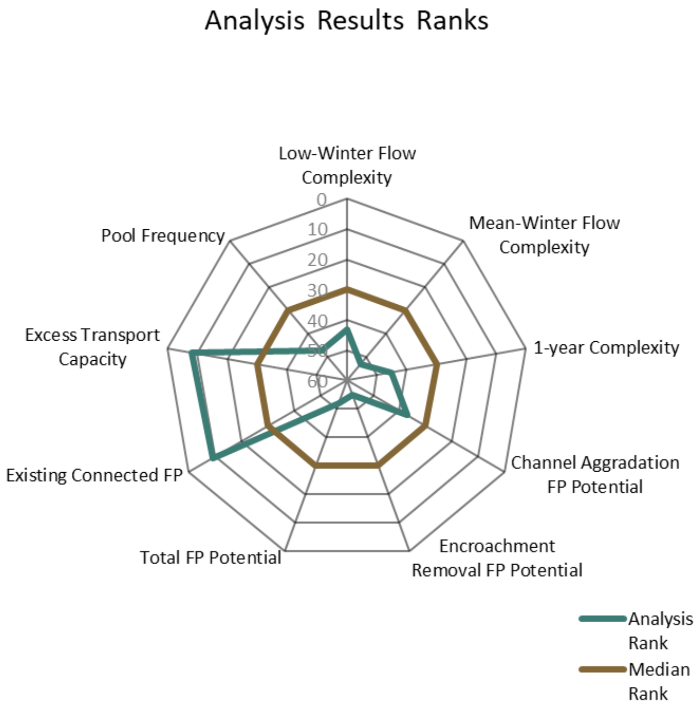
Real habitat benefits in this reach will likely only be gained by widening the floodplain to provide more available area for connection and connectivity. However, this would likely require a massive effort because incision is severe for most of the reach and often includes large rock.

Finally, PA 37 scores very poorly in pool frequency, likely due to the confined nature of this reach. The identified restoration strategies of adding instream wood and gravel augmentation should allow more complexity to form and create the conditions that will allow pools to form more regularly through natural geomorphic processes.

Summary of Restoration Opportunities Identified

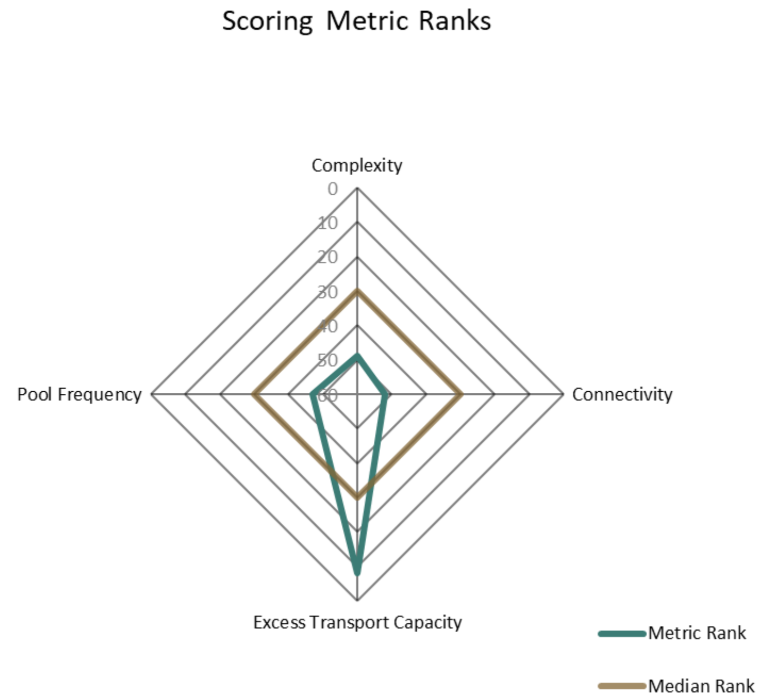
- Gravel augmentation
- Address encroaching features
- Add instream structure (LWD)
- Modify or remove obstructions

PA 33 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

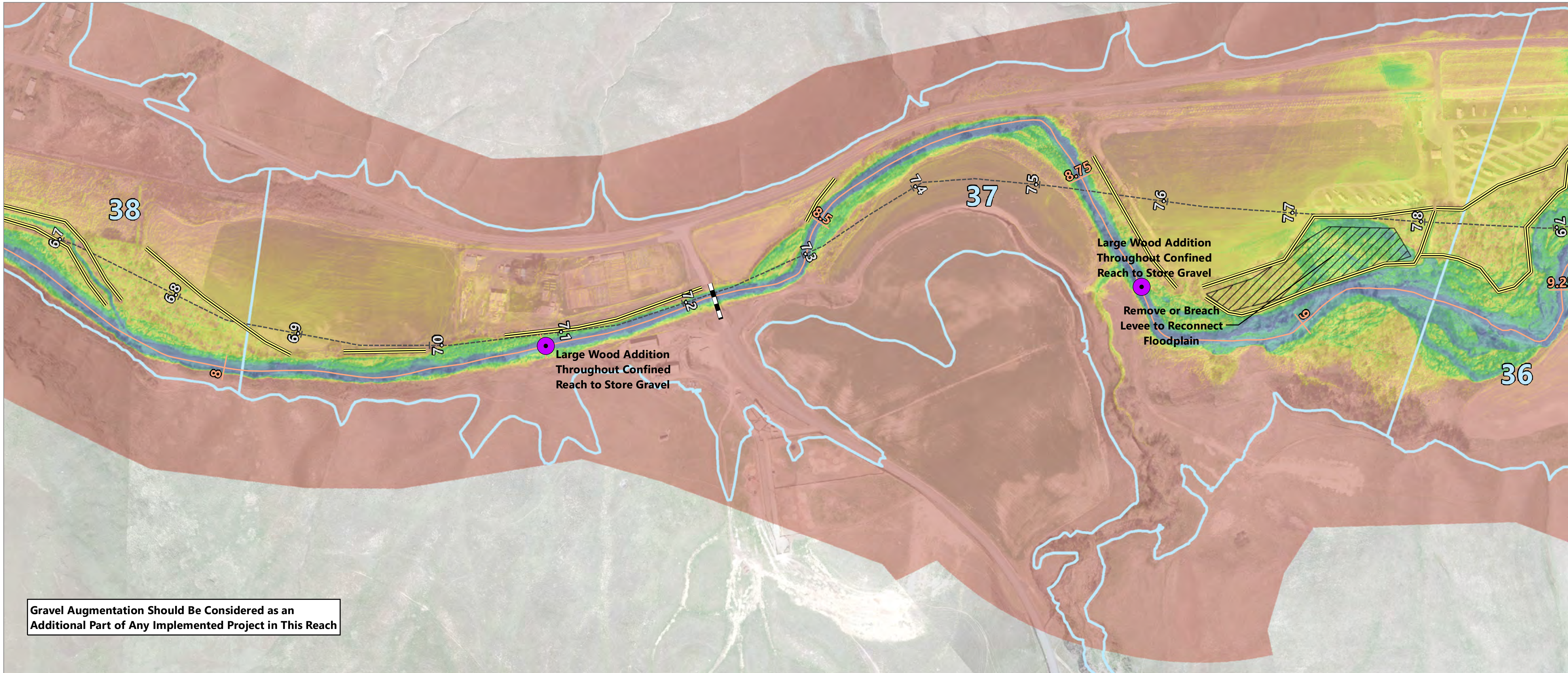
PA 33 Scoring Metric Ranks

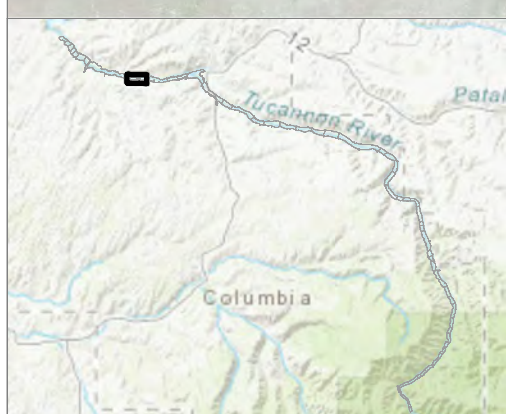


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 37 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.105	43	40%	Complexity	0.121	49	60% to 90%	4 of 5	1	40%	1.0	52	3	Untreated	32	3
Mean-Winter Flow Complexity	0.113	53	40%													
1-year Complexity	0.172	45	20%													
Channel Aggradation FP Potential	0.183	37	40%	Connectivity	0.123	52	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.013	55	40%													
Total FP Potential	0.223	52	20%													
Existing Connected FP	0.777	9	0%													
Excess Transport Capacity	0.18	8	100%	Excess Transport Capacity	3.000	8	10% to 30%	2 of 4	3	20%						
Pool Frequency	5.46	47	100%	Pool Frequency	0.140	47	60% to 90%	4 of 5	1	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 8.01
RIVER MILE END: 9.11
VALLEY MILE START: 6.86
VALLEY MILE END: 7.83

0 500
Feet

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ANCHOR QEA

Project Area 37
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 39.2 Description

Project Area 39.2 begins at VM 3.40 and extends upstream to VM 4.00, which is just upstream of the large lateral Starbuck levee. The 2017 RM length is 0.33 mile. Field observations for PA 39.2 were not conducted in 2018 as part of this assessment update, and the remainder of this site description was taken from the 2011 prioritization.

The river through PA 39.2 is a single-thread channel downstream of the Kellogg Hollow Road bridge and flows along the base of the Starbuck levee on the right bank. One large pool the Starbuck Swimming Hole) is located downstream of the Kellogg Hollow Road bridge at the bedrock outcrop located along the left bank.

The 2011 assessment noted that there was limited floodplain within the project area and the channel was highly confined due to the alignment of the Starbuck levee. The levee extends along the right bank throughout the entire project area, limiting channel migration and floodplain development along the right bank. This levee protects the town of Starbuck from high flood waters during peak flows. Along the left bank is a bedrock outcrop that limits floodplain connectivity and channel migration along the left bank. Some overbank area exists along the left bank immediately downstream of the Kellogg Hollow Road bridge. Along with the confluence with Kellogg Creek.

Project Area 39.2
Photograph taken from the 2011 prioritization showing the main channel just downstream of the Kellogg Road bridge with the Starbuck levee along the right bank. View is looking downstream.

Project Area 39.2 Reach Characteristics

VM Start (mi)	3.68
VM Length (mi)	0.31
Valley Slope	0.71%
RM Start (mi)	4.61
RM Length (mi)	0.33
Average Channel Slope	0.66%
Sinuosity	1.05
Connected FP (ac/VM)	10.22
Encroachment Removal (ac/VM)	0.00
Channel Aggradation (ac/VM)	2.48
Total FP Potential (ac/VM)	2.52
Encroaching Feature Length (ft)	1,791.59
Connected FP Rank	47

In 2011, the riparian zone through the project area was generally in poor to moderate health. Riparian vegetation along the right bank was limited due to the presence of the Starbuck levee. Recent vegetation removal of trees on the levee face was evident. U.S. Army Corps of Engineers levee requirements limit the diameter size of vegetation allowed to grow on the face and levee toe. Because of the limited riparian zone, channel shading is lacking throughout most of the project area.

Geomorphic Changes

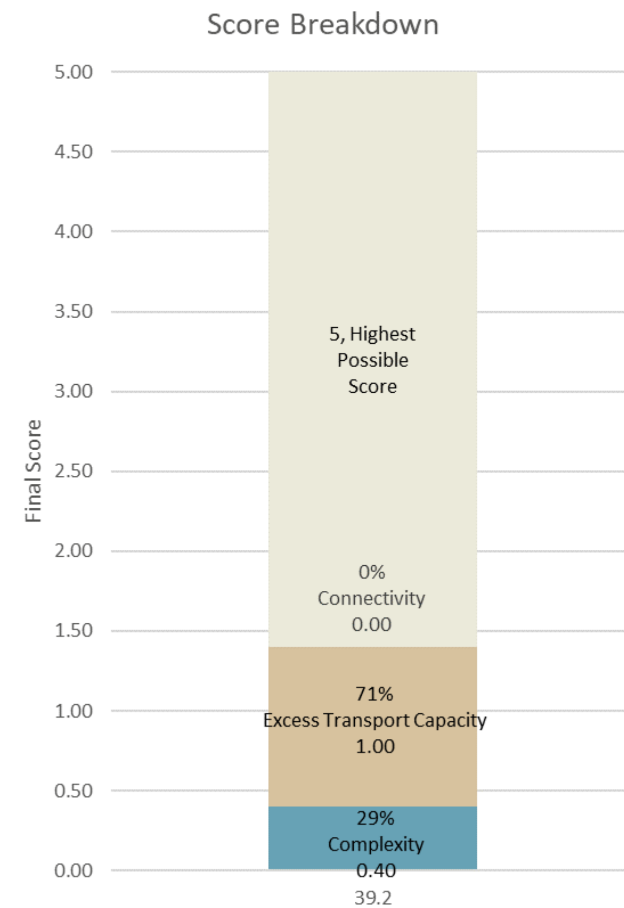
Analysis of the difference between the 2010 and 2017 LiDAR data shows two locations of significant geomorphic change. At the very upstream end of the project area, there is a depositional area on the left bank, and associated erosion on the right bank. This area is likely geomorphically associated with the major bank erosion occurring just upstream in PA 39.1 (box 1).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 39.2 receives the majority of its score from the Excess Transport Capacity metric. PA 39.2 receives no points for Connectivity and ranks in the bottom 25% of all project areas.

PA 39.2 receives a high score in the Excess Transport Capacity metric, indicating that this reach might have more transport capacity than average for the basin. This reach is highly confined by the levee for the town of Starbuck and there is

PA 39.2 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

likely little opportunity to widen the floodplain and decrease the transport capacity Therefore, the restoration strategy of adding instream wood should be considered if possible to slow flows and reduce transport capacity.

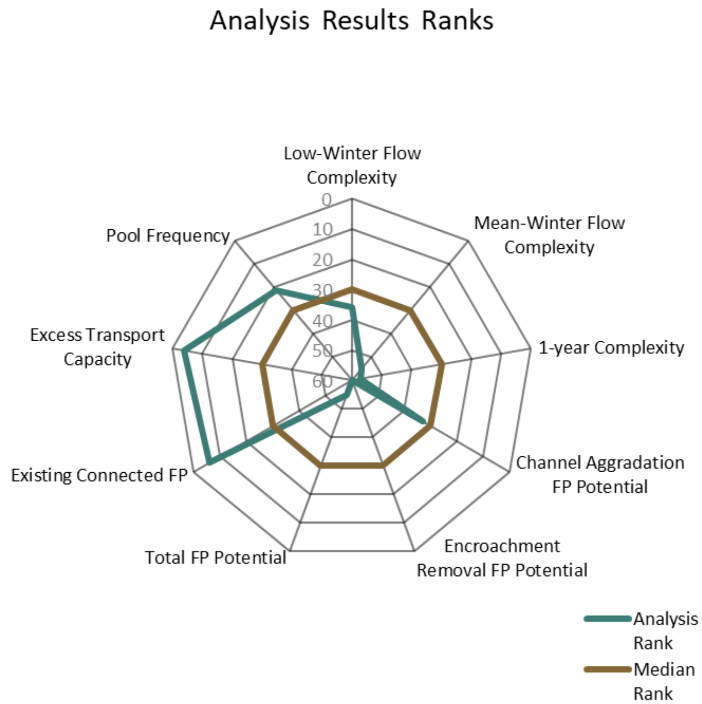
PA 39.2 ranks in the 10th percentile for Complexity, much lower the most of the other project areas. This range has been identified as having some complexity but would be difficult to achieve more. Because most of the reach is behind the levee for the town of Starbuck, adding side channels and split flows would be difficult or impossible. The most likely restoration strategy for this reach would be to add some instream wood as habitat features and in-channel complexity.

Finally, PA 39.2 ranks slightly above average among project areas in the Pool Frequency metric. Adding instream wood and gravel augmentation will promote changes towards an increase in channel complexity, promoting the formation of pools. These restoration strategies should be employed to target maintaining and increasing pool frequency in the reach.

Summary of Restoration Opportunities Identified

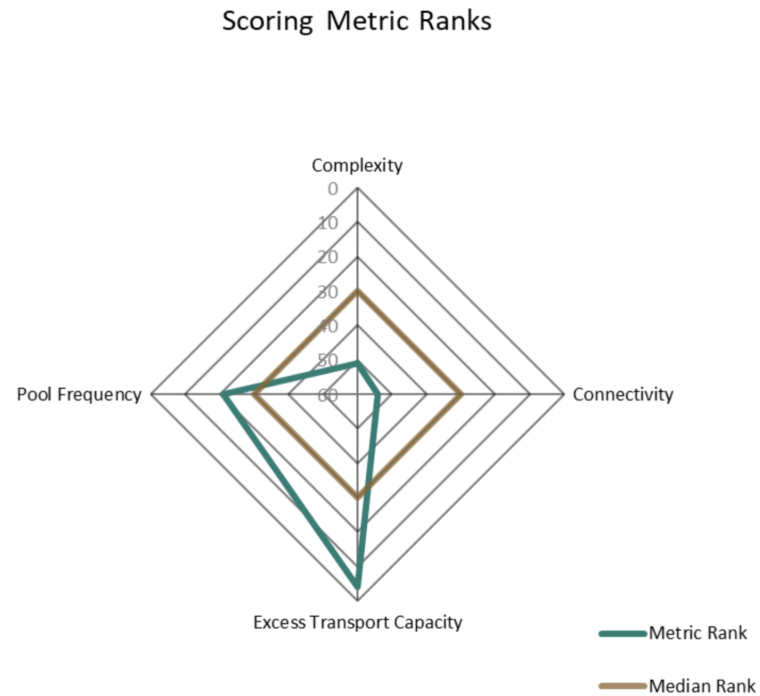
- Add instream structure (LWD)

PA 39.2 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

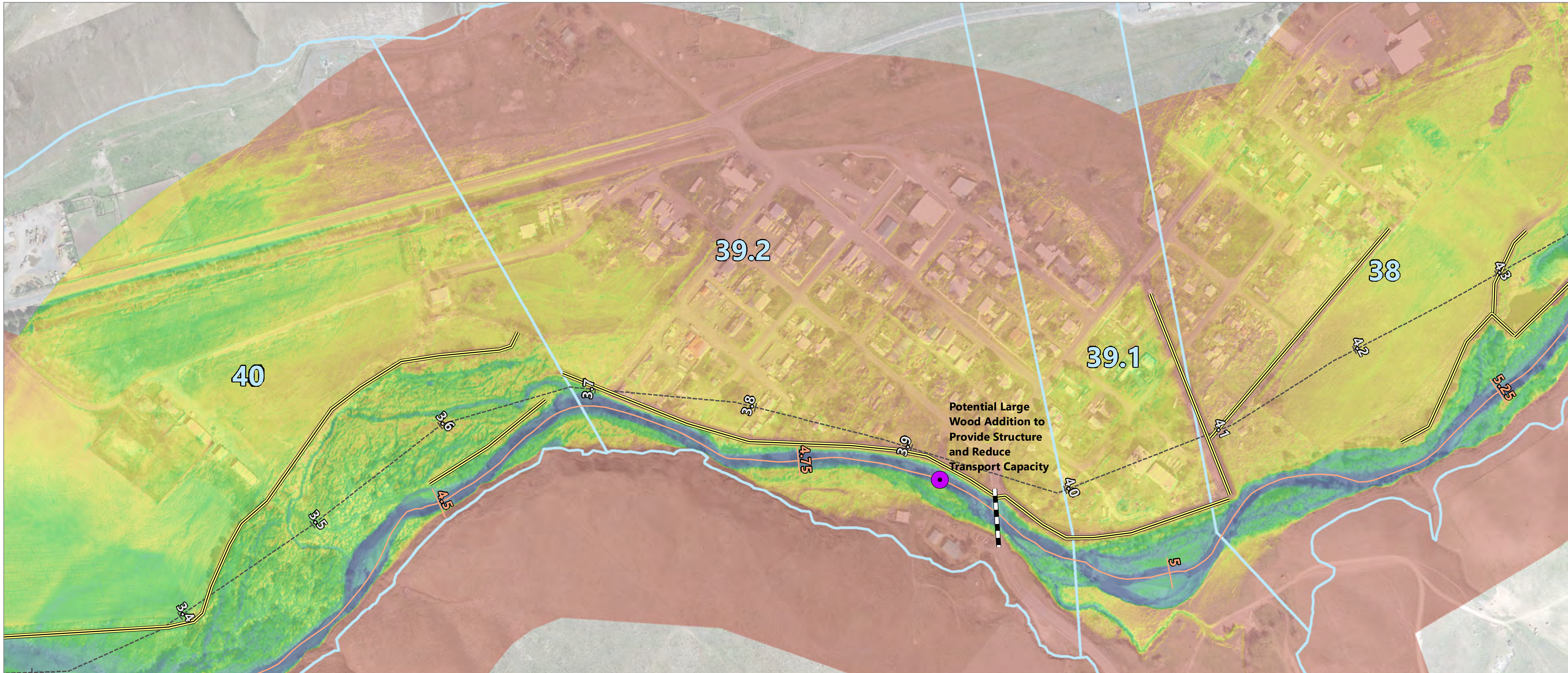
PA 39.2 Scoring Metric Ranks



This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 39.2 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.128	36	40%	Complexity	0.108	51	60% to 90%	4 of 5	1	40%	1.4	43	3	Untreated	26	3
Mean-Winter Flow Complexity	0.101	55	40%													
1-year Complexity	0.084	57	20%													
Channel Aggradation FP Potential	0.194	33	40%	Connectivity	0.117	54	75% to 100%	4 of 4	0	40%						
Encroachment Removal FP Potential	0.000	60	40%													
Total FP Potential	0.198	55	20%													
Existing Connected FP	0.802	6	0%													
Excess Transport Capacity	0.29	4	100%	Excess Transport Capacity	5.000	4	1% to 10%	1 of 4	5	20%						
Pool Frequency	14.39	21	100%	Pool Frequency	0.369	21	10% to 40%	2 of 5	3	0%						



LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 4.61
RIVER MILE END: 4.94
VALLEY MILE START: 3.68
VALLEY MILE END: 4

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Feet

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ANCHOR QEA

Project Area 39.2
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Project Area 45 Description

Project Area 45 begins at the first bridge crossing for the Tucannon Road at VM 1.58 and extends upstream to the Powers Road bridge at VM 2.01. The 2017 RM length is 0.52 mile. Field observations for PA 45 were not conducted in 2018 as part of this assessment update, and the following description of the reach is based on the 2018 aerial imagery.

PA 45 is the most downstream project area in the assessment, and the remainder of the Tucannon River is highly influenced by the water surface elevation of the Snake River. The channel here is highly sinuous and runs through a riparian corridor of mostly grass, reeds, and small trees.

At the upstream end at the Powers Road bridge, the riparian vegetation is sparse, particularly on the left bank that borders an agricultural field. The channel through this reach meanders from the edges of the riparian corridor several times. When the channel is on the left bank edge of the riparian corridor, it borders the nearby agricultural field and pasture. On the right bank, it borders the old railway grade, which was noted to be heavily riprapped in upstream reaches. The riparian corridor in general seems to have adequate mature vegetation, and where the channel meanders from one side to the other there is relatively good vegetative cover. Midway through the reach, the channel becomes more confined by a levee on the left bank and the railway line on the right bank, and the floodplain

Project Area 45
No site photograph available.

Project Area 45 Reach Characteristics

VM Start (mi)	1.58
VM Length (mi)	0.43
Valley Slope	0.46%
RM Start (mi)	1.96
RM Length (mi)	0.52
Average Channel Slope	0.38%
Sinuosity	1.23
Connected FP (ac/VM)	25.05
Encroachment Removal (ac/VM)	4.10
Channel Aggradation (ac/VM)	3.91
Total FP Potential (ac/VM)	13.48
Encroaching Feature Length (ft)	3,183.31
Connected FP Rank	7

continues to narrow until reaching the bridge opening at Tucannon Road.

Geomorphic Changes

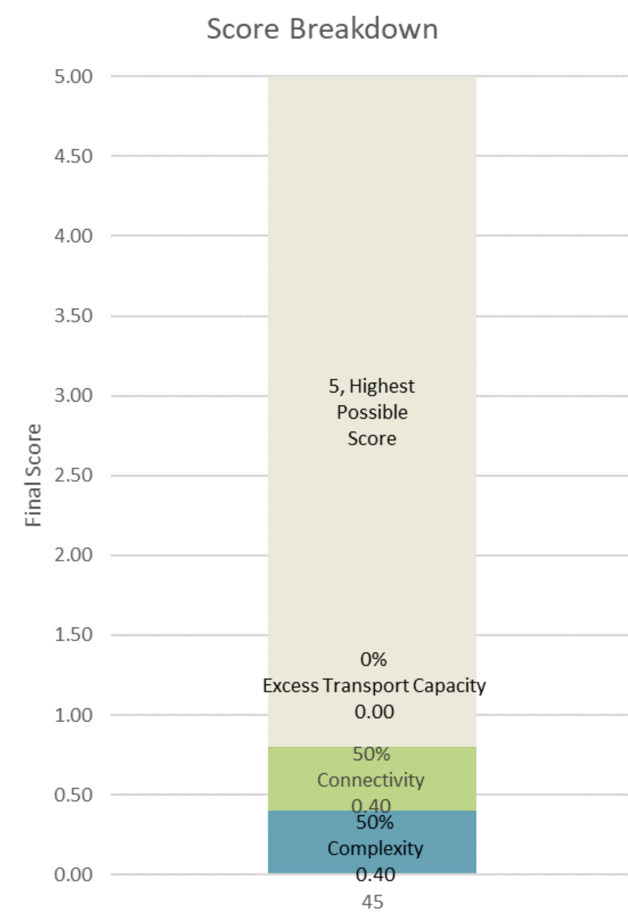
Analysis of the difference between the 2010 and 2017 LiDAR data shows several locations of significant geomorphic change. At the upstream end of the reach, a large depositional area has occurred on the left bank forming a point bar. On the opposite bank, erosion is occurring as the channel moves that way. Immediately downstream, erosion has occurred on the left bank and a slight meander bend may be forming here (box 1).

After the next bend downstream, erosion is occurring on the right bank and deposition is forming another point bar on the left bank as the channel moves closer to the old railway grade (box 2).

Geomorphic Characteristics and Restoration Strategies

As shown in the following graphs and table, PA 45 receives the majority of its score from a moderate score in the Connectivity metric. This score indicates that PA 45 ranks above average in the 50th to 75th percentile of all project areas for Connectivity potential. However, this rank is driven almost entirely by a high rank in the Encroachment Removal analysis result due to an area that may be difficult to reconnect. On the right bank, a large, low-lying area is disconnected from the active channel by

PA 45 Score Breakdown



This score breakdown shows how the three prioritization metrics contribute to the final prioritization score.

the old railway grade. This railway line acts as a large levee and is heavily reinforced with riprap in many locations. On the left bank, a large portion of the bordering agricultural field is disconnected by a levee as well. The primary restoration strategy for this reach should be to remove or breach these levees to reconnect this floodplain area, along with the addition of instream and gravel augmentation to promote geomorphic change into these new areas. Riparian vegetation enhancement will also be necessary in these areas because the current vegetation is grass and agricultural fields.

Should removal of these levees not be possible, the alternate restoration strategy should be to promote complexity. PA 45 receives a low score in the Complexity metric, indicating it ranks below average in the 10th to 40th percentile of project areas. This typically indicates that additional complexity could be difficult to achieve through restoration. However, PA 45 presents several opportunities for restoration in the form of disconnected side channels in the 2-year floodplain. The channels exist primarily on the left bank floodplain between the river and levee midway through the reach. Additionally, a long side channel on the right bank floodplain is currently connected at the 1-year flow but not at the two lower flows. This is reflected in the analysis results that have the 1-year flow ranked much higher than the two lower flows. Connecting these side channels to perennial flow would boost complexity across the entire reach. The primary restoration strategies for complexity should be to cut pilot channels to these side channels and add instream wood to promote geomorphic change in these locations. Gravel augmentation should also be considered to promote more frequent geomorphic change and to raise the channel bed and allow for easier connection of side channels.

Finally, PA 45 ranks very highly in the Pool Frequency metric, indicating a high amount of pools per river mile. The identified restoration strategies of adding instream structure and wood should promote geomorphic change towards more in-channel complexity and conditions where pools are likely to be maintained and continue to form with the natural processes of the reach.

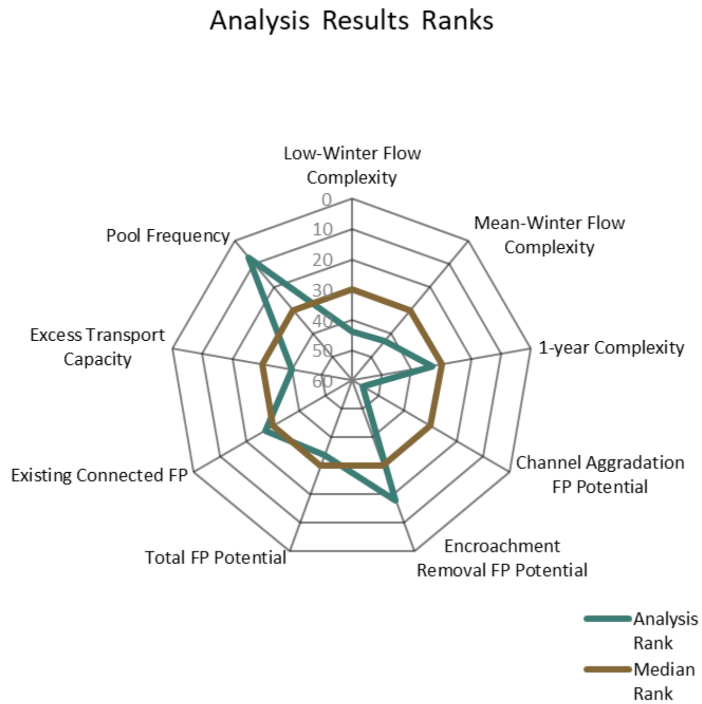
Summary of Restoration Opportunities Identified

- Gravel augmentation
- Reconnect side channels and disconnected habitats
- Address encroaching features
- Add instream structure (LWD)
- Riparian zone enhancement

Long-Term Opportunities in this Project Area

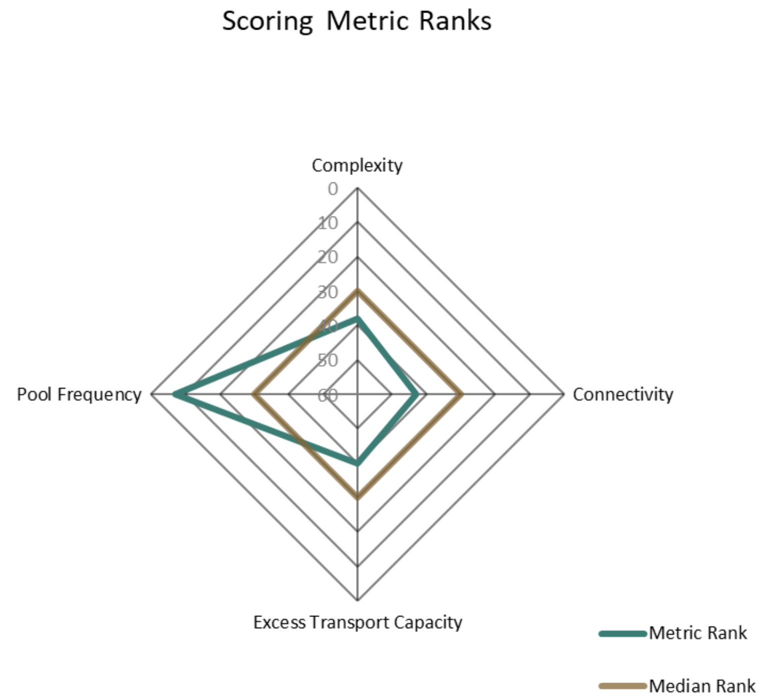
- Remove railroad grade, reconnect floodplain.

PA 45 Analysis Results Ranks



This analysis results summary shows how this project area ranks in relation to the rest of the basin for the nine metrics from the Geomorphic Assessment. The results are used as indicators for the geomorphic characteristics and restoration strategies. The median rank is highlighted in brown for comparison.

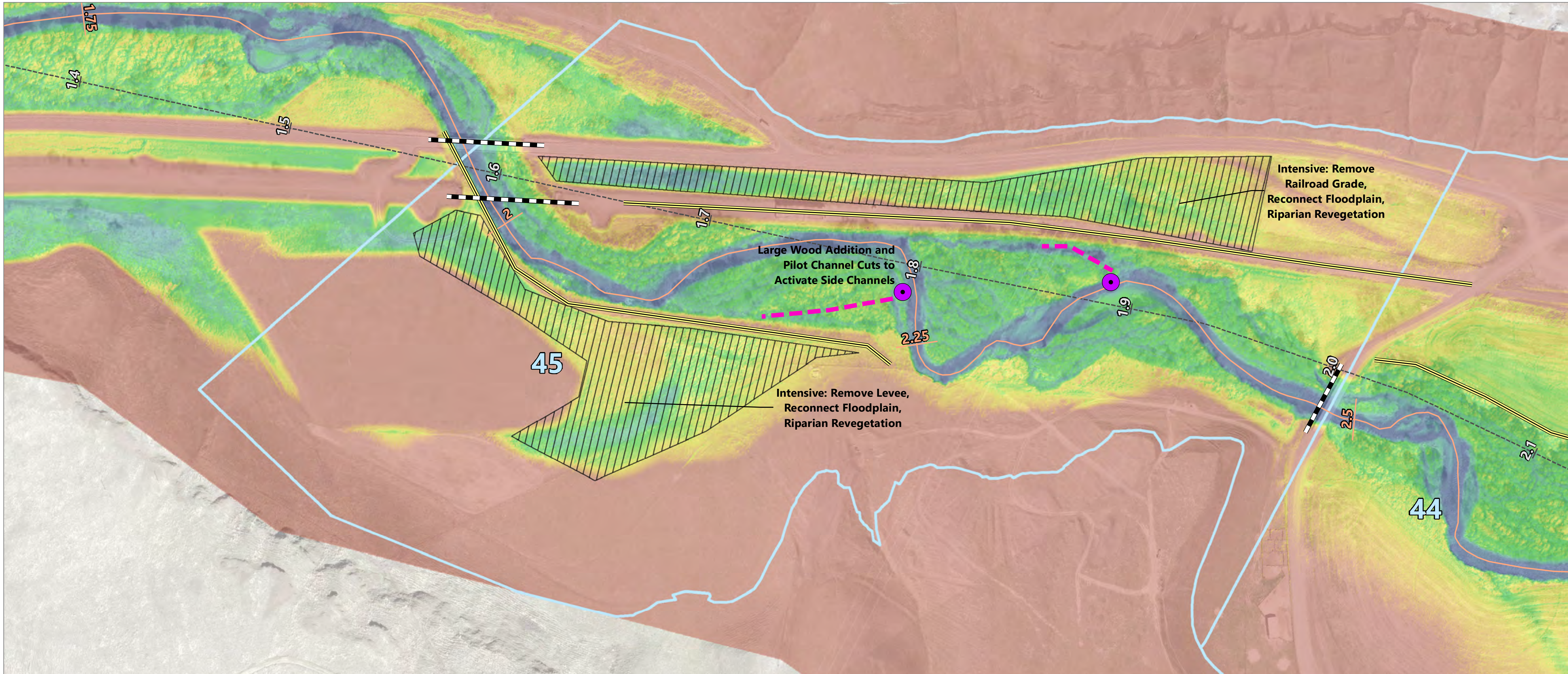
PA 45 Scoring Metric Ranks

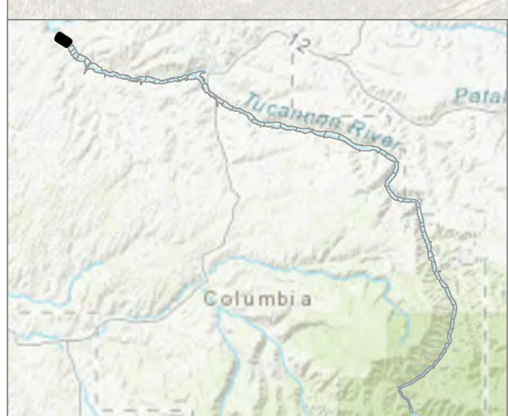


This prioritization scoring summary shows how this project area ranks in relation to the rest of the basin for the three prioritization metrics as well as pool frequency. The results are used as indicators for the geomorphic characteristics and restoration strategies, as well as to prioritize this project area. The median rank is highlighted in brown for comparison.

PA 45 Prioritization Ranking

Analysis	Analysis Result	Analysis Rank	Metric Weight	Metric	Metric Score	Metric Rank	Top Percent Range	Metric Class	Metric Class Score	Prioritization Weight	Final Score	Overall Rank	Overall Tier	Status	Status Rank	Status Tier
Low-Winter Flow Complexity	0.100	44	40%	Complexity	0.158	38	60% to 90%	4 of 5	1	40%	0.8	54	3	Untreated	33	3
Mean-Winter Flow Complexity	0.147	43	40%													
1-year Complexity	0.295	33	20%													
Channel Aggradation FP Potential	0.101	56	40%	Connectivity	0.153	43	50% to 75%	3 of 4	1	40%						
Encroachment Removal FP Potential	0.106	18	40%													
Total FP Potential	0.350	34	20%													
Existing Connected FP	0.650	27	0%													
Excess Transport Capacity	-0.08	40	100%	Excess Transport Capacity	0.000	40	52% to 100%	4 of 4	0	20%						
Pool Frequency	26.73	7	100%	Pool Frequency	0.686	7	10% to 40%	2 of 5	3	0%						





LEGEND:

- Tucannon Project Areas
- Tucannon River Centerline
- Tucannon Valley Line
- Delineated Levees
- Bridges Limiting Channel Migration
- Wood Addition Throughout Project Area
- Reconnect Side Channel
- Reconnect Floodplain or Levee Setback Potential

Relative Elevation in Feet

High : 15

Low : -0

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial Imagery provided by GeoTerra. Flown April 19, 2018.
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and opportunities in this map are based on LiDAR and aerial imagery from 2018. Flood events and geomorphic changes have occurred since then and may have changed the topography relative to what is shown.

RIVER AND VALLEY MILE DATA:

RIVER MILE START: 1.96
RIVER MILE END: 2.49
VALLEY MILE START: 1.58
VALLEY MILE END: 2.01

0 500
Feet

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Project Area 45
Conceptual Restoration Opportunities

Geomorphic Assessment and Conceptual Restoration Plan
Tucannon Basin Habitat Restoration

Appendix K
Riparian Vegetation Analysis

Appendix K
Riparian Vegetation Analysis

Riparian vegetation is a key part of a functioning fluvial system and has both direct immediate effects on instream habitat as well as longer process-based effects on the fluvial ecosystem. It holds information about the health of the ecosystem and the geomorphic state of the river corridor. Investigating the extent and type of coverage can provide useful information when planning restoration actions. This appendix provides information on why and how the vegetation analysis was conducted. The concept of riparian vegetation in fluvial systems, and its roles in the Tucannon River specifically, is explained in more detail in Section 10.4 of the main report.

Analysis Overview

The purpose of the riparian vegetation analysis is to identify the following:

1. What is the overall status of riparian vegetation for each project area?
2. Where has that riparian vegetation increased or decreased between 2010 and 2017?

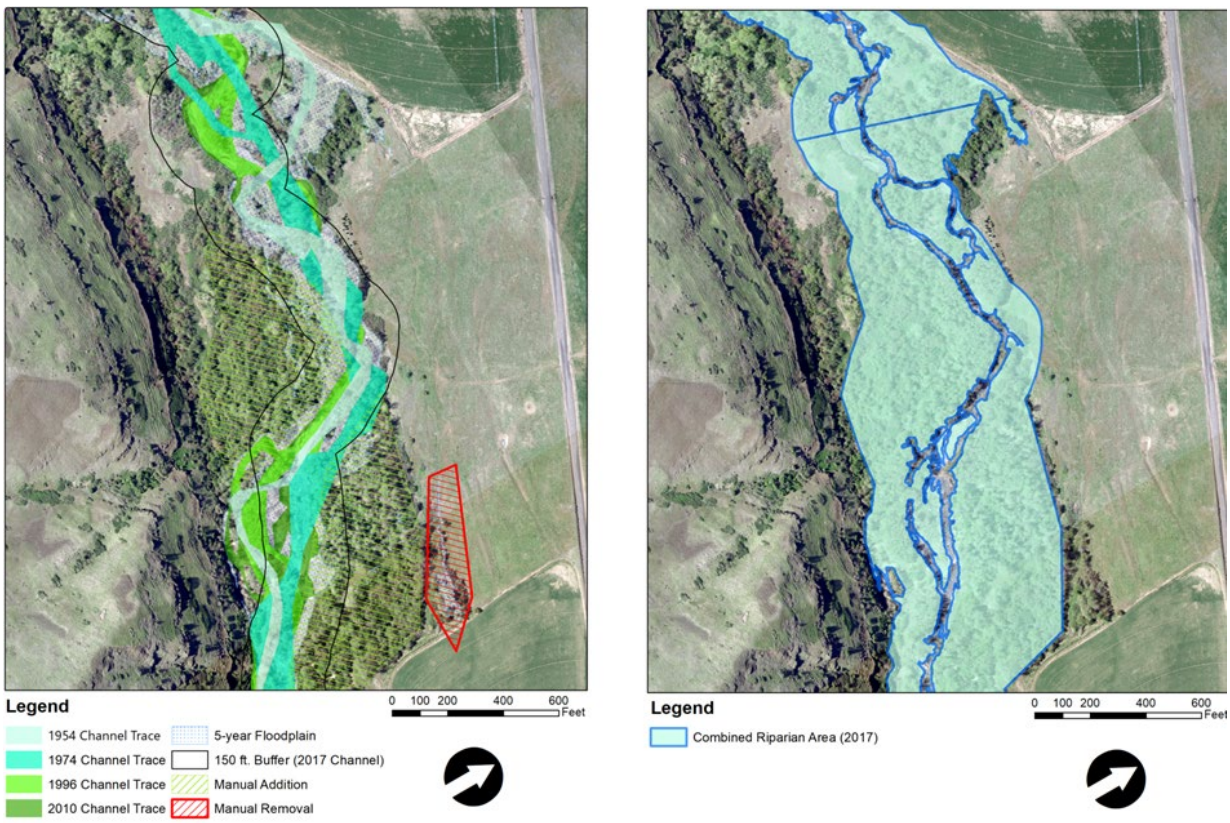
The riparian vegetation analysis for this report uses a Canopy Height Model (CHM) to quantify the extent of riparian vegetation in each project area, and classifies the vegetation based on height as shown in Table K-1. The CHMs were calculated as the difference between the first returns and the bare earth results from Light Detection and Ranging (LiDAR) datasets and sorted into vegetation size classes. Additionally, two CHMs were created using LiDAR data collected in 2010 and 2017 (Watershed Sciences 2010; QSI 2018). Comparing CHMs from different years allows for the quantification of change in the riparian vegetation. Interpretation of these results provides a way to assess the condition of riparian vegetation in each project area and to understand the trends of coverage and vegetation type over time. It also provides a baseline for future riparian vegetation analyses, which will help inform restoration efforts.

These results were trimmed to only include the "riparian area" of each project, so as to exclude results from areas captured by LiDAR but not directly relevant to the Tucannon River. The boundaries of this riparian corridor were defined as the combination of the following:

1. The channel centerline from the corresponding year (2010 or 2017), with a 150-foot buffer
2. Historical channel traces from digitized from aerial imagery
3. The 5-year available floodplain (defined in Appendix F, Connectivity Analysis)
4. Areas considered to be viable riparian habitat based on experiential knowledge and added manually

Areas deemed incorrectly included were manually removed; this also included areas that were marked as "Unobtainable" as defined in the Connectivity analysis, as well as areas with infrastructure such as in the area shown in Figure K-1. The wetted channel area for each year was removed because the 2017 LiDAR contains bathymetric data for the channel and the 2010 dataset does not, which would cause errors in comparing the two. Appendix D provides a more detailed discussion on the differences in the blue green LiDAR (2017) and the regular LiDAR (2010). Figure K-1 shows how these layers were combined for the 2017 dataset to define the boundary of the area with potential for riparian vegetation. These boundaries were chosen because they represent a reasonable delineation of the area available for riparian vegetation growth for a given year and can be determined using remote sensing techniques.

Figure K-1
Delineation of Riparian Area



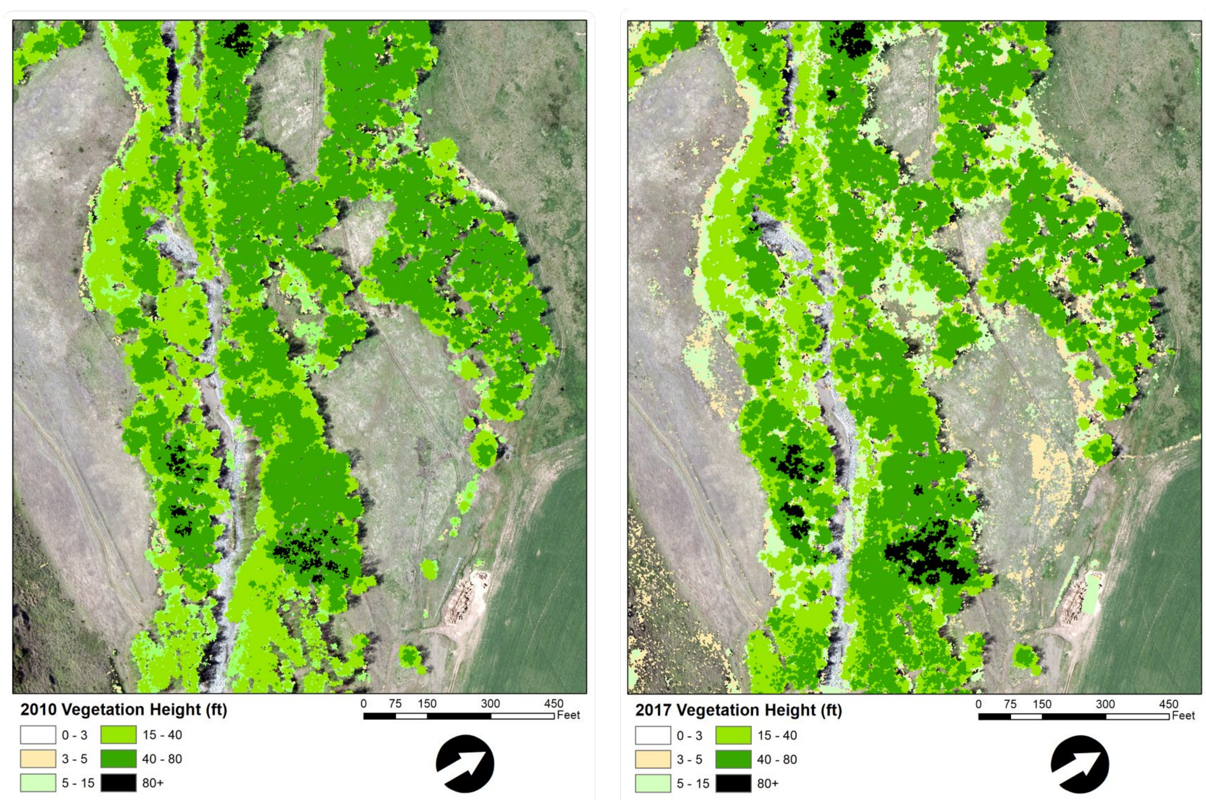
Further filtering of the data was deemed unnecessary because of the lack of man-made structures within the boundaries of the study area. Once calculated, the vegetation heights were separated into classes (listed in Table K-1) that are based on experiential knowledge of vegetation in the basin. Vegetation types are defined by ecological roles within the riparian corridor. A portion of the results are displayed in Figure K-2. The extent of coverage, the distributions of vegetation type, and the change in each vegetation type between the 2 years were investigated for each project area.

The tabulated results of this analysis can be found in Tables K-5 and K-6 at the end of this appendix. Table K-5 presents the data as acres of each vegetation size class per project area for each year, along with the total area change. Table K-6 presents each vegetation size class as a percent of the total riparian area.

Table K-1
Breakdown of Vegetation Classes

Size Range (feet)	Designed to Capture
0-3	Crops; grasses; wildflowers
3-5	Emergent or establishing woody vegetation like willows
5-15	Small deciduous trees like alders or elms
15-40	Intermediate range of large alders or smaller cottonwoods
40-80	Large, deciduous trees like cottonwoods
80+	Very old cottonwoods and large conifers in upper basin

Figure K-2
Results from Vegetation Analysis



Vegetation Analysis Results, Trends, and Patterns

Target values of 25% and 40% were set for the percentage of riparian area in each project area covered by the 15- to 40-foot and 40- to 80-foot vegetation classes, respectively, as summarized in Table K-2. These two vegetation classes are especially important for the health of the riparian corridor because they provide the most shade and shelter to the river and are the most commonly recruited as large woody material. The target values were chosen based on experiential knowledge of healthy riparian corridors and the Tucannon Basin. Secondary, 5% lower targets and a 7-year trend of riparian coverage were also evaluated to highlight project areas that are close to the target values or trending towards target value.

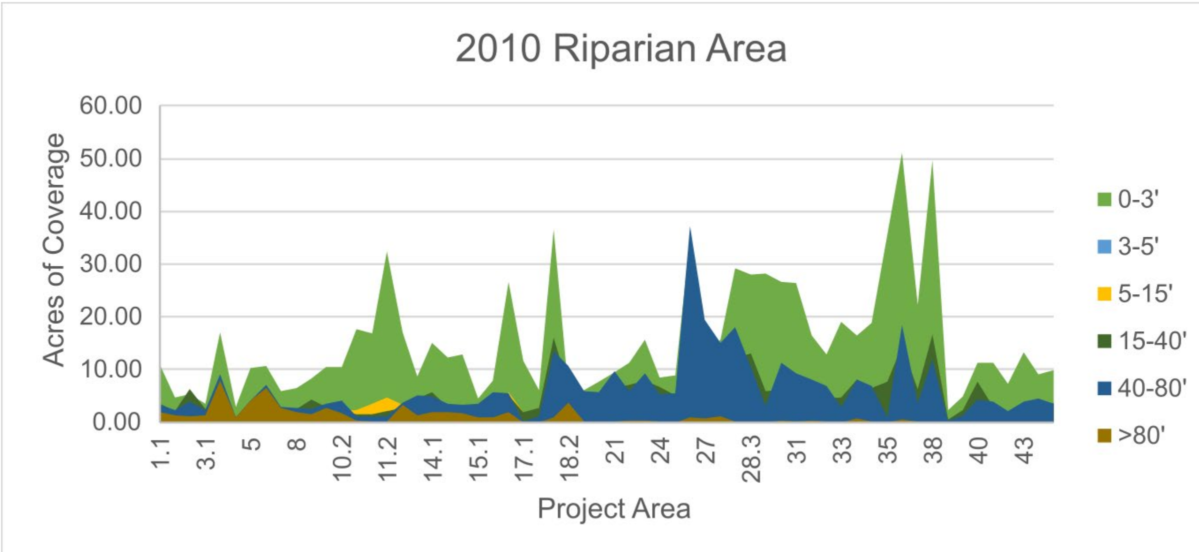
Table K-2
2017 Riparian Vegetation Targets

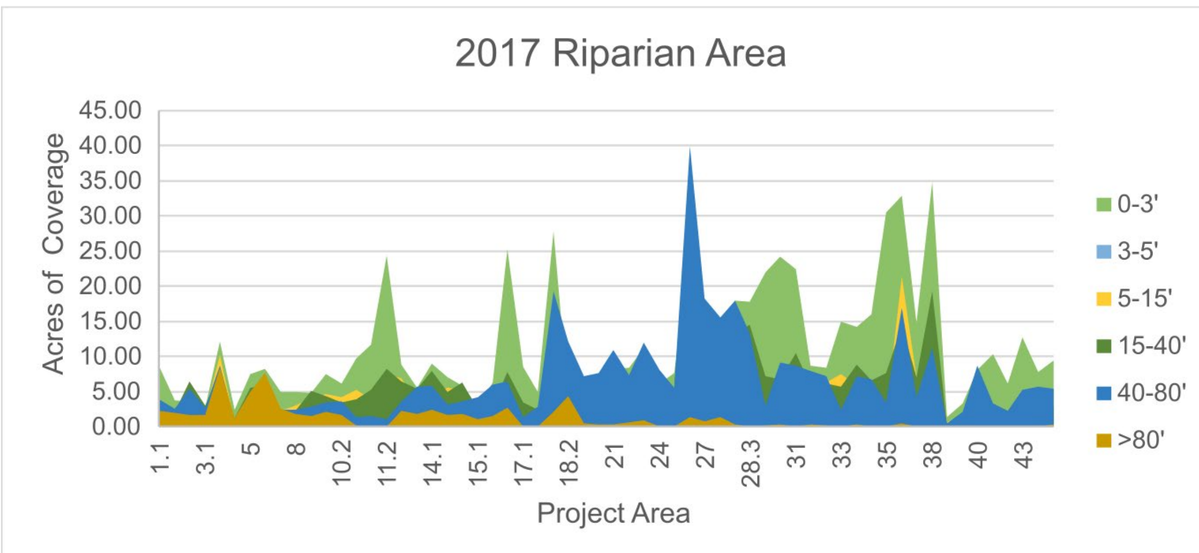
Size Class (feet)	Target	Near Target Level
15–40	25%	20%
40–80	40%	35%

Table K-7 lays out whether or not each project area meets any of the targets laid out in Table K-2, as well as if the project area nearly meets either of the two targets (within 5%). Table K-5 also provides how far each project area is from meeting either of the two targets. Finally, Table K-5 shows the 7-year trend for the two target size classes (15 to 40 feet and 40 to 80 feet) calculated as the percent difference between the 2010 vegetated area and the 2017 vegetated area in the size class. This trend can be used to infer whether or not the project area is moving towards or away from meeting the target in the respective size class.

Plots of the distributions of vegetation classes (Figure K-3) (stacked area graphs) show similar trends in coverage between the 2 years. They show lesser total amounts of coverage in the upper basin (possibly due to narrower valley widths), with a higher percentage of trees in the 80-foot-plus class. Moving downstream (left to right), total coverage of vegetation is variable with a slightly positive trend. There is a decrease in the percentage of the largest trees, and an increase in the percentages of the smallest vegetation class. Downstream of Project Area 17.2, the 40- to 80-foot vegetation class becomes dramatically larger in total and relative to the others. Downstream of Project Area 39.1, which contains the town of Starbuck, there is a noticeable drop off in total riparian vegetation.

Figure K-3
Distributions of Coverage by Project Area and Vegetation Class





Note Stacked area graphs show the total vegetative cover at each project area as the maximum, with proportions of each vegetation class shown by color.

Table K-3 shows the distribution of vegetation height classes for the 2010 and 2017 datasets averaged across all the project areas (the full table of results can be found in Tables K-4 and K-5). For both years, it shows bimodal distributions with most of the vegetation falling in the lowest height class, and a second peak in the 40- to 80-foot class. Comparison of the two distributions shows a shift from the lowest height class to the mid-range classes from 2010 to 2017, although a Two-Factor Analysis of Variance (ANOVA) shows that differences in heights between the 2 years are not statistically significant.

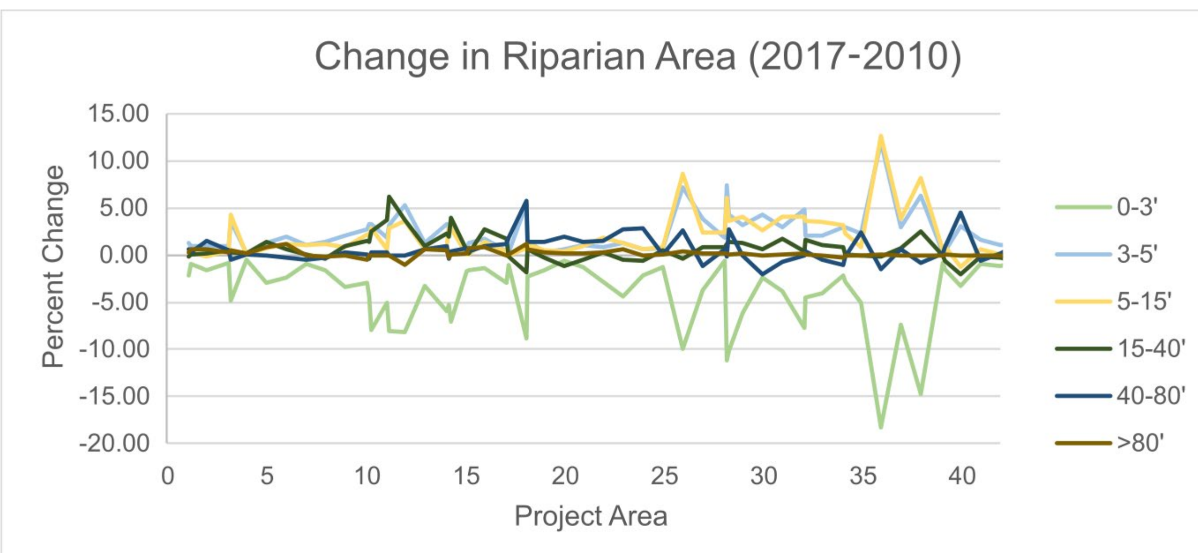
Table K-3
Distributions of Average Percentages of Vegetation by Height Class and Year

Year	0–3 feet	3–5 feet	5–15 feet	15–40 feet	40–80 feet	>80 feet
2010	48%	2%	10%	17%	19%	4%
2017	34%	9%	14%	18%	20%	4%

Note:
Percentages reflect averages from all project areas.

While not statistically different, Figure K-4 visually demonstrates the shift away from the smallest height class between 2010 and 2017. This trend may capture a portion of the cycle of vegetation growth in the riparian corridor, with younger vegetation growing into the larger height classes. The 15- to 40-foot height class and the 40- to 80-foot height class are the most geomorphically important because they represent the categories of vegetation that create shade and that are recruited into the river as LWM, respectively. A target value of 25% coverage from the 15- to 40-foot height class and 40% coverage from the 40- to 80-foot height class were set to evaluate existing conditions relative to ideal conditions. This comparison shows that for the 40- to 80-foot height class, none of the project areas hit the target value, although four (8%) of them fall within 5% and 32 (53%) have shown growth over the last 7 years (Table K-3). Of the 15- to 40-foot height class, four project areas reach the target value, 15 (25%) are within 5% of the target, and 29 (48%) have shown growth between 2010 and 2017.

Figure K-4
Change in Riparian Area, 2010 to 2017



Detailed Instructions for Performing this Analysis

Part of the purpose of this assessment is to define repeatable and data-driven methods for assessing project areas and how they have progressed in relation to their goals. This section provides the detailed steps taken to perform the riparian vegetation analysis so that these analyses can be repeated in the future for additional analyses and evaluation of progress. Table K-4 provides the data that will need to be collected to reassess the riparian vegetation in each project area.

Table K-4
Raw Data Needed to Perform this Analysis

Data Needed	Used For	Source
Canopy Height Model	Analyzing vegetation heights	LiDAR (difference of first returns and bare earth)
Active channel trace (plus 150-foot buffer)	Defining riparian area	Manual tracing/hydrology data
Historic channel traces	Defining riparian area	Manual tracing/historic data
5-year available floodplain	Defining riparian area	2D hydraulic modeling results and Connectivity Analysis
Project area delineations	Calculation of all metrics per project area	Project area shapefiles from this assessment

The following steps will assume the user has adequate GIS knowledge and access to the same data sources as those produced in this report.

1. This analysis uses historical channel traces from 1954, 1974, 1996, and 2010. These data were obtained through manual digitization of aerial imagery and are available as part of the GIS package of this geomorphic assessment. Future analyses will require any more recent channel traces, and judgement to discern which historic channels are still relevant for the analysis. These data were imported into GIS as polygon shapefiles.
2. The analysis requires channel centerline data from each year in which riparian vegetation data are being investigated. Centerlines were manually digitized from aerial imagery and relative elevation maps, imported into GIS as polyline shapefiles, and a 150-foot buffer was applied to them.
3. The 5-year available floodplain data created as part of the Connectivity analysis were imported into GIS. In future analyses, these data may need to be replaced if the topography of the valley has undergone significant changes.

4. Using GIS, a polygon was created from the maximum extent of the boundaries of the historic channel traces, 150-foot buffer, and 5-year available floodplain. The boundaries of the active channel for the year of a given vegetation analysis were subtracted from this area. This subtraction is only necessary if CHMs being compared were created using different types of LiDAR that would affect the results (e.g., bathymetric vs nonbathymmetric).
5. Using GIS, CHMs were created using LiDAR data by calculating the difference in elevation between the first returns and the bare earth topography. This calculation was only performed within the riparian area boundaries created for each year.
6. The results were classified based on their elevation into six groups: 0 to 3 feet, 3 to 5 feet, 5 to 15 feet, 15 to 40 feet, 40 to 80 feet, and greater than 80 feet.
7. Using GIS, the extent of coverage in each project area for each height class were extracted. These values were converted to percentages of vegetated area.
8. Change in vegetation was calculated by subtracting the coverage extent for each height in 2017 from those in 2010. These values were converted to percent change values.

Reference

QSI (Quantum Spatial, Inc.), 2018. *Tucannon River, Washington Topobathymetric LiDAR Technical Data Report*. Prepared for GeoTerra, Inc. March 1, 2018.

Watershed Sciences, 2010. *LiDAR Remote Sensing Data Collection: Tucannon River, Tucannon Headwaters, and Cummins Creek, WA*. July 30, 2010.

Tables

Table K-5

Vegetation Size Class Per Project Area

Project Area	2010 acres						2017 acres						DELTA (2017 vs. 2010 acres)						Total Analyzed Area (ac)		
	0-3 ft	3-5 ft	5-15 ft	15-40 ft	140-80 ft	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft	2010	2017	Delta (ac)
1.1	10.88	0.40	2.65	3.45	3.39	1.98	8.74	1.65	2.77	3.31	3.97	2.30	-2.14	1.25	0.13	-0.14	0.58	0.32	22.75	22.74	0.00
1.2	4.76	0.29	1.77	2.07	2.24	1.35	3.77	1.25	2.10	2.10	2.52	1.94	-0.99	0.96	0.32	0.03	0.29	0.59	12.47	13.68	1.21
2	5.29	0.44	3.42	6.28	3.92	1.04	3.66	1.38	3.31	6.48	5.48	1.64	-1.63	0.94	-0.11	0.20	1.56	0.61	20.39	21.95	1.56
3.1	3.57	0.24	1.74	2.47	2.21	1.37	2.74	1.21	2.21	2.97	2.69	1.68	-0.83	0.98	0.46	0.50	0.48	0.31	11.59	13.49	1.90
3.2	16.97	1.24	5.97	7.20	9.17	7.81	12.14	4.93	10.25	7.51	8.68	8.35	-4.83	3.68	4.29	0.31	-0.49	0.53	48.37	51.86	3.50
4	2.92	0.17	0.75	0.98	0.84	0.97	2.41	0.34	0.84	1.21	0.95	1.19	-0.51	0.18	0.09	0.22	0.11	0.23	6.63	6.94	0.31
5	10.35	0.55	3.46	4.15	4.14	4.18	7.47	1.88	4.21	5.55	4.13	5.04	-2.88	1.33	0.75	1.40	-0.01	0.86	26.83	28.27	1.44
6	10.64	0.87	5.70	5.26	7.16	6.39	8.24	2.80	6.91	5.86	6.90	7.59	-2.40	1.93	1.21	0.60	-0.26	1.19	36.03	38.31	2.28
7	5.97	0.33	1.19	1.53	2.90	2.67	5.03	1.35	2.28	1.58	2.47	2.57	-0.94	1.02	1.09	0.05	-0.44	-0.10	14.60	15.29	0.68
8	6.54	0.52	1.89	2.58	2.71	1.94	4.91	1.93	3.04	2.25	2.48	1.82	-1.63	1.42	1.15	-0.33	-0.22	-0.11	16.16	16.44	0.27
9	8.20	0.70	3.26	4.24	2.48	1.58	4.85	2.71	4.07	5.18	2.81	1.58	-3.34	2.02	0.82	0.93	0.33	0.00	20.46	21.21	0.75
10.1	10.45	0.61	2.44	2.90	3.44	2.62	7.51	3.33	4.65	4.37	3.49	2.16	-2.94	2.72	2.21	1.48	0.05	-0.45	22.45	25.51	3.06
10.2	10.54	0.70	2.14	2.04	4.02	1.76	6.12	4.01	4.17	3.48	3.69	1.69	-4.42	3.31	2.03	1.44	-0.33	-0.07	21.19	23.17	1.98
10.3	17.58	0.66	2.37	1.45	1.03	0.28	9.68	4.00	5.26	3.99	1.33	0.25	-7.90	3.34	2.88	2.55	0.30	-0.03	23.37	24.51	1.14
11.1	16.82	1.14	3.42	1.45	1.13	0.10	11.74	3.01	3.99	5.22	1.47	0.01	-5.07	1.88	0.57	3.77	0.34	-0.08	24.05	25.45	1.41
11.2	32.42	1.11	4.72	2.13	1.15	0.03	24.41	4.27	7.56	8.32	1.15	0.02	-8.01	3.15	2.84	6.19	-0.01	0.00	41.57	45.73	4.16
12	17.03	1.09	3.32	2.64	3.66	3.35	8.89	6.40	6.94	6.41	3.67	2.30	-8.13	5.31	3.62	3.77	0.01	-1.05	31.08	34.61	3.53
13	8.78	0.70	3.02	4.59	5.06	1.24	5.50	1.95	3.68	5.49	5.73	1.84	-3.28	1.25	0.66	0.90	0.67	0.60	23.38	24.19	0.80
14.1	14.97	0.56	3.85	5.62	4.83	1.99	9.07	3.82	4.85	7.94	5.84	2.47	-5.90	3.26	1.00	2.32	1.00	0.48	31.82	33.99	2.17
14.2	12.25	0.74	2.65	2.98	3.51	1.94	7.02	3.61	5.63	4.95	3.19	1.67	-5.23	2.87	2.97	1.96	-0.33	-0.27	24.09	26.07	1.98
14.3	12.92	0.86	2.50	2.46	3.34	1.81	5.88	3.87	5.34	6.38	3.70	1.84	-7.04	3.01	2.84	3.92	0.36	0.04	23.89	27.01	3.12
15.1	4.55	0.28	1.32	1.96	3.43	0.84	2.86	0.86	1.39	2.45	4.22	1.04	-1.69	0.59	0.07	0.49	0.79	0.20	12.39	12.83	0.45
15.2	7.97	0.40	2.80	2.87	5.64	0.83	6.34	1.66	2.86	3.08	6.06	1.51	-1.63	1.27	0.06	0.20	0.42	0.68	20.50	21.50	1.00
16	26.66	0.67	5.71	5.12	5.48	1.90	25.24	2.45	7.14	7.83	6.47	2.80	-1.42	1.77	1.43	2.71	1.00	0.90	45.54	51.93	6.39
17.1	11.59	0.28	1.93	1.84	0.19	0.00	8.60	0.66	2.38	3.52	1.33	0.00	-2.99	0.38	0.45	1.69	1.14	0.00	15.82	16.49	0.66
17.2	6.00	0.22	1.21	2.66	1.06	0.00	4.99	0.46	1.22	2.49	2.86	0.04	-1.01	0.24	0.01	-0.17	1.80	0.04	11.15	12.07	0.91
18.1	36.62	1.48	7.95	16.07	13.49	0.94	27.80	6.83	8.69	14.23	19.27	2.18	-8.82	5.35	0.74	-1.84	5.78	1.24	76.55	79.01	2.47
18.2	6.18	0.74	3.56	6.67	10.66	3.76	3.87	2.30	4.76	7.25	12.10	4.44	-2.31	1.57	1.20	0.57	1.44	0.67	31.58	34.72	3.14
19	6.01	0.28	1.54	4.20	5.87	0.21	4.40	0.62	2.11	3.94	7.23	0.55	-1.61	0.34	0.56	-0.26	1.36	0.34	18.13	18.85	0.73
20	7.76	0.22	0.98	4.69	5.63	0.09	7.16	0.81	1.42	3.50	7.64	0.32	-0.60	0.60	0.44	-1.19	2.01	0.23	19.37	20.86	1.49
21	9.53	0.64	2.44	6.47	9.61	0.18	8.23	1.65	3.43	5.94	11.01	0.31	-1.30	1.01	0.99	-0.53	1.39	0.13	28.88	30.57	1.70
22	11.17	0.94	3.93	7.02	5.85	0.37	8.38	1.74	5.82	7.25	7.33	0.61	-2.80	0.80	1.89	0.23	1.49	0.24	29.28	31.13	1.85
23	15.56	0.65	2.86	7.94	9.18	0.31	11.19	2.00	4.13	7.51	11.93	0.93	-4.36	1.34	1.27	-0.43	2.75	0.62	36.50	37.68	1.18
24	8.42	0.48	2.22	6.66	5.23	0.07	6.22	1.10	2.88	6.03	8.11	0.06	-2.21	0.62	0.67	-0.63	2.88	-0.01	23.08	24.41	1.33
25	8.87	0.27	1.21	5.10	5.52	0.01	7.60	1.05	2.02	5.56	5.59	0.03	-1.27	0.78	0.81	0.46	0.08	0.01	20.98	21.85	0.87
26	34.78	2.57	10.99	34.63	37.17	0.96	24.83	9.81	19.58	34.29	39.84	1.33	-9.95	7.24	8.59	-0.34	2.67	0.37	121.09	129.68	8.59
27	13.11	0.62	2.50	10.36	19.37	0.69	9.39	4.51	4.93	11.16	18.20	0.84	-3.73	3.89	2.42	0.80	-1.17	0.15	46.65	49.02	2.36
28.1	15.71	0.84	2.48	7.86	15.02	1.15	15.07	2.74	4.87	8.71	15.61	1.33	-0.65	1.89	2.39	0.84	0.59	0.18	43.07	48.32	5.25
28.2	29.13	1.02	3.97	12.16	18.05	0.20	17.98	8.43	10.01	13.32	17.92	0.32	-11.15	7.40	6.04	1.16	-0.12	0.13	64.52	67.99	3.46
28.3	27.98	0.47	3.69	13.04	10.54	0.00	17.81	4.82	7.32	14.46	13.29	0.03	-10.18	4.34	3.62	1.42	2.75	0.03	55.73	57.72	1.99
29	28.17	0.76	2.41	5.96	3.04	0.00	22.01	3.94	6.47	7.26	3.01	0.13	-6.16	3.17	4.06	1.30	-0.04	0.13	40.35	42.82	2.47
30	26.68	0.76	1.63	6.13	11.18	0.26	24.27	5.02	4.24	6.79	9.20	0.27	-2.41	4.26	2.61	0.66	-1.98	0.01	46.64	49.79	3.16
31	26.31	1.54	2.88	8.75	9.36	0.04	22.44	4.51	6.97	10.45	8.66	0.06	-3.87	2.97	4.09	1.70	-0.70	0.01	48.88	53.09	4.21
32.1	16.54	1.35	2.87	5.37	8.05	0.27	8.78	6.16	6.90	5.80	8.02	0.41	-7.77	4.81	4.03	0.43	-0.03	0.14	34.45	36.07	1.62
32.2	12.92	0.65	2.68	4.47	6.87	0.11	8.41	2.70	6.29	6.13	7.27	0.13	-4.51	2.05	3.61	1.67	0.40	0.03	27.69	30.94	3.25
33	19.04	1.91	4.03	4.77	2.88	0.00	15.01	4.00	7.57	5.79	2.38	0.00	-4.03	2.09	3.53	1.03	-0.51	0.00	32.64	34.75	2.11
34.1	16.46	0.81	2.69	8.03	8.18	0.65	14.30	3.76	5.91	8.88	7.16	0.36	-2.17	2.94	3.22	0.85	-1.02	-0.29	36.82	40.37	3.54
34.2	18.75	0.20	1.44	6.53	6.97	0.07	15.97	3.19	3.70	6.61	6.78	0.04	-2.78	3.00	2.25	0.08	-0.19	-0.04	33.96	36.28	2.32
35	35.50	0.28	1.32	7.70	0.99	0.00	30.44	2.61	2.14	7.67	3.41	0.00	-5.06	2.33	0.82	-0.04	2.41	0.00	45.80	46.27	0.47
36	51.20	1.96	8.66	14.48	18.47	0.42	32.95	13.99	21.32	14.37	16.96	0.54	-18.25	12.04	12.66	-0.11	-1.51	0.12	95.19	100.14	4.95
37	22.28	0.85	3.26	6.28	3.62	0.07	14.85	3.78	7.11	7.06	4.26	0.06	-7.43	2.94	3.84	0.78	0.64	-0.01	36.36	37.11	0.75
38	49.65	2.20	8.60	16.73	11.96	0.01	34.87	8.53	16.84	19.30	11.18	0.00	-14.78	6.33	8.24	2.57	-0.77	0.00	89.14	90.72	1.58
39.1	2.25	0.04	0.20	0.53	0.32	0.00	1.41	0.31	0.71	0.45	0.52	0.00	-0.84	0.27	0.52	-0.08	0.20	0.00	3.33	3.40	0.06
39.2	4.85	0.16	0.68	2.31	1.22	0.00	3.34	0.54	1.68	1.70	2.12	0.01	-1.51	0.39	1.01	-0.61	0.90	0.01	9.21	9.39	0.18
40	11.29	0.88	4.39	7.59	4.22	0.00	8.06	3.93	3.12	5.53	8.71	0.00	-3.23	3.05	-1.27	-2.06	4.49	0.00	28.37	29.35	0.98
41	11.31	0.22	1.53	2.98	3.93	0.00	10.33	1.82	2.15	2.85	3.39	0.00	-0.98	1.60	0.62	-0.13	-0.55	0.00	19.97	20.53	0.56

Table K-5

Vegetation Size Class Per Project Area

Project Area	2010 acres						2017 acres						DELTA (2017 vs. 2010 acres)						Total Analyzed Area (ac)		
	0-3 ft	3-5 ft	5-15 ft	15-40 ft	140-80 ft	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft	2010	2017	Delta (ac)
42	7.26	0.14	1.34	1.94	2.15	0.00	6.14	1.21	1.44	1.66	2.31	0.00	-1.12	1.08	0.10	-0.29	0.16	0.00	12.83	12.76	-0.07
43	13.17	0.17	1.41	3.05	3.90	0.00	12.67	1.19	1.12	2.17	5.23	0.00	-0.50	1.02	-0.29	-0.87	1.33	0.00	21.70	22.39	0.69
44	9.07	0.12	1.88	2.45	4.58	0.00	7.84	1.37	1.47	2.10	5.74	0.00	-1.23	1.25	-0.41	-0.35	1.15	0.00	18.11	18.52	0.42
45	9.78	0.28	2.28	3.79	3.46	0.00	9.47	2.27	2.52	2.81	5.39	0.33	-0.31	1.98	0.24	-0.98	1.93	0.33	19.60	22.80	3.20

Note:

ft: feet

Table K-6

Vegetation Size Class Per Project Area as a Percent of Total Area

Project Area	2010 acres						2017 acres						DELTA (2017 vs. 2010 acres)					
	0-3 ft	3-5 ft	5-15 ft	15-40 ft	140-80 ft	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft
1.1	48%	2%	12%	15%	15%	9%	38%	7%	12%	15%	17%	10%	-9%	5%	1%	-1%	3%	1%
1.2	38%	2%	14%	17%	18%	11%	28%	9%	15%	15%	18%	14%	-11%	7%	1%	-1%	1%	3%
2	26%	2%	17%	31%	19%	5%	17%	6%	15%	30%	25%	7%	-9%	4%	-2%	-1%	6%	2%
3.1	31%	2%	15%	21%	19%	12%	20%	9%	16%	22%	20%	12%	-11%	7%	1%	1%	1%	1%
3.2	35%	3%	12%	15%	19%	16%	23%	10%	20%	14%	17%	16%	-12%	7%	7%	0%	-2%	0%
4	44%	3%	11%	15%	13%	15%	35%	5%	12%	17%	14%	17%	-9%	2%	1%	3%	1%	3%
5	39%	2%	13%	15%	15%	16%	26%	7%	15%	20%	15%	18%	-12%	5%	2%	4%	-1%	2%
6	30%	2%	16%	15%	20%	18%	22%	7%	18%	15%	18%	20%	-8%	5%	2%	1%	-2%	2%
7	41%	2%	8%	10%	20%	18%	33%	9%	15%	10%	16%	17%	-8%	7%	7%	0%	-4%	-1%
8	40%	3%	12%	16%	17%	12%	30%	12%	18%	14%	15%	11%	-11%	9%	7%	-2%	-2%	-1%
9	40%	3%	16%	21%	12%	8%	23%	13%	19%	24%	13%	7%	-17%	9%	3%	4%	1%	0%
10.1	47%	3%	11%	13%	15%	12%	29%	13%	18%	17%	14%	8%	-17%	10%	7%	4%	-2%	-3%
10.2	50%	3%	10%	10%	19%	8%	26%	17%	18%	15%	16%	7%	-23%	14%	8%	5%	-3%	-1%
10.3	75%	3%	10%	6%	4%	1%	39%	16%	21%	16%	5%	1%	-36%	14%	11%	10%	1%	0%
11.1	70%	5%	14%	6%	5%	0%	46%	12%	16%	21%	6%	0%	-24%	7%	1%	14%	1%	0%
11.2	78%	3%	11%	5%	3%	0%	53%	9%	17%	18%	3%	0%	-25%	7%	5%	13%	0%	0%
12	55%	4%	11%	8%	12%	11%	26%	18%	20%	19%	11%	7%	-29%	15%	9%	10%	-1%	-4%
13	38%	3%	13%	20%	22%	5%	23%	8%	15%	23%	24%	8%	-15%	5%	2%	3%	2%	2%
14.1	47%	2%	12%	18%	15%	6%	27%	11%	14%	23%	17%	7%	-20%	9%	2%	6%	2%	1%
14.2	51%	3%	11%	12%	15%	8%	27%	14%	22%	19%	12%	6%	-24%	11%	11%	7%	-2%	-2%
14.3	54%	4%	10%	10%	14%	8%	22%	14%	20%	24%	14%	7%	-32%	11%	9%	13%	0%	-1%
15.1	37%	2%	11%	16%	28%	7%	22%	7%	11%	19%	33%	8%	-14%	4%	0%	3%	5%	1%
15.2	39%	2%	14%	14%	28%	4%	29%	8%	13%	14%	28%	7%	-9%	6%	0%	0%	1%	3%
16	59%	1%	13%	11%	12%	4%	49%	5%	14%	15%	12%	5%	-10%	3%	1%	4%	0%	1%
17.1	73%	2%	12%	12%	1%	0%	52%	4%	14%	21%	8%	0%	-21%	2%	2%	10%	7%	0%
17.2	54%	2%	11%	24%	10%	0%	41%	4%	10%	21%	24%	0%	-12%	2%	-1%	-3%	14%	0%
18.1	48%	2%	10%	21%	18%	1%	35%	9%	11%	18%	24%	3%	-13%	7%	1%	-3%	7%	2%
18.2	20%	2%	11%	21%	34%	12%	11%	7%	14%	21%	35%	13%	-8%	4%	2%	0%	1%	1%
19	33%	2%	9%	23%	32%	1%	23%	3%	11%	21%	38%	3%	-10%	2%	3%	-2%	6%	2%
20	40%	1%	5%	24%	29%	0%	34%	4%	7%	17%	37%	2%	-6%	3%	2%	-7%	8%	1%
21	33%	2%	8%	22%	33%	1%	27%	5%	11%	19%	36%	1%	-6%	3%	3%	-3%	3%	0%
22	38%	3%	13%	24%	20%	1%	27%	6%	19%	23%	24%	2%	-11%	2%	5%	-1%	4%	1%
23	43%	2%	8%	22%	25%	1%	30%	5%	11%	20%	32%	2%	-13%	4%	3%	-2%	7%	2%
24	36%	2%	10%	29%	23%	0%	25%	5%	12%	25%	33%	0%	-11%	2%	2%	-4%	11%	0%
25	42%	1%	6%	24%	26%	0%	35%	5%	9%	25%	26%	0%	-8%	4%	3%	1%	-1%	0%
26	29%	2%	9%	29%	31%	1%	19%	8%	15%	26%	31%	1%	-10%	5%	6%	-2%	0%	0%
27	28%	1%	5%	22%	42%	1%	19%	9%	10%	23%	37%	2%	-9%	8%	5%	1%	-4%	0%
28.1	36%	2%	6%	18%	35%	3%	31%	6%	10%	18%	32%	3%	-5%	4%	4%	0%	-3%	0%
28.2	45%	2%	6%	19%	28%	0%	26%	12%	15%	20%	26%	0%	-19%	11%	9%	1%	-2%	0%
28.3	50%	1%	7%	23%	19%	0%	31%	8%	13%	25%	23%	0%	-19%	7%	6%	2%	4%	0%
29	70%	2%	6%	15%	8%	0%	51%	9%	15%	17%	7%	0%	-18%	7%	9%	2%	-1%	0%
30	57%	2%	3%	13%	24%	1%	49%	10%	9%	14%	18%	1%	-8%	8%	5%	0%	-6%	0%
31	54%	3%	6%	18%	19%	0%	42%	8%	13%	20%	16%	0%	-12%	5%	7%	2%	-3%	0%
32.1	48%	4%	8%	16%	23%	1%	24%	17%	19%	16%	22%	1%	-24%	13%	11%	0%	-1%	0%
32.2	47%	2%	10%	16%	25%	0%	27%	9%	20%	20%	23%	0%	-19%	6%	11%	4%	-1%	0%
33	58%	6%	12%	15%	9%	0%	43%	12%	22%	17%	7%	0%	-15%	6%	9%	2%	-2%	0%
34.1	45%	2%	7%	22%	22%	2%	35%	9%	15%	22%	18%	1%	-9%	7%	7%	0%	-4%	-1%
34.2	55%	1%	4%	19%	21%	0%	44%	9%	10%	18%	19%	0%	-11%	8%	6%	-1%	-2%	0%
35	78%	1%	3%	17%	2%	0%	66%	6%	5%	17%	7%	0%	-12%	5%	2%	0%	5%	0%
36	54%	2%	9%	15%	19%	0%	33%	14%	21%	14%	17%	1%	-21%	12%	12%	-1%	-2%	0%
37	61%	2%	9%	17%	10%	0%	40%	10%	19%	19%	11%	0%	-21%	8%	10%	2%	2%	0%
38	56%	2%	10%	19%	13%	0%	38%	9%	19%	21%	12%	0%	-17%	7%	9%	3%	-1%	0%
39.1	67%	1%	6%	16%	10%	0%	41%	9%	21%	13%	15%	0%	-26%	8%	15%	-3%	6%	0%

Table K-6

Vegetation Size Class Per Project Area as a Percent of Total Area

Project Area	2010 acres						2017 acres						DELTA (2017 vs. 2010 acres)					
	0-3 ft	3-5 ft	5-15 ft	15-40 ft	140-80 ft	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft	0-3 ft	3-5 ft	5-15 ft	15-40 ft	40-80	>80 ft
39.2	53%	2%	7%	25%	13%	0%	36%	6%	18%	18%	23%	0%	-17%	4%	11%	-7%	9%	0%
40	40%	3%	15%	27%	15%	0%	27%	13%	11%	19%	30%	0%	-12%	10%	-5%	-8%	15%	0%
41	57%	1%	8%	15%	20%	0%	50%	9%	10%	14%	16%	0%	-6%	8%	3%	-1%	-3%	0%
42	57%	1%	10%	15%	17%	0%	48%	10%	11%	13%	18%	0%	-8%	8%	1%	-2%	1%	0%
43	61%	1%	7%	14%	18%	0%	57%	5%	5%	10%	23%	0%	-4%	5%	-1%	-4%	5%	0%
44	50%	1%	10%	14%	25%	0%	42%	7%	8%	11%	31%	0%	-8%	7%	-2%	-2%	6%	0%
45	50%	1%	12%	19%	18%	0%	42%	10%	11%	12%	24%	1%	-8%	8%	-1%	-7%	6%	1%

Note:

ft: feet

Table K-7
Riparian Vegetation Targets and Trends

Project Area	Total 2017 Riparian Area (ac)	2017 Riparian Area Per VM (ac/mi)	15-40'			40'-80'		
			Meets Target?	Off By	7-year Trend	Meets Target?	Off By	7-yearTrend
1.1	22.74	41.36	No	10%	-1%	No	23%	3%
1.2	13.68	34.87	No	10%	-1%	No	22%	1%
2	21.95	34.13	Yes	-5%	-1%	No	15%	6%
3.1	13.49	36.23	Nearly	3%	1%	No	20%	1%
3.2	51.86	36.01	No	11%	0%	No	23%	-2%
4	6.94	29.13	No	8%	3%	No	26%	1%
5	28.27	62.31	No	5%	4%	No	25%	-1%
6	38.31	51.55	No	10%	1%	No	22%	-2%
7	15.29	33.93	No	15%	0%	No	24%	-4%
8	16.44	36.48	No	11%	-2%	No	25%	-2%
9	21.21	52.95	Nearly	1%	4%	No	27%	1%
10.1	25.51	54.54	No	8%	4%	No	26%	-2%
10.2	23.17	32.16	No	10%	5%	No	24%	-3%
10.3	24.51	59.09	No	9%	10%	No	35%	1%
11.1	25.45	33.92	Nearly	4%	14%	No	34%	1%
11.2	45.73	47.55	No	7%	13%	No	37%	0%
12	34.61	53.13	No	6%	10%	No	29%	-1%
13	24.19	31.61	Nearly	2%	3%	No	16%	2%
14.1	33.99	55.68	Nearly	2%	6%	No	23%	2%
14.2	26.07	31.70	No	6%	7%	No	28%	-2%
14.3	27.01	37.51	Nearly	1%	13%	No	26%	0%
15.1	12.83	33.68	No	6%	3%	No	7%	5%
15.2	21.50	50.80	No	11%	0%	No	12%	1%
16	51.93	37.31	No	10%	4%	No	28%	0%
17.1	16.49	47.93	Nearly	4%	10%	No	32%	7%
17.2	12.07	39.37	Nearly	4%	-3%	No	16%	14%
18.1	79.01	73.09	No	7%	-3%	No	16%	7%
18.2	34.72	44.79	Nearly	4%	0%	No	5%	1%
19	18.85	33.59	Nearly	4%	-2%	Nearly	2%	6%
20	20.86	47.83	No	8%	-7%	Nearly	3%	8%
21	30.57	29.05	No	6%	-3%	Nearly	4%	3%
22	31.13	28.74	Nearly	2%	-1%	No	16%	4%
23	37.68	35.82	No	5%	-2%	No	8%	7%
24	24.41	32.24	Nearly	0%	-4%	No	7%	11%
25	21.85	40.50	Yes	0%	1%	No	14%	-1%
26	129.68	43.43	Yes	-1%	-2%	No	9%	0%
27	49.02	46.80	Nearly	2%	1%	Nearly	3%	-4%
28.1	48.32	55.67	No	7%	0%	No	8%	-3%
28.2	67.99	58.22	No	5%	1%	No	14%	-2%
28.3	57.72	49.57	Yes	0%	2%	No	17%	4%
29	42.82	38.31	No	8%	2%	No	33%	-1%
30	49.79	49.42	No	11%	0%	No	22%	-6%
31	53.09	35.57	No	5%	2%	No	24%	-3%
32.1	36.07	45.93	No	9%	0%	No	18%	-1%
32.2	30.94	44.55	No	5%	4%	No	17%	-1%
33	34.75	28.45	No	8%	2%	No	33%	-2%
34.1	40.37	35.30	Nearly	3%	0%	No	22%	-4%
34.2	36.28	46.43	No	7%	-1%	No	21%	-2%
35	46.27	67.08	No	8%	0%	No	33%	5%
36	100.14	58.89	No	11%	-1%	No	23%	-2%
37	37.11	33.78	No	6%	2%	No	29%	2%
38	90.72	30.52	Nearly	4%	3%	No	28%	-1%
39.1	3.40	32.73	No	12%	-3%	No	25%	6%
39.2	9.39	28.49	No	7%	-7%	No	17%	9%
40	29.35	51.07	No	6%	-8%	No	10%	15%
41	20.53	58.25	No	11%	-1%	No	24%	-3%
42	12.76	38.24	No	12%	-2%	No	22%	1%
43	22.39	52.21	No	15%	-4%	No	17%	5%
44	18.52	42.92	No	14%	-2%	No	9%	6%
45	22.80	43.53	No	13%	-7%	No	16%	6%

Notes:
ac: acre
mi: mile
VM: valley mile

Appendix L
Gravel Augmentation Plan Cut Sheets

LIST OF CONCEPTUAL GRAVEL AUGMENTATION SITES

Conceptual Gravel Augmentation Site	Located In Project Area	Appendix Page	Approx. Source Material Volume(cy)	Approx. Placement Volume Per Year (cy)
GA-1	1.1	L-1	22,484	1,000
GA-2	1.1	L-4	9,380	500
GA-3	1.1	L-7	7,654	800
GA-4	1.2	L-10	40,539	1,500
GA-5	1.2, 2	L-13	6,363	500
GA-6	3.1	L-16	10,912	1,000
GA-7	7	L-19	23,253	1,000
GA-8	8, 9	L-22	47,771	1,000
GA-9	10.1, 10.2	L-25	30,537	1,000
GA-10	10.2, 10.3	L-28	83,916	1,500
GA-11	13, 14.1	L-31	12,625	1,000
GA-12	14.2	L-34	0	500
GA-13	15.1, 15.2	L-37	77,828	0

GA-1

Gravel Placement Locations

This site is accessed from the Rattlesnake Trail dispersed campground on NF-4713. The target placement is 1,000 cy between three placement sites along the left bank annually. Location 1.1 can be accessed directly from the dispersed campground, and Locations 1.2 and 1.3 will require temporary roads traveling downstream from the campground.

Target Condition

The target condition in the floodplain is to have an established low-flow channel set back from the main channel and the potential for multiple channels to activate on the floodplain at the 2-year flood flow. The channels will have room to migrate and anastomose, recruit large wood, and incise to the elevation of lesser flood flows. Successful floodplain channel creation will lead to riparian growth and areas with successful benching will show emergent vegetation. The GA-1 figure displays the areas where material will be sourced. Benched areas should be connected and drain to the main channel or floodplain channel.

Approximate Placement Parameters for GA-1 (feet)

		Target Annual Placement (cy)		1,000
Location	**Height**	**Width**	**Length**	**Volume (cy)**
1.1	2	12	415	369
1.2	2	12	320	284
1.3	2	12	400	360
		Total Annual Placement (cy)		1,013

Implementation Plan

For all three placement locations, material will be sourced from the adjacent floodplain benching activity and floodplain channel creation. This activity will start directly next to the main channel and expand outwards from there. Material for the portions of placement locations that are not adjacent to benching sites will be sourced from the nearest ones. Annual monitoring (see Monitoring Form) will guide adaptive management based on the river's response to initial restoration efforts for both the excavation and placement of material.

GA-1 Gravel Placement Locations

Location 1.1

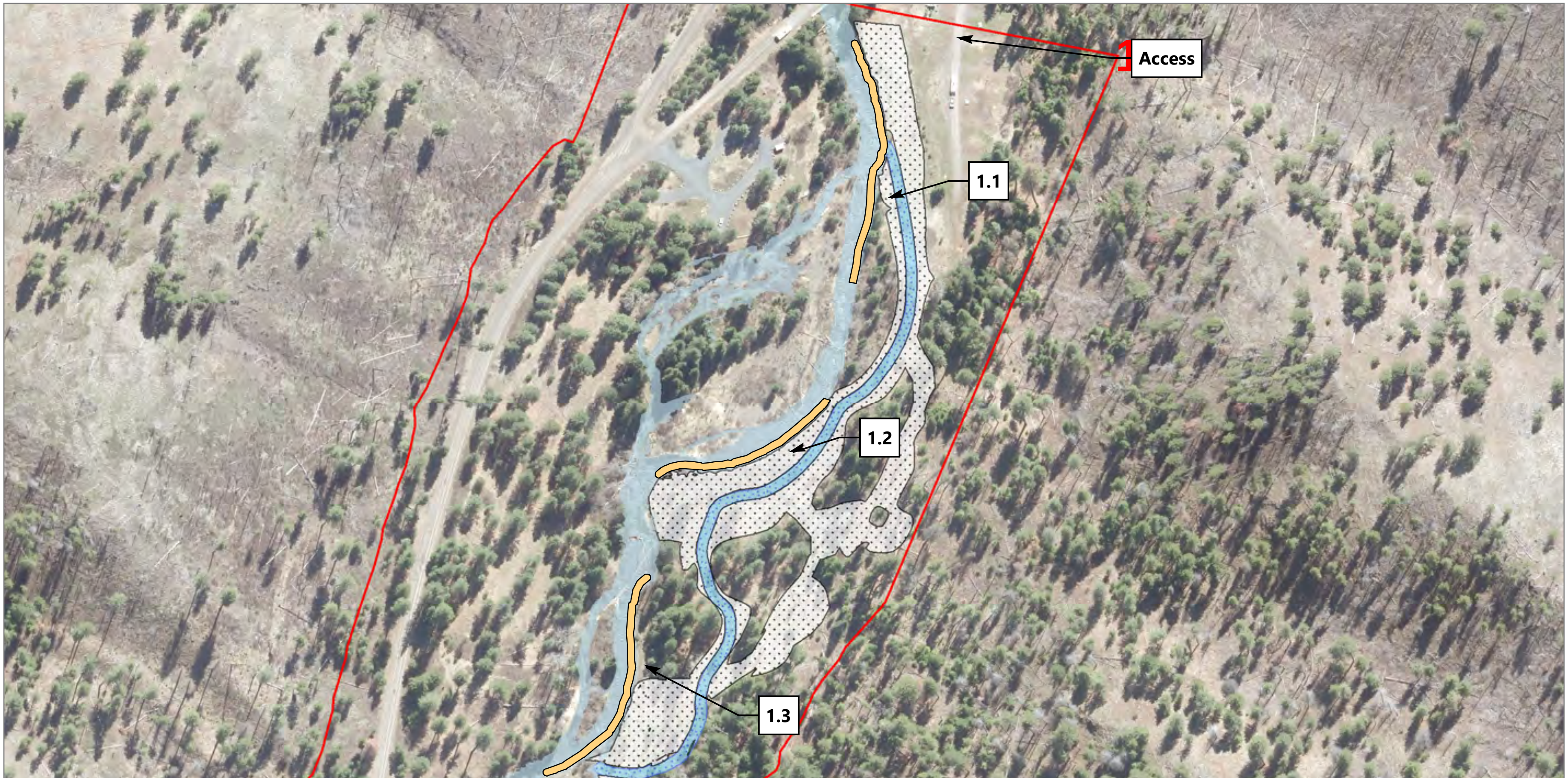
This material will be sourced from the adjacent floodplain benching and floodplain channel creation activity. It will come first by opening the floodplain channel and by benching the floodplain down the bank from the campground. Following this, the floodplain channel will be extended downstream, and benching will occur alongside it. Finally, the area that is set back from the floodplain channel will be benched.

Location 1.2

This material will be sourced from floodplain benching activity directly adjacent to the main channel. As the benching is widened, the floodplain channel will become a source and will be expanded with the benching in the upstream and downstream directions.

Location 1.3

Material for this location will be sourced first through the opening of the downstream end of the floodplain channel, and benching the floodplain along the main channel and upstream of the floodplain channel. Following this, both activities will expand upstream and up the bank until they connect with material sourcing activities associated with the other two placement locations.



LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Excavation (2-yr. floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial imagery provided by GeoTerra. Flown April 19, (2018).
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and recommendations in this map are based on LiDAR data from 2017 and site visits in 2019. Flood events and geomorphic changes have occured since then and may have changed the topography relative to what is shown.

0 650

Feet

ANCHOR QEA

GA-1

Conceptual Gravel Augmentation Opportunities

Conceptual Gravel Augmentation Plan

Tucannon Basin Habitat Restoration

GA-2

Gravel Placement Locations

This site is located on the right bank across from site GA-1. It is accessed from Tucannon Road (NF-47) from a dispersed campground. The placement target for this site is 500 cy of gravel annually between three placement locations. Access to Location 2.1 will require a temporary wooden bridge if the side channel between it and the road is active. Locations 2.2 and 2.3 will both be accessed by temporary roads extending from Tucannon Road.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the floodplain with the main channel as described in Section 9.3, Goals and Objectives, in the main report. The GA-2 figure displays the areas where material will be sourced. Successful material sourcing will show an established low-flow channel and the high, unvegetated patches in the floodplain lowered and connected to the main channel at the 2-year flood flow elevation.

Approximate Placement Parameters for GA-2 (feet)

	Target Annual Placement (cy)			500
Location	**Height**	**Width**	**Length**	**Volume (cy)**
2.1	2.2	12	130	127
2.2	2.2	12	140	137
2.3	2.2	12	225	238
	Total Annual Placement (cy)			502

Implementation Plan

For all three placement locations, material will be sourced from the adjacent floodplain benching activity and floodplain channel creation. Material for the portions of placement locations that are not adjacent to benching sites will be sourced from the nearest ones. Annual monitoring (see Monitoring Form) will guide adaptive management based on the river's response to initial restoration efforts for both the excavation and placement of material.

GA-2 Gravel Placement Locations

Location 2.1	Location 2.2
This material will be sourced from the adjacent floodplain on the bank of the island This material is relatively low already, so benching the entire floodplain features will not take long. It will begin at the upstream end of the island and expand until the entire island has been benched. Following this, material will be sourced from the portion of the floodplain between the floodplain channel and the road.	Sourcing for this location will begin by opening the upstream end of the floodplain channel and benching the floodplain directly adjacent. Following this, the floodplain bordering the placement location will be benched and expand upstream and downstream until it connects with the floodplain channel. Sourcing will continue down the floodplain channel until it meets with sourcing efforts coming up the floodplain channel from Location 2.3.
Location 2.3	
Initial material will be sourced by opening the floodplain channel and benching the surrounding floodplain. This effort will expand up the floodplain channel, benching the adjacent floodplain along the way. Finally, the area upstream of the placement location that is between the floodplain channel and the main channel will be benched.	

LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial imagery provided by GeoTerra. Flown April 19, (2018).
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and recommendations in this map are based on LiDAR data from 2017 and site visits in 2019. Flood events and geomorphic changes have occured since then and may have changed the topography relative to what is shown.

0 650
Feet

ANCHOR QEA

GA-2

Conceptual Gravel Augmentation Opportunities

Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-3

Gravel Placement Locations

This site is located on an island directly downstream from GA-2. The site will be accessed by a temporary road extending from Tucannon Road and a temporary bridge connected the right bank to the island at the upstream end of the island. The placement target here is 800 cy annually along one placement location.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the floodplain with the main channel as described in Section 9.3, Goals and Objectives, in the main report, and to reestablish channels across the island. The GA-3 figure displays the areas where material should be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation.

Approximate Placement Parameters for GA-3 (feet)

			Target Annual Placement (cy)	800
Location	**Height**	**Width**	**Length**	**Volume (cy)**
3.1	3	12	540	780
			Total Annual Placement (cy)	**780**

Implementation Plan

Material will be sourced from floodplain benching and floodplain channel creation. Placement will extend from the downstream end of the large midstream boulder to the bottom of the island. Material will be sourced sequentially (see Section 9.5), to prioritize providing immediate habitat benefits.

GA-3 Gravel Placement Locations

Location 3.1
Material for this location will be sourced first by opening the top and bottom of the floodplain channel. Floodplain channel creation will then expand from the upstream end along with floodplain benching adjacent to the floodplain channel. The floodplain along the main channel adjacent to the placement location will be benched once the floodplain channels are completed.

LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial imagery provided by GeoTerra. Flown April 19, (2018).
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and recommendations in this map are based on LiDAR data from 2017 and site visits in 2019. Flood events and geomorphic changes have occured since then and may have changed the topography relative to what is shown.

0 500
Feet

ANCHOR QEA

GA-3
Conceptual Gravel Augmentation Opportunities
Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-4

Gravel Placement Locations

This site will be accessed from a temporary road extending from Tucannon Road and a temporary bridge at the upstream end of the site. Temporary roads will extend from the bridge to each placement location and each source location as they are established. The placement target here is 1,500 cy annually between three placement locations on the left bank and one on the right bank.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the floodplain with the main channel as described in Section 9.3, Goals and Objectives, in the main report. The GA-4 figure displays the areas where material should be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. The target condition for the left bank is to have multiple established floodplain channels and a lowered floodplain extending all the way to the valley wall. For the right bank, the target condition is to lower a small part of the floodplain that is currently elevated and unvegetated.

Approximate Placement Parameters for GA-4 (feet)

			Target Annual Placement (cy)	1,500
Location	**Height**	**Width**	**Length**	**Volume (cy)**
4.1	2.6	12	230	266
4.2	2.6	12	405	468
4.3	2.6	12	295	341
4.4	2.6	12	185	382
			Total Annual Placement (cy)	**1,457**

Implementation Plan

Material will be sourced from floodplain benching and floodplain channel creation on the left bank and only floodplain benching on the right bank. Placement locations are concentrated at the upstream and downstream portions of the site on the left bank and the middle of the site on the right bank. Material will be sourced sequentially (see Section 9.5), to prioritize providing immediate habitat benefits and minimizing material transport across the site.

GA-4 Gravel Placement Locations

Location 4.1	Location 4.2
Material will be sourced first from opening both floodplain channels and benching the adjacent floodplain from the main channel to the valley wall. Floodplain benching and floodplain channel creation will expand simultaneously downstream until connecting with the efforts associated with Location 4.2.	Material will be sourced first from the opening of the outlets of both floodplain channels and benching of the adjacent floodplain. Following this, floodplain benching will expand upstream along the main channel until they connect with the benching associated with Location 4.1, and then they will expand over to the valley wall and continue back downstream creating the floodplain channel and benching the floodplain simultaneously.
Location 4.3	**Location 4.4**
Material will be sourced through floodplain benching starting at the upstream end of the marked floodplain on the right bank.	Material will be sourced from floodplain benching upstream of this location. Benching will begin at the floodplain channel outlet that is furthest downstream and continue downstream along a relic channel until it reaches the placement location.

LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial imagery provided by GeoTerra. Flown April 19, (2018).
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and recommendations in this map are based on LiDAR data from 2017 and site visits in 2019. Flood events and geomorphic changes have occured since then and may have changed the topography relative to what is shown.

0 920

Feet

ANCHOR QEA

GA-4

Conceptual Gravel Augmentation Opportunities

Conceptual Gravel Augmentation Plan

Tucannon Basin Habitat Restoration

GA-5

Gravel Placement Locations

Access for this site is through private property off Tucannon Road. Temporary roads will extend either from this private property or directly from Tucannon Road to the placement locations. The target placement is 500 cy annually between three placement sites.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the floodplain with the main channel as described in Section 9.3, Goals and Objectives, in the main report. The GA-5 figure displays the areas where material should be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. The target is to connect and lower the unvegetated portions of this floodplain by establishing multiple floodplain channels and benching the available floodplain around them.

Approximate Placement Parameters for GA-5 (feet)

			Target Annual Placement (cy)	500
Location	**Height**	**Width**	**Length**	**Volume (cy)**
5.1	2.4	12	95	101
5.2	2.4	12	195	208
5.3	2.4	12	195	208
			Total Annual Placement (cy)	**517**

Implementation Plan

Material for each placement location will be sourced from the closest floodplain channel creation or floodplain benching, which will continue to expand until they are all connected.

GA-5 Gravel Placement Locations

Location 5.1	Location 5.2
Material will first come from the opening of the floodplain channel nearest to the placement location and benching of the adjacent floodplain. The sourcing will expand downstream until it connects with the material sourcing associated with Location 5.2.	Material will first come from the opening of the floodplain channel nearest to this location, which will expand downstream until it reaches its confluence with the other floodplain channel. Then it will come from the floodplain adjacent to the main channel, starting at the upstream end and expanding downstream.
Location 5.3	
Material will come from the opening of the floodplain channel and benching of the adjacent floodplain. This will expand upstream until it connects with sourcing efforts associated with Locations 5.1 and 5.2.	

LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

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3. Aerial imagery provided by GeoTerra. Flown April 19, (2018).
4. LiDAR elevation data provided by QSI (2018).
5. The conditions and recommendations in this map are based on LiDAR data from 2017 and site visits in 2019. Flood events and geomorphic changes have occured since then and may have changed the topography relative to what is shown.

0 500
Feet

ANCHOR QEA

GA-5
Conceptual Gravel Augmentation Opportunities
Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-6

Gravel Placement Locations

Access for this site is the bridge on Tucannon Road and a small road near the downstream end of the site. Temporary roads will provide access to Locations 6.2 and 6.3. The placement target here is 1,000 cy between three placement locations.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the floodplain surrounding Locations 6.2 and 6.3 with the main channel as described in Section 9.3, Goals and Objectives, in the main report. The GA-6 figure displays the areas where material should be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. The target is to connect and lower the unvegetated portions of the floodplain and to establish one floodplain channel surrounding Location 6.2.

Approximate Placement Parameters for GA-6 (feet)

		Target Annual Placement (cy)		1,000
Location	**Height**	**Width**	**Length**	**Volume (cy)**
6.1	2.5	12	140	1,656
6.2	2.5	12	390	433
6.3	2.5	12	375	4,417
		Total Annual Placement (cy)		1,006

Implementation Plan

Material for Locations 6.2 and 6.3 will be sourced from the floodplain channel creation or floodplain benching nearest them. Material for Location 6.1 will be sourced from GA-10 and transported to this site.

GA-6 Gravel Placement Locations

Location 6.1	Location 6.2
Material will be transported here via dump truck and placed with the given dimensions during low flows, or placed en masse in the channel during high-flow events when the material will be entrained immediately.	Material will be sourced first by opening the upstream and downstream ends of the floodplain channel and then by benching the floodplain along the main channel and expanding up the bank until the floodplain channel is reached. Then the floodplain channel will be connected before benching continues farther up the bank.
Location 6.3	
Material will be transported to this placement location from the immediately surrounding floodplain area. Material will be sourced first from the upstream and downstream ends of the source area closest to the river to allow more floodplain connection as material is transported away from the placement location.	

LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

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2. Vertical datum is North American Vertical Datum of 1988, feet.
3. Aerial imagery provided by GeoTerra. Flown April 19, (2018).
4. LiDAR elevation data provided by QSI (2018).
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0 1,000
Feet

ANCHOR QEA

GA-6

Conceptual Gravel Augmentation Opportunities

Conceptual Gravel Augmentation Plan

Tucannon Basin Habitat Restoration

GA-7

Gravel Placement Locations

Access to the left bank at this site is from the road to the intake for Curl Lake. Access to the right bank will require a temporary bridge placed downstream of the intake. A temporary road along the right bank will provide access to Location 7.1. The target placement here is 1,000 cy annually placed between two locations.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the floodplain surrounding Locations 7.1 and 7.2 the main channel as described in Section 9.3, Goals and Objectives, in the main report. The GA-7 figure displays the areas where material should be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. The target here is to lower the unvegetated portions of the floodplain on the right bank through benching and establish one low-flow floodplain channel.

Approximate Placement Parameters for GA-7 (feet)

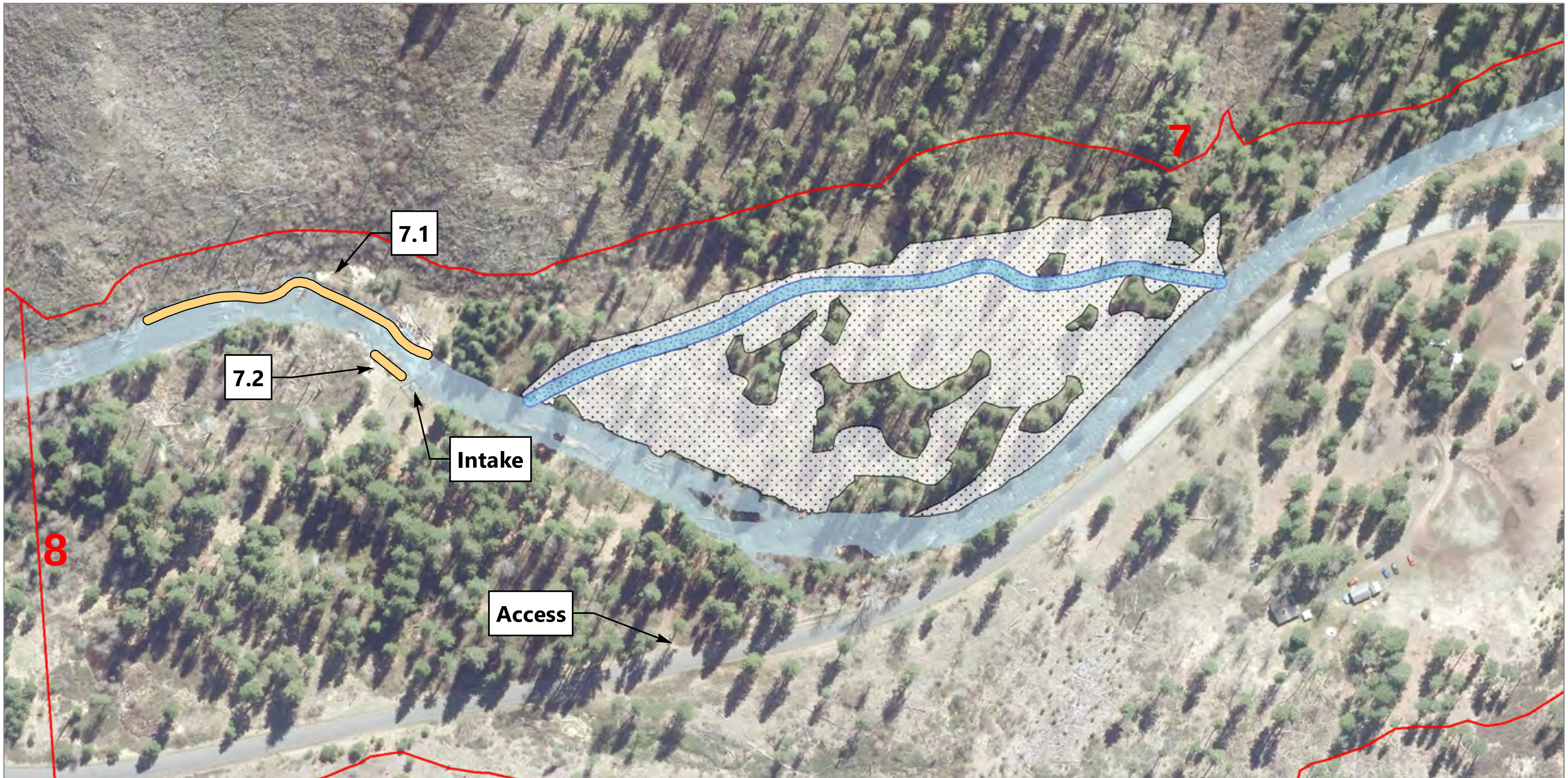
		Target Annual Placement (cy)		1,000
Location	**Height**	**Width**	**Length**	**Volume (cy)**
7.1	2.4	12	415	443
7.2	23	12	55	562
		Total Annual Placement (cy)		1,005

Implementation Plan

Material for Location 7.1 will be sourced from the nearest floodplain channel creation or floodplain benching activity, and material for Location 7.2 will be sourced from site GA-10.

GA-7 Gravel Placement Locations

Location 7.1	Location 7.2
Material will be sourced first by opening the outlet of the floodplain channel. It will then be sourced by expanding the floodplain channel upstream until it connects with its upstream portion and benching a narrow band of floodplain around it. Once the channel is connected, benching will expand across the floodplain at the connection point and then continue downstream.	Material will be sourced from GA-10 and transported to this site via dump truck. This placement location is only to be used during high-flow events when the material can be placed en masse and entrained immediately.



LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
2. Vertical datum is North American Vertical Datum of 1988, feet.
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4. LiDAR elevation data provided by QSI (2018).
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0 500
Feet

ANCHOR QEA

GA-7
Conceptual Gravel Augmentation Opportunities
Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-8

Gravel Placement Locations

Access to this site will require a temporary road extending from Tucannon Road and a temporary bridge to get across the river. The target placement here is 1,000 cy placed between two placement locations.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the floodplain upstream of the lake with the main channel as described in Section 9.3, Goals and Objectives, in the main report. Part of the objective here is to connect channels that have already formed on the downstream end of the lake with upstream counterparts and to transform the leaky lake into vibrant floodplain with complex channels. The GA-8 figure displays the areas where material should be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. Material should be sourced sequentially (see Sequencing of Material Sourcing) to prioritize providing immediate habitat benefits and minimizing material transport across the site.

Approximate Placement Parameters for GA-8 (feet)

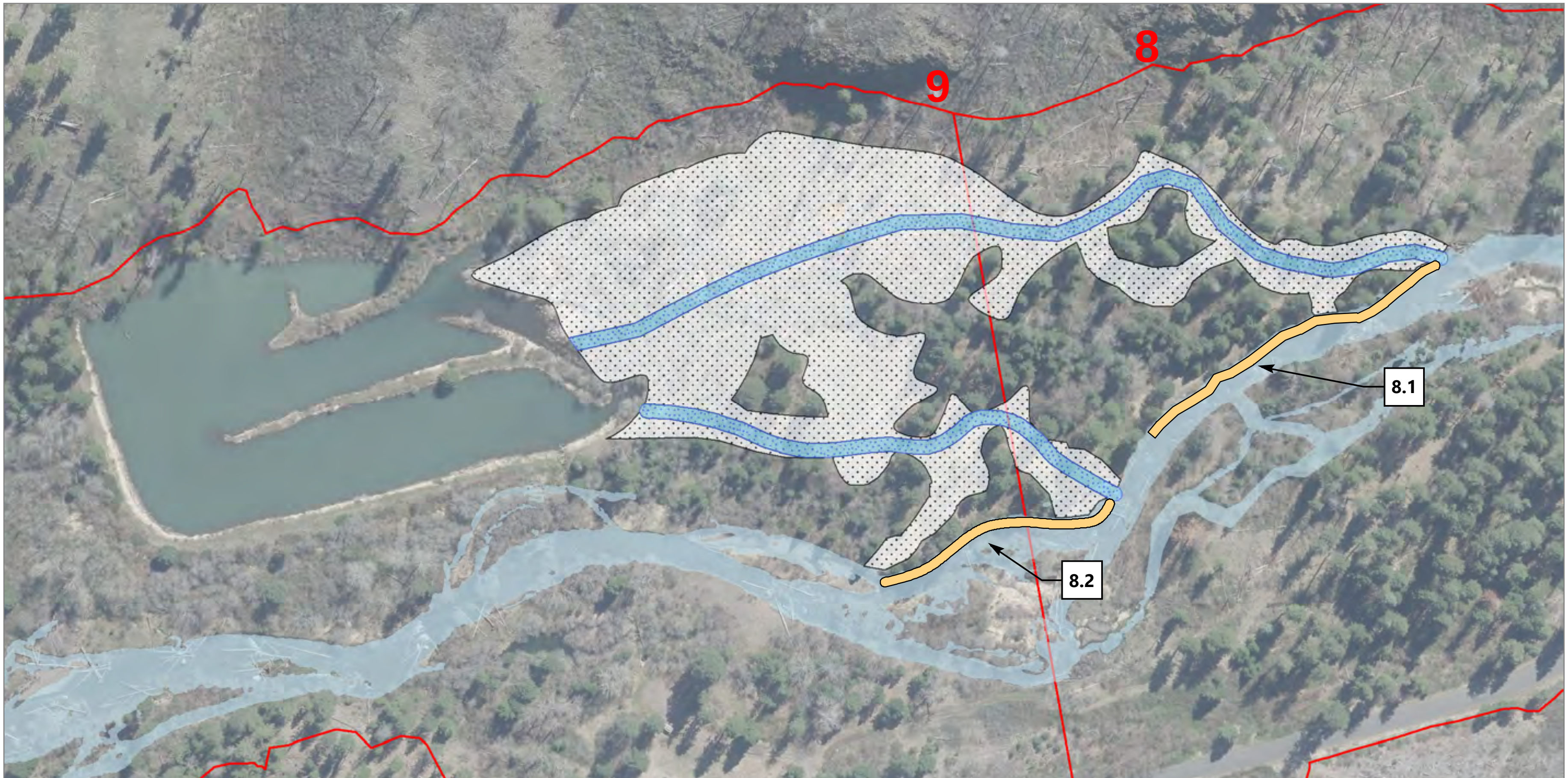
	Target Annual Placement (cy)			1,000
Location	**Height**	**Width**	**Length**	**Volume (cy)**
8.1	2.9	12	435	561
8.2	3	12	325	433
	Total Annual Placement (cy)			994

Implementation Plan

Material sourcing will begin on the upstream ends of the two floodplain channels and expand downstream until they connect with the lake. It will then expand to lower the remainder of the unvegetated floodplain on the upstream side of the lake.

GA-8 Gravel Placement Locations

Location 8.1	Location 8.2
Material will be sourced by opening the floodplain channel and benching the floodplain surrounding it. Both activities will continue downstream until the channel connects to the lake. Then, floodplain benching will continue up the bank from the floodplain channel to the valley wall.	Material will be sourced by opening the floodplain channel and benching the floodplain surrounding it. Both activities will continue downstream until the channel connects to the lake. Then, floodplain benching will continue up the bank until it reaches the other floodplain channel and down the bank until it reaches the main channel at the downstream end of the placement location.



LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

1. Horizontal datum is WA State Plane South, NAD83, U.S. Feet.
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0 500
Feet

ANCHOR QEA

GA-8
Conceptual Gravel Augmentation Opportunities
Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-9

Gravel Placement Locations

This site will be accessed via a temporary bridge at the downstream end of the site. Temporary roads will extend upstream to provide access to Locations 9.1 and 9.2. The target placement value is 1,000 cy annually between the three placement locations.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the unvegetated floodplain on the right bank with the main channel as described in Section 9.3, Goals and Objectives, in the main report. The GA-9 figure displays the areas where material should be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. Successful restoration here will show two established low-flow channels and the unvegetated portions of the floodplain lowered to the 2-year flood flow elevation.

Approximate Placement Parameters for GA-9 (feet)

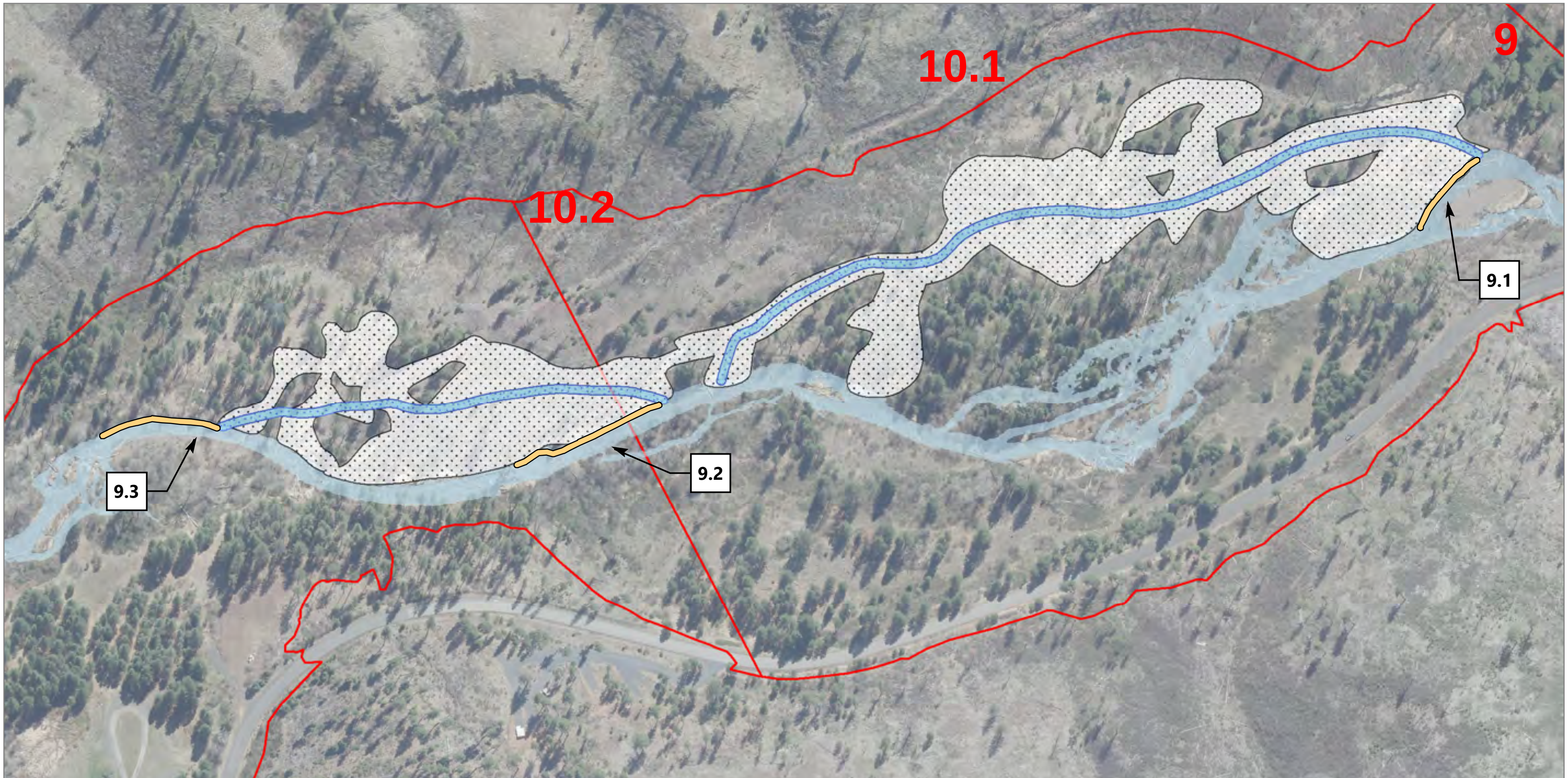
		Target Annual Placement (cy)		1,000
Location	**Height**	**Width**	**Length**	**Volume (cy)**
9.1	2.9	12	190	245
9.2	2.9	12	325	419
9.3	2.9	12	250	322
		Total Annual Placement (cy)		986

Implementation Plan

Material sourcing will begin on the upstream and downstream ends of the floodplain channels and extend towards each other, benching a narrow band of the floodplain along the way from the upstream direction only. Once the floodplain channels are established, benching will expand away from the floodplain channel both up and down the bank starting at the upstream ends.

GA-9 Gravel Placement Locations

Location 9.1	Location 9.2
Material will be sourced by opening the floodplain channel and benching the adjacent floodplain. Floodplain channel creation will continue downstream until the channel is established and then floodplain benching will expand up and down the bank from the floodplain channel starting on the upstream end and then extend downstream.	Sourcing will begin by opening the upstream end of the second floodplain channel and benching the surrounding floodplain. Floodplain channel creation will continue downstream until it connects with sourcing for Location 9.3 and then floodplain benching will expand up and down the bank from the floodplain channel starting on the upstream end. When this area is completely benched, material will be sourced from the floodplain surrounding the upstream floodplain channel.
Location 9.3	
Sourcing will begin by opening the downstream end of the second floodplain channel and benching the surrounding floodplain. Floodplain channel creation will continue upstream until it connects with sourcing for Location 9.2 and then floodplain benching will expand up and down the bank from the floodplain channel starting on the upstream end. When this area is completely benched, material will be sourced from the floodplain surrounding the upstream floodplain channel.	



LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

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0 800
Feet

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GA-9
Conceptual Gravel Augmentation Opportunities
Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-10

Gravel Placement Locations

Access to the left bank of this site will be directly from Tucannon Road, and access to the right bank will be via a temporary bridge at the downstream end. Access to each placement location will require temporary roads extending from Tucannon Road and from the bridge. The target placement value is 1,500 cy between six placement locations.

Target Condition

Along with providing material to feed to the main channel, the objective at this site is to reconnect the unvegetated floodplain on both sides of the river with the main channel as described in Section 9.3, Goals and Objectives, in the main report. The GA-10 figure displays the areas where material will be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. Successful restoration at this site will include the establishment of multiple low-flow channels and engagement of a large portion of the two 2-year floodplain on both banks.

Approximate Placement Parameters for GA-10 (feet)

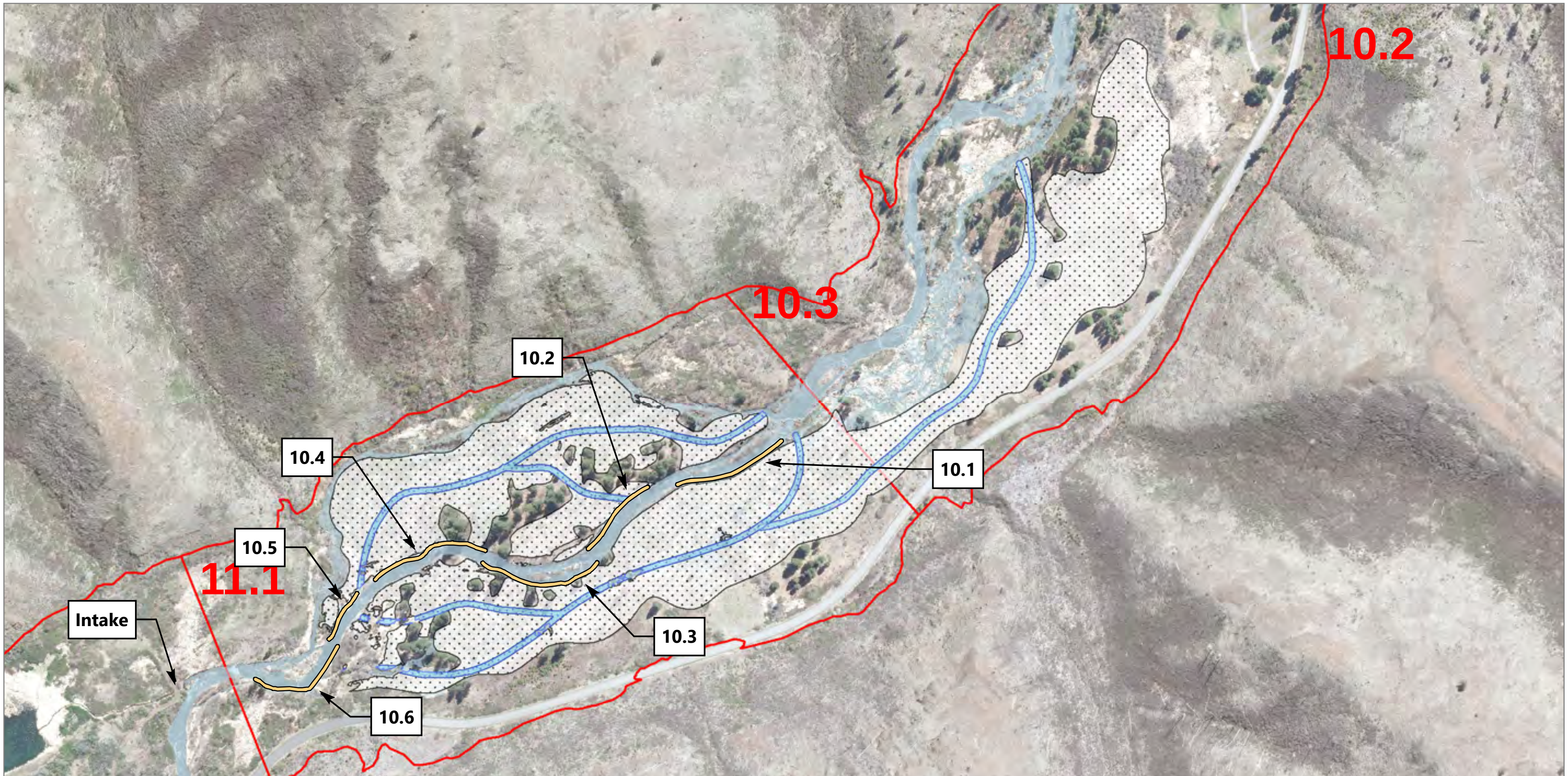
			Target Annual Placement (cy)	1,500
Location	**Height**	**Width**	**Length**	**Volume (cy)**
10.1	1.8	12	350	280
10.2	1.8	12	265	212
10.3	1.8	12	385	308
10.4	1.8	12	375	300
10.5	1.8	12	165	132
10.6	1.8	12	330	262
			Total Annual Placement (cy)	**1,494**

Implementation Plan

Material sourcing will start by opening the upstream and downstream ends of the floodplain channels and benching the available surrounding floodplain on the upstream end. The priority at this site is to establish the floodplain channels. After this is accomplished, floodplain benching will expand from the floodplain channels and up the bank from the main channel.

GA-10 Gravel Placement Locations

Location 10.1	Location 10.2
Material will be sourced initially from the upstream end of the most upstream floodplain channel and benching the surrounding floodplain. Floodplain channel creation will continue downstream with a narrow band of benched floodplain surrounding it until it reaches its confluence with the next floodplain channel. Following this, the floodplain will be benched along the main channel, and finally up the bank from the floodplain channel and into the area upstream of the first floodplain channel. Some of this material will be used for placement at GA-7.	Material will be sourced initially by opening the upstream end of the two floodplain channels on the right bank. Following this, the area surrounding the upstream floodplain channel will be benched, and then floodplain channel creation and benching will expand simultaneously downstream between the second floodplain channel and the valley wall. Finally, the second floodplain channel will be created down to its confluence with the first.
Location 10.3	**Location 10.4**
Material for this location will be sourced from benching the floodplain along the main channel adjacent to the placement location. It will then expand up the bank until it reaches the floodplain channel and continue up the channel until it reaches sourcing associated with Location 10.1. Following this, material will be sourced by benching the floodplain adjacent to the river upstream of the placement location and eventually up the bank from the floodplain channel.	Material for this location will come from benching the floodplain adjacent to the main channel and expanding back towards the floodplain channel. Following this, it will come from floodplain benching between the floodplain channel and the valley wall.
Location 10.5	**Location 10.6**
Material for this location will come first from opening the downstream end of the floodplain channel just upstream of it. It will continue up the floodplain channel until it connects with sourcing associated with Location 10.2.	Material for this location will come first from opening the downstream ends of the two floodplain channels on the left bank and expanding them upstream until they connect with the rest of the floodplain channel. Following this, material will be sourced by benching the floodplain between the two floodplain channels and between the floodplain channel and the road.



LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

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0 1,000
Feet

ANCHOR QEA

GA-10

Conceptual Gravel Augmentation Opportunities

Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-11

Gravel Placement Locations

Access to this placement location is from Tucannon Road and the Tucannon Fish Hatchery Access Road. Location 11.1 is upstream of the bridge that crosses the Tucannon River on the Fish Hatchery Access Road. Location 11.2 will be accessed from the Fish Hatchery Access Road, and Location 11.3 will be accessed from an established dirt road that extends from Tucannon Road. The target placement value at this site is 1,000 cy between the three placement sites.

Target Condition

Along with adding to the placement of gravel in the river that is associated with the management of the fish hatchery, goals at this site include reconnecting the high, unvegetated floodplain on the left bank with the main channel in the manner described in Section 9.3, Goals and Objectives, in the main report. The GA-11 figure displays the areas where material will be sourced over the course of the restoration effort through floodplain benching.

Approximate Placement Parameters for GA-11 (feet)

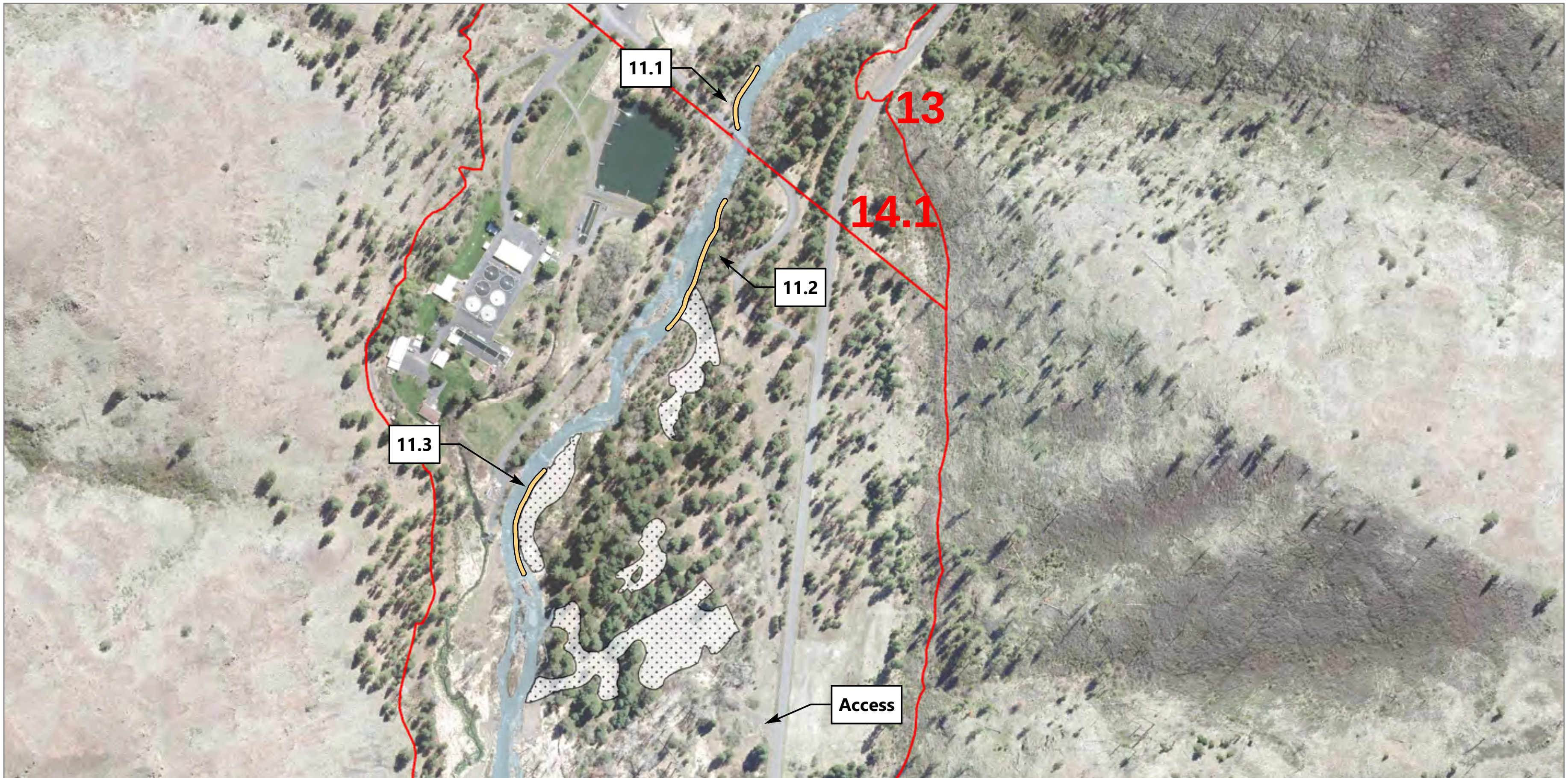
		Target Annual Placement (cy)		1,000
Location	**Height**	**Width**	**Length**	**Volume (cy)**
11.1	2.7	12	170	202
11.2	2.8	12	360	448
11.3	2.8	12	285	355
		Total Annual Placement (cy)		1,004

Implementation Plan

Material sourcing will begin with benching the floodplain adjacent to the main channel and expand up the bank to the high benches set back from the main channel. Material associated with the management of the fish hatchery will be incorporated into the placement at this site.

GA-11 Gravel Placement Locations

Location 11.1	Location 11.2
Material associated with the management of the fish hatchery will be placed at this location upstream of the dam. It can be placed with the given dimensions at low flow or en masse during high-flow events when it will be immediately entrained.	Material for this location will be sourced from benching of the unvegetated floodplain. Benching will begin adjacent to the main channel at the lower end of the placement area and continue up the bank and downstream until the entire marked area is benched. Following this, material will be sourced from the high unvegetated areas in the downstream part of the site. Sourcing material from here will require transporting it up through the site, which can be accomplished mostly using established dirt roads.
Location 11.3	
Material for this location will be sourced by benching the floodplain directly adjacent to it. This benching will begin on the upstream end and expand up the bank and then in the downstream direction. When benching is complete in this area, material will be sourced from the larger area downstream starting adjacent to the channel and moving up the bank.	



LEGEND:

- 1-year Flood Flow
- Gravel Placement Locations
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

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4. LiDAR elevation data provided by QSI (2018).
5. The conditions and recommendations in this map are based on LiDAR data from 2017 and site visits in 2019. Flood events and geomorphic changes have occured since then and may have changed the topography relative to what is shown.

0 1,000

Feet

ANCHOR QEA

GA-11

Conceptual Gravel Augmentation Opportunities

Conceptual Gravel Augmentation Plan

Tucannon Basin Habitat Restoration

GA-12

Gravel Placement Locations

Access to this site will be via temporary roads that will extend from Tucannon Road. Gravel placement at Location 12.1 will be from atop the high bank. Placement at Location 12.2 will start downstream of the deep pool on the outside of the bend.

Target Condition

This site has been slated as solely a gravel placement location. Material placed here will be sourced from GA-13. The target placement value is 500 cy annually between the two placement locations that are shown in the GA-12 figure.

Approximate Placement Parameters for GA-12 (feet)

			Target Annual Placement (cy)	500
Location	**Height**	**Width**	**Length**	**Volume (cy)**
12.1	3	12	170	227
12.2	3	12	205	273
			Total Annual Placement (cy)	**500**

GA-12 Gravel Placement Locations

Location 12.1	Location 12.2
Material placed here will be sourced from GA-13.	Material placed here will be sourced from GA-13.

LEGEND:

Gravel Placement Locations

1-year Flood Flow

NOTES:
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0 300
Feet

ANCHOR QEA

GA-12
Conceptual Gravel Augmentation Opportunities
Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

GA-13

Gravel Placement Locations

Access to this site is via private property off Mcgovern Lane on the left bank of the river. This location will be a source only and material from here will be used in GA-12 just upstream.

Target Condition

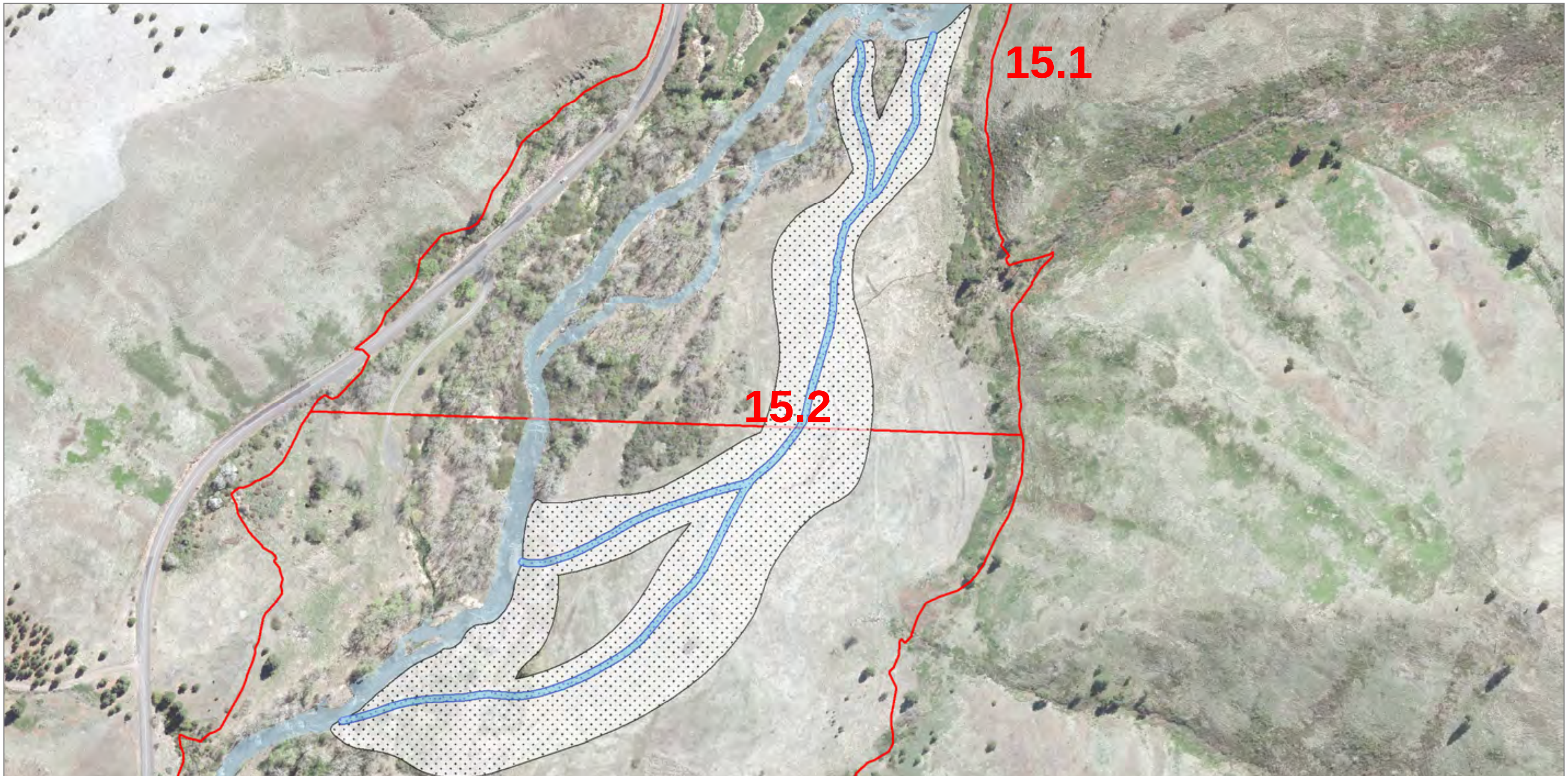
The main objectives at this site are to reconnect the unvegetated floodplain on the left bank with the main channel as described in Section 9.3, Goals and Objectives, in the main report, and also to mitigate flood risk to the properties downstream by increasing the flood storage capacity. The GA-13 figure displays the areas where material will be sourced over the course of the restoration effort through floodplain benching and floodplain channel creation. Material will be sourced sequentially to prioritize allowing water onto the floodplain.

Implementation Plan

Material sourcing at this site will begin with benching of the floodplain and creation of the two floodplain channels at the upstream end of the site. All the marked areas along the main channel will be sourced for material before moving downstream. Following this, the floodplain channel will be established with a narrow band of benched floodplain surrounding them, and finally floodplain benching will expand outwards from the floodplain channels. Material sourced from this site will be placed at the two placement locations in GA-12.

GA-13 Gravel Placement Locations

Location 13
Material for this location will be sourced as described above.



LEGEND:

- 1-year Flood Flow
- Sourcing (2-year floodplain elev.)
- Floodplain Channel (winter flow elev.)

NOTES:

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0 1,000
Feet

ANCHOR QEA

GA-13

Conceptual Gravel Augmentation Opportunities

Conceptual Gravel Augmentation Plan
Tucannon Basin Habitat Restoration

CONTRACT NO.: ____________________

DATE: ____________________

NO.: ____________________

FIELD INSPECTOR: ____________________

PROJECT / LOCATION: Tucannon River Gravel Augmentation / WA

REQUESTED ACTION FORM

Submitted to:	
Agency:	
Name:	
Contact Info:	

SOURCING RECOMMENDATIONS		
Action type	**Y/N**	**Description**
Floodplain benching		
Floodplain channel creation		
Existing stockpile		
Maintenance/Emergency management		

GRAVEL PLACEMENT RECOMMENDATIONS				
New placement dimensions (ft)				
Location	**height**	**width**	**length**	**volume (CYDs)**
.1				
.2				
.3				
.4				
.5				
.6				
Description:				

LIMITATIONS: The form represents the observations of the field inspector. Measurements taken are approximate and are intended to provide a general sense of the site conditions at the time. Notes on the site conditions and interpretations of those conditions made to complete this form are those of the field representative. The recommendations for action were made in consultation with the monitoring form reviewer.	Review Signature: ____________ *Date:*

Field Inspector Signature: ____________________ Date: ____________

County Review Signature: ____________________ Date: ____________

CONTRACT NO.:	
DATE:	
NO.:	
FIELD INSPECTOR:	
PROJECT / LOCATION:	**Tucannon River Gravel Augmentation / WA**

GRAVEL AUGMENTATION MONITORING FORM

Submitted to:		**RECOMMENDATIONS**		**Weather Temp. & Precip.**			
Agency:		**Continue plan**	**Modify**				
Name:		*Circle one*		**Times of Site Visits:**			
Contact Info:		When action is recommended see attached action form		From		To	

Discharge	cfs	*Link to gauge*

FLOODPLAIN CHANGE			
Floodplain Channels	**y/n**	**Floodplain Benching**	**y/n**
Are they connected to the main channel?		Is it connected to the main channel?	
Are they wetted during winter flows?		Is it wetted during the 2-year flow?	
Are they providing complexity/fish habitat?		Is it providing complexity/promoting veg.?	

Observations:

GRAVEL ENTRAINMENT				
Location	**Amt. Placed Yr. Prior**	**% remaining**	**Downstream travel (ft)**	**% channel spread**
.1				
.2				
.3				
.4				
.5				
.6				

Observations:

LIMITATIONS: The form represents the observations of the field inspector. Measurements taken are approximate and are intended to provide a general sense of the site conditions at the time. Notes on the site conditions and interpretations of those conditions made to complete this form are those of the field representative. The recommendations for action were made in consultation with the monitoring form reviewer.

Review Signature: ____________

Date:

Field Inspector Signature: ____________ Date: ____________

County Review Signature: ____________ Date: ____________

	CONTRACT NO.:	
	DATE:	
	NO.:	
GRAVEL AUGMENTATION MONITORING FORM	FIELD INSPECTOR:	
	PROJECT / LOCATION:	**Tucannon River Gravel Augmentation / WA**

Vegetation		
Describe extent/type of veg.	**% benched floodplain with emergent veg.**	**%**

Photographs - Vegetation	
Comment:	Comment:
	
Comment:	Comment:

Photographs - Sourcing	
Comment:	Comment:
Comment:	Comment:
Comment:	Comment:

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Field Inspector Signature: ______________________ Date: ____________
County Review Signature: ______________________ Date: ____________

CONTRACT NO.: ____________________

DATE: ____________________

NO.: ____________________

FIELD INSPECTOR: ____________________

PROJECT / LOCATION: **Tucannon River Gravel Augmentation / WA**

GRAVEL AUGMENTATION MONITORING FORM

Photographs - Placement	
Comment:	Comment:
Comment:	Comment:
Comment:	Comment:

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Field Inspector Signature: ____________________ Date: ____________

County Review Signature: ____________________ Date: ____________