Upper Salmon Subbasin Habitat Integrated Rehabilitation Assessment

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Acronyms and Abbreviations

Acronym or Abbreviation	Description
BLM	Bureau of Land Management
CHaMP	Columbia Habitat Monitoring Program
CWA	Clean Water Act
Chinook salmon	Snake River spring/summer Chinook salmon
ESA	Endangered Species Act
GIS	Geographical Information System
HUC	Hydrologic unit code
IDEQ	Idaho Department of Environmental Quality
IDWR	Idaho Department of Water Resources
IRA	Integrated Rehabilitation Assessment
ISEMP	Integrated Status and Effectiveness Monitoring Program
LiDAR	Light Detection and Ranging
MAT	Minimum abundance threshold
MPG	Major population group
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	NOAA National Marine Fisheries Service
NPCC	Northwest Power and Conservation Council
NRCS	Natural Resources Conservation Service
OSC	Office of Species Conservation
PBF	Physical and Biological Feature
QRF	Quantile Regression Forest
Reclamation	Bureau of Reclamation
RM	River mile
Science Team	Upper Salmon Assessment Team
SNF	Sawtooth National Forest
SNRA	Sawtooth National Recreation Area
TA	Tributary Assessment
TMDL	Total Maximum Daily Load
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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Executive Summary

Large-scale changes to aquatic ecosystems in the Pacific Northwest began with the fur trade, long before settlement and territorial governance. When beavers were removed from the landscape, the resiliency of the ecosystems diminished as channels became simplified and floodplain connectivity was reduced. As European settlement occurred, arable lands adjacent to water sources were homesteaded first, and the development of water for irrigation started a series of changes with cascading effects through the ecosystem. Natural resource extraction increased, placing additional pressures on the aquatic ecosystems. An exponential increase in the Columbia River Basin human population directly correlates with decreased salmon (and steelhead) available for harvest. Human influences have exerted significant changes in the freshwater, estuary, and ocean conditions under which salmon historically flourished. That change, which occurred on a relatively short time scale, is perhaps most apparent in tributary habitat, which has become degraded over time.

In response to dwindling Chinook salmon populations and loss of habitat, the Idaho Governor's Office of Species Conservation (OSC) and an interdisciplinary team of partners have created a biologically based evaluation called the Integrated Rehabilitation Assessment (IRA) to further the recovery of Endangered Species Act-listed Chinook salmon and steelhead populations in the Upper Salmon River Subbasin. The IRA uses empirically based quantile regression forest (QRF) models to estimate the number of redds and the number of juveniles that tributary habitat can support during summer (parr) and winter (presmolt) rearing, based on the quantity and quality of available habitat. These capacity estimates are compared to (1) current population capacity requirements, and (2) recovery plan goals. At a coarse scale, the resulting deficits are used to identify the magnitude, types, and generalized locations of habitat rehabilitation actions that will be most beneficial to help achieve recovery targets within a given watershed. Using guidance on restoration action types and locations provided by QRF models, a geomorphic analysis is employed to identify reaches within a given watershed that offer the opportunity to effectively and cost-efficiently implement restoration actions to increase capacity.

After completion of the IRA, the next step is the Multiple Reach Assessment (MRA) reports. There will be one report each for the Upper Lemhi River Basin, Lower Lemhi River Basin, Lower Pahsimeroi River Basin, and Upper Salmon River Basin above Redfish Lake Creek. The MRA will build upon the IRA to develop more detailed biologic and geomorphic characterization at the sub-reach and channel unit scale and directly tie into upcoming project work.

Recommended actions in all three watersheds from the IRA include increasing juvenile rearing capacity during summer and winter months by focusing on hydraulic diversity with instream velocity gradients, ample concealment cover, and complex habitat structure, accompanied by fine sediment reduction, especially in locations downstream of spawning areas. Complimentary actions would also address moderating water temperatures and instream flows by increasing floodplain connectivity, hyporheic flow, and the alluvial aquifer connection; improving riparian habitat; and reducing the stream width-to-depth ratio without increasing in-stream velocity. Actions specific to the three watersheds are detailed within watershed-specific chapters in the IRA, and will be further addressed in upcoming MRA reports.

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Section 1: Introduction, Background, and Approach

Introduction

The Idaho Governor's Office of Species Conservation (OSC) and an interdisciplinary team of partners have created this Upper Salmon Subbasin Habitat Integrated Rehabilitation Assessment (IRA). The IRA is a biologically based assessment of habitat conditions in the Upper Salmon River subbasin in central Idaho for spring/summer run Chinook salmon (*Oncorhynchus tshawytscha*; hereafter Chinook salmon) and summer run steelhead (*O. mykiss*; hereafter steelhead) listed under the Endangered Species Act (ESA). This assessment leverages estimates of tributary habitat capacity, a summary of watershed-scale geomorphic conditions, hydrologic and hydraulic analyses, and information on current and projected water temperatures to build a framework for describing the status of habitat conditions. Moreover, estimates of available habitat capacity and potential habitat capacity limitations relative to current conditions are compared to estimates of capacity requirements necessary to support National Oceanic and Atmospheric Administration (NOAA; 2017) delisting. This IRA framework is used to evaluate capacity limitations and associated geomorphic character to facilitate habitat rehabilitation planning efforts for Chinook salmon and steelhead populations in the Upper Salmon River subbasin. The IRA is a watershed-scale assessment intended to identify the problem, or life-stage-specific capacity limitations, in the Upper Salmon River subbasin. Future Multiple Reach Assessments (MRAs) will be developed to identify potential reach-scale, geomorphically appropriate target conditions and enhancement actions to inform the prioritization and development of specific enhancement projects.

This IRA is a collaborative, interdisciplinary effort intended to guide the development of habitat improvement actions in coordination with local objectives and constraints. It is not intended to be a stand-alone document that directs the design and implementation of projects in the Upper Salmon subbasin; rather, it is the first step in a science-based approach that identifies priorities and data gaps in existing knowledge that will be useful for future analysis and implementation. Based on the data and results presented in this document and the accompanying technical appendices, stakeholders can better plan both smaller-scale projects that can be implemented as opportunities arise, and larger, more complex projects that will require further assessment at a reach scale. This watershed-scale IRA was developed largely from existing data with limited field validation and was guided by previous assessments completed by the Bureau of Reclamation (Reclamation) in Columbia River tributaries and processes developed by the Northwest Fisheries Science Center. The next step will be to perform reach-scale assessments (e.g., MRAs) in high-priority areas identified by the IRA. Future MRAs are intended to refine analyses from the IRA by incorporating finer-resolution data, field work, and reach-specific rehabilitation targets, which will inform future habitat actions.

Both the IRA and MRA benefit from, and build on, the considerable knowledge accumulated by the work of research biologists, and capitalize on the observational wisdom of biologists, Tribes, and landowners. The IRA provides initial efforts to quantify necessary increases in available habitat capacity to support NOAA recovery plan goals. Additionally, these efforts build upon the well-established platform of the 1995 Model Watershed Plan (Idaho Soil Conservation Commission 1995) and process, the 2002

Northwest Power and Conservation Council Salmon Subbasin Plan, and a large suite of successful habitat implementation actions since the early 1990s. Additionally, this report builds on a continuing history of collaborative effort in the Upper Salmon Subbasin among landowners, irrigators, agricultural interests, community members, funders, and technical specialists from government and conservation entities who are instrumental for applying the concepts presented in this assessment. This IRA document is intended to engage a diverse audience including landowners, habitat rehabilitation practitioners, and regulatory agencies. It is our hope that this structure enables readers to engage at whichever levels of contextual and quantitative content interest them and that the IRA contributes to ongoing conversations to recover listed Chinook salmon and steelhead in the Upper Salmon River subbasin.

The IRA focuses primarily on Chinook salmon, and secondarily on steelhead; additional existing data are available for Chinook salmon beyond that available for steelhead, and therefore, allows for a more thorough assessment. Additionally, given the similarities in habitat needs for Chinook salmon and steelhead, the IRA framework assumes that any habitat rehabilitation actions that occur to improve conditions for Chinook salmon will also improve steelhead habitat. Within the Upper Salmon River subbasin, the IRA focuses on three tributaries: the Lemhi River, Pahsimeroi River, and Upper Salmon River upstream of the confluence with Redfish Lake Creek (Salmon River headwaters). These locations are emphasized because their populations are critical to Chinook salmon recovery (NOAA 2017), and they are identified as designated strongholds in the Nez Perce Fishery Management Plan 2013-2028 (Nez Perce Tribe 2013). However, the IRA additionally provides preliminary assessments and life-stage-specific habitat capacity evaluations for the other five watersheds in the Upper Salmon River subbasin (Valley Creek, Yankee Fork Salmon River, East Fork Salmon River, North Fork Salmon River, and Panther Creek) in the appendices. Due to limited available data, bull trout (*Salvelinus confluentus*) are outside of the scope of the IRA. Habitat rehabilitation actions to benefit Chinook salmon (and steelhead) would likely benefit (or do no harm to) existing bull trout populations in the Upper Salmon River subbasin.

After completion of the IRA, the next steps include completing the MRA reports. There will be one MRA report each for the Upper Lemhi Basin, Lower Lemhi Basin, Pahsimeroi Basin, and Upper Salmon Basin above Redfish Lake Creek. The MRA reports will build upon the IRA to develop more detailed biologic and geomorphic characterization at the reach, sub-reach, and channel unit scale and directly tie into upcoming project work (Figure 1). Additional MRAs may be completed at a later date.

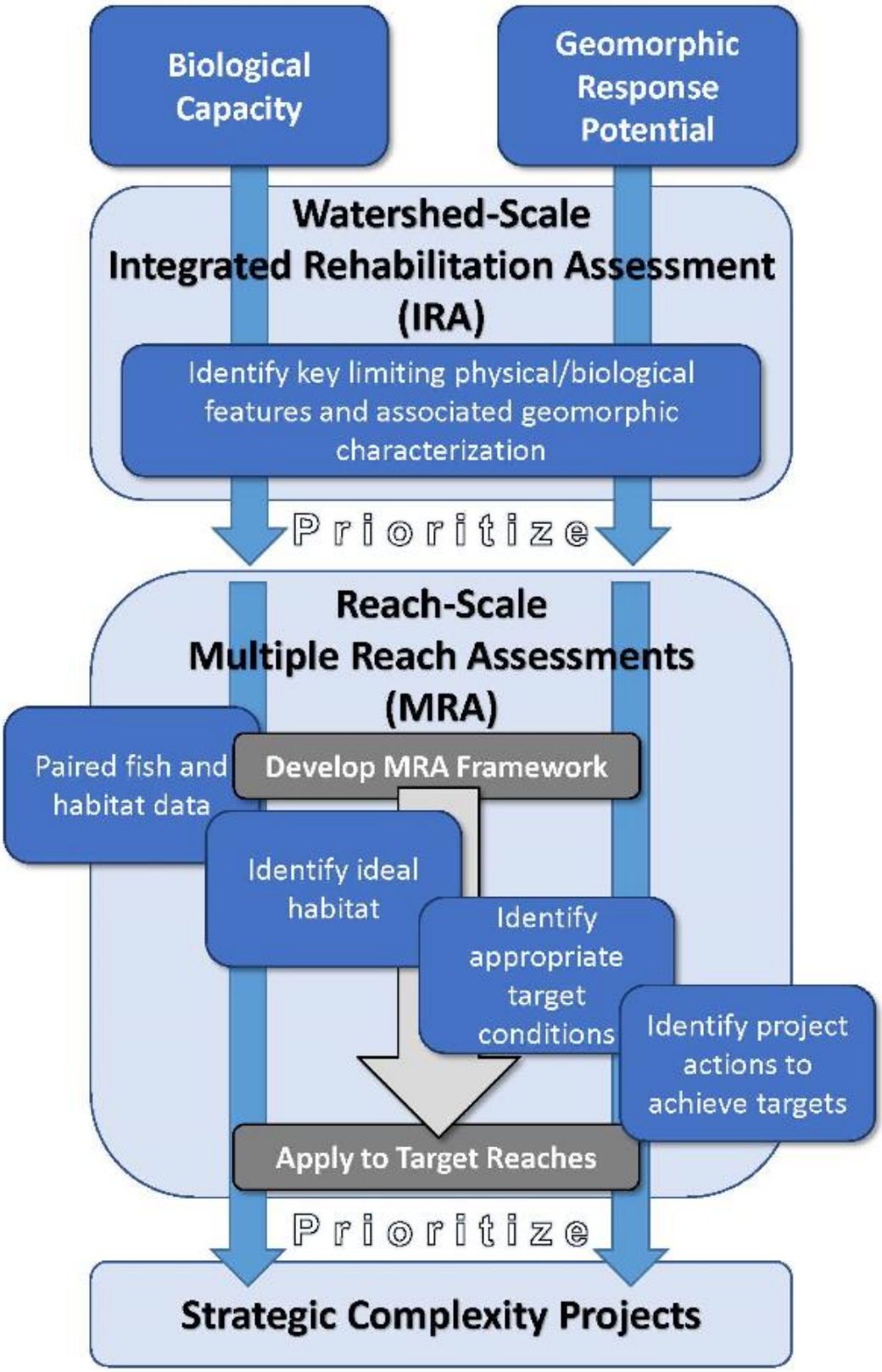


Figure 1. Flow chart illustrating the relationship of the Integrated Rehabilitation Assessment (IRA) and Multiple Reach Assessments (MRAs), including inputs and goals for the overall assessment framework.

Rationale

The life-history of anadromous salmonids can be usefully defined by two stages: 1) smolt to adult, describing the period when juveniles emigrate from freshwater to the ocean and subsequently return to freshwater as adults, and 2) adult to smolt, describing the period when adults enter tributary habitat for spawning, and encompassing the period of juvenile rearing in tributary habitat. The focus of the IRA framework is the latter, the period of the life cycle that occurs in tributary habitat. This focus is motivated by the fact that recovery, as presented in recently released Snake River recovery plans (NOAA 2017), requires that populations must be self-sustaining without reliance on hatchery production. As such, recovery necessarily requires the availability of suitable freshwater habitat to support all the physical and biological features (PBFs) for a species to complete all the freshwater life stages required of tributary habitat. PBFs are specific physical or biological features that provide for a species' life-history processes and are essential to the conservation and recovery of the species.

In completing habitat rehabilitation, our goal is to increase the capacity of the habitat to allow the productivity of target species to increase by identifying and addressing the most limiting PBFs by life-stage. This effort was initiated as a result of a combination of three events:

1. Interest on the part of the Bureau of Reclamation (Reclamation) in funding a Tributary Assessment (TA) of one major watershed in the upper-Salmon River subbasin.
2. Recently released recovery plans for spring/summer Chinook salmon and steelhead populations in the upper-Salmon River subbasin.
3. The advent of fish/habitat relationships from the Integrated Status and Effectiveness Monitoring Program (ISEMP) and Columbia River Habitat Monitoring Program (CHaMP) programs capable of estimating life-stage-specific habitat capacity across populations comprising a Major Population Group (MPG) and Distinct Population Segment (DPS).

Using the adult-to-smolt portion of the salmon/steelhead life-cycle model, we can identify needed habitat characteristics for each life stage (adult, egg, fry, parr, presmolt, etc.) to ensure the individual completes the life stage and transitions to the next successfully and in abundance to meet biological goals. Using fish-habitat models, we have identified capacity deficits for key life stages and bottlenecks in the quantity and quality of available connected habitats. Habitat available prior to European influence produced fish well in excess of our stated goals, as documented by numerous accounts of early explorers and fur traders. However, attempting to restore habitat to its exact pre-European-settlement condition is likely unrealistic.

Anthropogenic influences have exerted significant changes in the freshwater, estuary, and ocean ecosystems under which salmon historically flourished. Changes to tributary ecosystems in the Pacific Northwest began with the fur trade, long before settlement and territorial governance. Specifically, as beavers were removed from the landscape, the resiliency of ecosystems were diminished as channels became simplified and floodplain connectivity was reduced. As settlement occurred, arable lands adjacent to water sources were homesteaded first. As settlement continued, the development of water for irrigation started a series of changes with cascading effects through the ecosystem. Natural resource extraction increased over time, placing additional pressures on the aquatic ecosystems. Harvest records of Columbia River Basin salmon and steelhead stocks, because of their long period of data, are an indicator of ecosystem and stock health. Exponential increases in human population size in the Columbia River Basin are inversely correlated with the ability to harvest salmon and steelhead in the region (Figure 2).

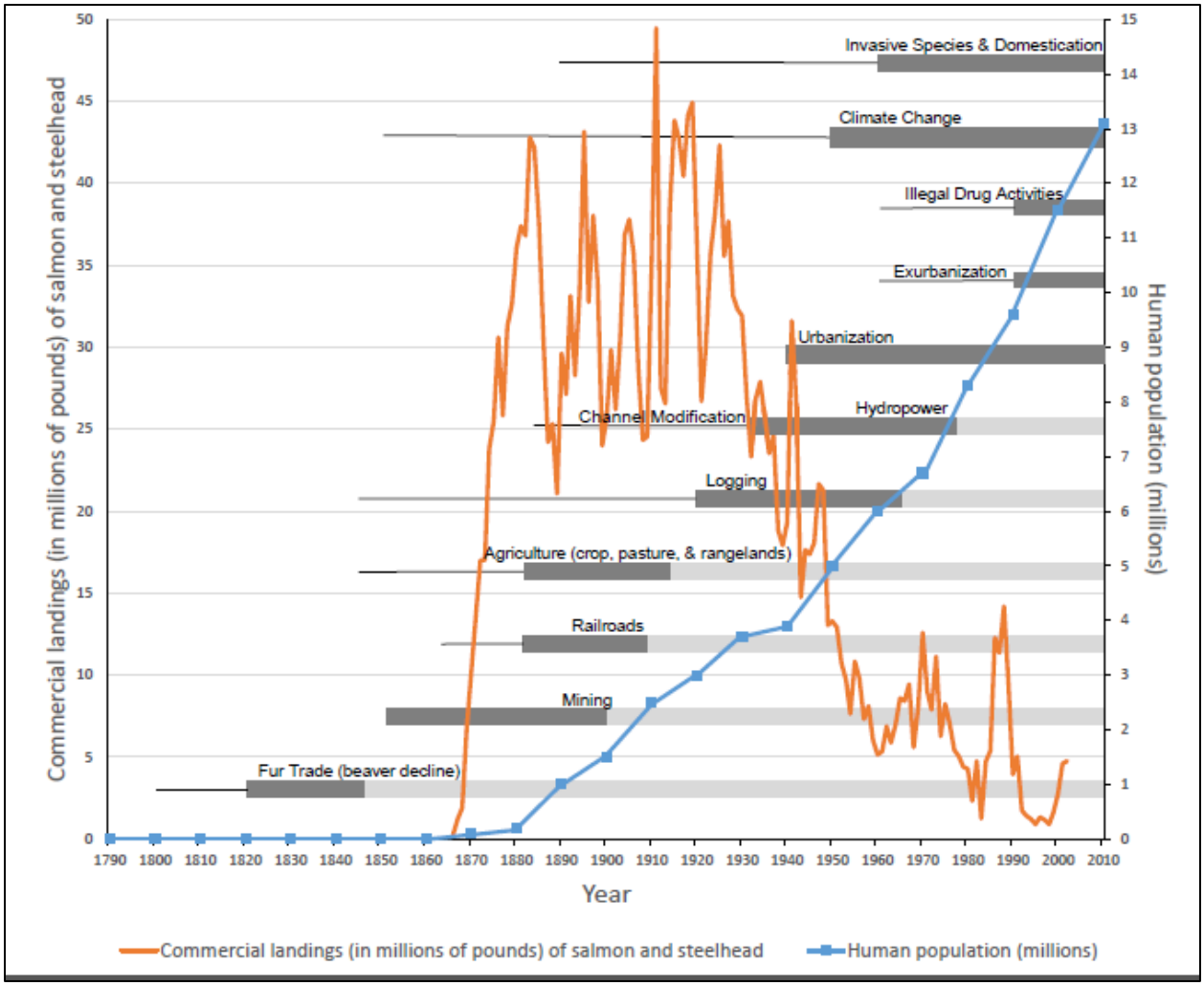


Figure 2. Human activities have had a dramatic effect on aquatic resources and in particular anadromous salmonids. The Y-axis above depicts harvest of salmon and steelhead in the Columbia as a surrogate for escapement due its long period of record. The Y2-axis depicts various activities, with the darker potion of the bar graph representing the peak of the activity.

In recent years, efforts to restore Chinook salmon and steelhead populations to historical conditions have shifted toward increasing the production and capacity in tributary spawning and rearing habitats, but project funders and policymakers have been frustrated over a lack of connection between habitat improvement and increases in adult salmon returns. However, a closer look at data reveals that habitat improvement efforts have benefited local populations in terms of increasing productivity and increasing abundance of juveniles and resident fish. Moving forward, monitoring programs should focus on collecting data to detect these increases in abundance in cohorts from life stage to life stage. As is discussed in further detail below, the efforts to date have benefited certain life stages of juvenile salmonids but either have not been enough to achieve recovery goals, or another subsequent life stage is further limiting the local population in question. Monitoring efforts such as ISEMP and CHaMP have begun to produce results that have helped to quantify the habitat deficiencies from life stage to life stage. This document further examines those deficiencies with the goal of focusing future efforts to increase the probability of sustainably improving adult salmon returns. Connecting implemented projects with quantitative estimates of their improvements in both physical habitat and fish population dynamics is key

to addressing the concerns of project funders and policy makers – ultimately supporting accountability for taxpayers and providing a roadmap to sustainable and profitable fisheries in concert with other valuable land management and agricultural requirements.

The IRA team and many other partners in the Upper Salmon subbasin recognize the need to improve communication of the successes and challenges facing anadromous fish recovery in this MPG with project funders and policymakers. Data collected throughout the MPG demonstrate that populations are currently density-dependent, and hatchery supplementation will not necessarily result in a sustained increase of smolts or returning adults (Venditti et al. 2018). To better understand this issue and what can be done to reverse this trend, project partners have worked to implement a new approach – including the IRA and subsequent MRAs.

Study Area

The Upper Salmon River subbasin includes the Salmon River watershed upstream of the Middle Fork of the Salmon River (Figure 3). This area includes approximately 6,334 square miles located within the Northern Rocky Mountain System physiographic region that comprises extensive parallel mountain ranges, intermontane valleys, and plateaus. Elevations in the watershed range from a low of 3020 feet at the confluence of the Middle Fork Salmon River to the numerous high mountain ranges in the headwater areas, climbing to around 11000 feet. The eastern part of the subbasin (Lemhi and Pahsimeroi watersheds) falls within the Middle Rockies Level III Ecoregion, which is characterized by linear mountain ranges of mixed lithology with large intermontane valleys. Land use includes logging, mining, and livestock grazing. Land cover includes spruce and fir in the uplands and predominantly shrub and grass-covered valleys. The western part of the subbasin (Panther Creek, Valley Creek, East Fork, and Upper Salmon River headwaters) falls within the Idaho Batholith Level III Ecoregion, which is characterized by dissected, partially glaciated, mountainous plateau with granitic lithology and deeply weathered acidic soils. Land use includes logging and grazing. Land cover includes spruce and fir in the uplands and pine, shrubs, and grasses in the valleys.

Major tributaries within the Upper Salmon River subbasin include the Upper Salmon River (above Redfish Lake Creek), Valley Creek, Yankee Fork Salmon River, East Fork Salmon River, Pahsimeroi River, Lemhi River, North Fork Salmon River, and Panther Creek. This IRA report includes high-level hydrologic, biologic, and geomorphic assessments for three of the watersheds: Lemhi River, Pahsimeroi River, and the Upper Salmon River upstream of Redfish Lake Creek.

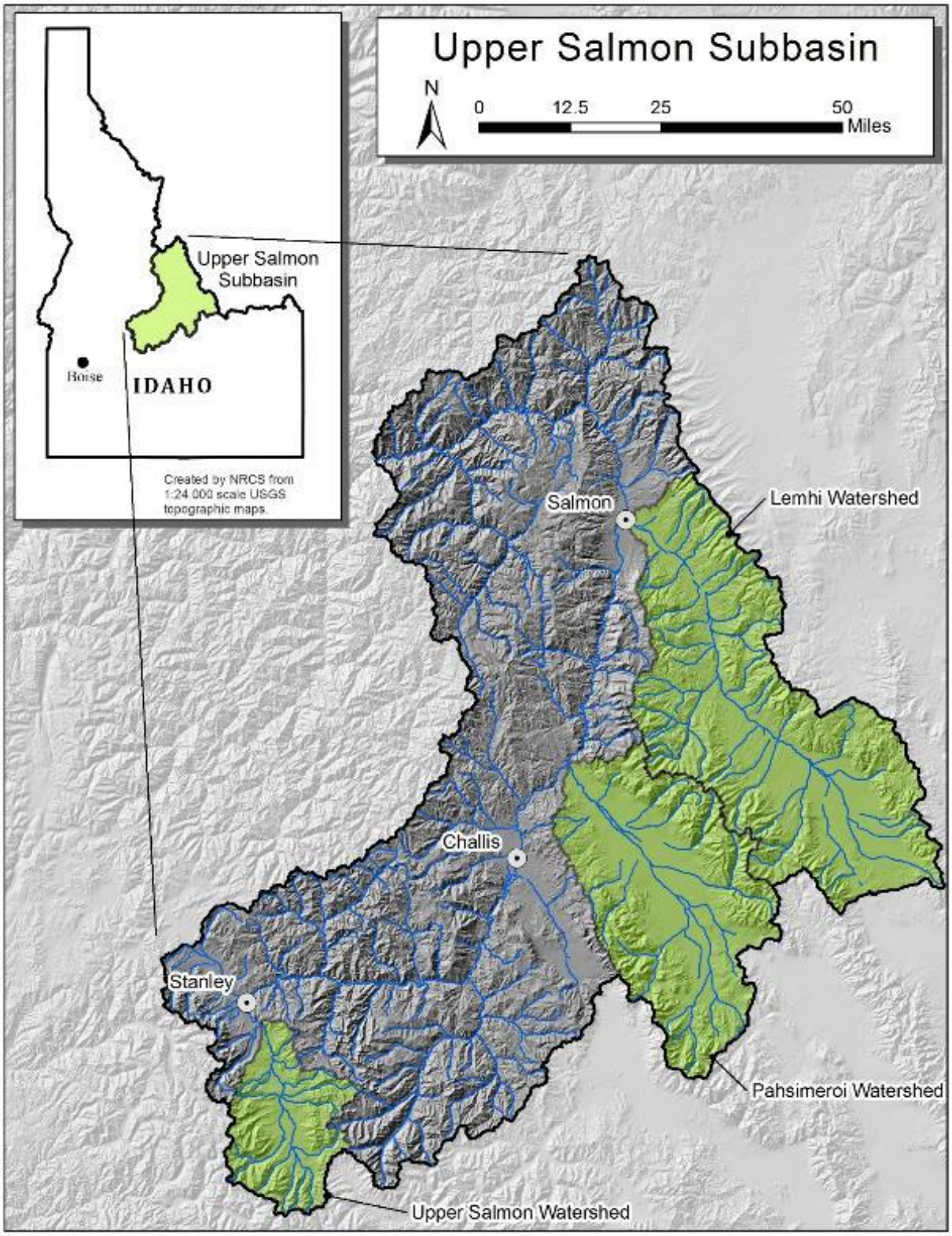


Figure 3. Upper Salmon subbasin (upstream of the Middle Fork Salmon River) vicinity map illustrating the three watersheds assessed in this report – Lemhi, Pahsimeroi, and Upper Salmon (upstream of Redfish Lake Creek).

Document Structure

The IRA document is structured as follows:

- **Section 1**: **Introduction, Background, and Approach.** Section 1 provides a high-level context for the IRA approach. Section 1 also provides rationale and relevant background for the IRA and an explanation of the overall assessment approach.
- **Section 2**: **Upper Salmon Basin Key Conclusions and Recommendations.** Section 2 provides high-level results from the IRA for focus populations and also for the Upper Salmon MPG (Chinook salmon) as a whole.
- **Section 3**: **Watershed-Level Results.** Section 3 provides more detailed results for the focus watersheds and is presented as three chapters, one for each of watershed (Lemhi River, Pahsimeroi River, Upper Salmon River above Redfish Lake Creek).
- **Appendices**: Appendices contain the greatest level of technical detail included in this document. Appendices provide additional context and background and are excluded from the main document for brevity. Four appendices are provided, including:
    - **Appendix A**: Detailed description of the spatially and temporally continuous temperature model used to evaluate potential temperature impediments at the watershed scale.
    - **Appendix B**: Detailed information on Quantile Regression and Random Forest (QRF) models developed for the spawning (redd), summer (parr), and winter (presmolt) life stages of Chinook salmon and steelhead. QRF models were used to estimated available habitat.
    - **Appendix C**: Detailed descriptions of habitat capacity requirement models used to estimate the amount of habitat necessary to support various levels of adult escapement, including escapement required for delisting (NOAA 2017) and recovery.
    - **Appendix D:** Detailed evaluation of watershed hydrology including peak flow frequency estimates, stream power assessments, discharge and water surface elevation measurements, and bottom sediment characteristics for the Lemhi, Pahsimeroi, and Upper Salmon watersheds.

Attribute Definitions

Summarized below are the geomorphic attribute definitions used to characterize the three watersheds in subsequent chapters. These definitions are listed one time here to provide context for the remainder of the report and to reduce potential redundancy within each of the three watershed chapters that follow.

- Valley Segment: spatial units delineated by HUC-10 confluences.
- Reach: spatial units delineated based on changes in measured valley confinement (entrenchment ratio), significant grade controls, and observed channel response characteristics.
- River Miles: measured along the centerline of the channel as interpreted from aerial photos from downstream to upstream.
- Valley Slope (ft/ft): change in elevation of reach divided by the centerline valley length.

- Average Valley Width (ft): approximation of valley width determined by taking the average of characteristic cross-sections of the assumed floodplain area interpreted from aerial photos.
- Average Constrained Valley Width: approximation of valley width (after accounting for road embankments and/or levees) determined by taking the average of characteristic cross-sections of the assumed floodplain area interpreted from aerial photos.
- Channel Slope: change in elevation of reach divided by the centerline river length.
- Average Channel Width: approximation of channel width determined by taking the average of characteristic cross-sections of the in-channel flow area interpreted from aerial photos.
- Sinuosity: channel centerline length divided by valley centerline length.
- Entrenchment Ratio: average valley width divided by average channel width.
- Constrained Entrenchment Ratio: average constrained valley width divided by average channel width.
- Human Disturbance Ratio (%): linear feet of mapped human features within 50 feet of the channel centerline, divided by the linear feet of mainstem channel per reach.
- Groundwater Characteristics: defines whether the reach is gaining, neutral, or losing surface flows due to groundwater seepage/springs, based on measured seepage runs, where available.
- Geomorphic Characterization: linear feet of mapped channel unit length (including side channels, main stem, and split-flow channels) characterized as Complex, Mixed, or Simplified, divided by total mapped linear feet of reach length (including side channels, mainstem, and split-flow channels).

Background

Integrated Rehabilitation Assessment

In 2015, Reclamation approached the Upper-Salmon Basin Watershed Program (USBWP) with the desire to collaborate on the completion of a TA for one watershed in the Upper Salmon River with goal of subsequent Reach Assessments (RAs) within that tributary to support more beneficial investments in tributary habitat enhancements. This was similar to the recent effort completed in the Yankee Fork of the Salmon River with Reclamation, the Shoshone-Bannock Tribe, Bonneville Power Administration (BPA), Trout Unlimited (TU), the U.S. Forest Service (USFS), OSC and others. After discussion, the USBWP concluded that the TA approach would benefit from the inclusion of newly developed fish/habitat relationships, clearly stated biological goals, and the application of these techniques to an entire MPG/DPS. A Request for Proposals was subsequently released by Reclamation to support the development and implementation of this new habitat assessment framework.

It was clear early in the proposal process that most partners in the USBWP were working at capacity; therefore, multiple contractors partnered with elements of the USBWP in proposal development. The Idaho Governor's OSC and the interdisciplinary team of Rio Applied Sciences and Engineering (Rio ASE), Quantitative Consultants Inc. (QCI), the Nature Conservancy (TNC), and TU (collectively the IRA Team) successfully competed for the development of the new habitat assessment framework and were awarded a Cooperative Agreement with Reclamation. The scope of the Reclamation Cooperative

Agreement included both the concept of a biologically enhanced TA known as the Integrated Rehabilitation Assessment (IRA) and multiple RAs now referred to as Multiple Reach Assessments (MRAs) across the entire Upper Salmon MPG/DPS over a 5-year period. The publication of this document marks the completion of the IRA and initiation of the MRAs. The high-level findings of the IRA process presented here are intended to guide current habitat enhancement efforts and the development of the MRAs, and will be broadly communicated to stakeholders, funders, and practitioners. The development of the MRAs marks the initiation of direct participation by the aforementioned groups through local technical teams in the Lemhi and Pahsimeroi River watersheds, and through the newly established Upper Salmon technical team subcommittee.

Salmonid Life History

Chinook salmon and steelhead are anadromous salmonids that emigrate from freshwater to the ocean as juveniles, returning to freshwater tributary habitat as adults for spawning. The life history stages of Chinook salmon and steelhead occurring in tributary habitat can be described briefly as spawning (redd construction), summer juvenile rearing (parr), overwinter juvenile rearing (presmolt), and emigration from tributary habitat in the spring (smolt). Chinook salmon in the Upper Salmon River MPG are stream-type, in which juveniles emigrate from tributary habitat to the ocean in the spring after the overwinter (presmolt) period. Similarly, steelhead within the Salmon River DPS, which includes the Upper Salmon Subbasin, may spend multiple years in tributary habitat, and most commonly emigrate from tributary habitat to the ocean in the spring. Although the tributary requirements for redd construction, summer rearing, and overwinter rearing share some commonalities, they occur over different seasons and spatial extents within tributary habitat.

This life history pattern can be described using a cone diagram (Figure 4), in which the width of the cone reflects the volume of habitat used by a given life stage. As juveniles transition from one life stage to the next, there is sufficient habitat capacity to provide the necessary PBFs for surviving juveniles under ideal conditions (Figure 4, optimal). Habitat degradation, or a reduction in habitat capacity, decreases the number of juveniles surviving to a subsequent life stage, and fewer juveniles survive to emigrate as smolts (Figure 4, actual).

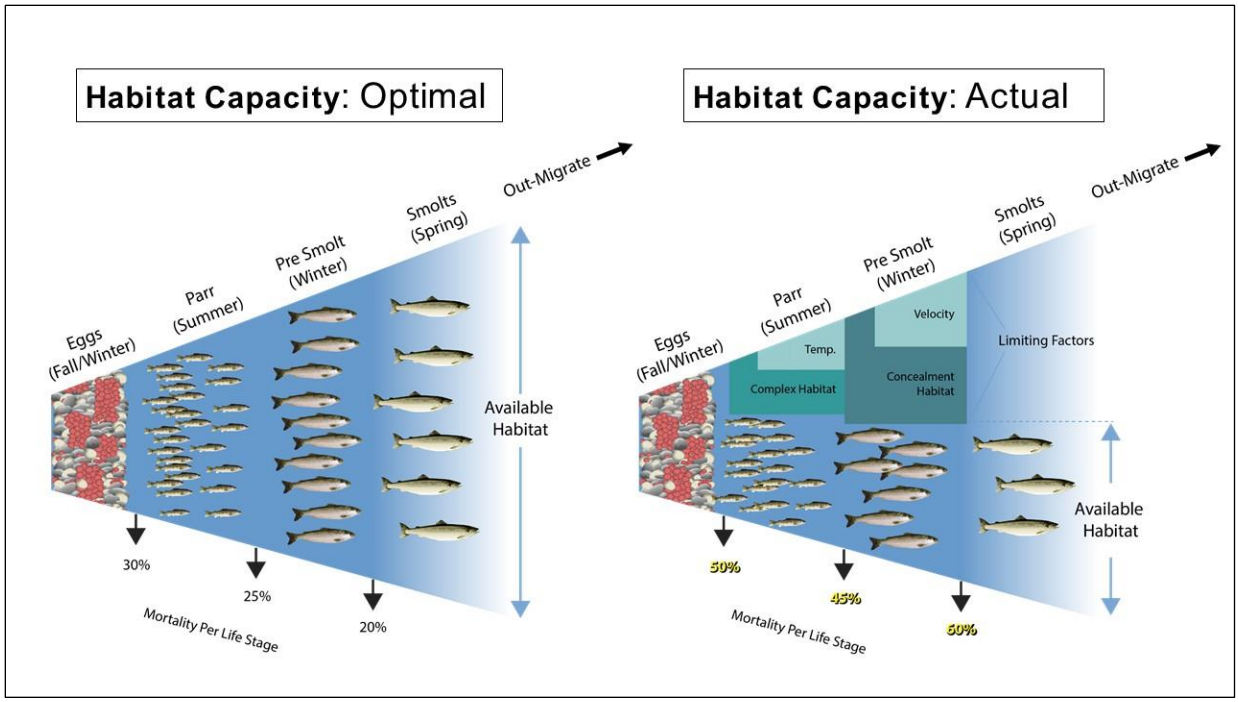


Figure 4. The chart above depicts an ideal scenario on the left with no limiting factors, while the graphic on the right depicts a river with significant limiting factors resulting in less habitat capacity and less production.

Here, the IRA focuses on Chinook salmon life stages and habitat preferences for those life stages. However, the framework assumes that any habitat rehabilitation actions aimed to improve conditions for a Chinook salmon life stage will also improve habitat for similar steelhead life stages. Steelhead life stages will be further explored in future assessments.

Chinook Salmon Life-Stages and Habitat Preferences

The geomorphic character defining the physical conditions also influence aquatic habitat. Some characteristics affect local habitat conditions (i.e., pool formation, bed armoring, and lack of cover) and others are more systemic (i.e., fine sediment and temperature) (Figure 5). Generally preferred habitat characteristics for key life-stages of spring/summer Chinook salmon are briefly described here.

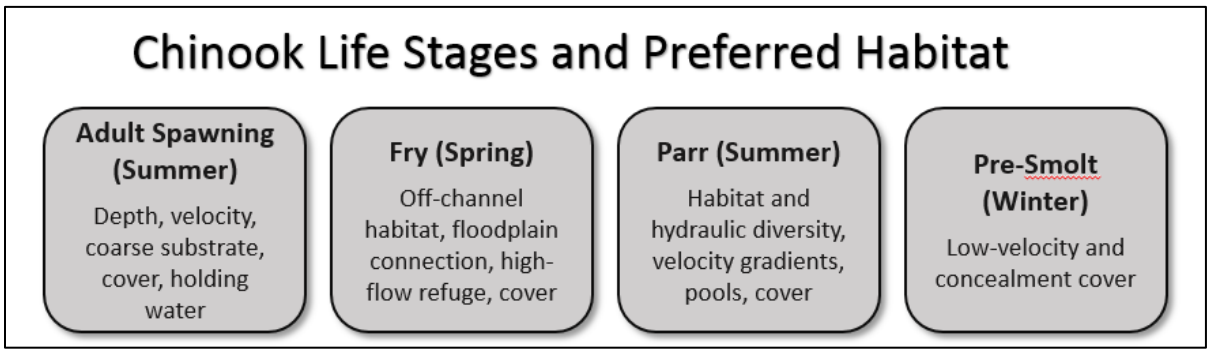


Figure 5. Summary of Chinook salmon life stages and key physical attributes associated with known habitat preferences.

Adult Spawning (Summer): Loose gravel/small cobble substrate, hyporheic flow to provide oxygen for eggs, water temperatures within stressful/lethal thresholds, pool/riffle complexes, proximity to cover or holding water, large woody debris, undercut banks, adequate depth and velocity (

Photograph 1).

Photograph 1. Examples of preferred habitat conditions for Chinook salmon adults (summer) holding and spawning, including appropriate cover and substrate accumulated in conjunction with instream woody material and healthy riparian vegetation. The left photograph is from the Middle Entiat River, Washington, and the right photograph is from the Upper Yankee Fork Salmon River.

Fry (Spring): Low- to zero-velocity streamflow, off-channel habitat, floodplain connection, low-velocity refugia, overhanging vegetation cover, presence of aquatic vegetation, large woody debris, interstitial

spaces (

Photograph 2).

Photograph 2. Example of preferred habitat conditions for Chinook salmon fry (spring) rearing with very low velocity and abundant cover. Photographs are from the Upper Yankee Fork (left) and Upper South Fork of the Salmon River (right).

Parr (Summer): Hydraulic diversity and habitat heterogeneity, velocity gradients, frequent pools, vegetation and large woody debris cover, undercut banks, summer temperatures below stressful/lethal thresholds, velocity refugia (Photograph 3).

Photograph 3. Example of preferred habitat conditions, including split flow, instream cover and hydraulic variability, which support Chinook salmon parr (summer) rearing. Photograph is from a constructed project in Catherine Creek in the Grande Ronde River watershed, Oregon.

Pre-smolt (Winter): Interstitial spaces for concealment, additional concealment cover (e.g., vegetation, large woody debris), deep pools, low velocity, coarse substrate (

Photograph 4).

Photograph 4. Examples of preferred habitat conditions for Chinook salmon pre-smolt (winter) rearing. Note large substrate (left) and dense woody material (right), both with significant interstitial space providing concealment cover for overwinter rearing. Photographs are from the Secesh River (left) and Catherine Creek in the Grande Ronde basin (right).

Historical Habitat Conditions

The existing Upper Salmon River subbasin was formed by a complex series of geologic events spanning more than 1 billion years. Prior to the formation of the Pacific Ocean, approximately 1.5 billion years ago, thick layers of sedimentary rock (Belt Supergroup) were deposited within a vast inland lake that spanned much of Idaho, Montana, and parts of eastern Asia (Winston and Link 1993). As the Pacific Ocean formed between Asia and North America, subsequent layers of sedimentary rock were deposited more than 100 million years ago along the continental margin, which covered much of Idaho, since the Oregon and Washington land mass had not yet formed (Link and Janecke 1999). These sedimentary rocks were uplifted and severely folded and faulted about 60 million years ago during the formation of the ancestral Rocky Mountains (Link and Janecke 1999). At roughly the same time, the subduction of the ancestral oceanic tectonic plate beneath the continental tectonic plate resulted in the emplacement of the granitic Idaho batholith, a large body of igneous granitic rock that comprises much of central Idaho (Johnson et al. 1988). Displacing and covering portions of the Idaho Batholith along its eastern margin were layers of volcanic rock deposited by a series of caldera-forming eruptions that created the Challis Volcanic Group about 45 million years ago (Moye et al. 1988).

Over the past several million years, the continental crust has expanded in parts of central and eastern Idaho due to the nearby Yellowstone hotspot (Pierce et al. 2007). Extensional faulting associated with the expansion has lowered some blocks of the crust, creating valleys, and raised others, forming mountain ranges (Simpson and Anders 1992). The previously deposited rock formations were faulted along roughly northwest-trending lines forming the Sawtooth, Pahsimeroi and Lemhi valleys (lowered blocks) and Sawtooth, Lost River, Pahsimeroi, Lemhi, and Beaverhead mountain ranges (raised blocks). The valleys have since partially filled with thick deposits of alluvial sediment from multiple episodes of hillslope erosion, mass wasting, stream deposition, and glacial deposition prior to and during the last ice age (Figure 6) (Meinzer 1924; Ungate 1988; Pierce and Scott 1982; Breckenridge et al. 1988). These thick alluvial deposits generally permit the presence of a local aquifer. Over the past several thousand years, streams have incised through surficial deposits of the alluvial valley fill, intercepting the aquifer in several locations and creating terraces with inset floodplains.

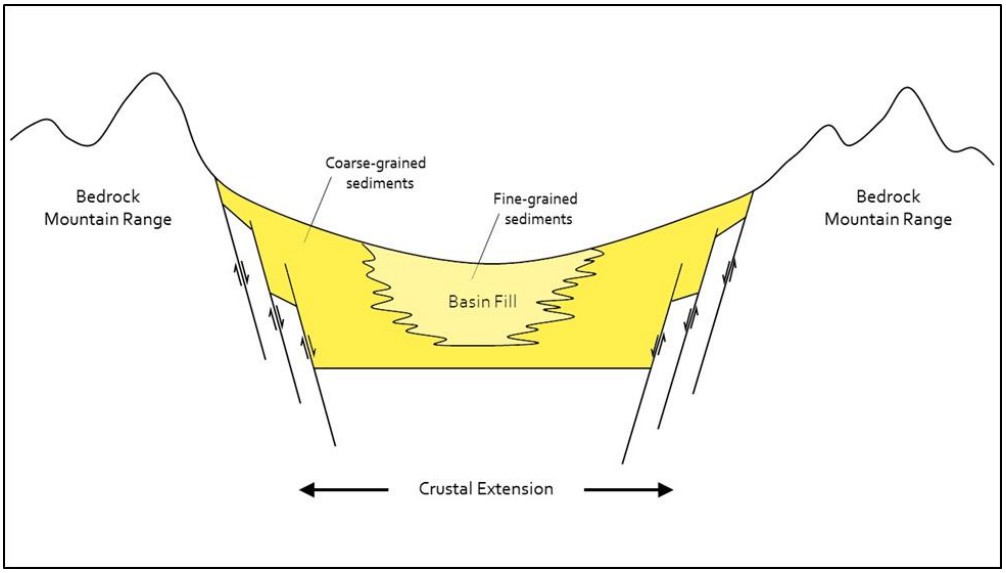


Figure 6. Generic basin-and-range faulting with valley fill sediment, illustrating how the Lemhi, Pahsimeroi, and Upper Salmon River headwaters have formed and partially filled with alluvial sediment.

In addition to the formation of the mountains and valleys in the Upper Salmon River subbasin, specific geologic features influence the existing channel character within each watershed uniquely. A prominent bedrock constriction roughly in the center of the Lemhi Valley provides local grade control, reducing upstream gradients and generally forcing greater groundwater contributions to the system upstream of that point. The depth of valley-fill alluvium in the Pahsimeroi Valley drives large shifts in surface-groundwater interactions throughout the watershed, with significant losses to the aquifer in the upper valley and large gains occurring in the lower valley. The Upper Salmon River headwaters are heavily influenced by glacial moraine deposits that extend well onto the valley floor, constricting the valley and creating moderately low gradient reaches, gaining from groundwater upstream of each constriction.

Common geomorphic characteristics associated with surface and groundwater interactions influence each of the watersheds assessed in this report. River reaches gaining flow from groundwater tend to exhibit similar traits, driven by geologic controls forcing groundwater to the surface, that also typically provide grade control, reducing upstream channel gradients. Prior to large-scale human disturbance, these heavily groundwater-influenced reaches were generally characterized by a highly sinuous, commonly multi-threaded (anastomosing) channel with multiple side channels and spring-fed tributary channels all occupying the same broad floodplain (Figure 7). The sediment regime was likely depositional (transport-limited), with varying amounts of coarse sediment, depending on the proximity to steeper reaches and tributaries supplying coarse sediment. Relic topographic variation from channel migration, occasional avulsions (the rapid abandonment of a river channel and the formation of a new river channel), beaver dams, and disturbance from grazing animals (bison, elk, and deer) likely created a mosaic of open water, emergent wetland, floodplain, and upland. The riparian community would have mirrored this diversity with areas of wetland meadow (rushes and sedges), floodplain shrubs (willow) and upland vegetation (sage and grass). The sinuous and multi-threaded channels likely exhibited a pool-riffle morphology (based on Montgomery and Buffington 1998) driven by sediment deposition, bank structure from willow vegetation, and in-stream woody structure (including beaver dams) where present (Figure 7).

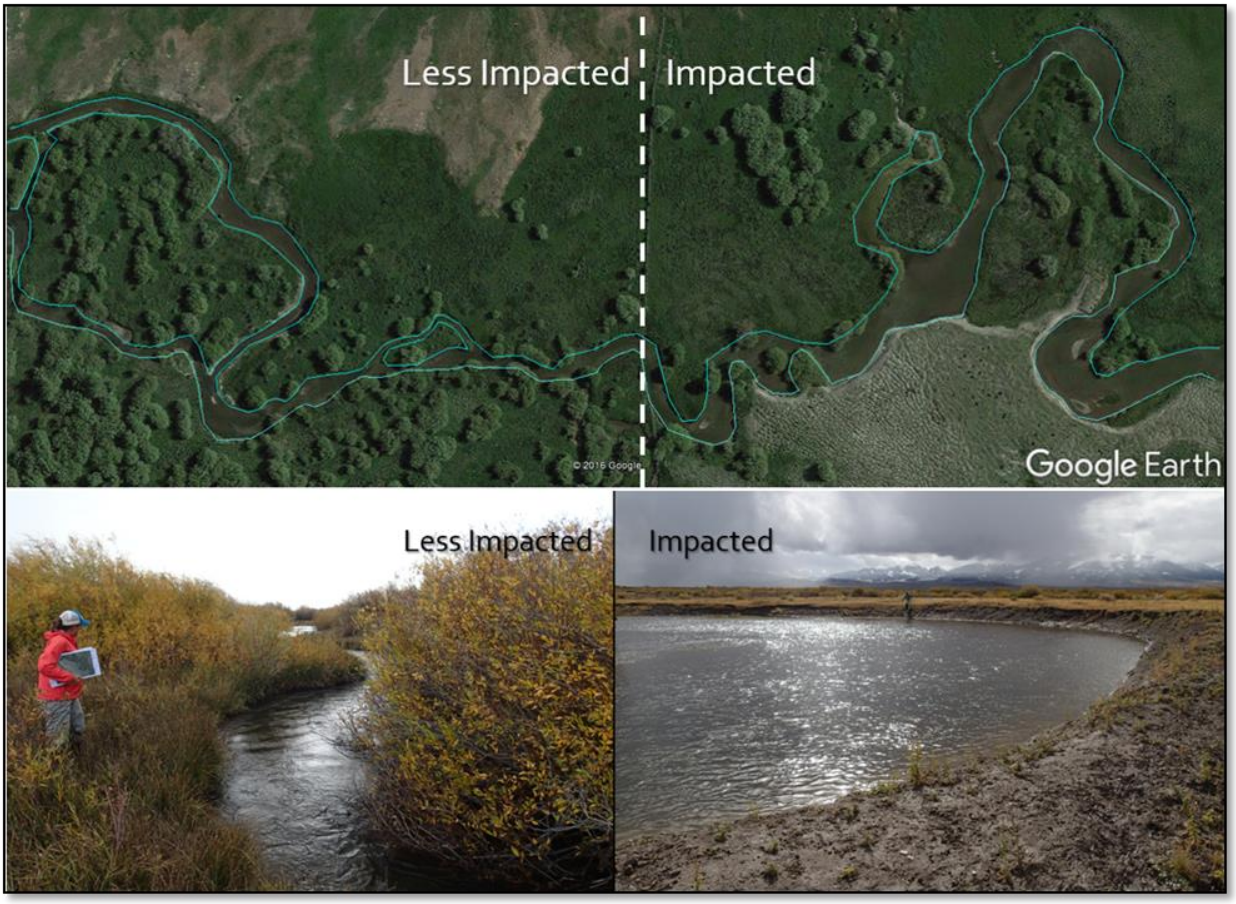


Figure 7. Representative example from the Upper Lemhi River illustrating groundwater-influenced characteristics, including a highly sinuous, multi-threaded channel with multiple spring-fed side channels and a diversity of riparian vegetation all occupying the same floodplain. Flow direction in the aerial photo is from right to left, and from the bottom of the image to the top in the surface photos.

Alternatively, river reaches that are either losing flow to the aquifer or are generally characterized by a predominantly snowmelt-influenced (i.e., peak flow) hydrology tend to exhibit different traits. Prior to large-scale human disturbance, these areas were generally characterized by a single-thread channel with active point bars, a seasonally active floodplain, and localized areas of island braiding where the stream is unconfined and in association with in-channel obstructions (i.e., log jams and/or stands of dense riparian vegetation) (Figure 8). The sediment regime was likely transport-dominated, with sufficient gradient and discharge to mobilize sediment and slowly incise the bed over thousands of years, creating a narrow, inset floodplain bound by relic terraces. The primarily single-threaded channel within the terraces was characterized by a relatively low sinuosity and a predominantly plane-bed morphology, although a forced pool-riffle morphology may have formed over small areas, given sufficient bank structure and/or woody debris loading (based on Montgomery and Buffington 1998). Areas that have been impacted by human activity, land use, and development are generally less sinuous, more incised, predominantly plain-bed, lacking in-stream structure, and no longer exhibit areas of complex island-braiding (Figure 8).

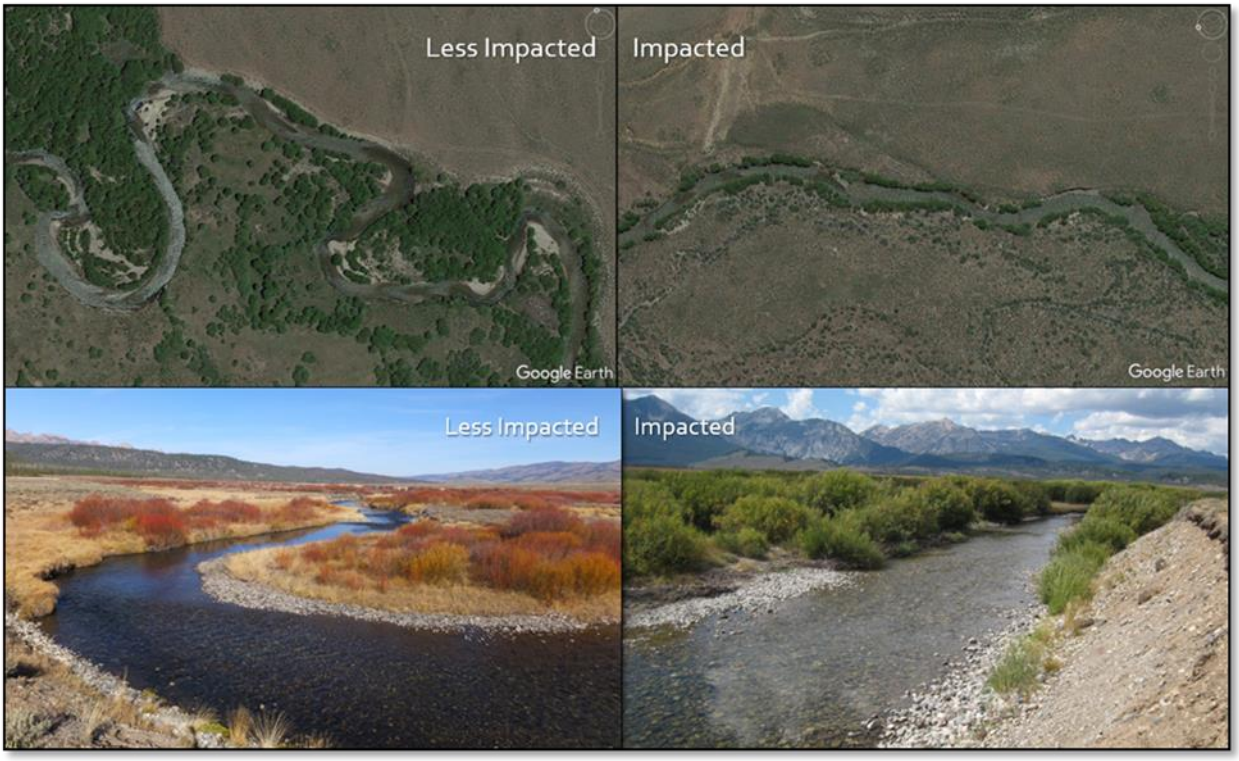


Figure 8. Representative example from the Upper Salmon River headwaters illustrating characteristics typical of a snowmelt-influenced (peak flow) hydrology, including a moderate to low sinuosity, single-thread channel, active point bars driving channel migration, and a predominantly plane-bed morphology. Flow direction is from the right side of the image to the left in the aerial photos and away from the photographer in the surface photos.

These generalized reach conditions, represented by the presence or absence of groundwater-influenced hydrology, exemplify the geomorphic character within each of the three watersheds assessed in this report. The Lemhi River is roughly split in half, with the Upper Lemhi (upstream of Hayden Creek) heavily influenced by the traits associated with groundwater hydrology, while the Lower Lemhi (below Hayden Creek) is more heavily influenced by traits associated with predominantly snowmelt-influenced hydrology. The Pahsimeroi River is the reverse of the Lemhi, with the Upper Pahsimeroi losing significant flow to the local aquifer and exhibiting primarily snowmelt-influenced characteristics, while the Lower Pahsimeroi is heavily groundwater-influenced. The Upper Salmon River headwaters is characterized by a predominantly snowmelt-influenced hydrology, with discrete areas of groundwater influence shaping individual reaches and sub-reaches, primarily upstream of prominent valley constrictions formed by glacial moraines.

Human Impacts

Relic and ongoing human impacts have significantly influenced channel character in all three watersheds. Many human-related impacts associated with visible features and/or relic or ongoing actions result in a less-complex, or more-simplified, geomorphic character. Overall, the physical and ecological processes in the upper tributary reaches are generally intact and functioning properly. However, there are localized impacts at mid- and lower elevations in all three watersheds that have negatively affected riverine process and form. These impacts include, but are not limited to, flow alteration from irrigation diversions, loss of

riparian vegetation, excessive fine sediment, and areas of channel and floodplain alteration from roads and infrastructure.

Irrigation diversions significantly reduce instream flows by diverting tributaries away from, and flow out of, the mainstem rivers (

Photograph 5). The many irrigation diversions in each watershed reduce the frequency and magnitude of peak flows, as well as the quantity of instream habitat through isolation (i.e., disconnected tributaries) and volume (i.e., linear feet of stream with adequate surface water). Irrigation diversions also alter the timing and spatial distribution of groundwater recharge. Diversions redistribute river water onto the floodplain during the summer months, artificially increasing groundwater levels in those locations. In some instances, the entire river has been diverted, leaving a dry, uninhabitable river bed that disconnects biologic and geomorphic processes between upper and lower river sections.

Photograph 5. Examples of irrigation diversions from the Upper Salmon River headwaters illustrating impacts to in-stream flow and fish passage.

Riparian vegetation has been removed to accommodate agriculture or lost due to overgrazing by livestock in many areas (

Photograph 6). Where dense riparian vegetation (primarily willow) has been lost, the channel commonly exhibits an over-widened and homogenous channel character. Dense riparian vegetation on the outside of bends stabilizes the bank and obstructs flow, forcing contraction and resulting in pool scour and a narrow width-to-depth ratio, often with undercut banks. Dense riparian vegetation also promotes channel response via side-channel formation and avulsion around the structure provided by the vegetation, rather than bank erosion and widening when vegetation is lacking. A reduction in the amount of bank and instream structure has resulted in a simplified, homogenous channel in several areas, characterized by an over-widened, predominantly plane-bed morphology. The over-widened condition also expands the cross-sectional area of the channel between the banks, enabling more water to pass between the banks during floods, reducing floodplain connection frequency and duration. Finally, in all areas where woody riparian vegetation has been lost, the channel is exposed to greater solar radiation and thermal heating from the loss of shade.

Photograph 6. Examples from the Upper Lemhi (left) and Middle Pahsimeroi (right) Rivers illustrating impacts associated with riparian vegetation removal.

Grazing and agricultural practices, as well as the development of dirt roads and trails, have had a cumulative effect on fine sediment accumulation within each watershed (Photograph 7). Sheetwash erosion and excessive bank erosion associated with lost riparian vegetation contribute elevated levels of fine sediment to the system from spring snowmelt and summer rainstorm runoff. Similarly, sheetwash and wind-blown fine sediment from roads and trails add to the amount of fine sediment contribution from

the watershed. Fine sediment fills interstitial spaces between gravels and cobbles, eliminating concealment cover for overwintering juvenile fish and reducing bed- and pool-scour potential through substrate embeddedness.

Photograph 7. Example from Lower Hayden Creek illustrating grazing impacts and associated lack of riparian vegetation.

Finally, channel and floodplain alterations from roads and infrastructure are prevalent throughout several reaches in each watershed. In many instances, portions of the channel have been straightened and confined to accommodate the infrastructure, and large portions of the floodplain have been disconnected from channel interactions (Photograph 8). Bridges commonly constrict bankfull and floodplain flow, often forcing contraction scour and incision, as well as a single-thread channel morphology. Channel-spanning weirs commonly obstruct the natural passage of fish and sediment. Bank armoring (i.e., riprap) prohibits natural channel migration and often concentrates flow along a hydraulically smooth surface, increasing rates of bank erosion and incision farther downstream.

Photograph 8. Oblique aerial photograph example of a straightened and armored section of the Upper Lemhi River just upstream of the Hayden Creek confluence.

Climate Change

The quantity, quality, and availability of tributary habitat is non-stationary, owing to natural and anthropogenic influences (e.g., as discussed in Budy and Schaller 2007). Thus, when considering the amount and/or types of restoration required to achieve long-term population stability, it would be shortsighted to assume that background conditions will remain static. For example, Dalton et al. (2013) documented a roughly 0.7° C increase in Pacific Northwest air temperature since 1900. Mantua et al. (2010) suggest that increases in air temperature may be accelerating and estimate a less than 1° C increase by 2020 and a 2 to 8° C increase by 2080. Even if water temperature currently does not impose an ecological limitation on the freshwater productivity of salmonids, anticipated changes in water temperatures could limit productivity. Processes that result in increased water temperature, and restoration to mitigate those processes, are often complex, typically relying on the reestablishment of riparian zones and reconnection of surface water and the alluvial aquifer (Poole and Berman 2001). Given that these restoration processes may require decades to achieve full effectiveness, early identification of future impairments is crucial.

Air and water temperatures in central Idaho are predicted to increase over time. While changes in air temperature can be somewhat reliably modeled, changes in precipitation are less predictable, ranging from a 4.7 percent reduction to a 13.5 percent increase (Mantua et al. 2010). The timing of snowmelt, and subsequently the seasonal availability of water, is expected to change substantially. Within the Snake River basin, a 3° C increase in air temperature would be anticipated to result in a decrease of 15 to 20 percent in spring stream flow, a 10 to 40 percent decrease in summer streamflow, and a substantial increase in winter streamflow (Tang et al. 2012).

Historical average streamflow projections (1950-1999) in Figure 9 (top panel) suggest that these sites are characterized by a late-spring/early-summer peak (April through July), with the largest average monthly values observed during June. Average monthly streamflows outside of the warm season (April through July) are typically lower in magnitude. Future streamflow projections (2000-2049) (middle panel of Figure 9) suggest that the average seasonal cycle across these sights is somewhat similar to historical conditions. The largest median percent increase is projected to occur in May (with a median increase from February through May), with the largest negative percent change projected to occur in June (with a median decrease from June through August).

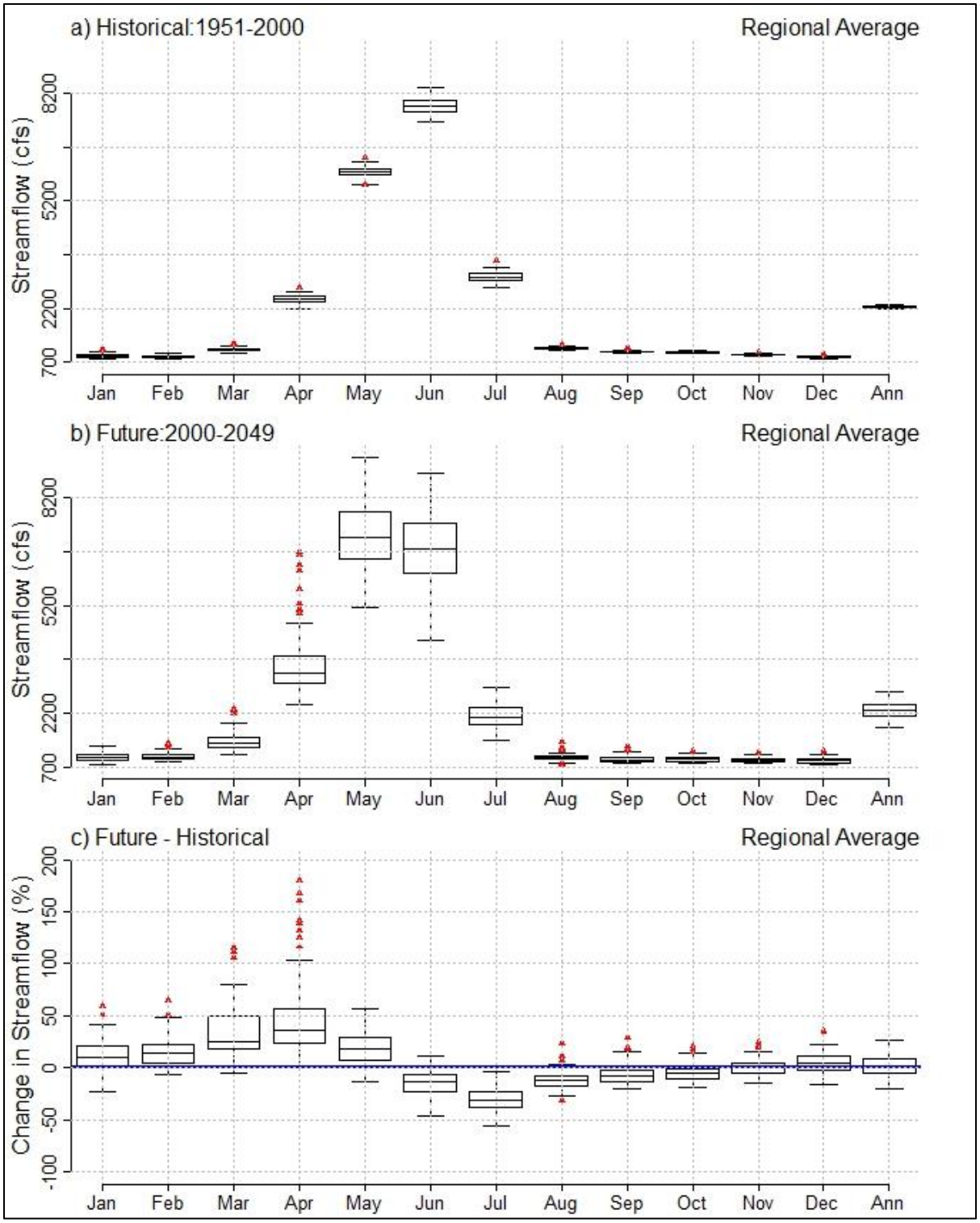


Figure 9. Box-and-whisker plot showing the distribution of regionalized average monthly and annual streamflow (cubic feet per second; cfs) during the (a) historical and (b) future periods for each of the 97 projection members. (c) Box-and-whisker plot showing the distribution of regionalized average monthly and annual percent changes in streamflow between the two periods (future-historical) for the same 97 projection members. The horizontal blue line in (c) demarks a 0 percent change.

Historical maximum streamflow projections (1950-1999) in Figure 9 (top panel) suggest these sites are characterized by a late-spring/early-summer peak (April through July), with the largest maximum monthly values observed during June. Maximum monthly streamflows outside of the warm season (April through July) are typically lower in magnitude.

Future streamflow projections (2000-2049) (middle panel of Figure 9) suggest that the maximum seasonal cycle across these sites is somewhat similar to historical conditions. Maximum monthly streamflow values for the future period peak during the same time of the year (April through July), while monthly streamflow values outside of this warm season remain relatively low.

Projected percent changes in regionalized maximum streamflow (bottom panel in Figure 9) show a combination of increases and decreases throughout the year. The largest median percent increase is projected to occur in March (with a median increase from January through May and December), with the largest negative percent change projected to occur in July (with a median decrease from June through August).

Past Projects

Habitat improvement work with a variety of agencies, landowners, and partners in the Upper Salmon subbasin has been ongoing since before the 1980s. These actions are categorized as 1) screening irrigation diversions, 2) improving spawning and rearing habitat access by removing barriers, 3) adding habitat complexity (quantity and quality), 4) increasing instream flow, and 5) improving riparian habitat, mostly by reducing grazing impacts from livestock. Over this time period, more than 200 improvement actions and 100 screening actions have been completed in the Lemhi River watershed. About 70 habitat improvement actions and 20 screening actions have been completed in the Pahsimeroi River watershed. More than 75 habitat improvement actions and about 20 screening actions have been completed in the Upper Salmon headwaters.

Below are examples of implemented actions that have occurred in select reaches of the Lemhi River, Pahsimeroi River, and the Upper Salmon River in recent years.

Lemhi River

Lower Lemhi River actions have focused on improving instream flow during the irrigation season, as well as irrigation diversion consolidation screening, barrier removal for habitat access and tributary flow

reconnection, and increasing floodplain and habitat complexity (

Photograph 9).

Photograph 9. Example from a completed side-channel and bank/riparian improvement project from the Lower Lemhi River (Eagle Valley Ranch Phase 2, completed in 2016).

Upper Lemhi River actions have focused on grazing management to improve riparian habitat, irrigation diversion consolidation screening, barrier removal for habitat access and tributary flow reconnection, and

increasing floodplain and habitat complexity (

Photograph 10).

Photograph 10. Overview of mainstem Lemhi River habitat enhancement (Amonson Ranch) immediately following construction (left aerial photograph) and 5 years following construction (right photograph).

Pahsimeroi River

Pahsimeroi River actions have focused on instream flow improvement during the irrigation season, grazing management to improve riparian habitat, irrigation diversion consolidation screening, barrier removal for habitat access and tributary flow reconnection, and increasing floodplain and habitat complexity (Photograph 11).

Photograph 11. Large woody debris installed to provide bank habitat and improve pool scour on the Pahsimeroi River as part of the P-16 irrigation improvement project completed in 2016.

Upper Salmon River

Upper Salmon River headwaters actions have focused on diversion consolidation screening, barrier removal for habitat access and tributary flow reconnection, instream flow improvement during the irrigation season, grazing management to improve riparian habitat, irrigation, and increasing floodplain and habitat complexity (

Photograph 12).

Photograph 12. The Pole Creek Diversion Replacement in the Upper Salmon watershed included improvements to an irrigation system and fish screen, providing increased instream flow for Pole Creek and the Salmon River. In addition, a diversion structure (left) that blocked fish passage was replaced with a fish-passable low-head rock weir and improved channel geometry (right).

Assessment Approach

From a biological standpoint, two overarching themes drive the thought process within the IRA framework: density dependence and the degraded status of fish habitat found in the Upper Salmon River subbasin. Notably, there has been a shifting baseline of perception of what good habitat is and what range of juvenile densities can be supported by good habitat. By the time Chinook salmon and steelhead were listed as threatened under the Endangered Species Act, many tributaries in the Upper Salmon River subbasin, and elsewhere, were disconnected from the mainstems of rivers; furthermore, the mainstem of many rivers did not provide complete connectivity. Massive amounts of effort and funding have since been put into reconnecting tributaries and providing flow for functional passage. After the herculean effort to re-water and reconnect tributary habitat, it is timely to look at the quality of the habitat. The question then becomes *"What does the habitat need to look like to support the Minimum Abundance Threshold (MAT) goals and how much of this habitat does there need to be?"* This IRA document aims to first identify the problem by identifying limiting life stages for Chinook salmon and steelhead in the Upper Salmon subbasin, and then identify capacity deficits in habitat. Future MRAs will attempt to identify broad solutions by further describing what the habitat should look like to support MAT goals.

The overall approach of the IRA is to integrate biological assessment results, including the habitat capacity modeling, with high-level geomorphic (hydrology, hydraulics) and temperature assessments, to form applicable results and conclusions. The intended outcomes include actions that capitalize on local expertise to improve implementation. These can then guide understanding of current conditions and future habitat enhancement activities. Following, we provide additional details for each the biological, geomorphic, and temperature assessments. We then provide overall conclusions and recommendations for the Upper Salmon subbasin as a whole, as well as more detailed results, conclusions, and recommendations for each of the three target tributaries (Lemhi River, Pahsimeroi River, and Upper Salmon River above Redfish Lake Creek).

Biologic Assessment

Snake River Chinook salmon and steelhead have been ESA-listed since 1992 and 1997, respectively. The State of Idaho and partners have since worked with the National Marine Fisheries Service (NOAA Fisheries) to develop the 2017 Recovery Plan (NOAA 2017). The plan develops MATs for extant populations across the Snake River basin that provide an easily adoptable biological target to guide tributary habitat enhancement. Because the MATs set forth in NOAA (2017) are assessed using a 10-year geometric mean, it is necessary to ensure that adult escapement into each tributary equals or exceeds MAT. To accommodate this, the IRA team included a 25 percent buffer (MAT + 25%) to ensure goals will be met or exceeded. A margin of safety also provides a buffer due to variability in ocean conditions, conditions in the downstream migration corridor, and potential climate change scenarios.

The biological assessment focuses primarily on Chinook salmon and secondarily on steelhead. The Lemhi and Pahsimeroi River Chinook salmon populations are included because those populations have had extensive habitat enhancement in the past 20 years and are critical to salmon recovery. The Upper Salmon population is also critical to recovery efforts and has different physical attributes compared to the other two watersheds.

Potential capacity deficits due to potential limitations in habitat quantity and quality were assessed at three life stages for both Chinook salmon and steelhead: spawning (redd) capacity, and juvenile rearing capacity during both summer (parr) and winter (presmolt) months. First, life-stage-specific capacity required to support both contemporary adult abundance and adult abundance to achieve recovery goals was estimated using Generalized Capacity Models (described in Appendix C). Following, currently available redd and juvenile rearing capacity were estimated using recently developed quantile regression and random forest (QRF) models (described in Appendix B). Finally, life-stage-specific required capacities were compared to available habitat capacities to identify capacity deficits for both Chinook salmon and steelhead.

Required Habitat Capacity

Having identified population-specific adult escapement goals, including MAT and a buffer (MAT + 25%), the framework uses population-specific empirical data, where available, to estimate the number of redds, summer parr, and winter presmolts expected or required to achieve those goals. For those species and/or populations/tributaries lacking empirical and/or juvenile abundance and survival data, we relied on information from neighboring populations or regions. The models used to estimate required capacity are described in detail in Appendix C; namely, we use the Generalized Capacity Model described therein. Our approach explicitly assumed that tributary habitat must be capable of supporting redd and juvenile abundance accompanying MAT + 25% to sustainably support and maintain that level of escapement. Ultimately, the required capacity model leads to an estimate of the number of redds, summer parr, and winter presmolt that the tributary habitat occupied by a given population must support.

In addition, the IRA evaluated whether currently available habitat is sufficient to support contemporary estimates of life-stage-specific requirements based on recent adult abundance. Required capacity was calculated using both the mean and maximum observed adult abundance from the target tributaries; similar to above, those adult escapements were propagated across life stages using a combination of empirical and literature values (Appendix C). Observed abundance data were available for the following:

- **Lemhi River:** Chinook salmon (2000-2016); steelhead (2010-2015)

- **Pahsimeroi River:** Chinook salmon (2000-2015); steelhead (2011-2015)
- **Upper Salmon River:** Chinook salmon (2011, 2013); steelhead (2011, 2013)

Available Habitat Capacity

The IRA uses recently developed QRF models that enable spatially continuous estimates of available habitat capacity given existing conditions and for key life history stages of Chinook salmon and steelhead. Currently, available QRF models allow evaluation of three anadromous life stages: 1) spawning capacity (i.e., the number of redds that can be supported), 2) summer juvenile rearing capacity (i.e., the number of parr that can be supported during summer months), and 3) winter juvenile rearing capacity (i.e., the number of presmolts that can be supported during winter months). The QRF models that estimate available habitat capacity using available habitat data with more detailed results are described in Appendix B.

We define habitat (carrying) capacity as the maximal abundance or load the habitat can support for a given species and life stage given current resources and habitat quantity and quality. The QRF models predict carrying capacity using empirically derived fish-habitat relationships, recently collected habitat data, and globally available attribute (GAA) data. The juvenile QRF models pertain to juvenile rearing in wadeable streams during both summer (parr) and winter (presmolt) months; the adult model assesses fish-habitat relationships for spawning areas and predicts habitat capacity to support redds. The habitat data used in the QRF model are from the Columbia Habitat Monitoring Program (CHaMP; https://www.champmonitoring.org), and fish and habitat data were paired at CHaMP sites (e.g., 200 to 500 m) where fish survey data were available. Importantly, the QRF models place no constraints on fish-habitat relationships; instead, relationships are estimated from the data regardless of being positive, negative, linear, non-linear, etc. Based on the observed fish-habitat relationships, we then predict habitat capacity at any location using measurements of the same habitat covariates used to populate the model (i.e., at all CHaMP sites). Finally, predictions at CHaMP sites can be extrapolated across larger scales using an extrapolation model and GAA data.

In summary, inputs to the QRF models to estimate available habitat capacity include (additional details in Appendix B):

- **Paired fish and habitat data:** Habitat data used in the QRF models are available from CHaMP; paired fish abundance/density information from CHaMP sites are available from the Integrated Status and Effectiveness Monitoring Program (ISEMP). Paired fish-habitat data are used to identify habitat covariates most highly associated with observed fish densities at CHaMP sites. Fish-habitat relationships are then developed for select habitat covariates used in the QRF models.
- **Spatial extent information:** Predictions of available habitat capacity can be extrapolated to larger spatial scales (e.g., watershed, population). However, a spatial extent must be provided that determines the scale at which total available capacity will be extrapolated and predicted. The QRF model uses shapefiles of a list of Generalized Random Tesselation Stratified (Stevens and Olsen 1999, 2004) master sample sites that CHaMP sites were initially selected from. Shapefiles can then be trimmed for any given watershed to a domain used by Chinook salmon or steelhead. The domain for any given watershed was determined either by StreamNet (http://www.streamnet.org) or using expert opinion from location biologists. For the IRA, the Upper Salmon spatial extents were determined using local expert opinion (Mark Moulton,

personal communication) based on observed distributions across recent decades. Lemhi River spatial extents were available from recent juvenile fish surveys (Braden Lott, personal communication); all other watershed extents were from StreamNet. The spatial extent of model extrapolation is an important consideration when estimating total available capacity in a watershed. Extrapolation to too large or small of a spatial extent can lead to overestimates or underestimates, respectively, of available capacity.

- **Globally available attribute data:** The QRF models can be used to estimate available capacity an any location where the habitat covariates used in the model are available (i.e., at all CHaMP sites). However, in the case of the IRA, the goal was to estimate total capacity for all watersheds in the Upper Salmon River subbasin. Therefore, an extrapolation model was used that leverages GAA data to make predictions at all master sample sites within the determined spatial extent.

The IRA provides estimates of available habitat capacity for two species (Chinook salmon and steelhead), three life stages (redds, summer parr, winter presmolts), and three watersheds (Lemhi, Pahsimeroi, Upper Salmon River above Redfish Lake). Additionally, Appendix B provides results for the remaining five watersheds in the Upper Salmon River subbasin, including: Valley Creek, Yankee Fork Salmon River, East Fork Salmon River, North Fork Salmon River, and Panther Creek.

Habitat Capacity Deficits

Finally, species and life-stage-specific habitat capacity requirements, described above, are then compared to estimated available habitat capacity (assuming existing conditions) via QRF models. This comparison identifies 1) the life stages that may be limited for a given species and watershed under current conditions and to achieve recovery, and 2) the relative amount of capacity deficit that exists as MAT + 25% is approached. Adult escapement served as the starting value to maintain consistency with delisting criteria, which are expressed as an adult escapement goal.

Geomorphic Assessment

All streams evolve over time, and human impacts have, in some instances, altered the rate, magnitude, and form of that evolution, potentially impacting instream and off-channel habitat. A geomorphic assessment measures and compares various channel characteristics over time to better understand past channel evolution and associated human influences to develop predictions regarding future channel evolution and possible enhancement opportunities. In an alluvial system, channel processes are continually working to maintain a fairly stable condition by adjusting numerous variables that are mutually interdependent. For example, channel geometry and shape change in response to fluctuations in peak flow and/or sediment supply, which in turn controls the amount and timing of erosion and deposition. Erosion occurs in portions of the channel where velocity increases enough to scour bed/bank material and transport it downstream. Meanwhile, deposition results in other portions of the channel where velocity decreases to a point where sediment cannot be maintained in transport. Defining the channel character as it relates to habitat, then identifying the geomorphic processes that shape and maintain those habitat features, informs the type, location, and relative level of effort for potential rehabilitation actions.

Channel character generally refers to the shape (form) of the channel and processes responsible for the creation and maintenance of those forms (e.g., sediment transport, large wood recruitment, channel migration, etc.). For the geomorphic assessment, channel forms were remotely mapped using a

geographical information system (GIS), aerial photography, and available digital elevation models (10-meter and/or LiDAR where available). Available past reports and data regarding groundwater hydrology, irrigation diversions, fish habitat, riparian conditions, and geologic features were synthesized to expand the team's understanding of the geomorphic character. Hydrology information and associated hydraulic calculations provided further explanation regarding channel process with regard to flooding and sediment transport. Limited on-site observations and measurements were made in select locations to field-verify remotely mapped features, to document site-specific features not visible in remote data (pools, under-cut banks, bed and bank composition, riparian vegetation, etc.), and to observe the most recent changes in channel form. Individual stream segments were then divided into distinct geomorphic reaches and channel units based on the observed differences and/or similarities in channel form and process, as interpreted from the available data. Specific channel segments were further broken down into three geomorphic categories of Complex, Mixed, and Simplified and further described based on typical channel responses.

In an effort to consistently and systematically compare the diverse and variable geomorphic character within each assessed river, the dominant geomorphic character associated with each reach (thousands of feet) was mapped at the channel unit scale (hundreds of feet). Geomorphic character was divided among three categories (Table 1, Figure 10) and further described based on typical channel response.

Channel Units

Channel units were remotely mapped using GIS, the NAIP September 10, 2015, aerial photography, and with limited field observations. Similar geomorphic characteristics were grouped based on observed channel forms and interpreted channel response (Table 1). This channel assessment method was developed specifically for the high-level analysis of the IRA, understanding the limitations of available data and the upcoming refined reach-scale assessments in future MRAs. The goal of the channel unit evaluation was to compare overall channel character and likely response potential between reaches to inform high-level decision-making and future MRA prioritization.

Table 1. Geomorphic characterization and description.

Geomorphic Characterization	Description
Complex	Characterized by a sinuous, low-gradient, unconfined channel(s) with dense riparian vegetation. Typical channel response is **dynamic,** including split flow, avulsion, lateral channel migration, pool scour, riffle deposition, and floodplain connection.
Mixed	Characterized by a moderate sinuosity, variable width and confinement, often lacking dense riparian vegetation. Typical channel response is **variable,** including lateral and downstream channel migration, widening, pool scour, riffle deposition, and moderate floodplain connection.
Simplified	Characterized by a straight, high-gradient, confined channel with sparse riparian vegetation. Channel response is **minimal,** including bed armoring, incisions, bank erosion, and poor floodplain connection.

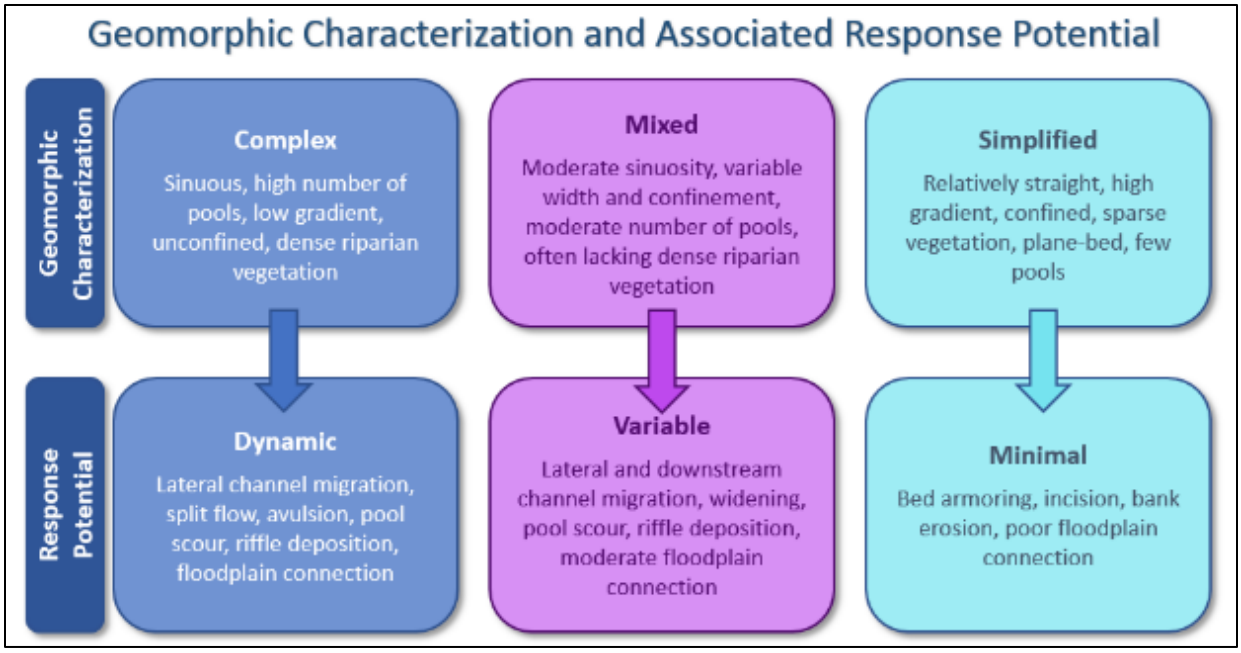


Figure 10. Geomorphic characterization and associated response potential as used to map individual channel units to differentiate and categorize reaches within the Lemhi, Pahsimeroi, and Upper Salmon Rivers.

A **complex** geomorphic character was assigned to channel units exhibiting two or more of the following characteristics: high sinuosity, multiple side channels, observable instream variability (including pools and riffles), moderately dense riparian vegetation, and an unconfined floodplain. The observed channel character in these areas suggest a **dynamic** geomorphic response potential when disturbed by high flow, significant sediment inputs, and/or channel obstruction. Dynamic channel response tends to increase channel complexity via lateral channel migration, split flow and avulsion, pool scour, sediment deposition, and floodplain activation (

Photograph 13).

Photograph 13. Example of complex geomorphic character exemplified by the Upper Lemhi River with extensive riparian vegetation and sinuosity (left) and a larger channel in the Upper Salmon River with split flow and undercut banks. Photograph is looking downstream (right).

A **mixed** geomorphic character was assigned to channel units exhibiting two or more of the following characteristics: moderate sinuosity, primarily single-thread, variable width and confinement, comparatively few pools, and lack of dense riparian vegetation. The observed channel character in these areas suggests a **variable** geomorphic response potential when disturbed by high flow, significant sediment inputs, and/or channel obstruction. Variable channel response can either increase or decrease channel complexity via channel migration (lateral or downstream), channel widening, scour, deposition, and moderate floodplain activation (

Photograph 14).

Photograph 14. Examples of mixed geomorphic character with excellent riparian structure in some areas but limited riparian vegetation in other areas due to land use activities, resulting in bank erosion and unnatural channel widening (Upper Pahsimeroi River on left and Upper Texas Creek, tributary to Lemhi River, on right).

A **simplified** geomorphic character was assigned to channel units exhibiting two or more of the following characteristics: fairly straight channel, high gradient, confined, lack of dense riparian vegetation, and minimal instream variability, including pools (i.e., plane-bed morphology). Simplified character was commonly associated with anthropogenic channel modification, including channel straightening, confinement, and bank armoring, although some channel units are naturally simplified, typically in high-gradient, confined reaches. The observed channel character in these areas suggests a **minimal** geomorphic response potential when disturbed by high flow, significant sediment inputs, and/or channel obstruction. Simplified reaches are typically sediment-transport dominated and often require much larger disturbances to evoke a significant response. Common channel response to disturbance includes incision followed by bed armoring, bank erosion, and poor floodplain activation (

Photograph 15).

Photograph 16 and

Photograph 17 provide regional examples of pre- and post-habitat construction projects to improve simplified geomorphic conditions.

Photograph 15. Examples of simplified geomorphic character on the Lower Lemhi River, where the channel has been historically straightened and armored and riparian vegetation removed.

Photograph 16. Pre- and post-habitat construction project improving simplified geomorphic condition on Catherine Creek, Oregon.

Photograph 17. Pre- and post-habitat construction project improving simplified geomorphic condition on the Lower Pahsimeroi River, with multiple rootwad structures installed along the bank to reduce unnatural rates of bank erosion and provide fish habitat.

Reach Delineation

Reach delineation enables the categorization of similar attributes across a relatively broad spatial scale to facilitate data collection and analysis, providing consistency and efficiency in reporting, and ultimately, treatment. Areas exhibiting similar physical conditions are typically formed in the same way and therefore exhibit similar channel response character. Evaluating site-specific characteristics at one location within the reach can generally be extrapolated to the remainder of the reach, thereby greatly improving evaluation efficiency. Similarly, trends in channel response character can be assessed by comparing variation within the reach associated with site-specific disturbance. The response to a disturbance at a singular site represents likely response conditions to a similar disturbance at other sites within the reach. Additionally, systemic channel responses, such as incision, sediment transport, and flooding, tend to operate differently between reaches and may be controlled by reach-defining geologic or human grade controls (e.g., bridge, culvert, bedrock exposure).

Reaches were delineated within the project area by changes in measured valley confinement (entrenchment ratio) and observed channel response character (transport-limited response reaches versus supply-limited transport reaches). Response segments have a lower gradient in which significant morphologic adjustment occurs in response to increased sediment supply (Montgomery and Buffington 1998).

Hydraulics

Cross-sections were measured using a combination of LiDAR data (both land- and bathymetry-based, where available) and survey data from 2015 and 2016. Cross-sections were located in areas that were representative of the local reach based on aerial image interpretation. Cross-sections were obtained across the entire floodplain to assess existing conditions and observe potential historical differences. Cross-sectional elevation data were replaced with channel stage data, with a starting stage at the minimum elevation of the channel bed.

The cross-sections were analyzed using normal-depth water surface calculations for various flood frequency discharges at each site, based on the hydrologic methods described in Appendix D, to develop an approximate rating curve for the cross-section and to assess channel bed mobility. Normal-depth calculations were estimated using Manning's equation, which is shown in Equation 1 below.

Equation (1)

$$Q = \frac{1.49}{n} A \left(\frac{A}{P}\right)^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where: Q = Discharge (cfs)

n = Manning's Roughness

A= Cross-sectional Area (ft^2)

P = Wetted Perimeter (ft)

S = Channel Slope (ft/ft)

Cross-sections were assigned various Manning's n-values to represent the approximate channel and floodplain roughness at each site. A range of n-values was typically assigned within the channel and floodplain, while the average n-values were used in the reported hydraulic results. Local channel slope was estimated from approximate digital elevation model topographic slopes at each location. Cross-sectional area and wetter perimeter were calculated for each discharge estimate.

Hydraulic parameters estimated at these locations include top width, average channel velocity, average channel shear, average channel stream power, the approximate D_{50} mobilization discharge based on channel shear (i.e., incipient motion), the approximate entrenchment ratio, and the estimation of an armored or unarmored bed. Entrenchment ratio was approximated by dividing the 100-year water surface top width by the 1.25-year water surface top width. The bed was assumed to be armored if it took greater than a 5- to 10-year event to begin mobilizing the D_{50} sediment size determined from Wolman-style pebble counts (see Figures 39-41, 83-85, and 116-118 for specific cross-sectional information from the Lemhi, Pahsimeroi, and Upper Salmon Rivers, respectively).

Icing and Surface Water Interactions

River ice can be a powerful geomorphic forcing agent that influences channel-floodplain interactions, avulsions, and bed scour. River ice is generally composed of three phases: ice formation, growth, and break-up. Each phase is driven by several factors, including but not limited to, water and air temperatures, water depth and velocity, discharge, and ice transport or retention and jamming. During the winter months, low overall discharge and cold temperatures favor ice formation in turbulent areas that are not thermally buffered by major groundwater inputs. In these areas, anchor ice can form when the air temperature is well below freezing and the water temperatures quickly drop to the freezing point. Turbulent heat exchange draws bubbles of super-cooled air below the water surface, freezing the water around each bubble and creating small platelets of ice called frazil ice. These small platelets can collect in calm water, occupying the interstitial space between grains of cobbles and boulders on the river bed and banks, creating a progressively larger ice surface, which grows into blocks of anchor ice (Hammar and Shen 1995). Anchor ice can become large enough that the combination of shear and buoyancy can dislodge the ice, often disturbing the bed and/or banks in the process. Anchor ice also obstructs flow by occupying space within the cross-sectional area of the channel, increasing the potential for over-bank flow. Anchor ice is less frequently formed in deeper, less-turbulent areas, and/or areas influenced by warmer groundwater.

In addition to anchor ice, surface ice may also form on portions of the Lemhi River in areas of low water velocity, particularly along the banks. Surface ice accumulation can become significant, creating ice dams when broken apart at the end of the cycle during high flows. Surface ice sheets start growing across the

tailouts of pools and runs, where flow velocities decrease to less than 1 ft/s. Once bank-to-bank ice cover forms, a process known as ice cover progression lengthens the cover in the upstream direction as arriving ice accumulates. Arriving frazil ice floes and slush can be drawn beneath the upstream edge of the ice cover to deposit in the form of a freeze-up ice jam. Flow conduits beneath the jams can become ice-clogged, forcing flow onto the surface of the ice cover and/or onto the floodplain.

Gradual ice break-up in the spring can extend over weeks, with minimal effect on the channel bed, banks, floodplains, and instream structures. Conversely, break-up ice runs can happen rapidly when the concentration of the moving ice floes exceeds the hydraulic conveyance capacity of the channel. These break-up ice runs can scour and erode the channel bed and banks, damage or destroy instream structures, and/or result in sudden flooding.

Photograph 18. Photograph illustrating how anchor ice can fill interstitial space and alter channel geometry. (Source: www.monolake.org/today/2008/12/18/hydrology-update-for-121808/)

Water Quality

Surface water quality standards apply to a waterbody, depending on its designated uses and/or existing uses. Pursuant to the Clean Water Act (CWA), Idaho recognizes existing uses, which are uses present or attained in a water body on or after November 28, 1975. When water bodies do not have designated beneficial uses, they are assigned a presumed use protection. All water bodies are classified for more than one beneficial use and must meet the fishable/swimmable intent of the CWA.

Under Idaho's water quality standards, beneficial uses are categorized as aquatic life, recreation, water supply, wildlife habitat, and aesthetics. For the Upper Salmon River watershed, beneficial uses that are not fully supported are: (1) aquatic life, which includes salmonid spawning and cold-water aquatic life beneficial uses, and (2) and contact recreation that includes primary and secondary contact recreation.

The Idaho Department of Environmental Quality (IDEQ) completed a subbasin assessment for the Upper Salmon River watershed in 2003 (IDEQ 2003). Total maximum daily loads (TMDLs) were developed for

water bodies not supporting their beneficial uses and impaired by a pollutant. In Idaho's 2002 Integrated Report (September 30, 2005), streams were converted from water-quality-limited segments to assessment units (AUs) based on Strahler Stream Order within a Waterbody ID.

Temperature and Climate Change Assessment

Temporally and spatially continuous water temperature models were developed for each of the target tributaries (Lemhi River, Pahsimeroi River, and Upper Salmon River above Redfish Lake Creek) to assess whether seasonal temperatures may limit the use of specific stream reaches for one or more life stages of anadromous salmonids. A combination of modeled temperature predictions and predictions of life-stage-specific temperature thresholds were used to evaluate whether current water temperatures might limit the ability of Chinook salmon or steelhead to use available habitat. Further, a simple warming scenario describing potential increases in stream temperature expected to result from climate change was used to assess whether the implementation of restoration actions to reduce temperatures may be necessary. The temperature model and species-specific temperature thresholds are described in more detail in Appendix A. Spatially and temporally continuous modeled water temperature data (McNyset et al. 2015) were available for the following:

- Lemhi River: 2011-2015
- Pahsimeroi River: 2011 and 2013
- Upper Salmon River: 2011 and 2013

Average modeled water temperatures (across years) for each of the watersheds were then compared to minimum, maximum, and acute temperature criteria adopted for various life stages of Chinook salmon and steelhead (Carter 2005) to identify seasons and life stages where temperature may be limiting.

Finally, an assessment was made to evaluate potential future limitations resulting from a climate change scenario. Although climate change could lead to a change in stream temperature, published estimates of anticipated changes in the Salmon River subbasin have not been found. However, by the year 2100, water temperature models for the Cook Inlet Basin, Alaska, suggest that water temperatures could increase by 1.2 to 7.1° C (Kyle and Brabets 2001). As an initial assessment, 3° C (a median value based on scenarios from Kyle and Brabets 2001) were added to average temperatures to evaluate how a potential climate change scenario might influence the vitality of Chinook salmon and steelhead. Combined with changes in the timing of water availability, increased temperature can be expected to exert a substantial influence on the timing of juvenile emergence, among other traits.

Biologic and Geomorphic Assessment Integration

The Upper Salmon River Subbasin IRA is a biologically driven assessment intended to guide the development of future assessments (e.g., MRAs) or habitat enhancement project development and implementation. To be actionable, however, the biological results provided herein must be integrated with a geomorphic assessment. First, the biological assessment identifies key Chinook salmon and steelhead life stages within each watershed that are limited. Potential effects to those life stages resulting from increased water temperatures associated with climate change are also acknowledged. Next, the geomorphic assessment identified physical forms and processes within each watershed and categorizes the relative geomorphic character as complex, mixed, or simplified. The biologic and geomorphic assessments are integrated by identifying the geomorphic character of preferred habitat for key life stages

and identifying the relative level of rehabilitation effort required to improve habitat of an existing geomorphic character. The IRA team further applied fluvial geomorphology concepts to identify the most appropriate locations to focus future efforts (assessments and/or projects) to address factors or processes that limit these local fish populations. The biological and geomorphic analyses were closely coordinated with local professionals and stakeholders to leverage local knowledge and maximize local support. As a result of this work and planned follow-on, refined analyses (MRAs), designs and implementation efforts can be scientifically supported and strategically coordinated among local watershed teams and landowners.

Habitat rehabilitation actions can be undertaken to address identified limiting PBFs in priority areas, as discussed in Section 2 below. The level of rehabilitation effort will depend in part on the geomorphic character of the stream reach and the desired habitat conditions relative to capacity limitations within that reach. Depending on the intrinsic geomorphic character associated with each area, rehabilitation efforts may enhance or expedite existing geomorphic trends (passive treatments requiring less effort) or create new conditions otherwise unlikely to occur given existing impacts (active treatments requiring more effort). Generally, less rehabilitation effort is required in order to improve habitat in areas currently defined by complex geomorphic character, and greater rehabilitation effort is required in areas defined by simplified geomorphic character (Figure 11). An evaluation of the relative level of effort (i.e., cost) should always be contrasted with the likely potential benefit of a particular action when considering project identification and prioritization. Additional reach- and site-scale analysis may also be necessary, along with political, social, and funding considerations, in order to most appropriately prioritize and develop potential rehabilitation efforts.

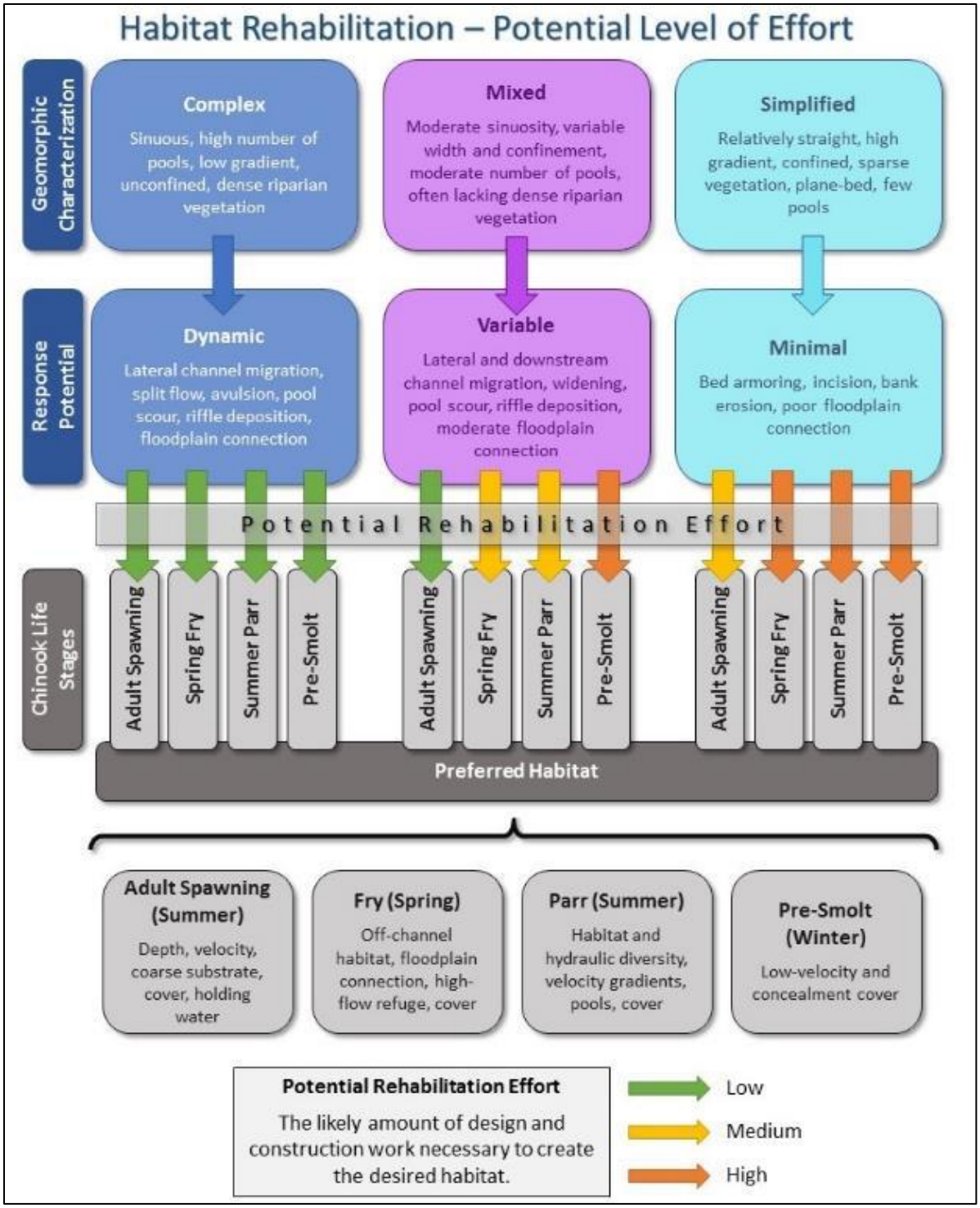


Figure 11. Summary of the habitat rehabilitation effort based on the relationship between geomorphic characterization and preferred habitat conditions per life stage. In general, more complex geomorphic character naturally yields conditions preferred by more life stages. Rehabilitation efforts may be undertaken within an area defined by any geomorphic character, but the level of effort required to elicit and/or maintain the desired channel response will vary, as illustrated in this figure.

Next Steps

The next steps will facilitate the transition from basin-wide efforts in this document to fill data gaps and provide higher-resolution information that informs future recovery efforts, including:

- Address data gaps using LiDAR; a juvenile salmon tracking study; and reach-scale geomorphic, hydraulic, and instream habitat data collection and evaluation;
- Expand capacity modeling to encompass the entire MPG; and
- Collaborate with local stakeholders to fill data gaps, share knowledge, and plan future efforts.

The above efforts are intended to help local practitioners and scientists identify and implement projects that maximize fish benefits and expedite recovery of ESA-listed species moving forward in the Upper Salmon River subbasin.

Section 2: Upper Salmon Subbasin Key Conclusions and Recommendations

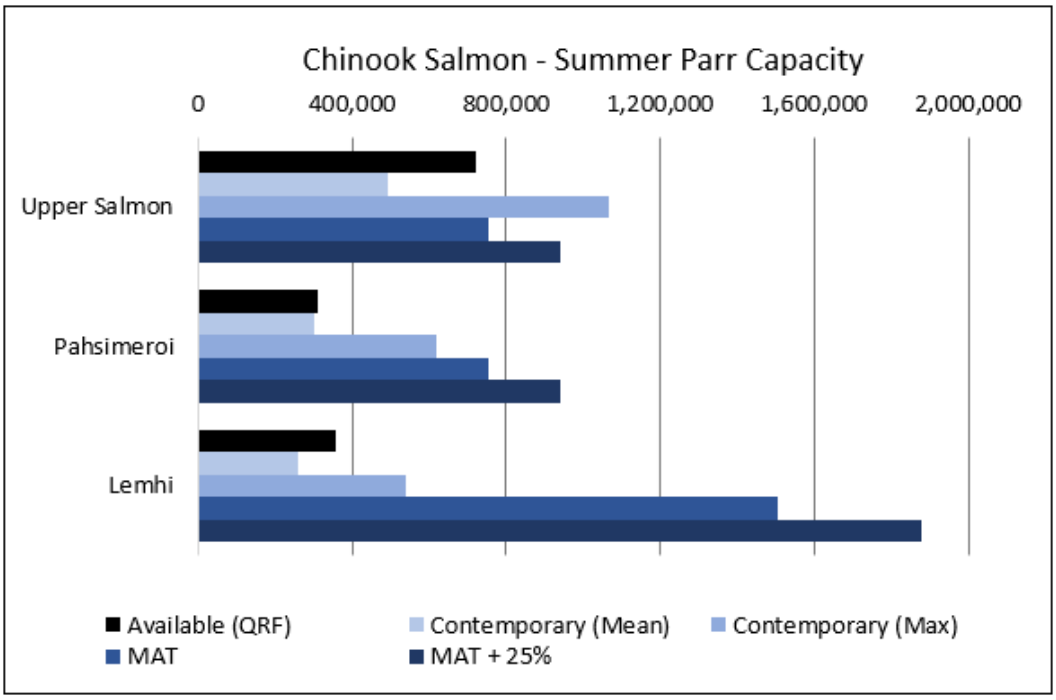
Habitat Enhancement Recommendations Summary

This section includes a summary of key conclusions and recommendations associated with the Upper Salmon River subbasin as a whole, as well as for the Lemhi River, Pahsimeroi River, and Upper Salmon River headwaters, respectively. General and/or common conclusions and recommendations are summarized for the subbasin, while more specific details and recommendations are summarized for each respective watershed. In all instances, the conclusions and recommendations are supported by data and other information discussed in the following watershed-specific chapters and appendices.

Basin-wide Actions

Chinook Salmon Capacity Limitations

Across the Upper Salmon River spring/summer Chinook salmon MPG, we conclude that deficits in available summer and winter juvenile rearing capacity are the primary factor limiting growth of populations. As expected, estimates of available rearing capacity are sufficient to support contemporary mean escapements for the three watersheds (with the exception of Pahsimeroi winter rearing) (



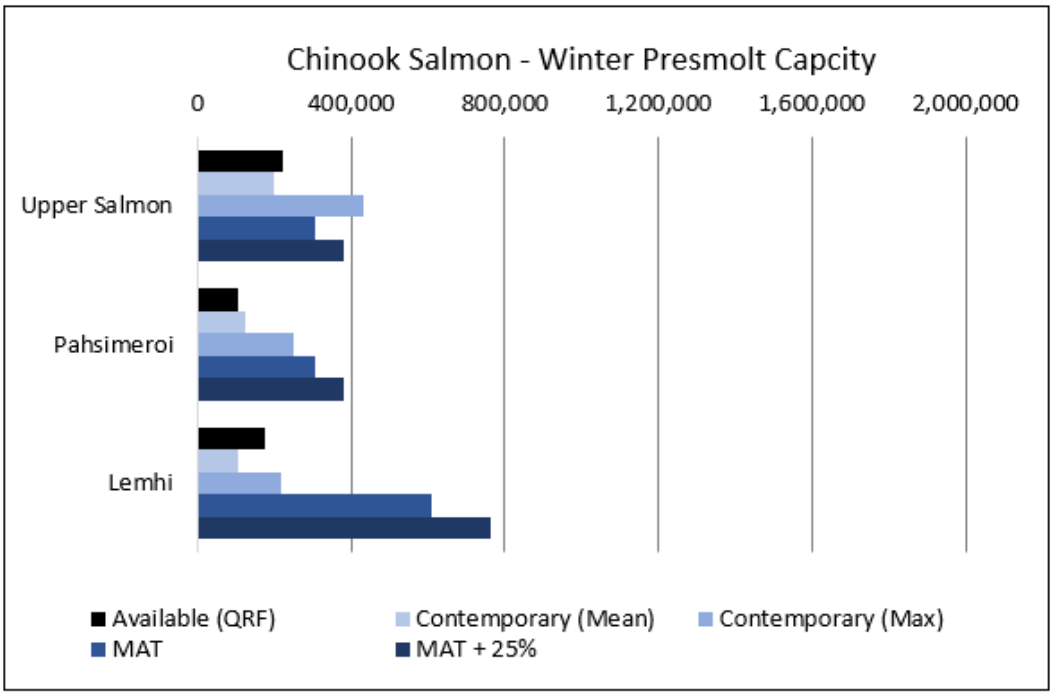


Figure 13 and

Figure 14); however, available rearing habitat is not sufficient to support recent high escapement ,and the issue is exacerbated when evaluating requirements to support MAT and MAT + 25%. In contrast, our estimates of spawning (redd) capacity suggest that the adult spawning life stage is likely not limiting in the Upper Salmon River subbasin (

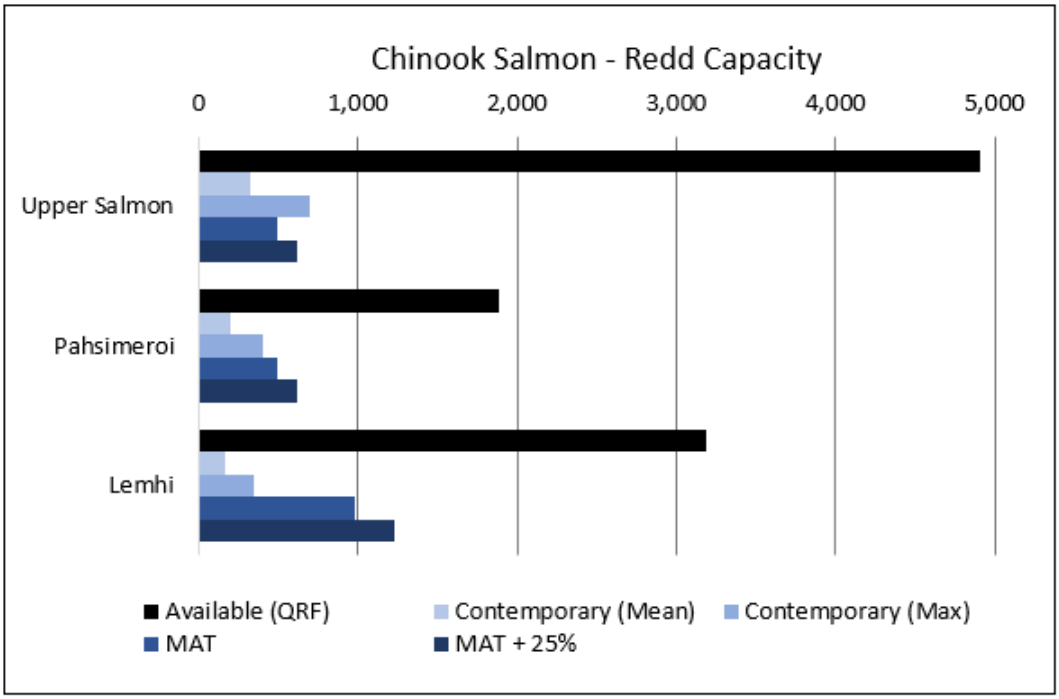
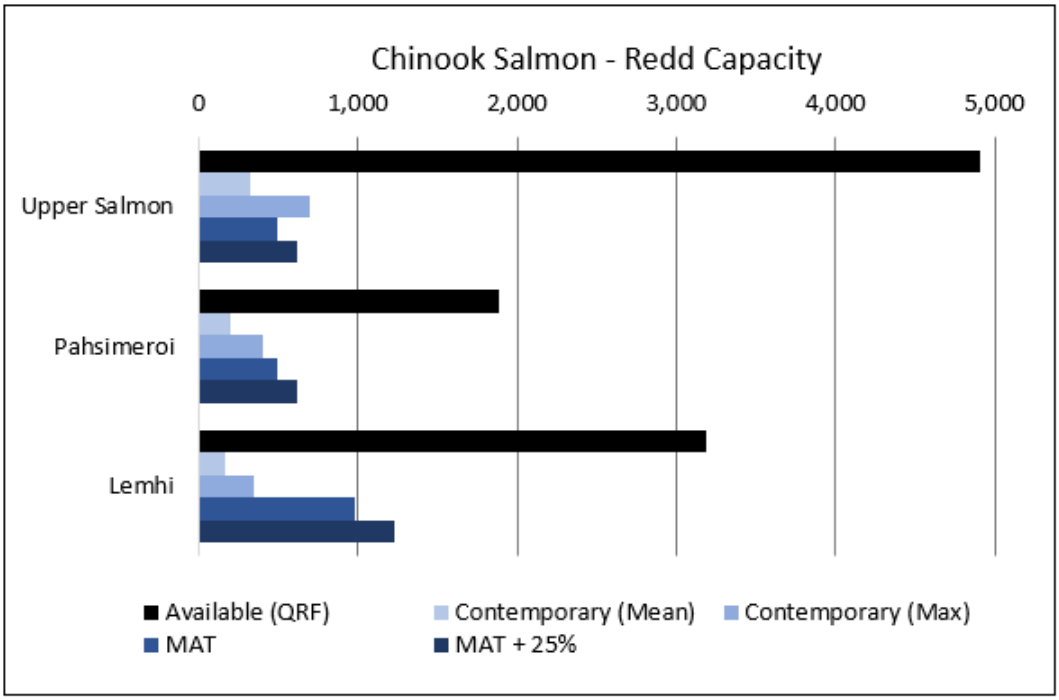


Figure 12). Lastly, we conclude that seasonal variation in temperature is extreme, likely limiting growth in particular life stages and contributing to mortality.


Chinook Salmon - Redd Capacity
0
1,000
2,000
3,000
4,000
5,000
Upper Salmon
Pahsimeroi
Lemhi
Available (QRF)
Contemporary (Mean)
Contemporary (Max)
MAT
MAT + 25%

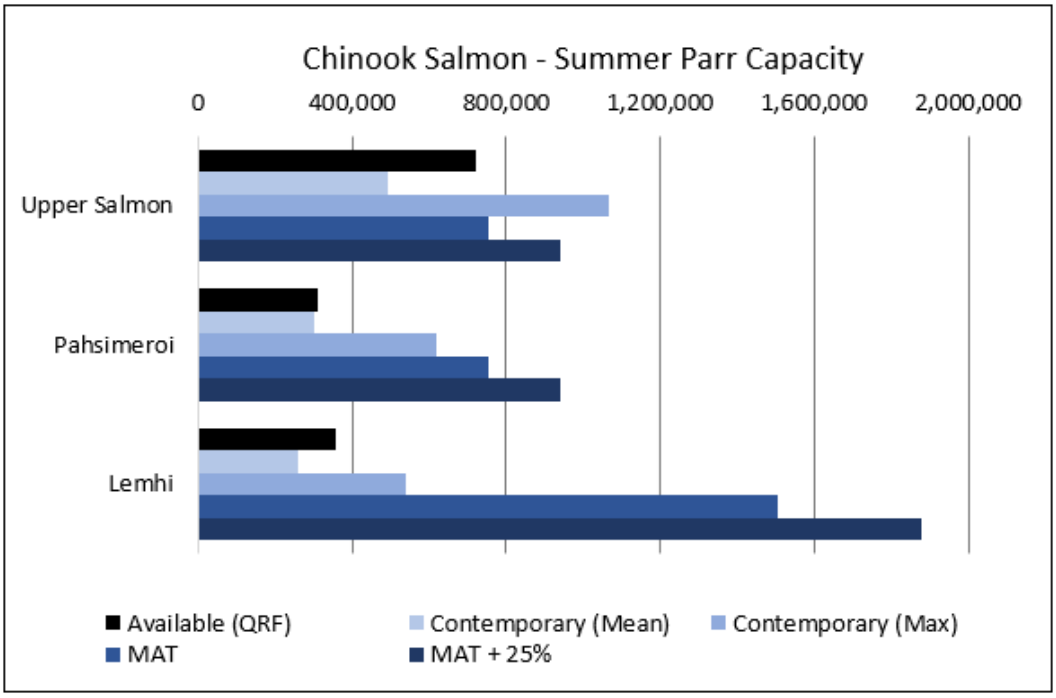

Chinook Salmon - Summer Parr Capacity
0
400,000
800,000
1,200,000
1,600,000
2,000,000
Upper Salmon
Pahsimeroi
Lemhi
Available (QRF)
Contemporary (Mean)
Contemporary (Max)
MAT
MAT + 25%

Figure 12,

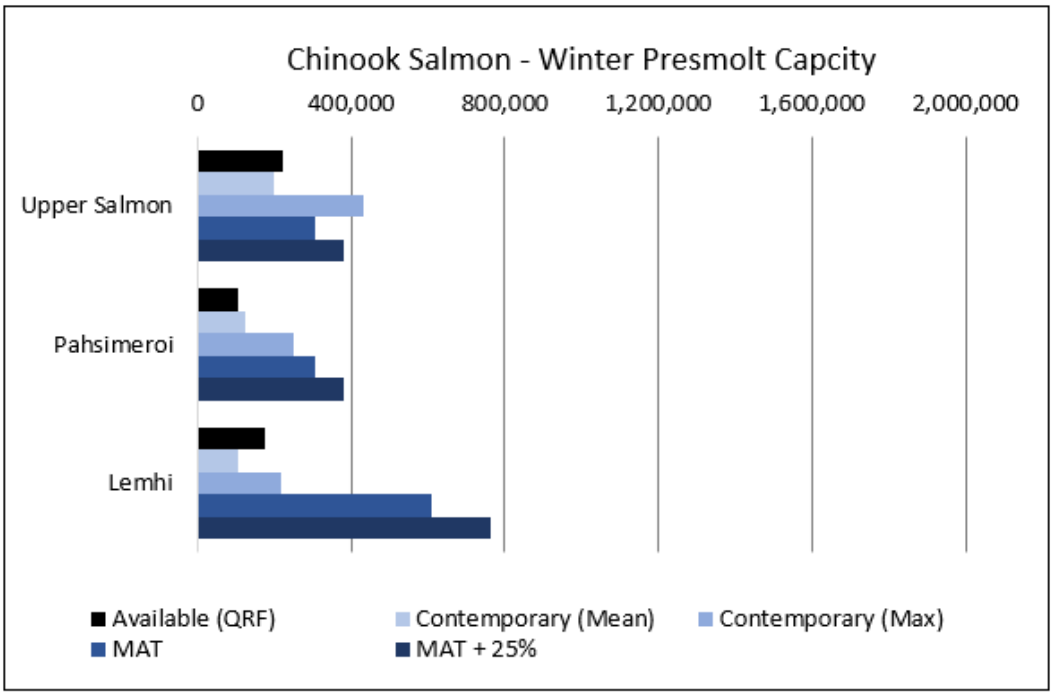


Figure 13, and Figure 14 show comparisons of available habitat capacity from QRF versus capacity required to support various levels of adult abundance, including mean and maximum recent escapement, MAT, and MAT + 25% for the redd, summer (parr) rearing, and juvenile (presmolt) rearing life stages, respectively. Comparisons are for Chinook salmon and the three focal watersheds. Comparisons for the remaining five watersheds in the Upper Salmon River subbasin are provided in Appendix B.

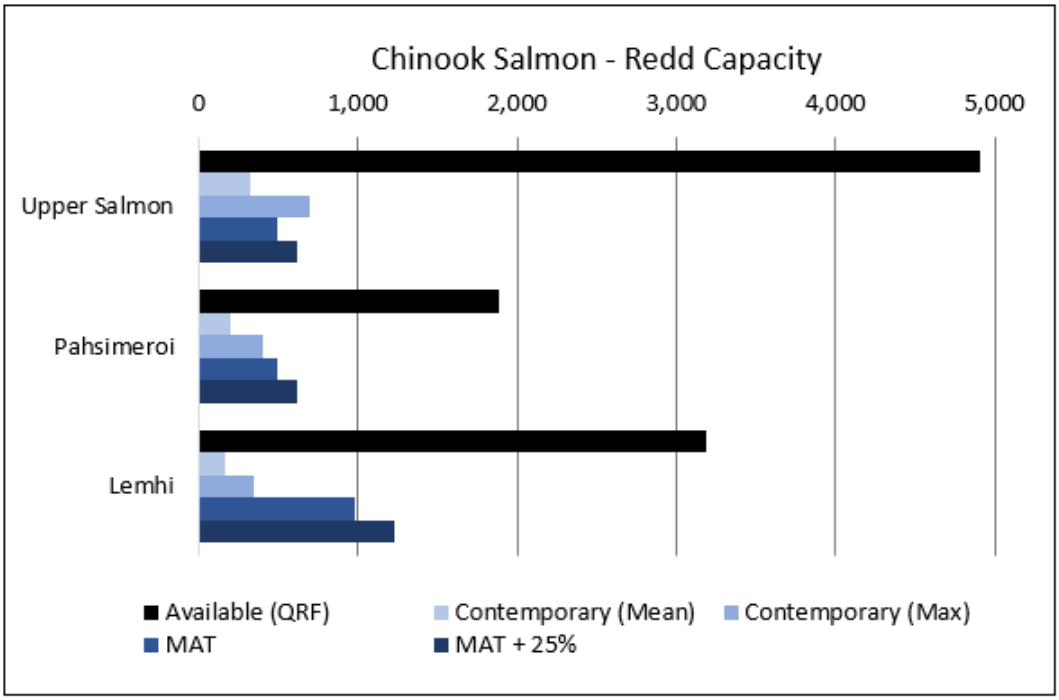


Figure 12. Estimates of available spawning (redd) capacity for Chinook salmon given current habitat conditions, made using quantile regression and random forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

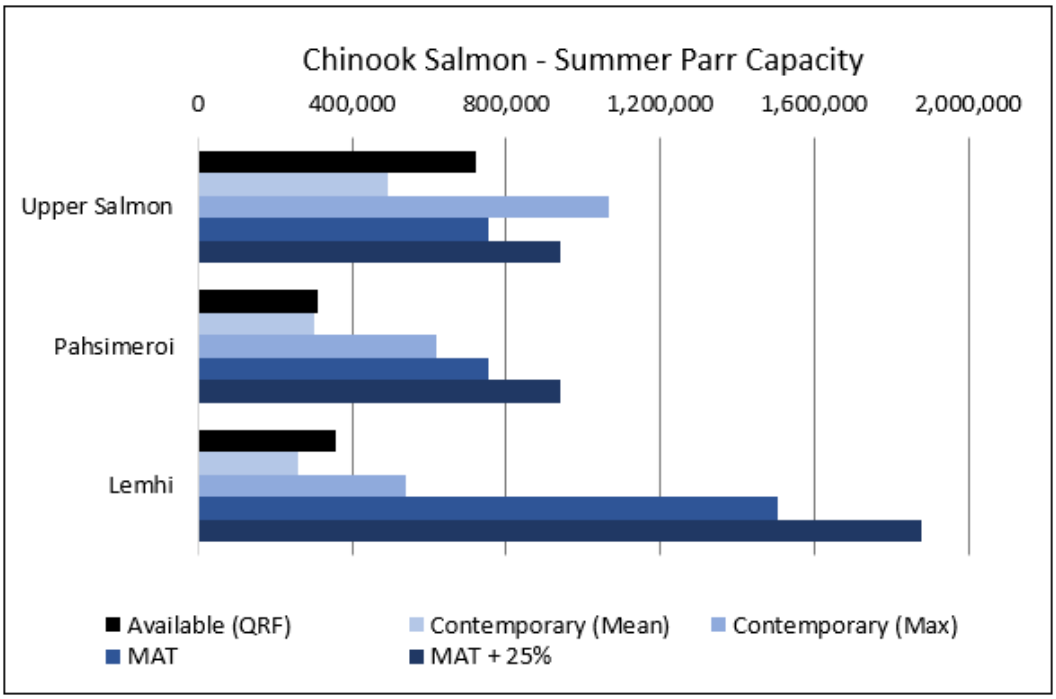


Figure 13. Estimates of available summer juvenile (parr) rearing capacity for Chinook salmon given current habitat conditions, made using quantile regression and random forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

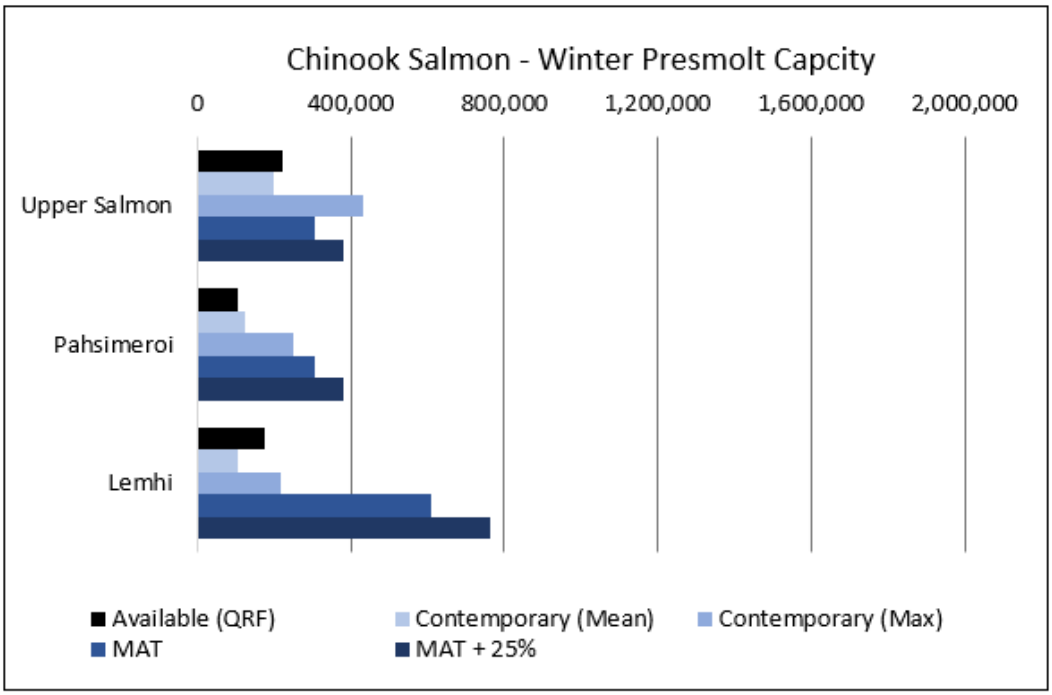


Figure 14. Estimates of available winter juvenile (presmolt) rearing capacity for Chinook salmon given current habitat conditions, made using quantile regression and random forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

Steelhead Capacity Limitations

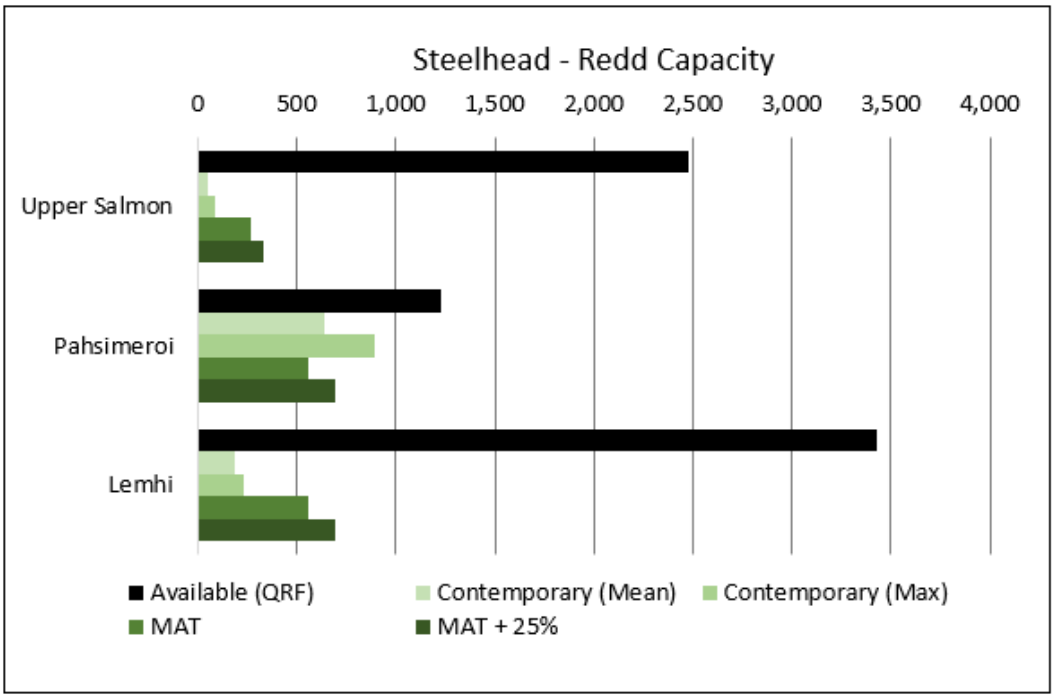
Results for the steelhead available capacity estimates are considered preliminary. Models to estimate available habitat capacity for spawning (redds) and summer (parr) and winter (presmolt) rearing were completed in 2018 and are available. However, two considerations should be made when interpreting results from the juvenile steelhead models:

1. Juvenile steelhead may rear in natal tributaries for multiple years, whereas juvenile Chinook only rear in freshwater for a single year before emigration to the ocean. In addition, steelhead populations can contain a considerable number of residualized individuals.
2. All spatial modeling extents for the QRF and extrapolation models were done using StreamNet domains, and in initial discussions with local biologists, it appears the StreamNet domain may, in cases, overestimate the spatial extent of habitat available for steelhead spawning and rearing. Modeling too large of a spatial domain can result in overestimates of available capacity, and in turn, portray that capacity deficits do not exist when, in fact, they may.

Due to these considerations, steelhead results should be interpreted with caution. We hope to improve the spatial extents for the steelhead QRF models in the near future with collaboration from local biologists and experts. Improved model results can be incorporated into future reach-scale assessments.

For populations of steelhead across the Upper Salmon River subbasin, we conclude that sufficient available habitat exists for both the spawning (redd) and juvenile (presmolt) rearing life stages in each of

the three target watersheds (Lemhi River, Pashimeroi River, and Upper Salmon River above Redfish



Lake Creek) (

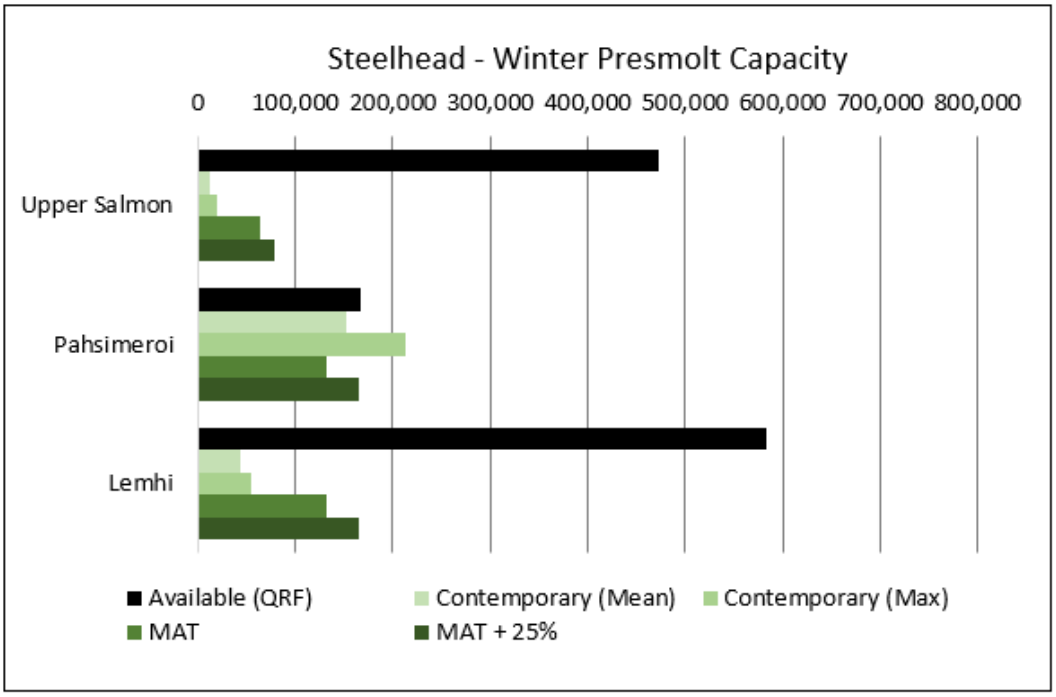


Figure 15 and

Figure 17). However, we did conclude that summer (parr) rearing is limiting in at least the Pahsimeroi River watershed to support contemporary escapement and escapement necessary for delisting (

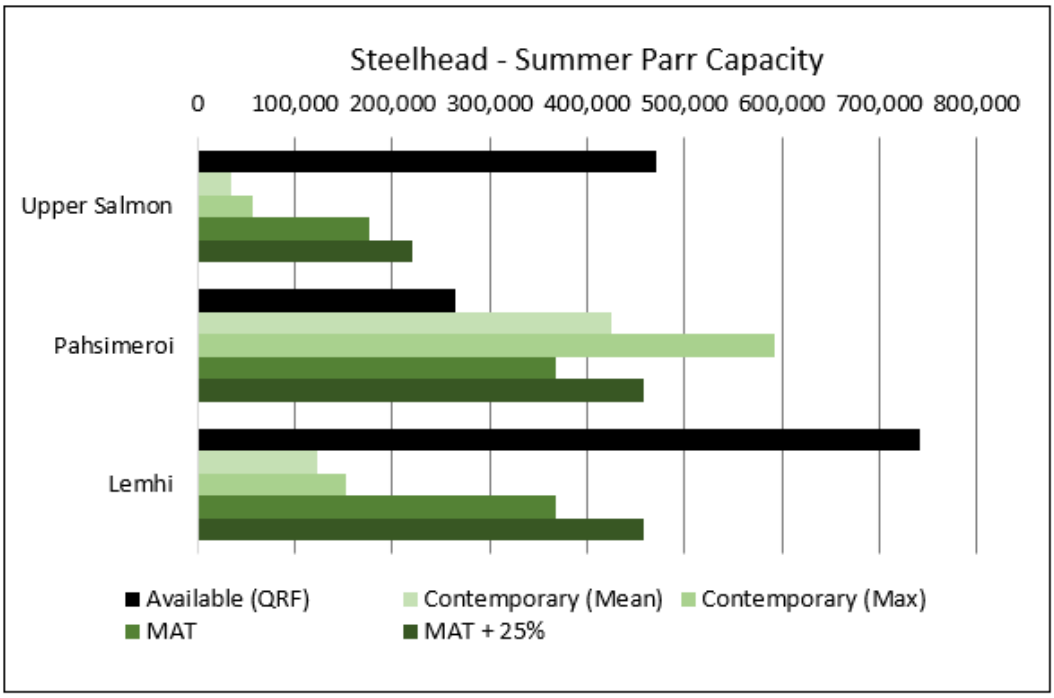
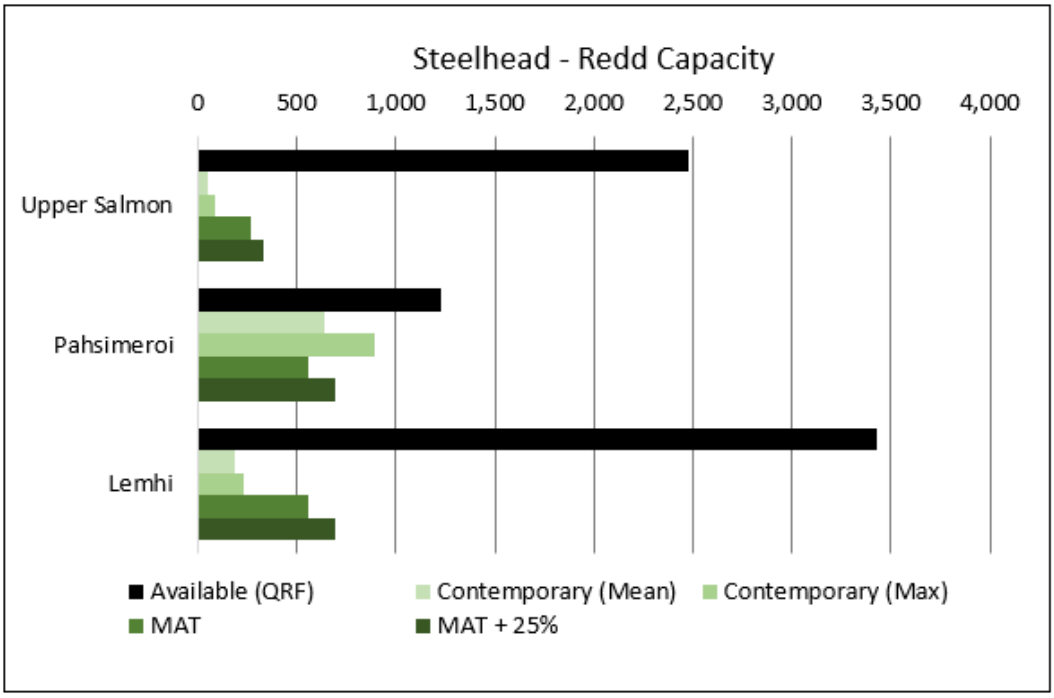
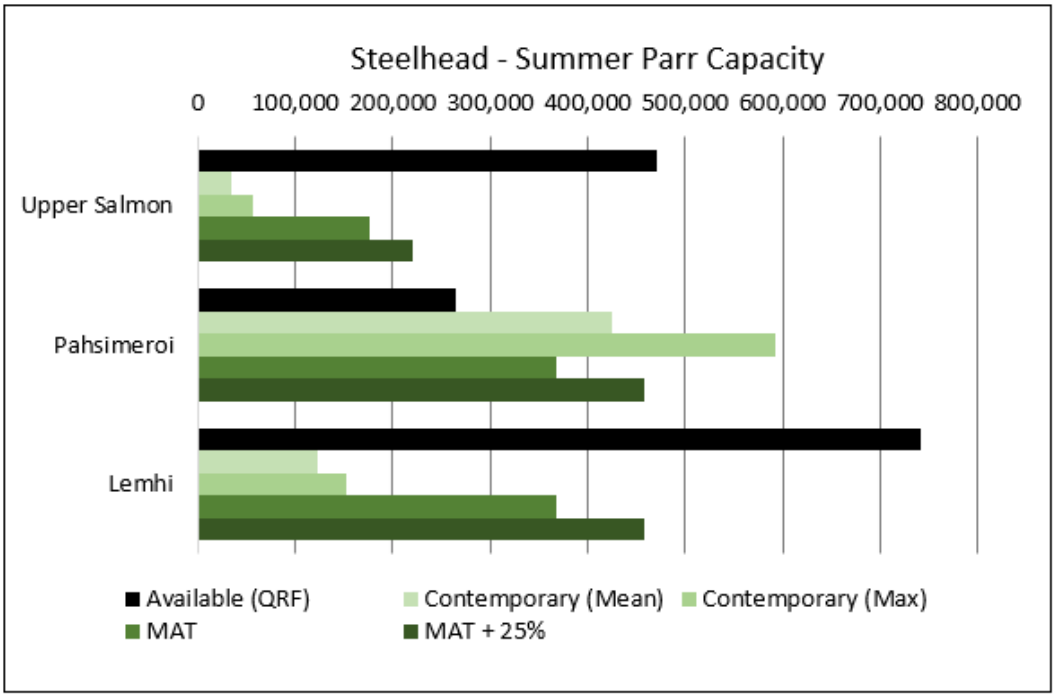


Figure 16). Finally, of note, we conclude that water temperatures during the summer are above the optimum range for *O. mykiss* for at least a portion of the season for each of the three target watersheds, and the issue is exacerbated by the climate change scenario that we present.





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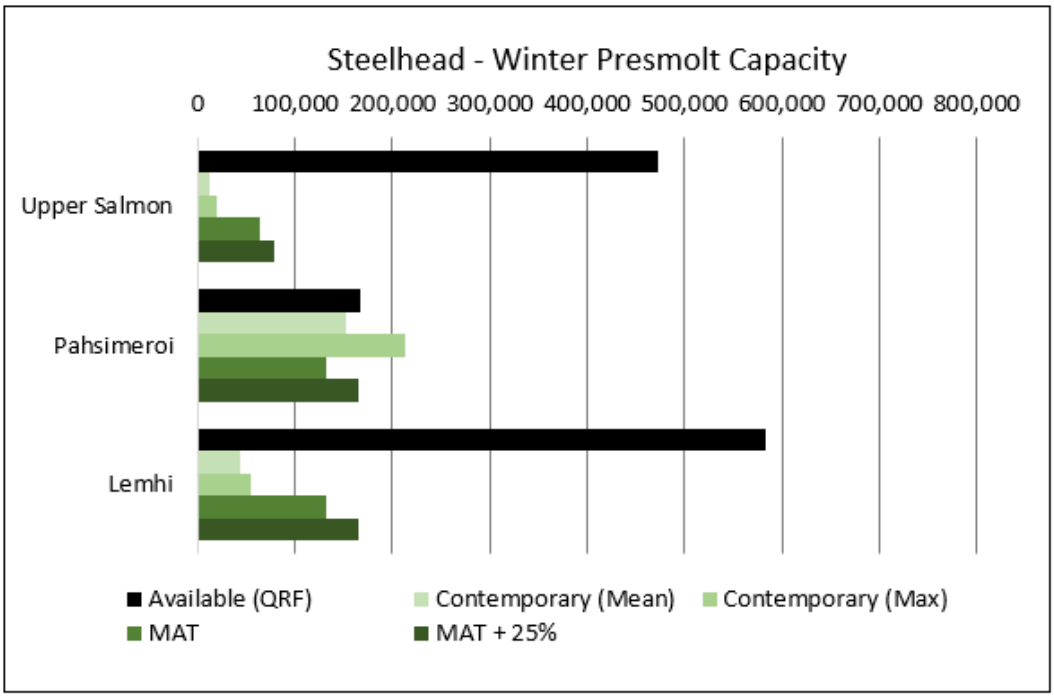

Figure 16, and

Figure 17 show comparisons of available habitat capacity from QRF versus capacity required to support various levels of adult abundance, including mean and maximum recent escapement, MAT, and MAT + 25% for the redd, summer (parr) rearing, and juvenile (presmolt) rearing life stages, respectively. Comparisons are for steelhead and the three focal watersheds. Comparisons for the remaining five watersheds in the Upper Salmon River subbasin are provided in Appendix B.

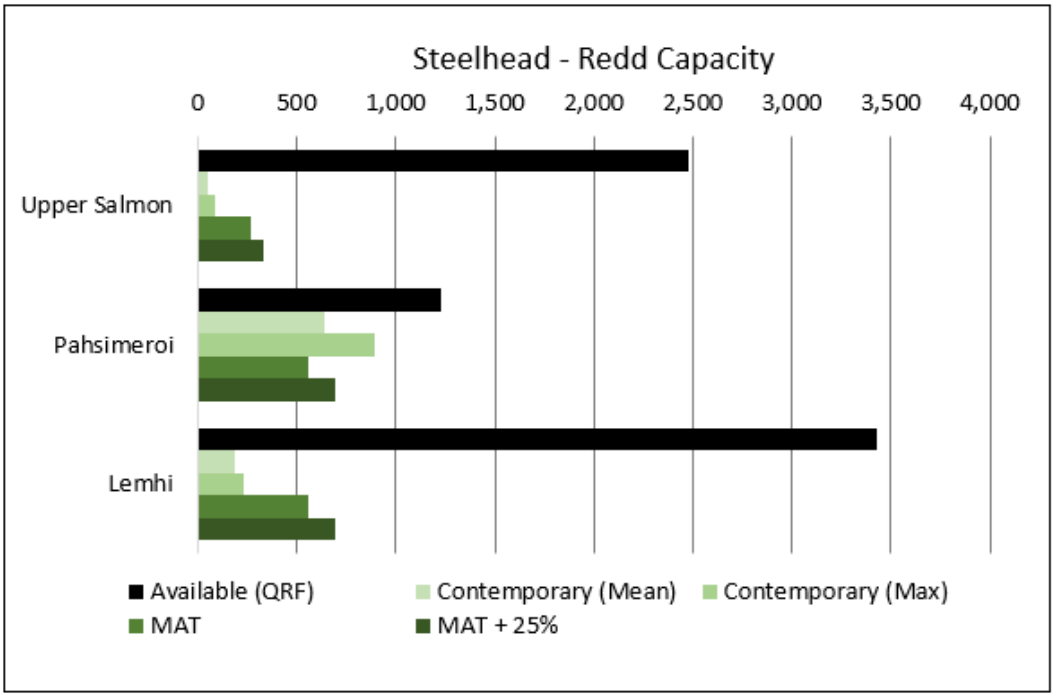

Figure 15. Estimates of available spawning (redd) capacity for steelhead given current habitat conditions, made using quantile regression random forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

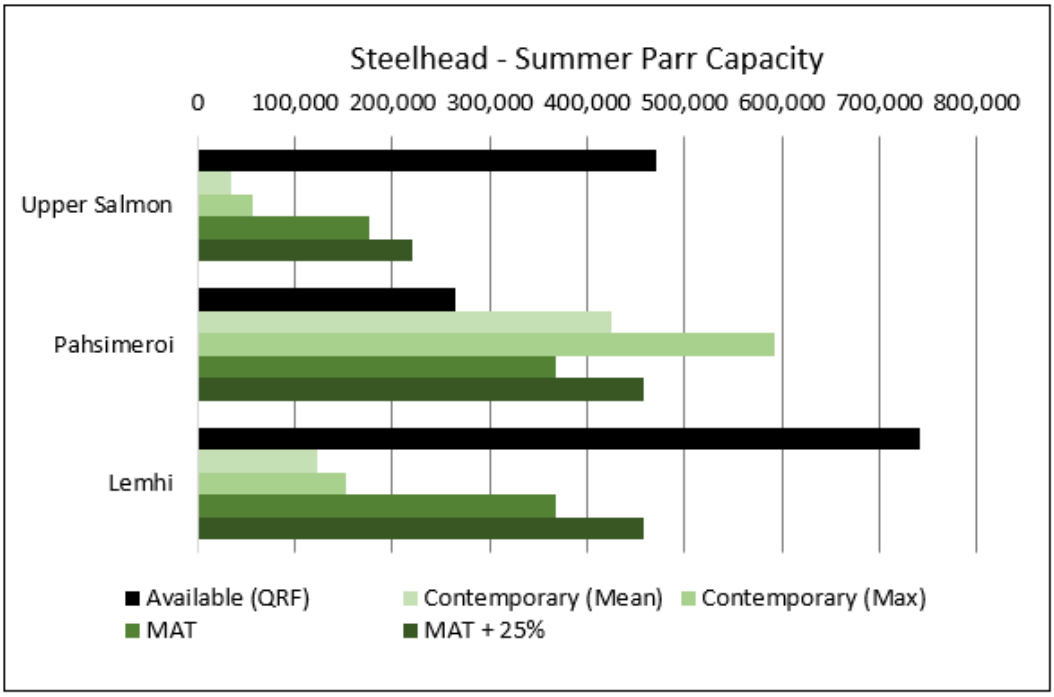

Figure 16. Estimates of available summer juvenile (parr) rearing capacity for steelhead given current habitat conditions, made using quantile regression random forest models (black bars) versus the capacity

required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

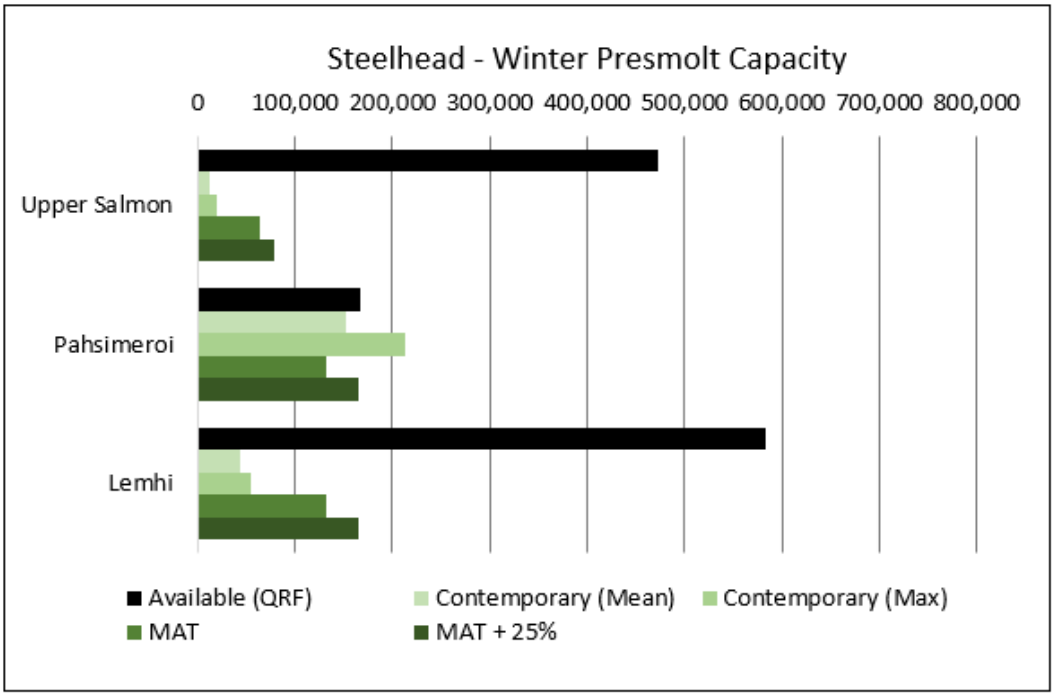

Figure 17. Estimates of available winter juvenile (presmolt) rearing capacity for steelhead given current habitat conditions, made using quantile regression random forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

General Recommendations and Actions

The general recommendations and actions provided by the IRA are targeted toward Chinook salmon, as steelhead available capacity model results are still preliminary at the time of publication of this document. Steelhead model results will be improved and incorporated into future reach-scale assessments as appropriate.

Further investigation in the MRA step will allow us to more closely link specific life-stage habitat requirements, but for now our investigation suggests that actions aimed at increasing low- to zero-velocity pool habitat with cover, increased interstitial spaces, and improved hyporheic flow should be prioritized, to both improve freshwater population productivity and buffer against changes in stream temperatures due to climate change.

From an implementation standpoint, we recommend actions be implemented in all three focal watersheds focused on increasing summer and winter rearing capacity by reducing width-to-depth ratios, increasing floodplain connectivity and complex habitat structure, increasing low- to zero-velocity pool habitat with cover, providing side channel habitat, and reducing sediment. Additional required actions include moderating water temperatures and instream flows by increasing hyporheic flow and alluvial aquifer connections and improving riparian habitat.

The following conclusions and recommendations apply to the entire Upper Salmon River subbasin as a whole, based on the Generalized Capacity and QRF models, key limiting factors analysis, and local expertise:

- Summer (parr) and overwinter (presmolt) rearing are the key limited life stages for Chinook salmon production throughout all three watersheds (Lemhi River, Pahsimeroi River, and Upper Salmon River). Available capacity for summer (parr) and winter (presmolt) rearing are significantly below levels required to support current adult escapement levels required for MAT and MAT + 25%.
- Limiting PBFs associated with the lack of summer (parr) rearing habitat include limited hydraulic and habitat complexity (i.e., velocity gradients, pool and side channel frequency, etc.).
- Limiting PBFs associated with the lack of winter (presmolt) rearing habitat include lack of concealment cover within low- and zero-velocity areas.
- Concealment cover for all juvenile life stages is lacking due to embedded substrate, a lack of woody debris, a lack of deep complex pools, a lack of undercut banks, and in places, fast water velocities.
- The lack of available juvenile rearing capacity required increased juvenile movement to seek suitable habitat (including to mainstem Salmon River reaches), resulting in increased exposure and survival risk.
- Available spawning habitat (i.e., redd capacity) is not limiting in any of the target watersheds (Lemhi River, Pahsimeroi River, and Upper Salmon River above Redfish Lake Creek). However, providing sufficient adult holding (prespawn) habitat should be considered and would be provided by increased habitat complexity.
- Spawning habitat historically occurred farther upstream than current core areas, especially in the Upper Salmon River headwaters, effectively reducing the area currently available for rearing (i.e., area downstream of spawning).

In addition to the limiting PBFs described in this document, NOAA (2017) identified the following seven tributary habitat limiting factors for Chinook salmon in the Lemhi, Pahsimeroi, and Upper Salmon Rivers:

- Reduced stream complexity and channel structure,
- Excess fine sediment,
- Impaired fish passage,
- Diminished streamflow during critical periods,
- Elevated summer water temperatures,
- Degraded riparian conditions, and
- Reduced floodplain connectivity and function (Upper Salmon only).

Beyond the PBFs identified here and the tributary habitat limiting factors identified by NOAA (2017), the lack of marine-derived nutrients should also be recognized as a potential PBF limiting Chinook salmon

vitality throughout the Upper Salmon River subbasin. However, analyses of marine-derived nutrients within watershed are outside of the scope of the IRA.

Below, we describe additional details regarding limiting factors, recommendations, and priority areas for each of the three target watersheds based on the watershed-scale IRA. We expect these recommendations and priority areas will be further refined as part of the future MRA process.

The Lemhi River Watershed

In addition to general conclusions and recommendations listed above, the following are watershed-specific conclusions, priority areas, and recommendations for Chinook salmon in the Lemhi River watershed.

Limiting Physical and Biological Features

The key limiting PBF for population productivity in the Lemhi River is summer and winter juvenile fish rearing habitat downstream of current spawning habitat. Within the Lemhi River, we estimated that roughly twice as much spawning (redd) capacity currently exists than required to achieve MAT + 25%; however, summer juvenile rearing capacity must be increased by approximately four-fold and winter rearing capacity by approximately three-fold, relative to current conditions, to support MAT + 25%.

- Summer (parr) and winter (presmolt) juvenile rearing capacity were each identified as high-priority PBF limiting Chinook salmon production in the Lemhi River.

Priority Areas

Priority enhancement areas within the Lemhi River watershed include the upper and lower Lemhi and Hayden Creek:

- **First priority: mainstem Lemhi River downstream of Hayden Creek.** This section currently does not support Chinook salmon spawning but provides key summer and winter rearing for fish spawned in the upper Lemhi River and Hayden Creek.
- **Second priority: mainstem Lemhi River upstream of Hayden Creek.** This is the section of the Lemhi River watershed where about two-thirds of the spawning occurs on average.
- **Third priority: Hayden Creek.** This is the section where about one-third of the spawning occurs on average.

Recommendations

In the lower Lemhi River and Hayden Creek (characterized as peak-flow dominated), habitat complexity enhancements are preferred, including diversifying the mostly single-thread channel to multi-threaded and island-braided channels with large cottonwood tree recruitment for pool formation and cover. Actions should also maintain and improve tributary stream connections to the mainstem Lemhi River.

In the Upper Lemhi River (characterized as groundwater-influenced), treatments that improve habitat complexity are also preferred, including a return to multi-threaded channels, reduction in width-to-depth ratios, stabilization of stream banks, and increased riparian shrub-dominated habitat to increase both pool area/frequency and associated instream cover.

The following recommended actions can increase habitat quantity and quality in the Lemhi River:

- In the lower mainstem Lemhi River (downstream of Hayden Creek), increase habitat complexity by increasing the sinuosity of the single-thread main channel while creating areas of island braiding with complex instream structure, hydraulic variability, and low-velocity areas with cover. Provide structure with large wood (cottonwood) while accommodating active channel migration. Mediate summer water temperatures and provide low-velocity cover areas for winter rearing.
- In the upper mainstem Lemhi River (upstream of Hayden Creek), increase habitat complexity by creating multi-threaded channels, narrow width-to-depth ratios, stable banks, and willow-dominated riparian areas.
- Maintain and improve instream flow and tributary stream connections to the mainstem Lemhi River.
- Reduce fine sediment inputs to the watershed from upland and instream sources to improve substrate conditions for interstitial spaces, providing overwinter concealment habitat for juvenile fishes.
- Increase seasonal floodplain connection to improve floodwater storage, hyporheic exchange, fine sediment storage, high-flow juvenile refugia, nutrient exchange, and riparian vegetation, and to reduce instream velocities.

Biological and Geomorphic Assessment Integration

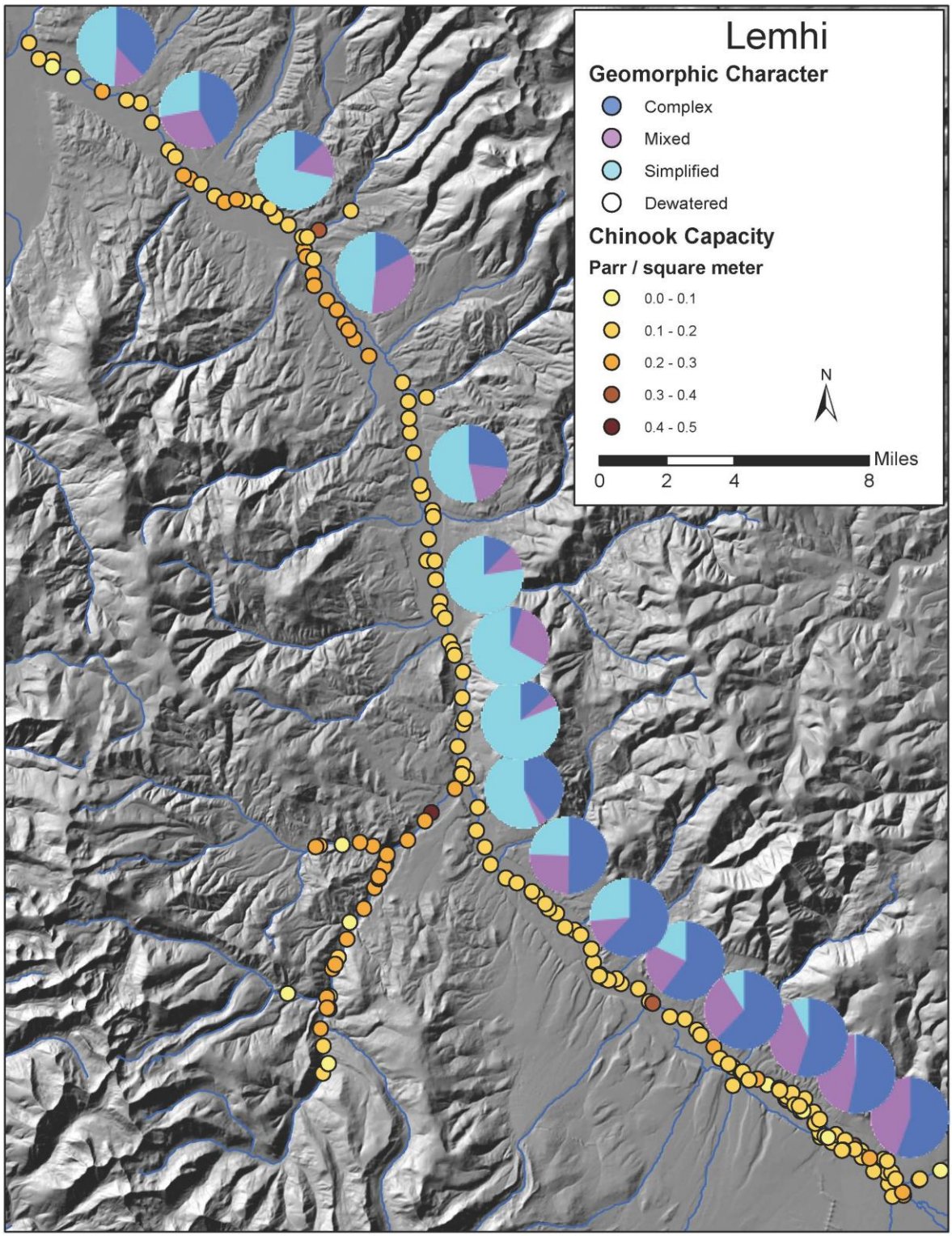

Figure 18. Lemhi River map spatially illustrating geomorphic character per reach (pie charts) and predicted existing capacity for Chinook salmon parr (graded orange to yellow dots).

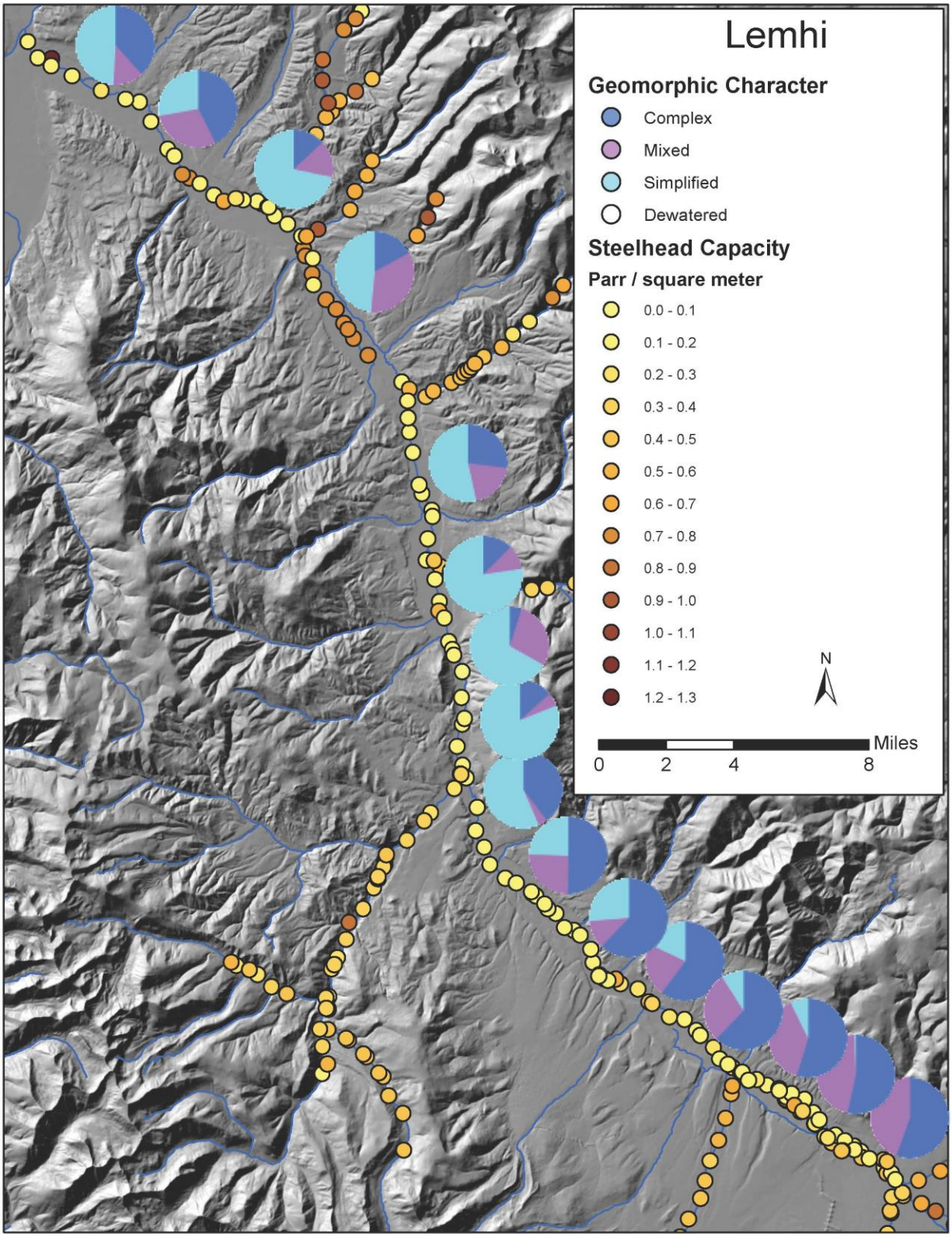

Figure 19. Lemhi River map spatially illustrating geomorphic character per reach (pie charts) and predicted existing capacity for steelhead parr (graded orange to yellow dots).

The Pahsimeroi River Watershed

In addition to general conclusions and recommendations listed above, the following are watershed-specific conclusions, priority areas, and recommendations for Chinook salmon in the Pahsimeroi River watershed.

Limiting Physical and Biological Features

The key limiting PBF for population productivity in the Pahsimeroi River is summer and winter juvenile fish-rearing habitat. Within the Pahsimeroi River, we estimated that roughly twice as much spawning (redd) capacity currently exists than required to achieve MAT + 25%; however, summer juvenile rearing capacity must be approximately doubled and winter rearing capacity must be increased by approximately 2.5 times, relative to current conditions, to support MAT + 25%.

- Summer (parr) and winter (presmolt) juvenile rearing capacity were each identified as high-priority PBF limiting Chinook salmon production in the Pahsimeroi River.

Priority Areas

Priority areas within the Pahsimeroi River watershed include the mainstem Pahsimeroi River and (Patterson) Big Springs Creek.

- **First priority: Pahsimeroi River from the mouth to Hooper Lane.** Hooper Lane is currently the upstream-most extent of Chinook salmon spawning and rearing, except for Big Springs Creek.
- **Second priority: (Patterson) Big Springs Creek.** This is the portion of the creek within the Pahsimeroi valley bottom.

Recommendations

The following recommended actions can increase habitat quantity and quality in the Pahsimeroi River:

- Increase habitat quantity by adding more channels within groundwater-influenced reaches that provide high-quality, complex habitat, including split flows, side channels, spring channels, and alcoves.
    - Reconnecting upstream habitat may be limited in certain areas (e.g., upstream of Goldberg Creek) due to geologic conditions, resulting in significant surface water losses to the aquifer (i.e., dry river).
- Increase stream length by increasing sinuosity, which also increases hyporheic flow.
- Establish a robust, riparian community along the banks and floodplain, increasing shade, improving bank structure and habitat, and providing a buffer from upland and floodplain sediment sources.
- Reduce fine sediment (systemic throughout the Pahsimeroi River basin) by increasing bank stability and decreasing surface water runoff.
- Improve and/or provide tools to landowners and land manager to protect land uses that benefit and maintain fish habitat.

- Increase seasonal floodplain connection to improve flood water storage, hyporheic exchange, fine sediment storage, high-flow juvenile refugia, nutrient exchange, riparian vegetation, and to reduce instream velocities.

Biological and Geomorphic Assessment Integration

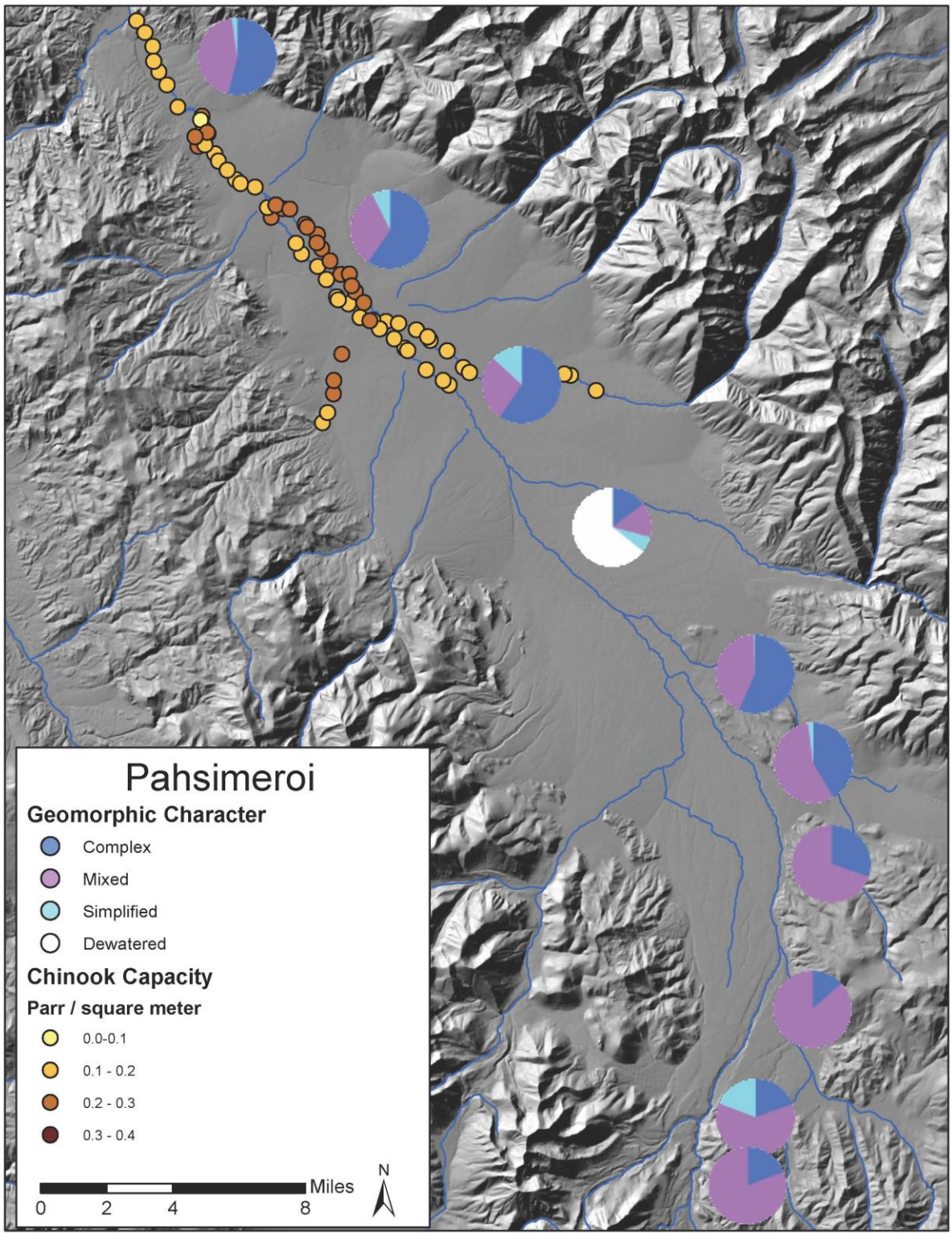

Figure 20. Pahsimeroi River map spatially illustrating geomorphic character per reach (pie charts) and predicted existing capacity for Chinook salmon parr (graded orange to yellow dots).

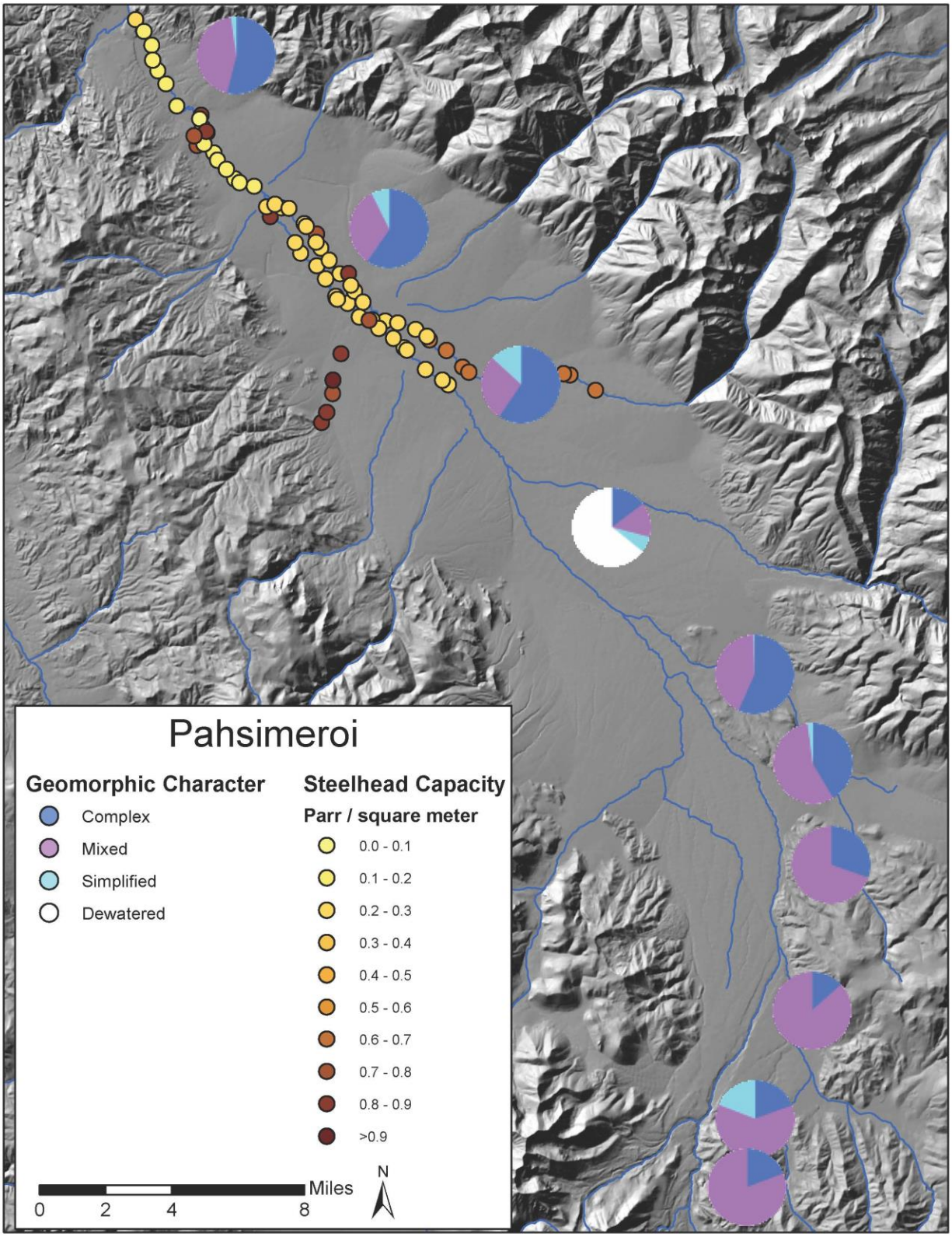

Figure 21. Pahsimeroi River map spatially illustrating geomorphic character per reach (pie charts) and predicted existing capacity for steelhead parr (graded orange to yellow dots).

The Upper Salmon River (Headwaters) Watershed

In addition to general conclusions and recommendations listed above, the following are watershed-specific conclusions, priority areas, and recommendations for Chinook salmon in the Upper Salmon River (headwaters) watershed.

Limiting Physical and Biological Features

Limiting PBFs for population productivity in the Upper Salmon River (above Redfish Lake Creek) include summer and winter juvenile fish-rearing habitat. Within the Upper Salmon River, we estimate that available spawning (redd) capacity is ample to support MAT + 25%; however, summer juvenile rearing capacity must be increased by approximately 30 percent and winter rearing capacity by approximately 70 percent, relative to current conditions, to support MAT + 25%. However, the downstream boundary of juvenile rearing for this sub-population is uncertain. Summer flow is also a limitation in some reaches. Problematically, most of the habitat currently used for spawning and rearing is concentrated in the lower valley just upstream of the Sawtooth fish hatchery, limiting juvenile use of the majority of available upstream habitat.

- Winter (presmolt) juvenile rearing habitat was identified as a high-priority PBF limiting Chinook salmon production in the Upper Salmon River (headwaters).
- Summer (parr) juvenile rearing habitat was identified as a medium-priority PBF limiting Chinook salmon production in the Upper Salmon River (headwaters).

Priority Areas

Priority areas in the upper Salmon River (headwaters) include lower-gradient reaches of the Salmon River around Decker Flats, the Alturas Lake Creek confluence area, and the Pole Creek area.

- **First priority: mainstem Upper Salmon from Alturas Creek to Redfish Lake Creek.** This section is where the majority of the Chinook salmon production currently occurs.
- **Second priority: Alturas Lake Creek and the mainstem Upper Salmon above Alturas Lake Creek, including Pole Creek.**

Recommendations

The following recommended actions can increase habitat quantity and quality in the Upper Salmon River:

- Redistribute spawning to take advantage of available rearing habitat in the upper and middle watershed above currently used spawning habitat. This could potentially be accomplished using current supplementation programs in place in the area, and Venditti et al. (2018) note that there are at least three goals appropriate for supplementation programs, including: (1) maintain smolt production during low escapements, (2) seed unoccupied or restored habitats, and (3) restore or maintain harvest opportunity concurrent with population recovery.
- Increase habitat complexity by creating and/or enhancing multi-threaded channels, narrow width-to-depth ratios, instream structure provided by large woody debris, and willow-dominated riparian areas within groundwater-influenced response areas immediately upstream of geologic controls composed primarily of glacial moraine deposits.

- Maintain and improve instream flow and tributary stream connections to the mainstem Upper Salmon River. Summer flow limitations continue to exist upstream of the Alturas Lake Creek confluence.
- Increase seasonal floodplain connection to improve flood water storage, hyporheic exchange, fine sediment storage, high-flow juvenile refugia, nutrient exchange, and riparian vegetation, and to reduce instream velocities.

Biological and Geomorphic Assessment Integration

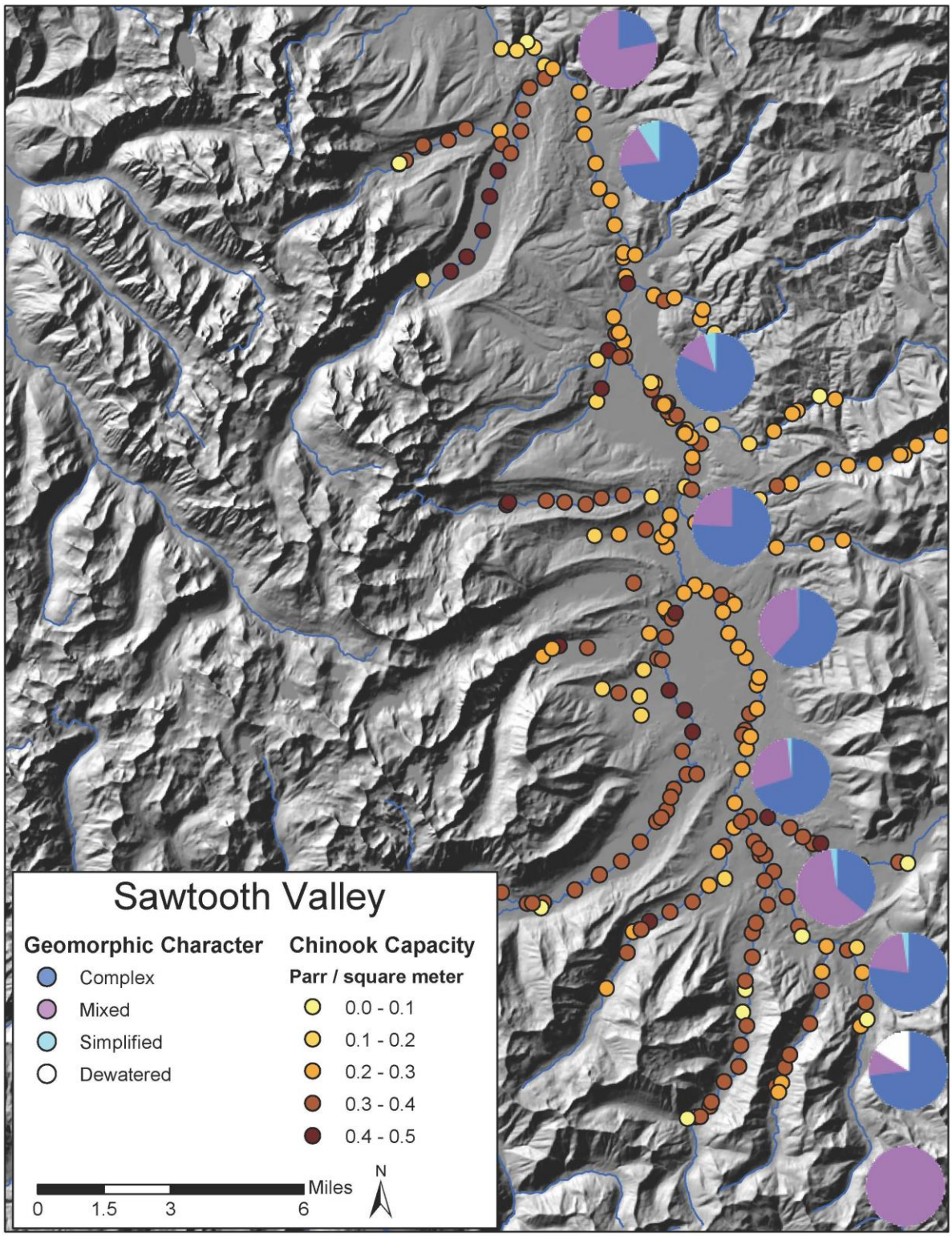

Figure 22. Upper Salmon River headwaters map spatially illustrating geomorphic character per reach (pie charts) and predicted existing capacity for Chinook salmon parr (graded orange to yellow dots).

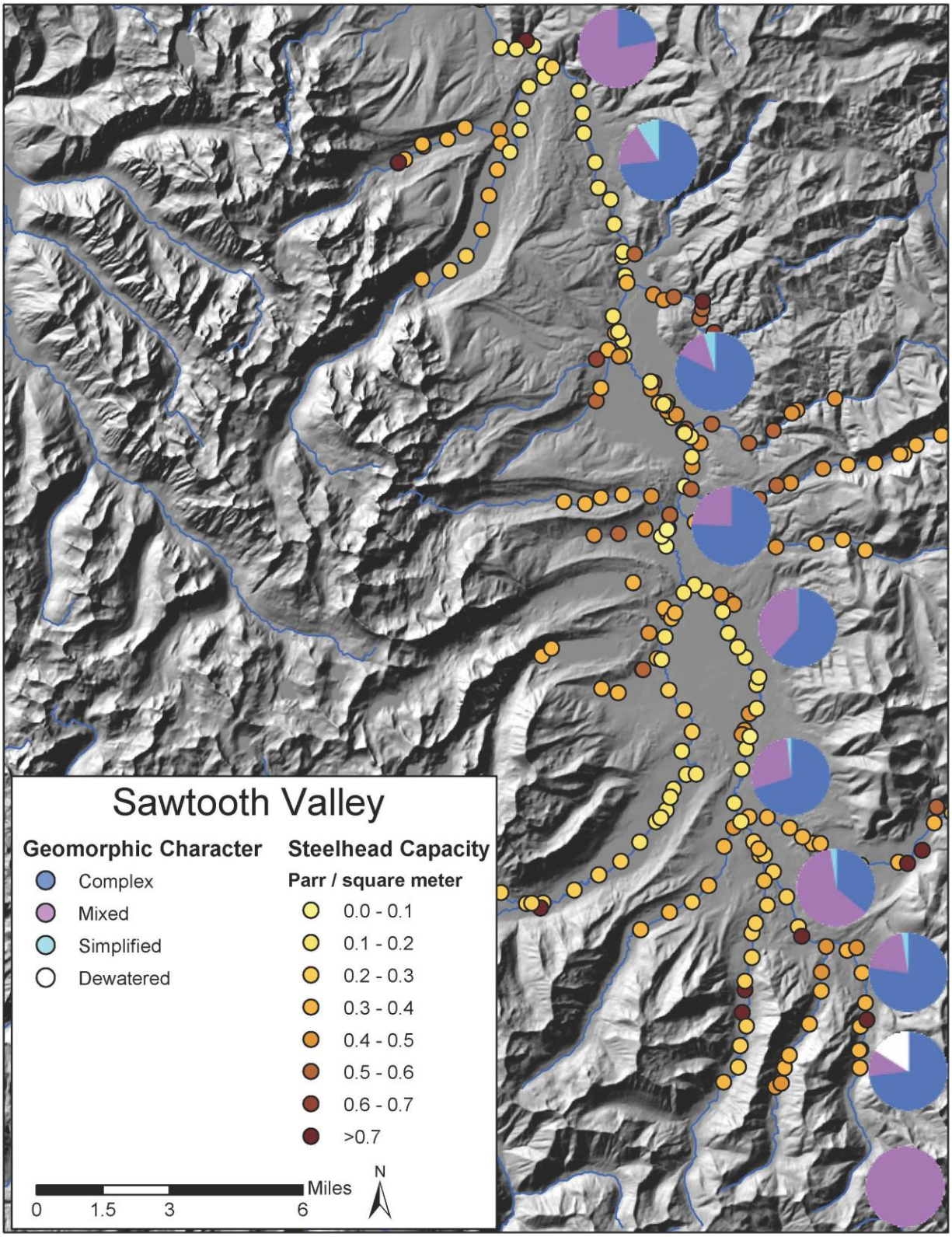

Figure 23. Upper Salmon River headwaters map spatially illustrating geomorphic character per reach (pie charts) and predicted existing capacity for steelhead parr (graded orange to yellow dots).

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Section 3: Watershed-Level Results

Chapter 1 – Lemhi River Watershed

Location and Watershed Description

The Lemhi River watershed is located in the Northern Rocky Mountain System physiographic region that comprises extensive parallel mountain ranges, intermontane valleys, and plateaus (Figure 24). Elevations in the watershed range from a low of about 4,000 feet to a high of 11,000 feet, with the lowest elevations along the Lemhi valley floor and the highest elevations along the bounding Beaverhead Mountains to the north and Lemhi Range to the south. The watershed is in the Dry Intermontane Sagebrush Valleys Ecoregion (17AA), characterized by stream terraces, floodplains, saline areas, and alluvial fans. Water availability and potential for cropland agriculture are low because the Ecoregion is in the rain shadow of high mountains, receives little mountain runoff, and is underlain by highly permeable valley fill deposits. Its deep gravels are unlike the basalts of Ecoregion 12. Sagebrush grassland is widespread and contrasts with the open-canopied forests of the more-rugged and higher Ecoregion 17e. Shadscale and greasewood grow on alkaline soils that receive fewer than 8 inches of precipitation annually. Grazing is the dominant land use (McGrath *et. al*. 2002).

The Lemhi River watershed is a hydrologic unit code (HUC) 8th field basin (HUC 8 – 17060204) within the Salmon River Subbasin and the Columbia River Basin. The watershed covers about 1,260 square miles in east-central Idaho and is entirely within Lemhi County, Idaho. About 80 percent of the land is owned by the Federal government and administered by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM). Federal lands are located primarily in the higher elevations, whereas the 20 percent private ownership is predominantly located in lower elevations along the valley bottoms.

The Lemhi River is predominantly an alluvial stream flowing over gravel and cobble originating at the confluence of Hawley, Eighteenmile, and Texas Creeks near the town of Leadore, Idaho. The river flows to the northwest for about 63 miles, where it discharges to the Salmon River near Salmon, Idaho.

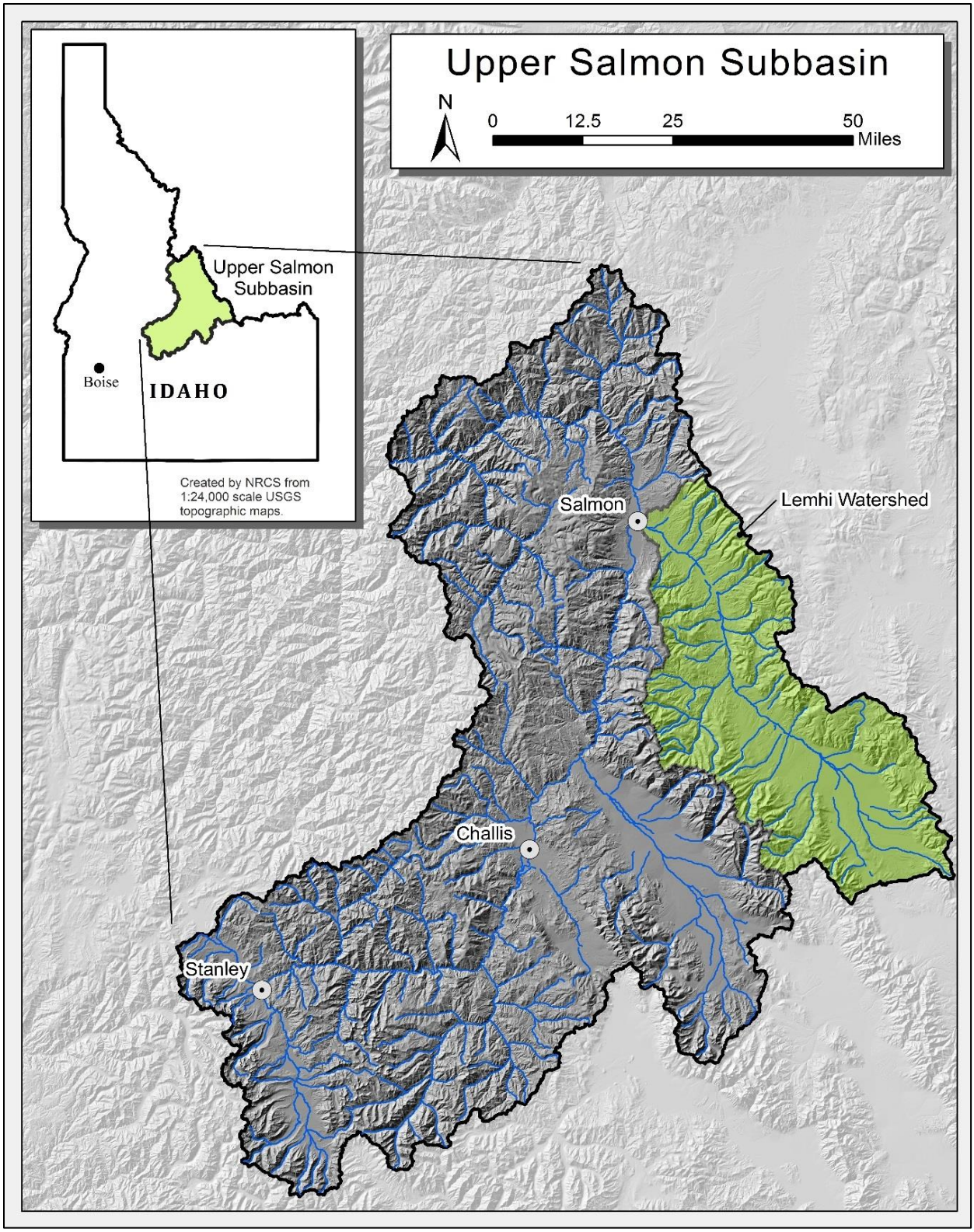


Figure 24. Location of the Lemhi River watershed within the Upper Salmon River subbasin.

Biological Assessment

The Lemhi River maintains populations of three fish species listed under the ESA: Chinook salmon, steelhead, and bull trout. The watershed also supports westslope cutthroat trout (*O. clarki lewisi*), which has been petitioned for listing under the ESA. As described in the journals of Lewis and Clark, the Lemhi Valley was completely overgrown with willows, from valley shoulder to valley shoulder, and the river itself had multiple deep channels, rendering the valley bottom nearly impassable. Early reports of tribal fishing (Walker 1994) estimated Chinook salmon and steelhead harvest at 60,000 pounds per year. However, by 1872, the effects of downstream commercial fishing were apparent as estimated salmon and steelhead harvest in the Lemhi River was reduced to approximately 10,000 pounds (Walker 1994). Historical harvest and abundance estimates support the NOAA (2017) classification of the Lemhi River Chinook salmon population as Very Large and the Lemhi River steelhead population as Intermediate.

In its current form, the Lemhi River is heavily affected by legacy mining impacts, railroad construction, road construction, and agriculture. Of its 31 major tributaries, only Hayden Creek and Big Springs Creek retained a constant hydraulic connection to the mainstem Lemhi until tributary reconnection efforts began in 2001. Diversions and agricultural activity have increased water temperature and fine sediment (IDEQ 2013). These anthropogenic influences, combined with out-of-subbasin sources of mortality, have resulted in a high-risk finding for Lemhi River Chinook salmon (NOAA 2017). Lemhi River steelhead were identified as being maintained (6 to 25 percent risk of extinction, NOAA 2017), but that listing is tentative due to insufficient data for Lemhi River steelhead. Among recent years (2010 through 2015), the Lemhi River has a mean adult escapement of 347 Chinook salmon, with a maximum of 718 in 2015. In those same years, mean adult escapement for steelhead was 337, with a maximum of 417 in 2010. Despite legacy degradation, primary productivity in the Lemhi River remains high relative to other Idaho rivers, and groundwater influence continues to modulate water temperatures (Bjornn 1978).

Habitat Capacity

Chinook salmon

Current Conditions

Contemporary estimates of life-stage-specific capacity requirements were generated based on the mean (347) and maximum (718) adult Chinook salmon escapement observed in the Lemhi River from 2010 to 2015. Those adult escapements were then propagated through to four additional life stages to estimate life-stage-specific capacity requirements for Chinook salmon in the Lemhi River; capacity requirements were then compared to available habitat capacity estimated using QRF models (Table 2).

Table 2. Estimated current life stage specific capacity requirement versus estimated available capacity for Chinook salmon in the Lemhi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	Mean	Max		
Escapement	347	718		
Redd	170	352	2,641	0
Eggs	899,027	1,861,128		
Summer Parr	260,718	539,727	550,562	0
Winter Presmolt	105,635	218,681	173,375	45,306

Using contemporary escapement estimates, habitat capacity does not appear to limit the production of redds or summer parr in the Lemhi River under current conditions; however, it does appear that juvenile (presmolt) rearing capacity is limited during the winter months (Table 2). The finding of limited winter hearing habitat is further supported by three lines of evidence:

1. Bjornn (1971) identified winter habitat capacity limitations in Big Springs Creek, a tributary to the Lemhi River, and later confirmed those observations in subsequent experiments in Hayden Creek, the largest tributary to the Lemhi River (Peery and Bjornn 2004).
2. A time-series process model (described in Appendix C) for Chinook salmon in the Lemhi River found density-independent production from the adult-to-parr transition but found evidence of density-dependent production from the presmolt-to-smolt life history transition.
3. The majority of juvenile Chinook salmon emigrate from the Lemhi River as age-0 presmolts prior to the winter (Appendix C). This is consistent with behavior, observed by Bjornn (1971) and Peery and Bjornn (2004), potentially resulting from winter habitat limitations.

We estimate an approximately 20 percent deficit in winter (presmolt) rearing habitat to support even a recent escapement of 718 adult Chinook salmon, which is far below desired escapement. Additionally, on average, 72 percent of juvenile emigrants from the Lemhi River emigrate during the parr (2 percent) or presmolt (70 percent) life stage. This suggests that a substantial increase in winter habitat capacity would be required to support current Chinook salmon productivity in the Lemhi River.

Desired Conditions

NOAA (2017) delisting requirements include a minimum annual escapement (i.e., MAT) of 2,000 Chinook salmon adults to the Lemhi River. Based on this requirement, life-stage-specific capacity requirements were recalculated consistent with 2,000 adults (MAT) and 2,500 adults (MAT + 25%) using the same methods as above. Those capacity requirements were also compared to estimates of currently available habitat capacity to identify potential habitat limitations if delisting is desired (Table 3). Potential limitations (capacity deficit) were calculated as the life stage-specific capacity requirements needed to achieve a MAT of 2,000 plus a 25 percent buffer minus available capacity.

Table 3. Estimated life stage specific capacity requirements to accommodate ESA delisting and estimated available capacity for Chinook salmon in the Lemhi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	MAT	MAT + 25%		
Escapement	2,000	2,500		
Redd	980	1,225	3,192	0
Eggs	5,184,200	6,480,250		
Summer Parr	1,503,418	1,879,273	357,948	1,521,325
Winter Presmolt	609,140	761,425	173,375	588,049

There appears to be sufficient redd capacity in the Lemhi River to support 2,500 adult Chinook salmon (Table 3). However, the available juvenile rearing capacity during summer (357,948) and winter (173,375) are far from sufficient to support the potential parr and presmolt production from 2,500 adult Chinook salmon (Table 3). Therefore, to achieve delisting of Chinook salmon in the Lemhi River, both summer and winter juvenile rearing capacity would need to be increased.

Summary

There appears to be sufficient spawning (redd) capacity in the Lemhi River to support both current escapement and additional escapement required to achieve delisting criteria for Chinook salmon (

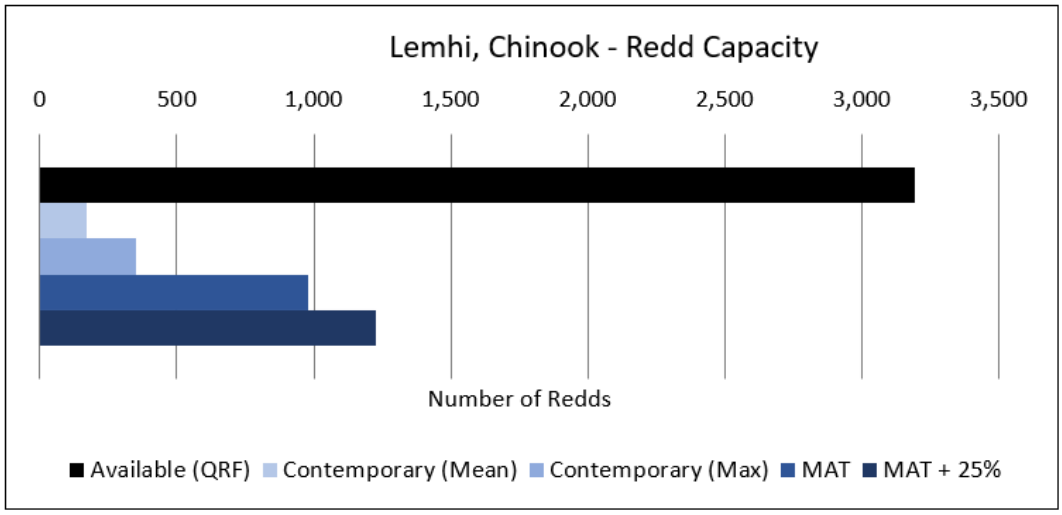
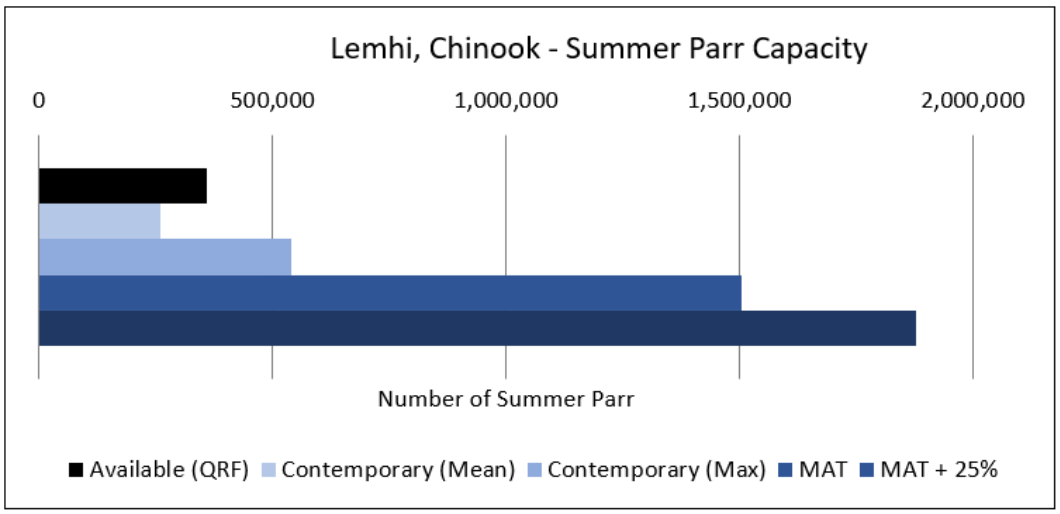


Figure 25). Although available summer and winter juvenile rearing capacity appears sufficient to support recent (2010-2015) mean escapement, juvenile habitat appears to be limiting for recent high escapements and far below juvenile rearing habitat necessary to achieve delisting criteria (NOAA 2017) for Lemhi River Chinook salmon (



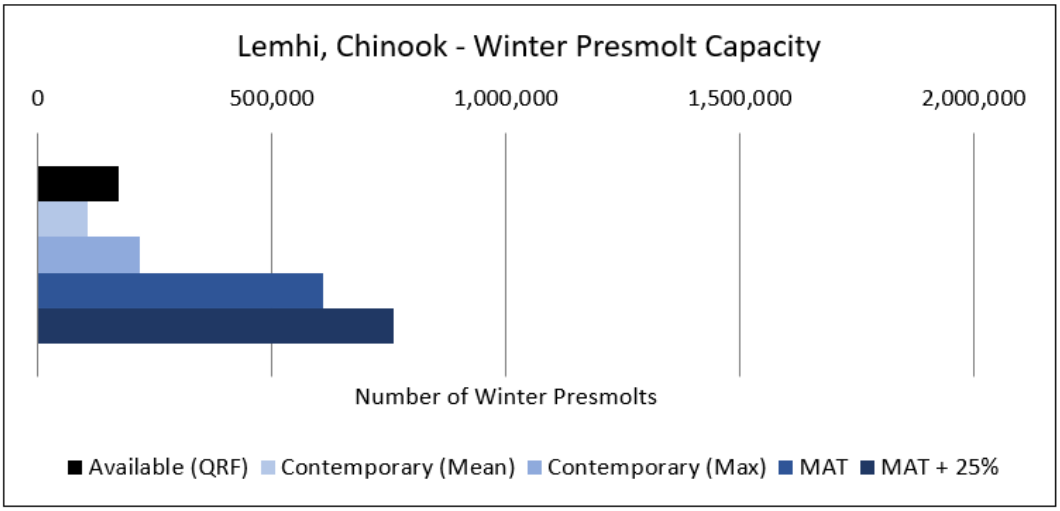


Figure 26 and Figure 27).

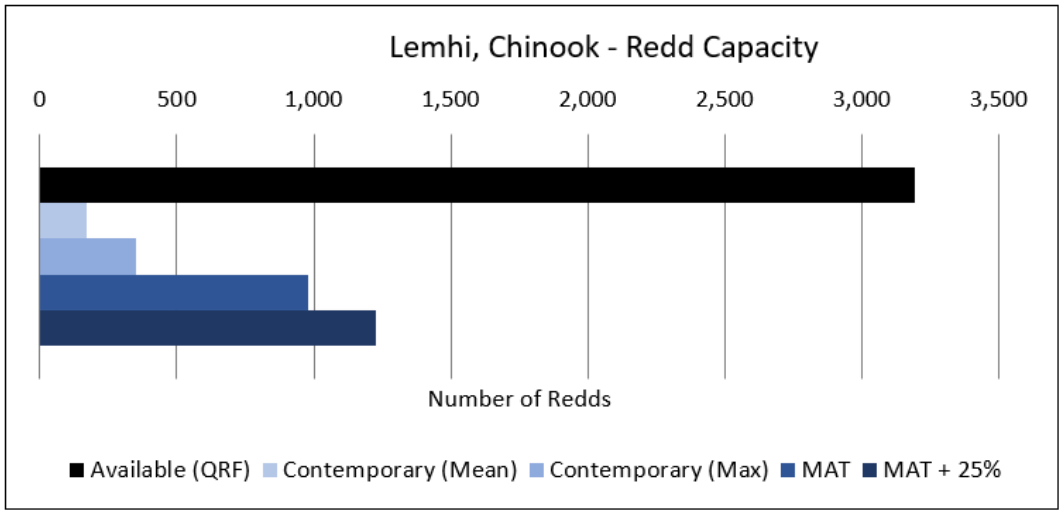


Figure 25. Estimates of available spawning (redd) capacity given current habitat conditions for Chinook salmon in the Lemhi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

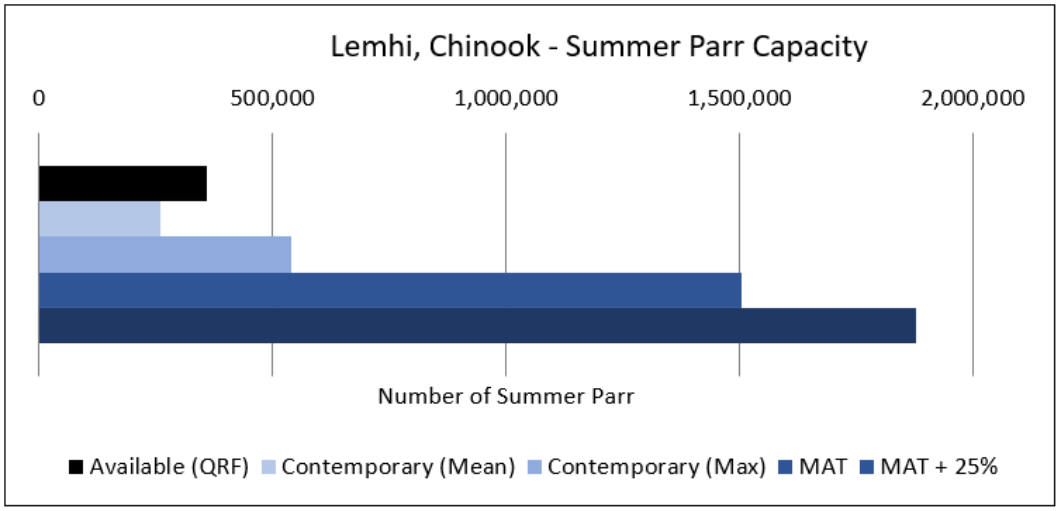


Figure 26. Estimates of available summer juvenile (parr) rearing capacity given current habitat conditions for Chinook salmon in the Lemhi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

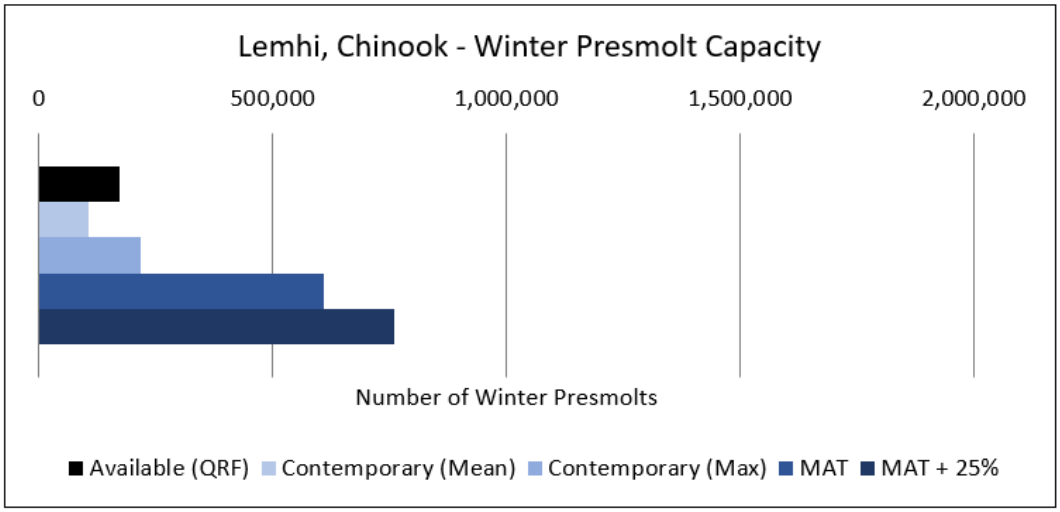


Figure 27. Estimates of available winter juvenile (presmolt) rearing capacity given current habitat conditions for Chinook salmon in the Lemhi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

Bjornn (1971) identified winter habitat capacity limitations in Big Springs Creek (Lemhi River) and confirmed those observations in subsequent experiments in Hayden Creek, the largest tributary to the Lemhi River (Peery and Bjornn 2004). Hillman et al. (1987) likewise observed winter habitat limitations in the Red River (Clearwater River Subbasin) and confirmed those observations by evaluating habitat improvements.

Steelhead

Available habitat capacity estimates from QRF models are considered preliminary for steelhead in the Lemhi River due to unknown spatial extents of available habitat for steelhead spawning and rearing. The IRA team will work with local biologists and experts to more appropriately identify the extents of habitat in the Lemhi River available to steelhead. Available habitat capacity estimates can be improved in future reach assessments or as needed with local groups.

Current Conditions

Using contemporary escapement estimates, available habitat capacity does not appear to limit spawning (redd) or juvenile rearing for steelhead in the Lemhi River under current conditions (Table 4).

Table 4. Estimated current life-stage-specific capacity requirements versus estimated available capacity for steelhead salmon in the Lemhi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	Mean	Max		
Escapement	337	417		
Redd	187	231	3,425	0
Eggs	920,357	1,139,967		
Summer Parr	123,558	153,041	741,594	0
Winter Presmolt	44,311	54,885	583,442	0

Desired Conditions

NOAA (2017) delisting requirements include a minimum annual escapement (i.e., MAT) of 1,000 steelhead adults to the Lemhi River. Based on this requirement, life-stage-specific capacity requirements were recalculated consistent with 1,000 adults (MAT) and 1,250 adults (MAT + 25%) using the same methods as above. Those capacity requirements were also compared to estimates of currently available habitat capacity to identify potential limitations (Table 5). Potential limitations (capacity deficit) were calculated as the life stage-specific capacity requirements needed to achieve a MAT of 1,000 plus a 25 percent buffer minus available capacity.

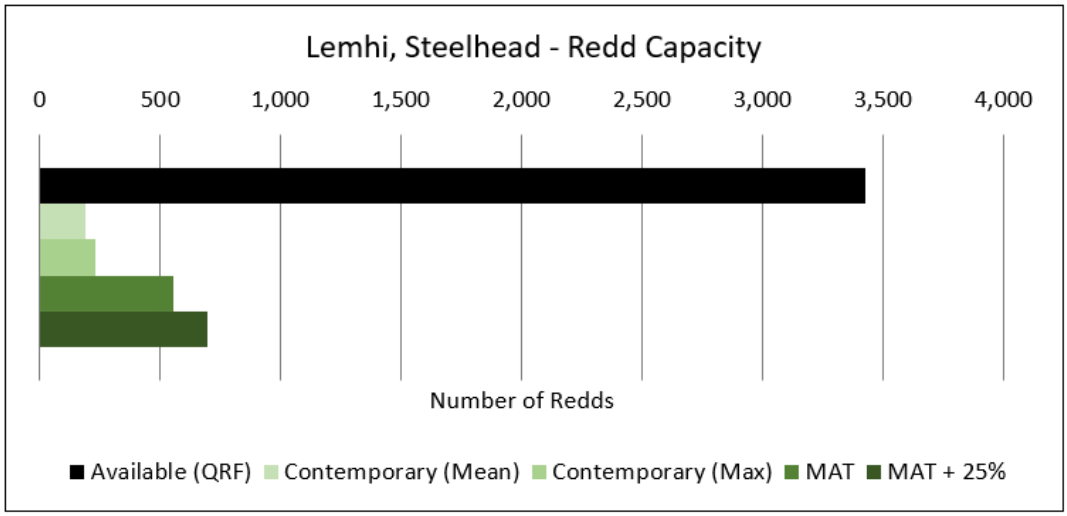
Table 5. Estimate life-stage-specific capacity requirements to accommodate ESA delisting and estimated available capacity for steelhead in the Lemhi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	MAT	MAT + 25%		
Escapement	1,000	1,250		
Redd	555	694	3,425	0
Eggs	2,733,733	3,417,166		
Summer Parr	367,004	458,755	741,594	0
Winter Presmolt	131,618	164,522	583,442	0

There appears to be sufficient redd and juvenile rearing capacity for steelhead to support 1,250 adult steelhead in the Lemhi River (Table 5).

Summary

There appears to be sufficient spawning (redd) and juvenile rearing capacity for steelhead in the Lemhi River to support contemporary escapement and escapement required to achieve delisting criteria for



steelhead (

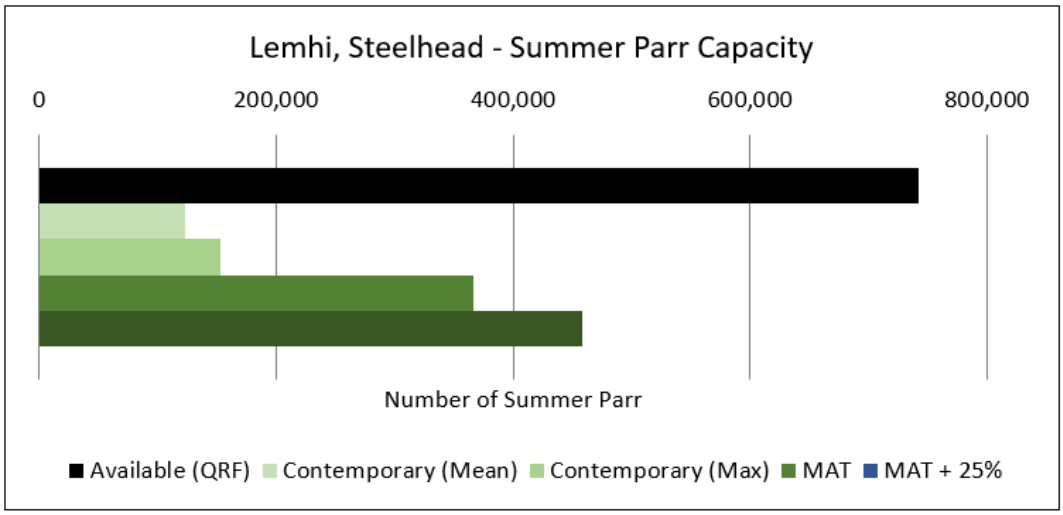
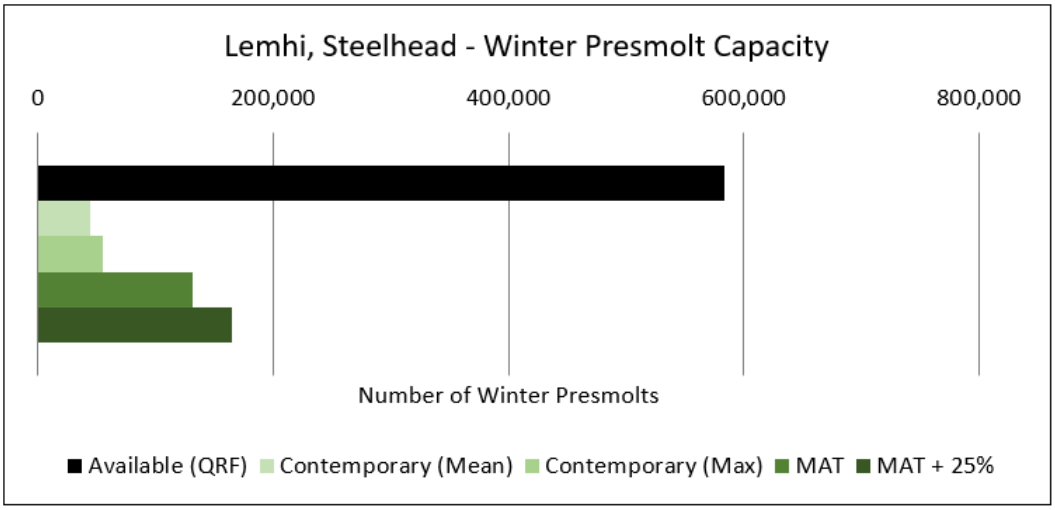


Figure 28,



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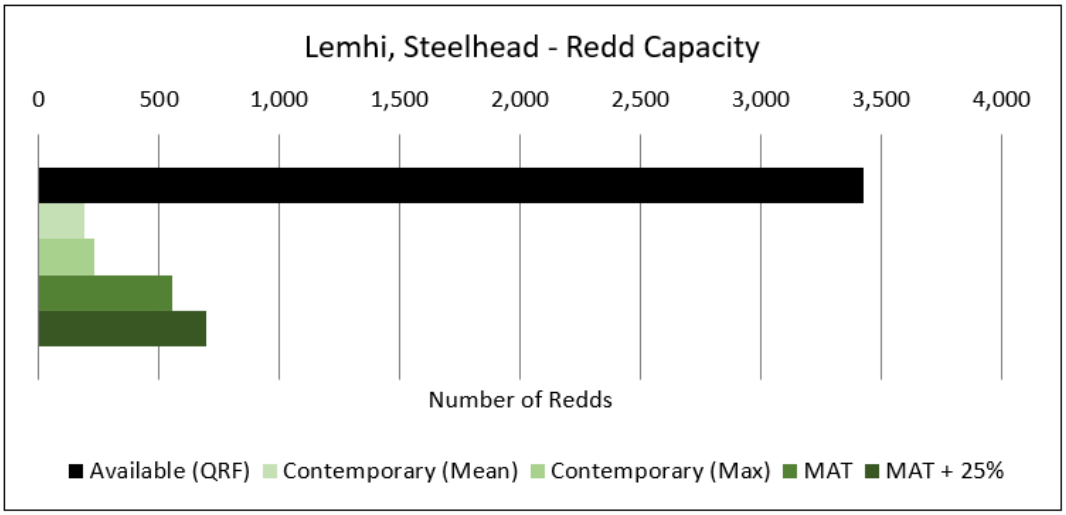

Figure 28. Estimates of available spawning (redd) capacity given current habitat conditions for steelhead in the Lemhi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

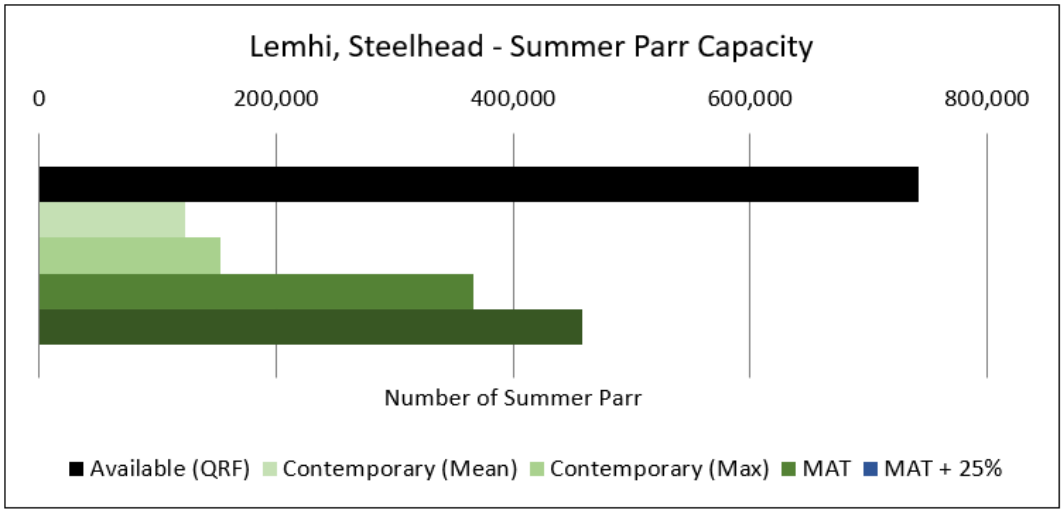

Figure 29. Estimates of available summer juvenile (parr) rearing capacity given current habitat conditions for steelhead in the Lemhi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

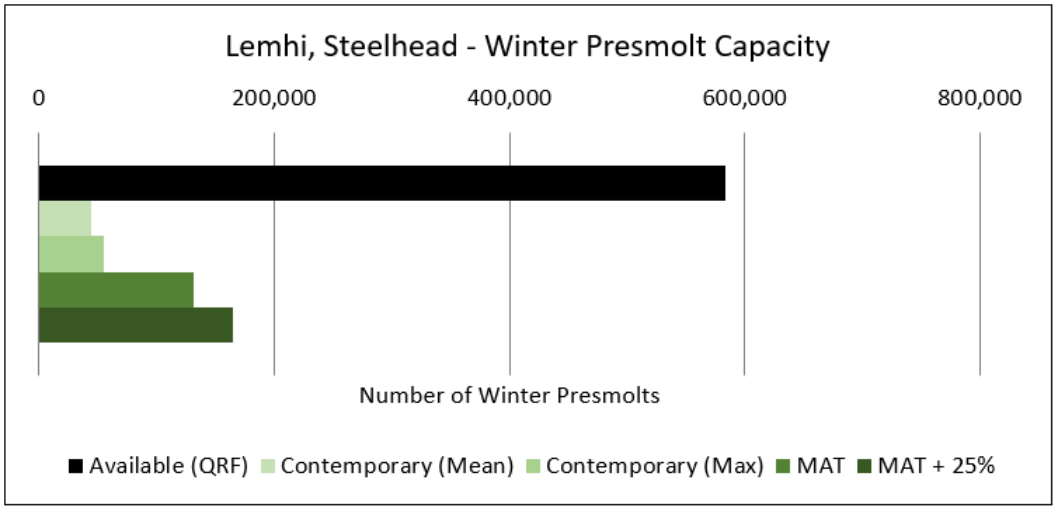

Figure 30. Estimates of available winter juvenile (presmolt) rearing capacity given current habitat conditions for steelhead in the Lemhi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

Geomorphic Assessment

Much of the geomorphic assessment in this report has been compiled in an effort to help paint a better picture of historical and potential target conditions (qualitative), recognizing that detailed (quantitative) target conditions will be generated as part of the MRA for select reaches in the future.

Historical Watershed Conditions

The Lemhi River is located within a northwest-trending valley between the Lemhi Range to the southwest and the Beaverhead Range on the Idaho-Montana border to the northeast. The valley is a block of the northern Rocky Mountain overthrust belt that dropped along basin-and-range normal faults during the past several million years (Link and Janecke 1999). Folded and faulted Precambrian, Paleozoic, and Mesozoic sedimentary rocks are exposed in the mountains on either side of the valley, while the Lemhi Valley itself is composed of deep deposits of valley-fill alluvium accumulated primarily during the warm/dry Pliocene (3 to 5 million years ago; Alt and Hyndman 1989). Beginning with the onset of the cool/moist Pleistocene ice age (2 million years ago), the Lemhi River carved a broad, erosional valley into the thick deposits of alluvium, leaving remnant benches of the original basin-fill surface along the valley margins that persist today.

Thick deposits of unconsolidated alluvium underlain by bedrock permit the presence of an aquifer in the Lemhi basin. A prominent bedrock constriction roughly in the center of the watershed, near the town of Lemhi, Idaho, forces the aquifer to the surface, driving greater groundwater contributions to the system upstream of that point. The bedrock constriction also provides upstream grade control, which has resulted in a lower gradient in the upper half of the valley relative to the lower half. Additionally, the watershed's largest surface-water tributary (Hayden Creek) enters the Lemhi in this area, further differentiating the upper and lower halves of the basin. Largely as a result of differing hydrologic conditions, the upper half of the Lemhi River likely exhibited traits similar to multi-thread, groundwater-influenced systems, while the lower half exhibited traits more similar to single-thread, snowmelt-dominated systems (Figure 31).

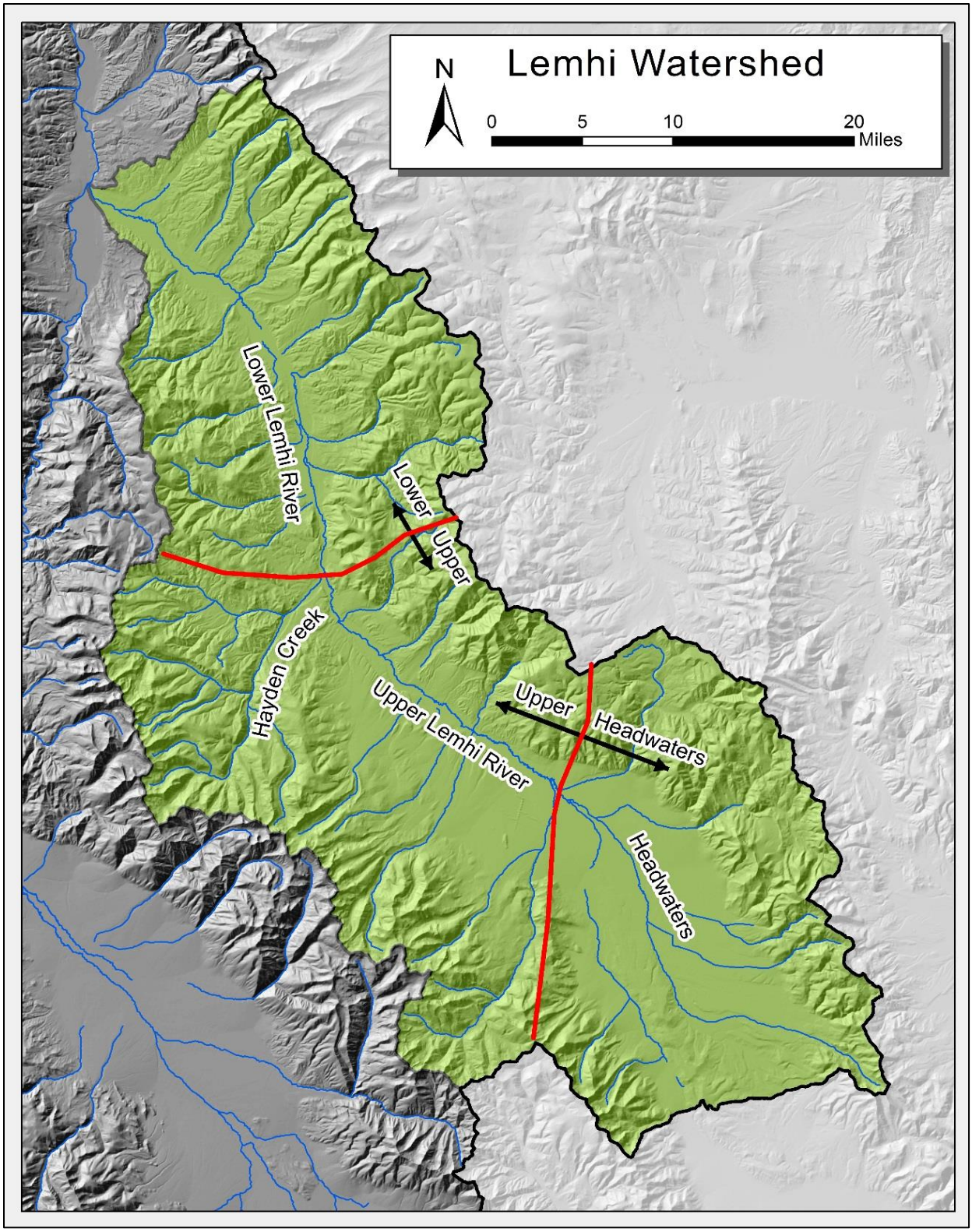

Figure 31. Map showing delineation between the upper and lower Lemhi River.

Historically, the upper Lemhi River (above Hayden Creek) was likely characterized as a fairly stable, multi-threaded (anastomosing), highly sinuous, groundwater-influenced stream with multiple side

channels and spring-fed tributary channels all occupying the same floodplain. Observations of reference analogues from Horse Prairie Creek (Montana) and a lack of obvious meander scrolls visible in recent detailed LiDAR topography suggest the channel migration rates were historically low, and channel response tended toward episodic split flow and avulsion.

Beaver and their associated dams likely had a significant impact on the historical geomorphology of the upper Lemhi River. Modern bank exposures reveal 4 to 5 feet of silt and clay sediment overlying coarse gravel and cobble. The extent, depth, and continuity of the fine sediment suggest that widespread slack-water conditions (e.g., beaver dam-influenced wetlands) persisted for long periods of time throughout the valley bottom. The lack of coarse sand and gravel layers in bank exposures suggests that sediment from episodic debris flows and/or catastrophic events were attenuated or arrested at the valley margin, further supporting a broad slack-water environment spanning the majority of the valley bottom. Trapper journals (Ferris 1830-1835) also noted large numbers of beavers, documenting the capture of 50 to 60 beavers per day in the vicinity of the Lemhi River.

Historical riparian conditions in the upper Lemhi River likely reflected a consistent groundwater-influenced hydrology and associated high water table punctuated by periods of extended flooding associated with beaver activity. Relic topographic variation from occasional avulsions, beaver dams, and disturbance from grazing animals (bison, elk, and deer) likely created a mosaic of open water, emergent wetland, floodplain, and upland. The riparian community would have mirrored this diversity with areas of wetland meadow (rushes and sedges), floodplain shrubs (willow) and upland vegetation (sagebrush and grass). Most riparian vegetation had to tolerate fine, poorly draining soils and extended periods of submergence. Few sporadic stands of cottonwood or aspen trees may have established on well-draining soils, particularly near the mouths of snowmelt-dominated tributaries that could occasionally produce the disturbance (i.e., sand and gravel deposition) required for germination and establishment. The lack of coarse sediment inputs to the channel likely severely limited rates of point bar development and channel migration, suggesting the banks were fairly stable and able to maintain mature vegetation.

The lower Lemhi River below Hayden Creek has a slightly steeper gradient, a more snowmelt/surface-flow-dominated hydrology, and greater coarse sediment availability from large tributaries compared to the upper Lemhi River. The historical lower Lemhi River was likely dominated by a single-thread channel with a seasonally active floodplain; localized areas of island braiding were unconfined and in association with in-channel obstructions (i.e., log jams and stands of dense riparian vegetation).

The more-pronounced snowmelt-dominated hydrograph and greater coarse sediment inputs enabled significant portions of the lower Lemhi River to migrate on a year-to-year basis, punctuated by episodic avulsions. From the 2016 Upper Lemhi Riparian Management Plan (Cardno 2016):

> *Although there are no known measurements of channel geometry prior to large-scale settlement and disturbance, there are several anecdotal accounts of the river's form from historic journals and maps as well as ancient channel scars visible on the floodplain from detailed LiDAR topography. From the journals of W. A. Ferris (1830-1835), the lower Lemhi River is described as "forty paces wide, bordered with willows, and birch, and aspen, and flows norwestward fifty miles to Salmon River." It is likely that stream crossings occurred at unobstructed riffles where the water was shallow and wide and the riparian vegetation was limited, suggesting the widest portion of the channel may have been upwards of 80-100-feet on the lower river. Identification of the "principal stream" by W. A. Ferris (1830-1835) also suggests a primary channel with side channels. A true multi-threaded (anabranching) stream does not have a principal thread, while a single-threaded stream with no side channels would not warrant mention of the "principal"*

stream, which implies multiple branches. Additionally, maps from Lewis and Clark (1805) show a single-threaded stream with areas of multiple side channels and many tributaries flowing through the valley bottom further supporting this characterization (Figure 32).

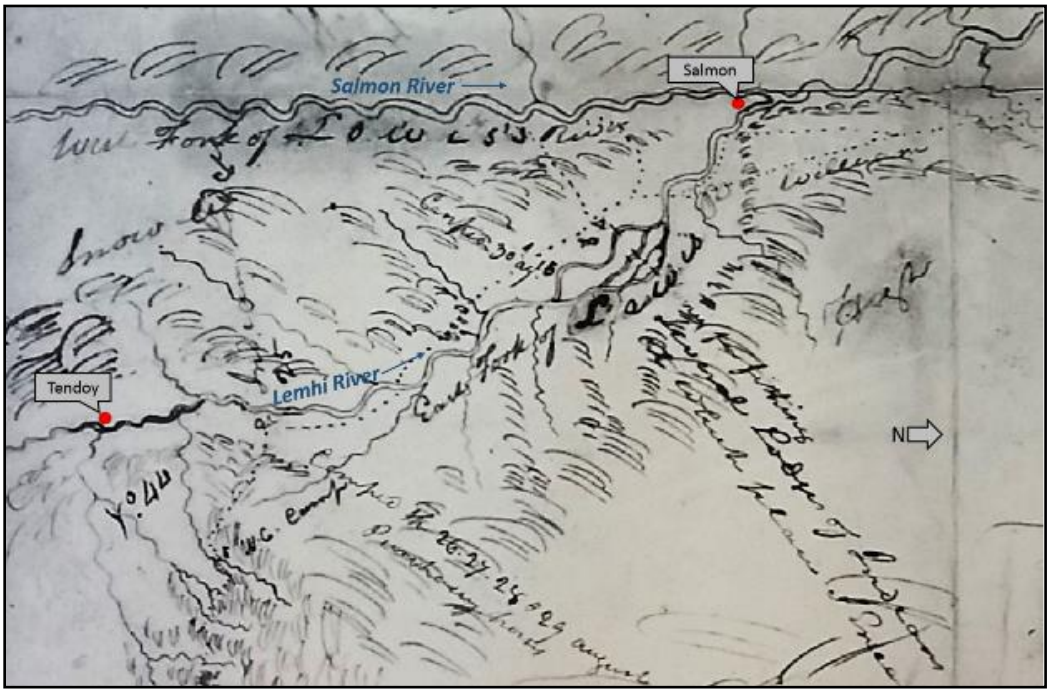

Figure 32. Lewis and Clark map (Moulton 1983) illustrating the lower Lemhi River (called the East Fork of the Lewis River by Lewis and Clark). The modern towns of Tendoy and Salmon are shown for reference.

Although the upper Lemhi River banks were likely somewhat more stable than the lower Lemhi River due to the fairly flat, groundwater-influenced hydrograph and lack of coarse sediment input, both the upper and lower Lemhi were historically characterized by stable banks and a low width-to-depth ratio enabled by dense riparian vegetation (willow shrubs and/or cottonwood) and a low gradient. Mature riparian vegetation provided bank structure along the outside of bends, forcing flow convergence that created pools with associated tail-out riffles. The lack of observed buried wood in bank exposures on the upper Lemhi River and likely beaver-dam-influenced wetland conditions suggest little to no large woody material likely recruited historically in the upper valley. The flashier hydrology and increased coarse sediment load in the lower valley likely created a disturbance regime more suitable for the establishment and propagation of cottonwood and aspen trees, in addition to willows and other shrubs. It is likely that large woody material has been recruited to the lower Lemhi River via local windfall for thousands of years. Large floods and debris torrents from tributaries may have transported large wood from the uplands episodically, but research suggests that wood is unlikely to transport through such small streams with low channel width and meander radius of curvature (Braudrick and Grant 2001). Hayden Creek is likely the only tributary large enough to have consistently transported large woody material to the Lemhi River.

Prior to Euro-American settlement, the Lemhi region was most likely inhabited by a group of Northern Shoshone known as the *Tu'kudeka*,or Sheepeaters, who lived in the area (Rossillon 1980). Reports from Lewis and Clark suggest their impacts on the land were primarily confined to their encampments, where tribes from the region would congregate and trade their goods. Lewis and Clark also reported on the abundance of fur-bearing animals west of the divide, which spurred the business of fur trade. Independent fur trappers, as well as several companies (including the Hudson Bay Company and the American Fur

Company) made their way into the northwest to explore and exploit the region. By the early 1840s, local beaver populations were brought to the brink of extinction and the bison had disappeared from the Salmon River region (Albers et al. 1998).

The discovery of gold in California in 1848 began a western mining craze, leading to an influx of prospectors into Idaho and the discovery of gold there. Mining in the area consisted of placer mining along some tributaries and some hard-rock mining. Miners and other settlers were interested in acquiring the Shoshone Tribe's lands and waterways to support their growing agrarian and mining enterprises, and homesteads sprang up across the lower-elevation lands (Albers et al. 1998). Timber was an important commodity during this time, as lumber and poles were needed for building construction and livestock fencing. Timber harvests and associated management activities affected the watershed during this time and led to increased runoff, erosion, and sedimentation in many of the tributaries that discharge into the Lemhi River.

Beginning in the 1880s, irrigation development and associated water rights were established in the mainstem Lemhi and tributaries (ISCC 1995). Irrigation ditches withdrew water from the river and distributed it across the floodplain. In the mid-1900s, significant stream channeling and straightening was undertaken by the state highway department and local ranchers, which together altered roughly 21 percent of the channel length (Gebhards 1958). Between 1908 and 1954, Idaho Power operated a roughly 6-foot-tall diversion dam that spanned the lower Lemhi River about 1 mile upstream of its confluence with the Salmon River (Figure 33). Historical fisheries reports are unclear regarding the passage of fish at the dam, but they suggest that upstream, adult fish passage must have been possible during high water, "otherwise the salmon run would surely have been eliminated" (Gebhards 1959). The dam likely affected fish migration and impounded sediment. In 1959, approximately 5 percent of the flow (15 cubic feet per second (cfs)) was being discharged at the mouth of the river, while 95 percent (312 cfs) was diverted into the power plant (Gebhards 1959). Anecdotal accounts suggest the lower river was completely dry in other years.

Figure 33. Idaho Power diversion dam on the lower Lemhi River (Source: Oregon State University, downloaded March 14, 2017, from https://oregondigital.org/sets/streamsurvey/oregondigital:df66q392q)

Presently, livestock grazing is the predominant land use activity that occurs on both private and public lands within the Lemhi valley. Grazing on Federal lands provides nearly 30 percent of the feed base for cattle in the Lemhi River watershed (ISCC 1995). Generally, cattle are grazed on higher-elevation Federal lands from May to October and then return to private lands in the valley for the remainder of the year (ISCC 1995). Historical grazing practices resulted in riparian vegetation clearing and associated streambank destabilization, as well as increased surface-water runoff and erosion (Photograph 19).

Photograph 19. Hummocks observed on the floodplain of the upper Lemhi River reveal 2 to 3 feet of fine sediment erosion (area between hummocks) associated with historic cattle grazing. Similar hummocks are common throughout large areas of the Lemhi River floodplain.

Existing Watershed Conditions

Hydrology/floods

The Lemhi River flow regime is predominantly snowmelt-dominated, with numerous diversions that are in operation from April through September. While diversion locations and volumes are regulated, exact withdrawal rates on a seasonal and daily basis are unknown. Groundwater is another important component of the Lemhi River water budget. Groundwater levels are highest from May to September due to snowmelt and irrigation. A natural constriction occurs between river miles (RM) 34 and 25 that divides the upper and lower regions of the basin. Flood-frequency peaks were estimated at two U.S. Geological Survey (USGS) gages and two Idaho Department of Water Resources (IDWR) gages using the PeakFQ program, and at 23 ungaged locations, applying a drainage area ratio (Table 6).

Table 6. Summary of Lemhi River hydrology.

River Mile	Drainage Area (mi^2)	Valley Segment	Estimated Flood-Frequency Values (cfs)						
			1.5	2	5	10	25	50	100
0.1	1,260	4	912	1,223	2,059	2,638	3,371	3,913	4,444
19.1	1,055	3	771	1,018	1,670	2,113	2,666	3,069	3,462
32.7	733	2	463	586	892	1,089	1,326	1,494	1,654
60.4	470	1	197	228	257	292	331	357	381

Irrigation Use and Natural Hydrograph Shape

During the growing season, there are numerous diversions throughout the basin that remove surface water for irrigation. The volume of water removed from the Lemhi during the irrigation season (groundwater and surface water) can impact the peak flow hydrograph, potentially altering the hydrologic regime. Streamflow data from the IDWR gage at Cottom Lane from a heavy-snowpack year (2010) was compared with streamflow data from a low-snowpack year (2014) to assess the variation in the hydrograph at this location. It was assumed that irrigation starts around the beginning of May and ends near the beginning of October upstream of this location. The hydrographs for these 2 years were assessed to estimate the base flow through the irrigation season with and without irrigation. The difference between these two base flows is the approximate loss due to irrigation withdrawals, as seen in Figure 34. This difference for each day was added back into the recorded daily average flow hydrograph to approximate what a natural hydrograph may have resembled without irrigation. The overall shape of the hydrograph doesn't change, but the peak magnitude and the rising and falling limbs of the hydrograph increase, as seen in Figure 35 and Figure 36 for a dry and wet year, respectively.

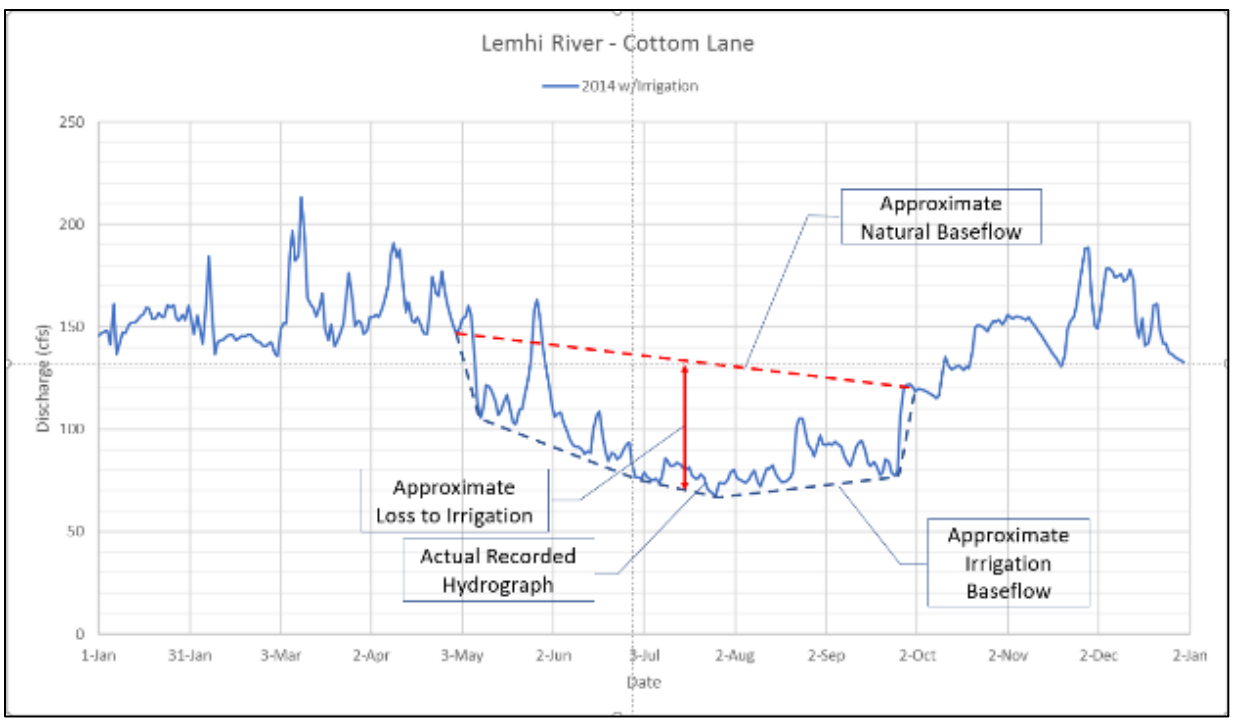

Figure 34. Estimation of discharge lost to irrigation.

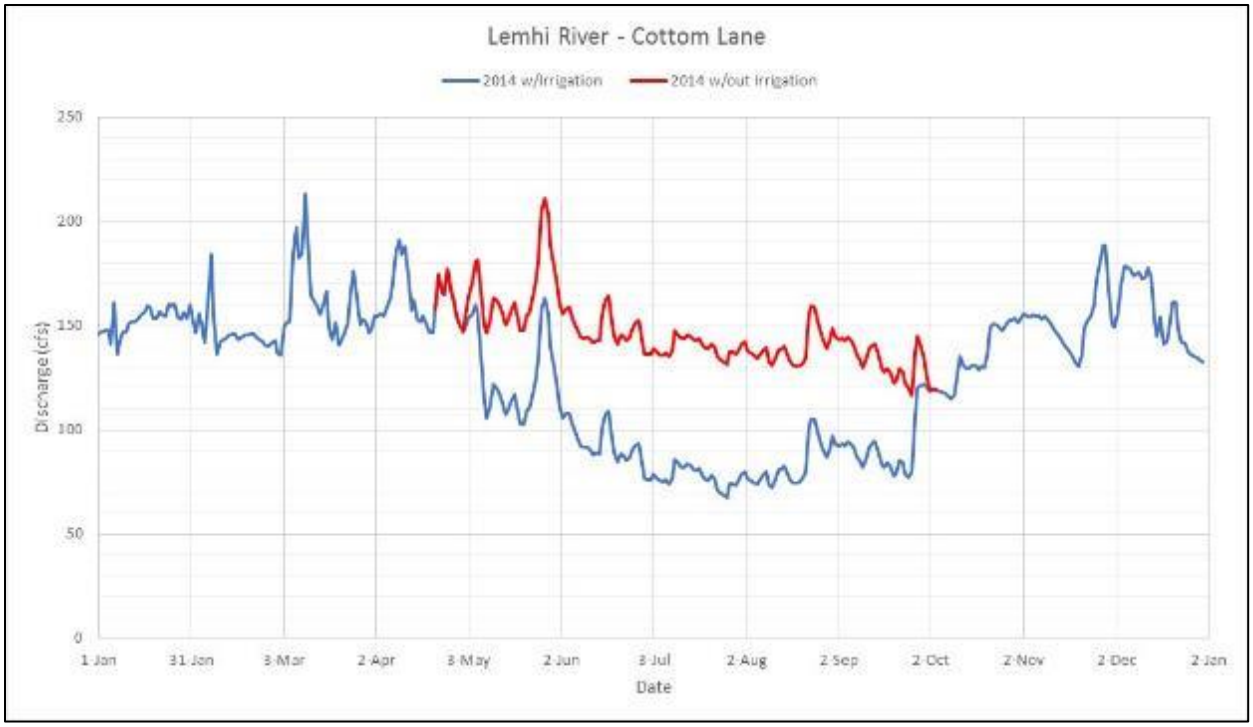

Figure 35. Comparison of actual and natural hydrographs for a dry year on the Lemhi River at Cottom Lane.

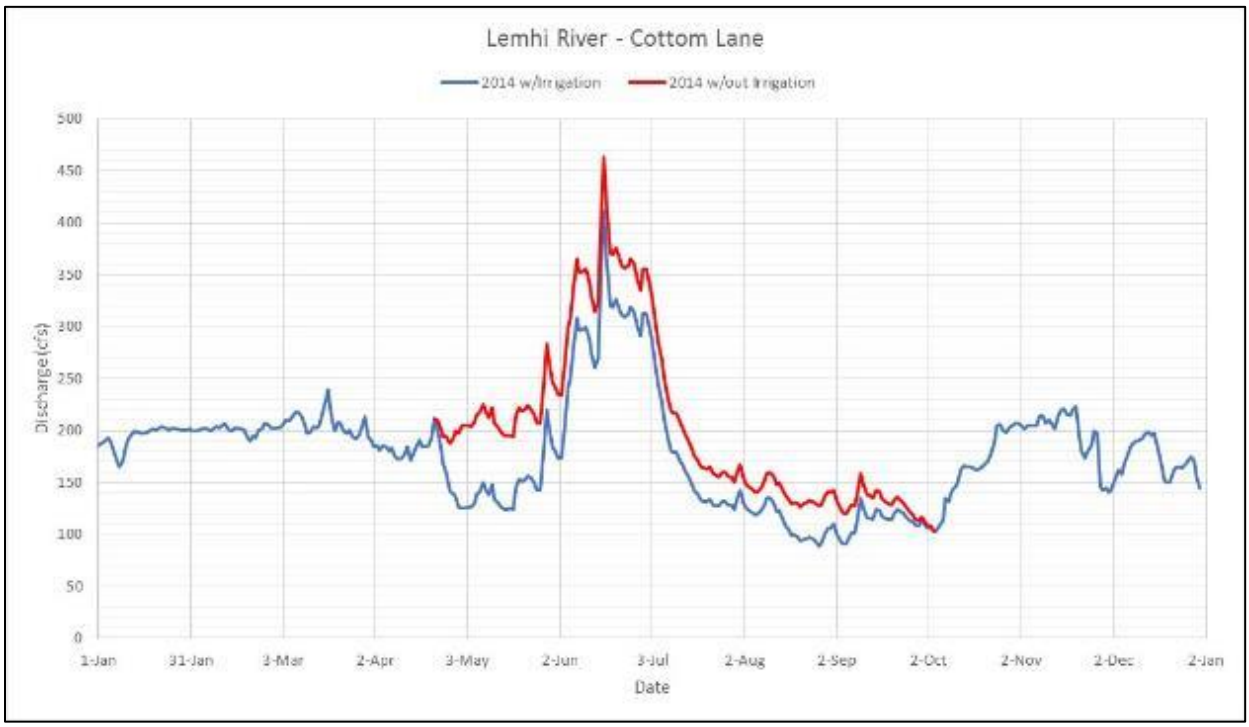

Figure 36. Comparison of actual and natural hydrographs for a wet year on the Lemhi River at Cottom Lane.

This procedure can be refined and completed at all the gages on the Lemhi River or other tributary of interest to develop a theoretical natural flow hydrograph. This can inform water users and regulators of

the significance and timing of flushing flows. Irrigation users often begin to divert water earlier in the season during high-flow years, and this could affect the baseflow timing. These variations should be accounted for in future analyses to more accurately estimate the irrigation withdrawals.

Surface and Groundwater Interactions

In the Lemhi River, water consumption is primarily for agricultural and domestic purposes. More than 70 diversions direct water from the Lemhi River and its tributaries to irrigate about 90,000 acres of cropland and to water livestock. The irrigation season starts in early spring and continues through early fall. Much of the diverted water for irrigation returns to the Lemhi River by surface and groundwater flows. The highest measured streamflow in the Lemhi River is from late spring through mid-summer and usually peaks in early June, when the mountain snowmelt occurs. The lowest streamflow generally is in the fall.

Most of the Lemhi River typically gains discharge from groundwater in early August, during the peak of the irrigation season, with the greatest volume of gains in the areas near the towns of Leadore (RM 60), Tendoy (RM 25), and Salmon (RM 1) (Figure 37 and Figure 38; Donato 1998; IDWR 2017). Groundwater contributions to the Lemhi River decrease after the irrigation season in almost all locations, except near RM 11 and RM 34, where groundwater discharge increases slightly, and near Leadore (RM 60), where groundwater discharge remain relatively unchanged.

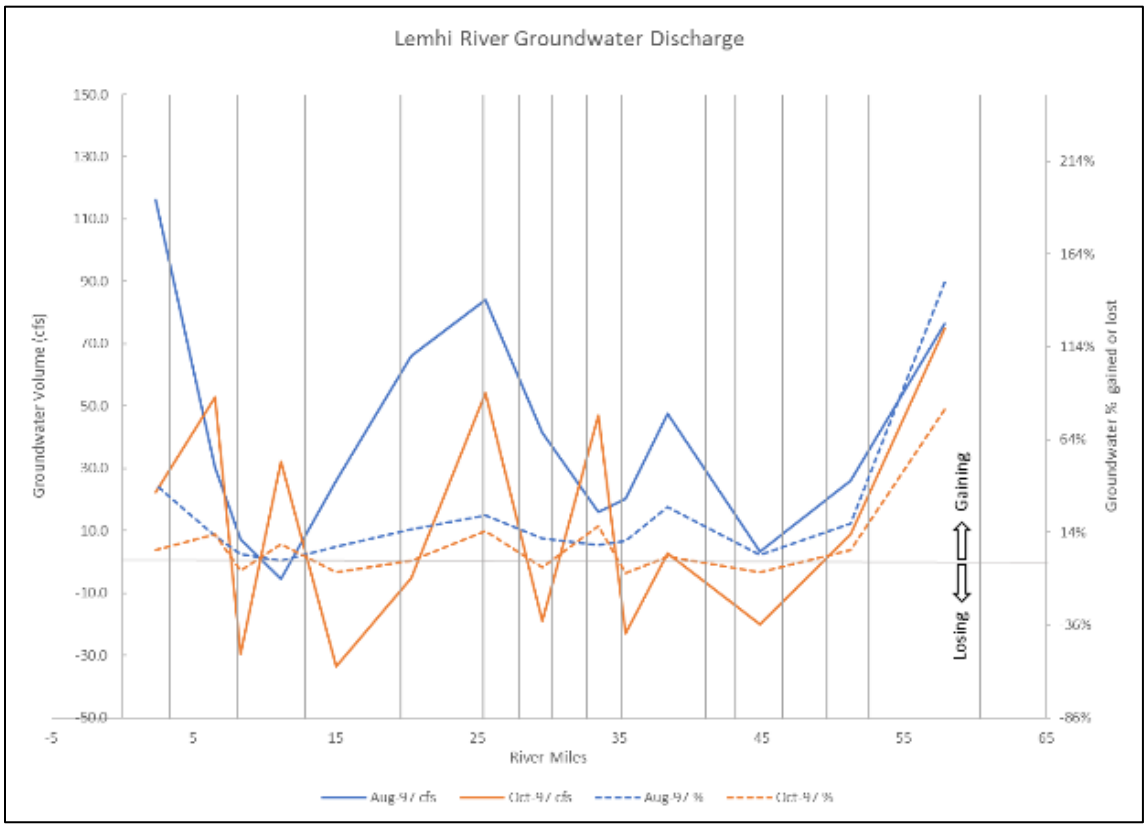

Figure 37. 1997 Lemhi River groundwater discharge graph, illustrating groundwater volume (solid lines) and percent of total discharge (dashed lines) for August during the peak of irrigation (blue lines) and October after irrigation season (orange lines) (interpreted from Donato 1998).

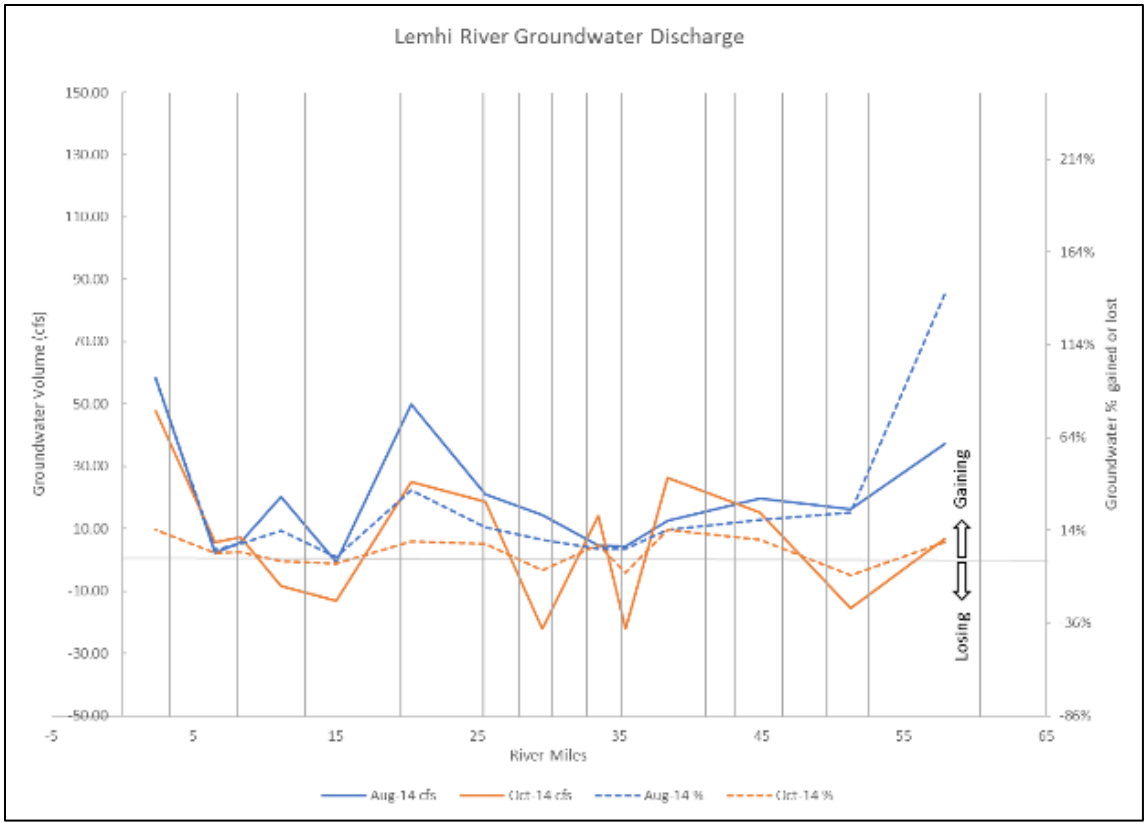

Figure 38. 2014 Lemhi River groundwater discharge graph illustrating groundwater volume (solid lines) and percent of total discharge (dashed lines) for August during the peak of irrigation (blue lines) and October after irrigation season (orange lines) (interpreted from IDWR 2017).

Hydraulics

Coarse, at-a-station hydraulic analyses were completed from three representative locations within the watershed to provide context for the geomorphic conditions discussed below. More-detailed two-dimensional hydraulic modeling will be completed as part of the future MRA process for select reaches. Three typical cross-sections located throughout the Lemhi River watershed were measured and evaluated to assess representative existing hydraulic characteristics and to determine if any generalizations can be inferred from these calculations. Cross-sections were measured at RM 60.4 (Valley Segment 2, Geomorphic Reach 2, Figure 39), RM 35.9 (Valley Segment 2, Geomorphic Reach 7, Figure 40), and RM 9.8 (Valley Segment 4, Geomorphic Reach 14, Figure 41).

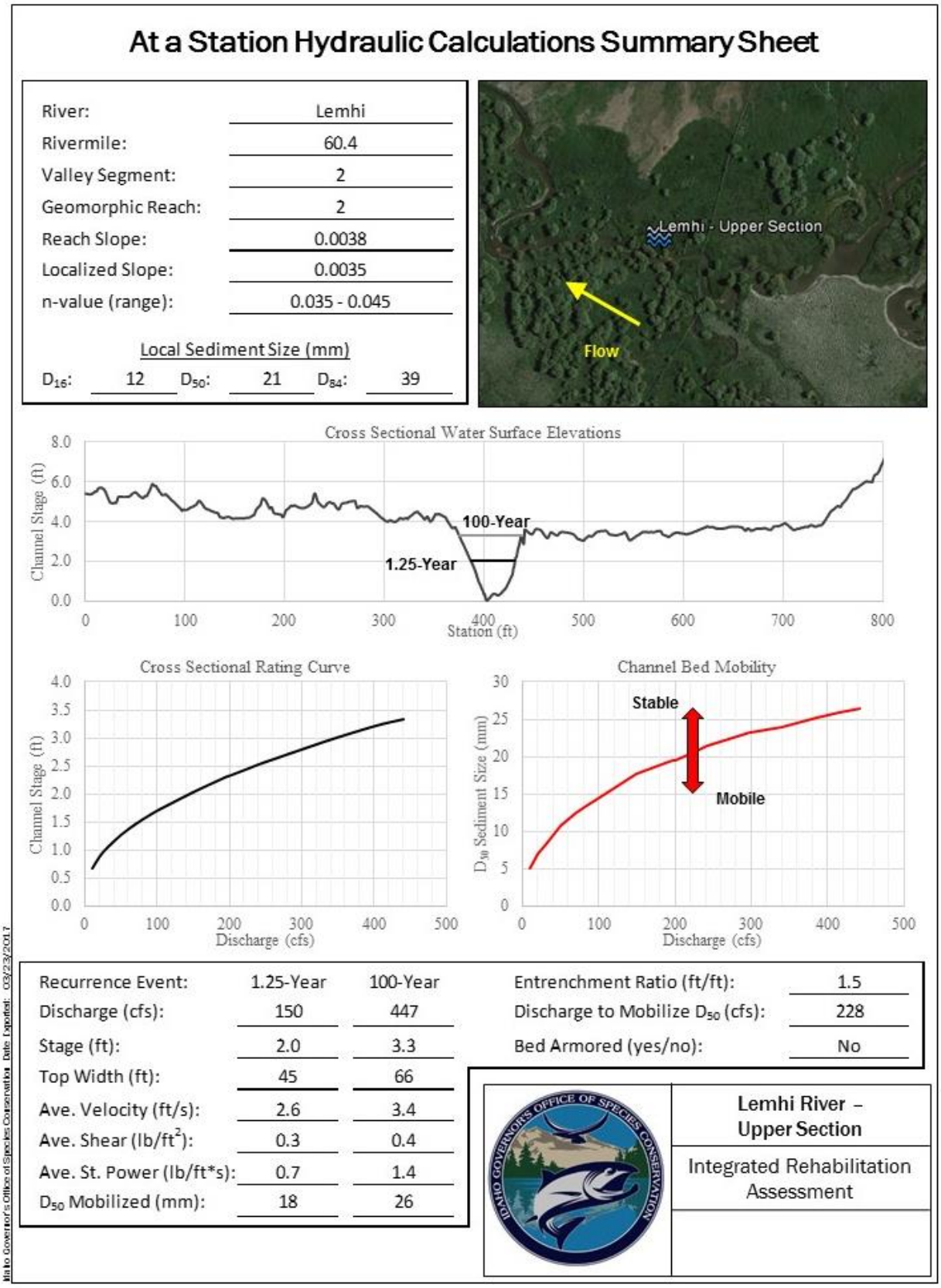

Figure 39. Summary of representative hydraulic conditions at Site 1.

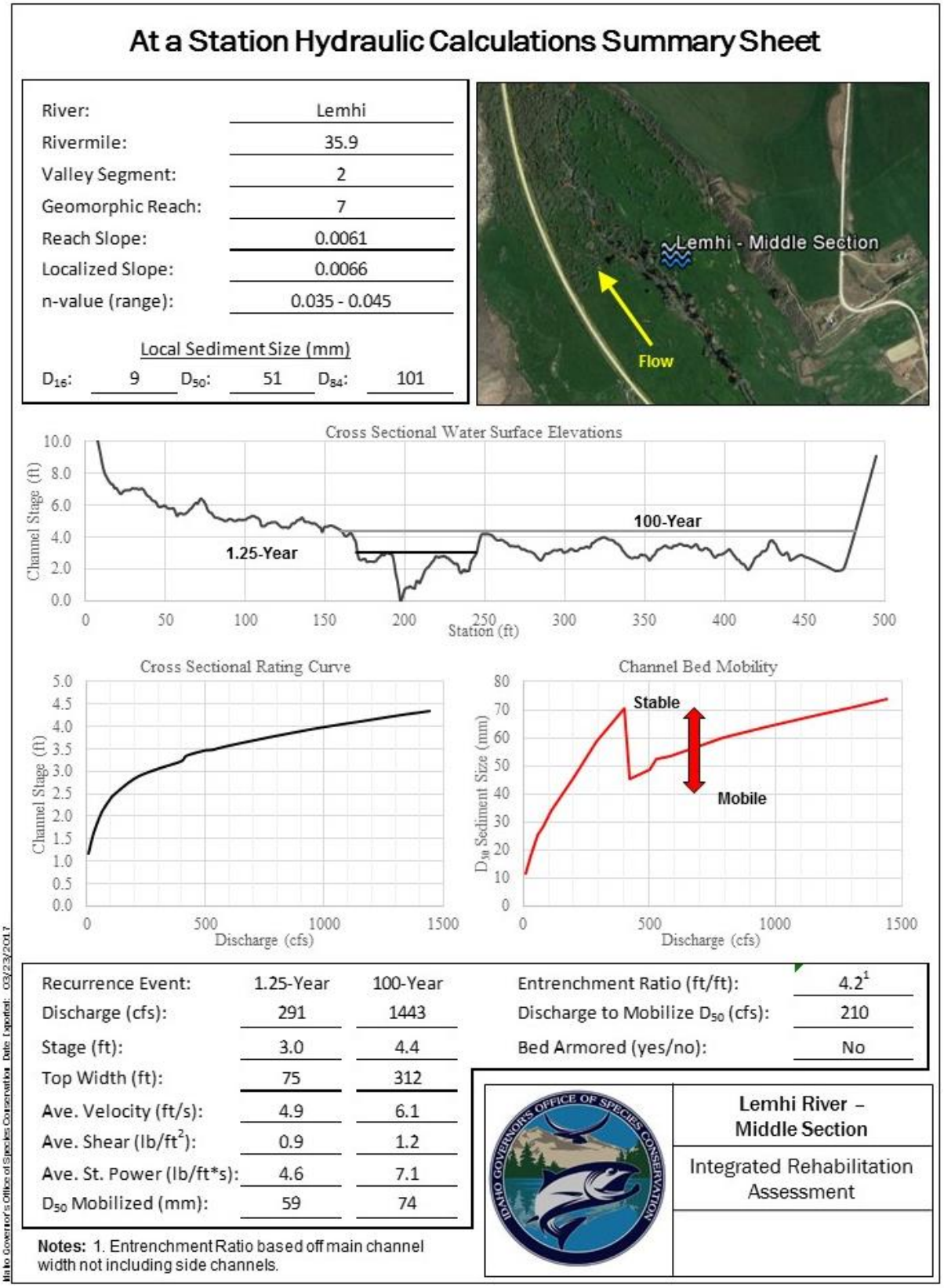

Figure 40. Summary of representative hydraulic conditions at Site 2.

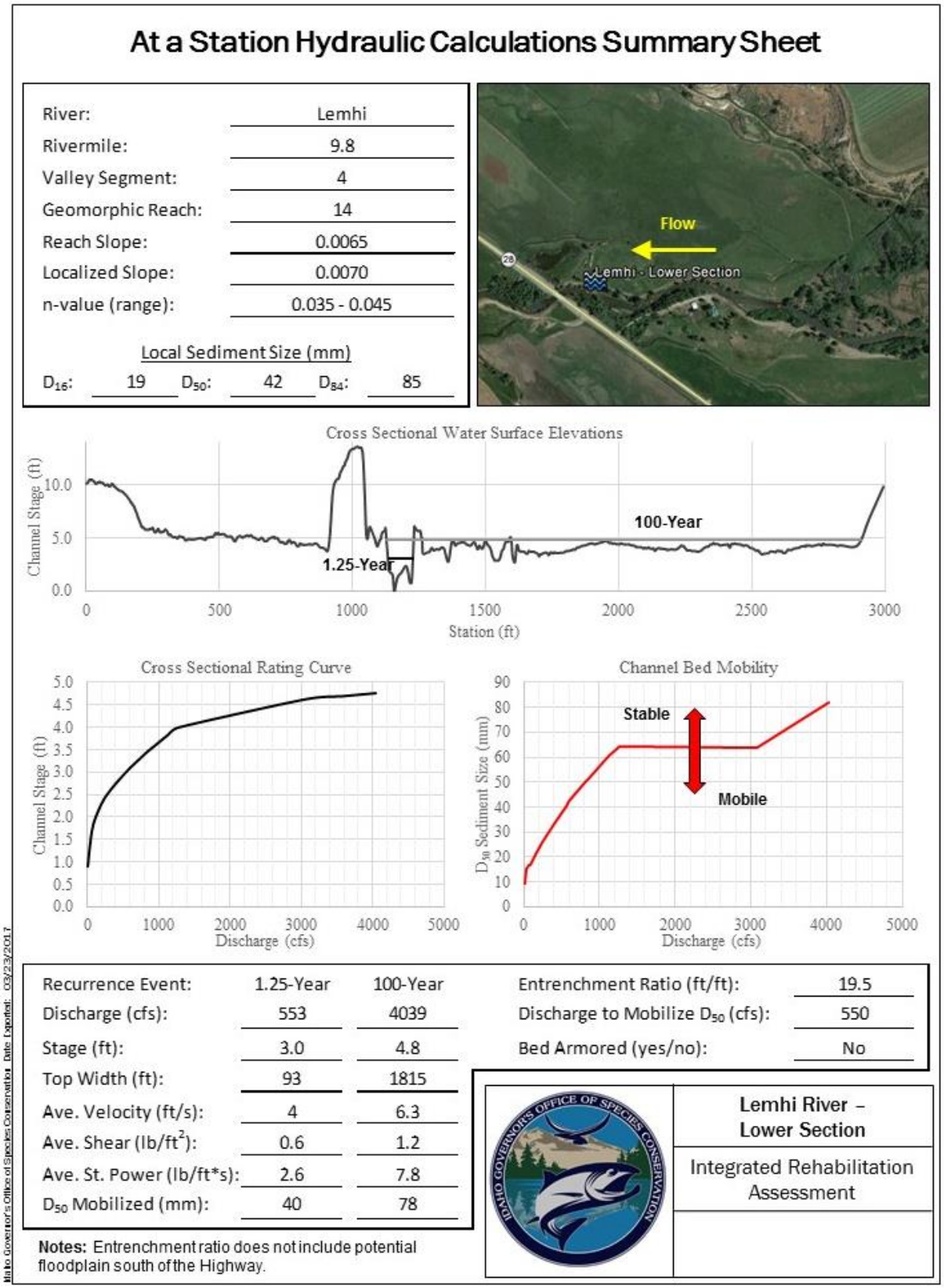

Figure 41. Summary of representative hydraulic conditions at Site 3.

In the groundwater-influenced flow regime of the upper Lemhi River, there is less variation from the 1.25 to the 100-year discharge, which results in a lower entrenchment ratio (1.5). The section modeled shows the 100-year discharge contained primarily within the main channel banks. The sediment size was showing bed mobilization beginning near the 2-year event, which allows the channel to scour and maintain pools. Fine-grained sediment filling interstitial space between larger clasts (embeddedness) may limit bedload mobilization. Channel velocities varied from 2.5 feet per second at the 1.25-year up to 3.5 feet per second at the 100-year event. Shear stresses also had minor variation from 0.3 to 0.4 lb/ft^2 between these two events. The groundwater-dominated hydrology results in fairly uniform and consistent flow patterns through this section.

The middle section is located a short distance upstream of Hayden Creek and is located at the beginning of a gaining reach. There are much larger variations in flow differences between the 1.25-year and 100-year discharge at this location compared to the upper Lemhi River. The channel geometry is such that the 1.25-year event is slightly out of bank and the 100-year event accesses a good portion of its floodplain, which increases the entrenchment ratio to approximately 4.2, assuming that the floodplain actively conveys flow downstream. Local sediment sizes suggest that the bed may begin to mobilize near 200 cfs, which is less than the 1.25-year event, although sediment embeddedness may limit actual bedload mobilization. Channel velocities range from 5 ft/sec. to upwards of 6 ft/sec. Depending on how and when the channel accesses a large portion of its floodplain at this section, there is a lot potential variation in flood hydraulics, and further study would be required to assess those characteristics.

The lower section is located upstream of an existing crossing of Highway 28 and is in the snowmelt-dominated segment of the Lemhi River. The main channel is partially channelized, with discontinuous levees or high ground on each river bank. Assuming that the levees are ineffective at holding back flood flows, the 100-year discharge extends across the valley floor, creating a high entrenchment ratio of 19.5. Channel velocities range between 4 and 6.5 ft/sec for the 1.25- and 100-year discharge events, respectively. Shear stresses vary from 0.6 up to 1.2 lb/ft^2 for the same two flow events. The channel appears to be unarmored through this section of river, beginning to mobilize the D_{50} near the 1.25-year event. Sediment embeddedness may limit bedload mobilization. (Note: the highway cuts off a portion of the accessible floodplain at this location and throughout significant portions of the Lemhi River valley.)

General trends observed between these three cross-sections are that the floodplain becomes more accessible to flood waters in downstream reaches, assuming levees cannot contain all flow. While this is largely due to the gradual shift from groundwater-dominated to snowmelt-dominated hydrology, this trend could be exacerbated by channel widening in the upper region and channelization through the lower region. Incipient motion calculations suggest that the channel bed appears not to be heavily armored and becomes mobilized on a regular basis. To the contrary, field observations, including a lack of gravel bars and vegetative growth on bed material, suggest bedload mobilization does not occur as frequently as the incipient motion calculations predict. This suggests that the bed material is embedded with sand and silt, reducing mobilization frequency. It is likely that areas of flow constriction (outside of bends or adjacent instream structure) exhibit sufficient additional shear stress to overcome the embedded condition of the substrate to develop or create self-sustaining pools and sort of gravels on a regular basis.

A stream power assessment was also completed to investigate the potential sediment transport capacity of each geomorphic reach. Stream power is a function of discharge and slope but does not incorporate channel geometry (i.e., width), which is important in understanding where deposition and scour are likely to occur. More-refined sediment transport analyses will be possible with refined reach-scale analyses that incorporate detailed hydraulic modeling. Results of the stream power analysis show that stream power

was primarily dependent on the discharge input; thus, overall stream power increased in the downstream direction with increasing peak discharge.

Basin Geometry

Domains within a watershed can be characterized as zones that are governed by sediment supply, alluvial fan formation, sediment transfer, or deposition (Figure 42). The headwaters streams of the Lemhi River basin are generally classified as sediment supply zones, dominated by weathering and erosion of steep slopes, where tributaries collect and transport sediment downslope to the alluvial fan zone. The alluvial fan zone is where coarse sediment has accumulated across broad alluvial fans and piedmont belts, creating terraces along the valley margins. Here, the basin-fill sediments are porous, and the river commonly loses surface water to the aquifer. Unlike most streams, the Lemhi River exhibits a pronounced deposition zone below the alluvial fan zone before entering a sediment transfer zone.

Below the alluvial fan zone, tributaries flow across the broad, low-gradient valley bottom, where they are unable to transport coarse sediment, creating a pronounced deposition zone characterized by fine sediment and a highly sinuous, multi-threaded channel. A longitudinal profile of the channel from Leadore near RM 63 to Salmon at RM 0 shows a convex profile, with the lowest gradient near Leadore and a generally increasing slope in the downstream direction (

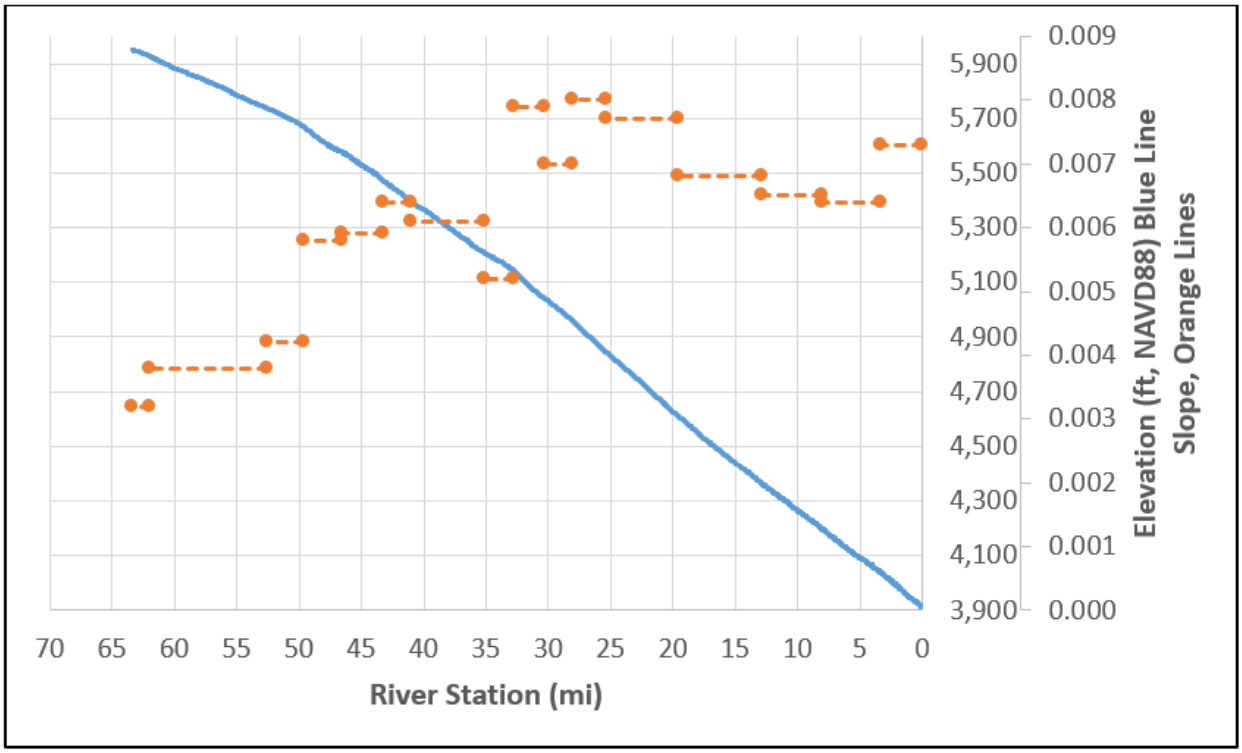

Figure 43). These conditions are the result of a prominent mid-valley grade control associated with shallow bedrock near the confluence of Hayden Creek (RM 32.9). The combination of a low gradient and a broad valley promotes coarse sediment deposition on the valley margins in the alluvial fan zone, and fine sediment deposition in the broad floodplain of the deposition zone upstream of Hayden Creek.

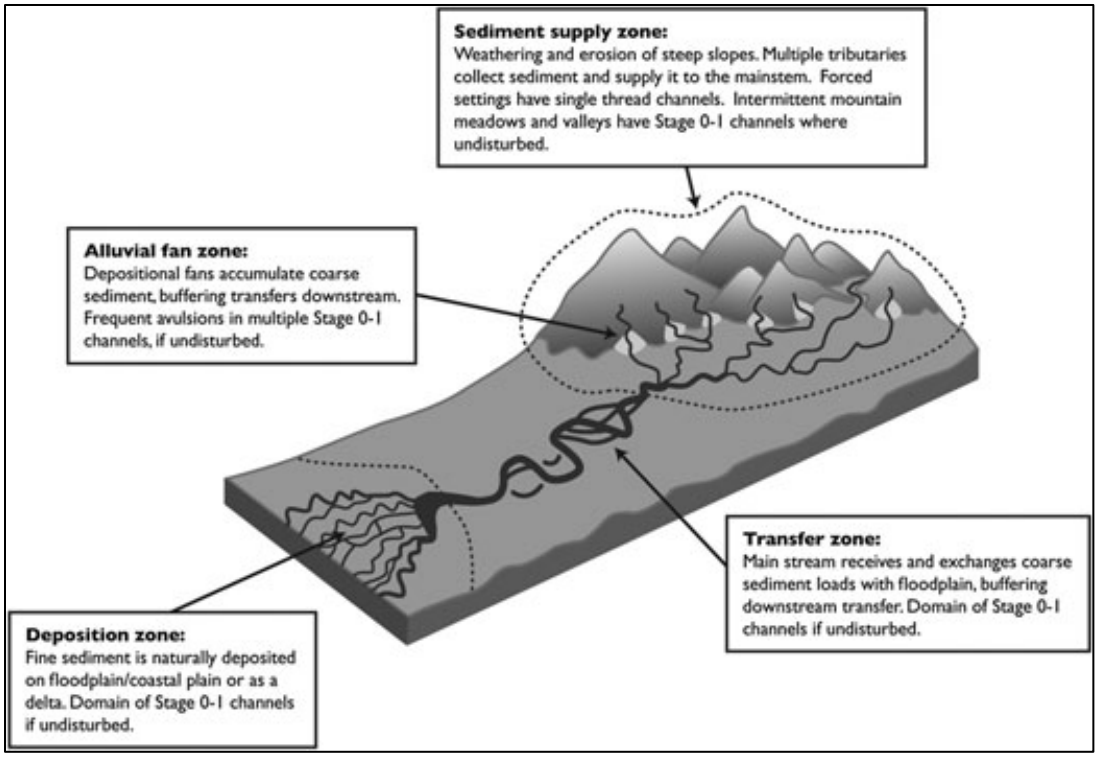

Figure 42. Locations of sediment domains within a typical watershed (Cluer and Thorne 2013). Unlike typical watersheds, a pronounced, low-gradient deposition zone occurs immediately below the alluvial fan zone on the Lemhi River resulting from a mid-valley bedrock grade control near the confluence of Hayden Creek (RM 32.9), followed by a transfer zone characterized by greater sediment availability and transport.

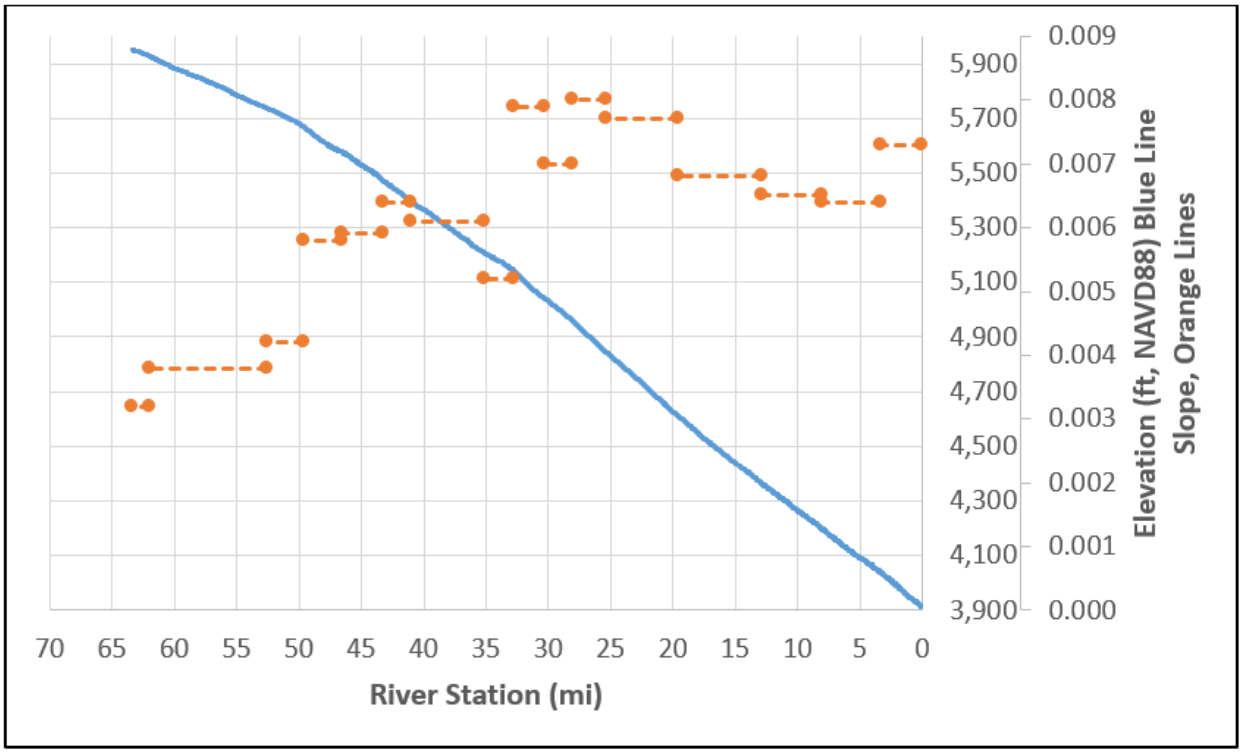

Figure 43. Lemhi River longitudinal profile (blue line) and average reach slope (dashed orange lines) by river mile. The gradient is generally lower upstream of an area of shallow bedrock that coincides with the Hayden Creek confluence near RM 32.9.

The width of the Lemhi River floodplain, as defined by the location of confining terraces and/or valley margin, is generally wide. Dividing the width of the floodplain by the width of the bankfull channel produces a result called the entrenchment ratio. A small entrenchment ratio means the channel has less-accessible floodplain area and therefore less ability to dissipate flood energy on the floodplain, resulting in deeper, higher-velocity, more-forceful flood flows, increasing the potential for erosion and/or incision (i.e., transport reach). Large entrenchment ratios are representative of channels with broadly accessible floodplains that can dissipate flood energy outside the banks of the channel, resulting in less-forceful flood flows and a tendency for deposition (i.e., response reach). The entrenchment ratio on the Lemhi is generally lower in areas of groundwater-influenced hydrology as a result of lower peak flows and possibly minor incision. The entrenchment ratio increases in the lower Lemhi River, where greater peak flows occur due to a more snowmelt-dominated hydrology. Human features such as levees, road embankments, and other obstructions have unnaturally confined the floodplain in several locations, particularly in the middle and lower Lemhi, greatly reducing the local entrenchment ratio in those areas.

Soils

Geomorphic features in the Lemhi valley bottom include the active channel, floodplains, alluvial fans, stream terraces, and outwash fans and fan terraces. Soils that have formed on these features are described in Table 7. Soil descriptions are based on the NRCS detailed soil maps and the Detailed Soil Map Units section in the report (NRCS 2003).

Table 7. Geomorphic features along the valley bottoms and margins, and associated soils.

Geomorphic Feature	Soil Description and Other Information
Active Channel	Water. Soils that have formed adjacent to or in the channel (gravel bars and islands) are described in the Floodplains soil description.
Floodplains	Soil description: a very deep, poorly drained to somewhat excessively drained soil that is dark-colored, silty loam to very cobbly sandy loam, and on floodplains and old stream channels. Slope range: 0 to 4 percent; Elevation range: 3700 to 7400 feet; Average annual precipitation: 8 to 18 inches; Average annual air temperature: 34 to 47° F; Frost-free season: 5 to 90 days; Depth class: very deep; Drainage class: very poorly drained to somewhat excessively drained; Permeability: moderately slow to very rapid; Available water capacity: 1 to 12 inches; Effective rooting depth: 10 inches to more than 60 inches; Runoff: slow; hazard of water erosion: slight; Range site: basin big sagebrush, western wheatgrass, black cottonwoods, willows, and sedges
Alluvial Fans and Stream Terraces	Soil description: a very deep, poorly drained to somewhat excessively drained soil that is light-colored; silt loam over silty clay to very gravely loamy silt, and on alluvial fans and stream terraces Slope range: 1 to 8 percent; Elevation range: 3700 to 6600 feet; Average annual precipitation: 7 to 20 inches; Average annual air temperature: 36 to 46° F; Frost-free season: 30 to 100 days; Depth class: very deep; Drainage class: poorly drained to somewhat excessively drained; Permeability: moderate in the upper part to very rapid in the lower part to moderately slow; Available water capacity: 2 to 11 inches; Effective rooting depth: 10 inches to more than 60 inches; Runoff: slow to medium; Hazard of water erosion: slight to moderate; Range site: Wyoming big sagebrush, bluebunch wheatgrass, threetip sagebrush, and Idaho fescue
Outwash Fans and Fan Terraces	Soil description: a very deep, somewhat poorly drained soil that is a darker-colored, gravely loam, and on outwash fans and fan terraces. Slope range: 2 to 10 percent; Elevation range: 6000 to 7500 feet; Average annual precipitation: 8 to 22 inches; Average annual air temperature: 35 to 42° F; Frost-free season: 30 to 80 days; Depth class: very deep; Drainage class: well drained; Permeability: moderate in upper part and very rapid in lower part to moderately slow; Available water capacity: 3.5 to 5.5 inches; Effective rooting depth: 40 inches to more than 60 inches; Runoff: slow; Hazard of water erosion: slight; Range site: mountain big sagebrush, Idaho fescue, Wyoming big sagebrush, and bluebunch wheatgrass

Water Quality

Surface water quality standards apply to a waterbody, depending on its designated uses and/or existing uses. Pursuant to the Clean Water Act (CWA), Idaho recognizes existing uses, which are uses present or attained in a water body on or after November 28, 1975. When water bodies do not have designated

beneficial uses, they are assigned a presumed-use protection. All water bodies are classified for more than one beneficial use and must meet the fishable/swimmable intent of the CWA.

Under Idaho's water quality standards, beneficial uses are categorized as aquatic life, recreation, water supply, wildlife habitat, and aesthetics. For the Lemhi River watershed, beneficial uses that are not fully supported are: (1) aquatic life, which includes salmonid spawning and cold-water aquatic life beneficial uses, and (2) and contact recreation that includes primary and secondary contact recreation.

The Idaho Department of Environmental Quality completed a subbasin assessment for the Lemhi River watershed in 1999 (IDEQ 2012). Total maximum daily loads (TMDLs) were developed for water bodies not supporting their beneficial uses and impaired by a pollutant. In Idaho's 2002 Integrated Report (September 30, 2005), streams were converted from water-quality-limited segments to assessment units (AUs) based on Strahler stream order within a waterbody ID.

Additional AUs identified by IDEQ's Beneficial Use Reconnaissance Program monitoring were added to the 2008 and 2010 Integrated Reports. Further investigation by IDEQ determined that some listed AUs are ephemeral and therefore should not be listed as water-quality limited (Section 5: TMDL needed) but rather placed in Section 4C (impaired but not due to a pollutant). Under the CWA, lack of flow is not considered pollution, and no TMDL can be calculated. The 2012 Addendum updated water bodies and pollutants for which TMDLs have been developed (Table 8).

Table 8. Streams and pollutants listed in the 1999 and 2012 reports with TMDLs

Water Body	1999 TMDL	2012 TMDL Addendum
Lemhi River	Fecal coliform bacteria	Temperature
Bohannon Creek	Sediment	Temperature
Canyon Creek		Bacteria (E. coli)
Eighteenmile Creek	Sediment	Temperature
Geertson Creek	Sediment	
Kirtley Creek	Sediment	Temperature
Little Eightmile Creek		Temperature
McDevitt Creek	Sediment	
Sandy Creek	Sediment	Temperature
Wimpey Creek	Sediment	

Source: IDEQ 2012

Land Use

The Lemhi River watershed covers about 1,260 square miles, and about 80 percent of the land is owned by the Federal government and administered by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM). Private lands are located predominantly along the more-fertile valley bottom. The primary land uses in the watershed are livestock grazing, irrigated pasturelands and hay fields, developed and dispersed recreation, and timber harvests. Livestock grazing occurs on both public and private lands across much of the middle and lower elevations in the watershed. Livestock typically graze on public lands from May to October, and then return to private lands for the remainder of the year. Irrigated pasturelands and hay fields are on private lands along the Lemhi Valley bottom and margins. The effects of irrigation and grazing in the valley bottom include diversion of flows from the mainstem Lemhi River, diversion of tributaries away from the mainstem Lemhi River, stream alterations, native vegetation clearing, increasing sedimentation and water temperatures, and entrainment of juvenile and adult fish in irrigation facilities (NPCC 2004; NOAA 2015).

Developed and dispersed recreation, several small mining claims, and small timber harvests are additional land uses that are believed to have minimal impact on the modern Lemhi River.

Land Cover and Riparian Conditions

The upper Lemhi River has areas of dense, native riparian vegetation comprising several species of willow, birch, and dogwood, with an understory of sedge and grass. About 60 percent of the streambanks have woody riparian vegetation along the stream corridors, and about 40 percent of the streambanks have grassland along the stream corridors (Trapani 2002). Land clearing and livestock grazing have altered the riparian vegetation through consumption and soil compaction, resulting in the replacement of native sedge and willow species with grass and other species that do not have the bank-stabilizing effects that natural woody riparian vegetation provides.

The lower Lemhi has fewer areas of dense, native riparian vegetation compared with the upper Lemhi, and more than 65 percent of the streambanks have a thin (less than 30 feet wide) or discontinuous woody riparian vegetation corridor along the river (Trapani 2002). Livestock grazing has altered the riparian vegetation, resulting in the replacement of native sedge and willow species with grass species, and many of the grass-lined banks have been armored with riprap. Large tracts of floodplains have been converted to grasslands and used for pastures or for hay production. Near the town of Salmon, much of the floodplain areas have been leveed to protect residential areas from flooding.

Most of the tributary drainages exhibit degraded riparian conditions due to livestock grazing and irrigation withdrawals. Riparian corridors have been converted to grassland, with discontinuous woody riparian vegetation resulting in bank instability, sedimentation, and high water temperatures (Trapani 2002).

Channel Migration

Despite channelization and straightening in multiple locations, ancient coarse-grained sediment underlying fine-grained floodplain soils across most of the valley bottom has limited the potential for widespread channel incision. The inability of the system to dissipate energy by mobilizing sediment on the bed has resulted in excess energy forced downstream and onto the river banks. In the absence of dense, riparian vegetation that prevents erosion, bank recession has occurred, resulting in channel widening. Channel widening was observed via aerial photographs throughout the Lemhi River but was more pronounced in the upper Lemhi River, while both widening and channel migration (i.e., erosion on one bank with concurrent deposition on the other) were observed in the lower Lemhi River (Photograph 20). The increased channel width associated with widening increases the cross-sectional area of the channel, allowing greater conveyance between the banks and resulting in less over-bank conveyance during floods (i.e., less frequent floodplain inundation) and less scour potential for forming pools (i.e., more frequent plane-bed morphology).

Photograph 20. Example of significant channel widening in the upper Lemhi River (Reach 2). Photograph is looking upstream, where the channel width exceeds 100 feet. Estimated historic and existing reference widths for this reach are on the order of 20 to 30 feet.

In addition to channel migration and widening, the Lemhi River also exhibits lateral channel movement via abrupt channel relocation (called avulsion). Avulsions generally occur via meander cut-off or channel obstruction. Meander cut-off avulsion typically occurs when high flows bypass a large, looping meander by cutting through the narrow neck on either end of the meander. The shorter flow path rapidly expands to capture most or all of the flow, abandoning the old meander as an oxbow pond or alcove. An avulsion created by an obstruction occurs when the main flow path is blocked sufficiently to force enough flow across the floodplain to scour a new channel. Typical obstructions resulting in avulsion include excessive sediment deposition, debris jams, and/or beaver dams. With less discharge and coarse sediment input, channel migration on the upper Lemhi River was likely heavily influenced by avulsion. Rather than meander bends forming as a result of persistent channel migration in the upper Lemhi River, it is more likely that fairly stable meanders formed each time the stream avulsed around a beaver dam or other obstruction.

The presence or absence of dense, woody riparian vegetation also influences the direction and shape of avulsion channel formation in the Lemhi. A lack of dense riparian vegetation allows the channel to adjust to an obstruction by widening, rather than overtopping, the banks and forming a new channel. Furthermore, without floodplain roughness in the form of dense vegetation, avulsion channels and newly formed side channels are more likely to be straighter and less complex than the original or mainstem channel.

Where channel migration and avulsion occur, channel bedform morphology (i.e., pools and riffles) depends largely on the presence and maturity of riparian vegetation. Where dense riparian vegetation comes in contact with a channel due to either migration or avulsion, the root mass of the vegetation creates a relative hard point in the channel. The structure of the root mat stabilizes the bank, enabling greater local velocity and shear stress capable of scouring the bed and forming a pool. Without the

stabilizing function of the riparian root mass, excessive stream velocity and shear would be attenuated on the erosion-prone bank, rather than the bed, resulting in widening rather than localized pool scour.

Channel Planform and Morphology

Channel planform on the Lemhi River is generally sinuous, with several channel segments that have been straightened adjacent to roads or other human features. In an alluvial valley, sinuosity is typically inversely proportional to gradient, with lower sinuosity in areas of steeper gradient. This is the case on the Lemhi, where reach-averaged sinuosity ranges from over 2 in the low-gradient, upper Lemhi River, to as low as 1.1 in the somewhat steeper, lower Lemhi River, where the channel has also been straightened along Highway 28. In the upper Lemhi River, low gradients, high sinuosity, groundwater-influenced hydrology, dense riparian vegetation, and beaver activity likely led to a historically multi-threaded channel system. Over the past 100+ years, the removal of riparian vegetation and loss of beaver, along with irrigation diversions and channel manipulation, have created a largely single-thread system. Where riparian vegetation has been removed, the bankfull width of the channel has increased to 2 to 3 times the width of undisturbed areas. The lower Lemhi River, with lower sinuosity, greater sediment supply, higher gradient, and more pronounced peak flows, was historically a single-threaded system with several island-braided areas likely associated with in-stream obstruction (i.e., log jams) (Photograph 21). Channelization, levees, the removal of riparian vegetation, and other human impacts on the lower Lemhi River have all but eliminated the areas of island braiding and have significantly reduced the sinuosity and entrenchment of the channel. As with the upper Lemhi River, the reduction of riparian vegetation in many areas has led to areas of increased bank erosion.

Photograph 21. Island-braided channel network along the lower Lemhi River within Reach 15 from RM 3.5 to RM 4.5. Although the area has been impacted by land use, irrigation, and other human activities, it represents the best reference condition for an island-braided reach in the lower Lemhi River watershed.

Beaver

The existing influence from beavers has been severely limited as a result of legacy fur trapping. Limited evidence of beaver activity on the Lemhi River was observed during 2016 field work, suggesting

population numbers remain extremely low, which is a marked difference from historical conditions. As discussed previously, beaver activity likely played a significant role in modifying and developing the historic Lemhi River morphology. Beavers generally require 40 to 60 percent tree/shrub canopy closure and shrub height greater than 6.6 feet within a broad/intact riparian corridor (Slough and Sadleir 1977). Beavers also require trees less than 6 inches in diameter for food source, preferring aspen, willow, cottonwood, and alder (in that order) (Denney 1952). These conditions are present in discontinuous patches throughout the valley and suggest that beaver reestablishment is possible.

Watershed Impacts

The higher-elevation areas along the Beaverhead Mountains southwest of the Continental Divide and the Lemhi Range are on public lands that are administered by the Salmon-Challis National Forest. The Eighteenmile Creek headwaters are currently being considered for wilderness designation. The middle- and lower-elevation areas along the foothills and piedmont belts are on public lands administered by the BLM Challis Field Office and on private lands. The valley bottoms of the Lemhi Valley are predominantly private lands.

Forested, higher-elevation areas along the Beaverhead Mountains and Lemhi Range have been minimally impacted by human activities. Road density, timber harvests, and dispersed recreation have had minor impacts on the watershed. However, at middle and lower elevations, there are significant, localized human impacts that have negatively affected riverine processes. These impacts include, but are not limited to, flow alteration from irrigation diversions, loss of riparian vegetation, channel and floodplain alteration from roads, and increased fine-sediment deposition.

Irrigation diversions significantly reduce instream flows by diverting tributaries away from and out of the mainstem Lemhi River. The many irrigation diversions have nearly eliminated an important intermittent disturbance regime associated with the spring freshet and channel-forming flows. It also reduces the quantity of instream habitat available through isolation (i.e., disconnected tributaries) and volume (i.e., cubic feet of water in the mainstem). Another effect of the irrigation diversions is an alteration of the timing and spatial distribution of groundwater recharge. Diversions redistribute river water onto the floodplain during the summer months, artificially increasing groundwater levels in those locations. Conversely, many naturally wet meadows have been ditched and drained to lower the groundwater table in those areas.

The loss of dense riparian vegetation (primarily willow in the upper Lemhi River and willow/cottonwood in the lower Lemhi River) has resulted in an over-widened and homogenous channel. Dense riparian vegetation on the outside of bends stabilizes the bank and obstructs flow, forcing contraction and resulting in pool scour and undercut banks. Dense riparian vegetation also promotes channel response via side-channel formation and avulsion around the structure provided by the vegetation, rather than bank erosion and widening when vegetation is lacking. A reduction in the amount of bank structure and instream structure have resulted in a simplified, homogenous channel exemplified by an over-widened, predominantly plane-bed morphology. The over-widened condition also expands the cross-sectional area of the channel between the banks, enabling more water to pass between the banks during floods, reducing floodplain connection frequency and duration. In the lower Lemhi River, the lack of cottonwood vegetation has also limited large woody material recruitment to the stream, resulting in low levels of instream structure, cover, and associated habitat. In all areas where woody riparian vegetation has been lost, the channel is exposed to greater solar radiation and thermal heating from the loss of shade.

Channel and floodplain alterations from roads are most prevalent in the middle to lower Lemhi River valley. Highway 28 significantly constrains the floodplain from near Mill Creek (RM 45) downstream to the area below Geertson Creek (RM 7), where 28 to 67 percent of the floodplain has been disconnected by the highway. County roads and levees further constrain the channel near the town of Salmon, Idaho (RM 0 to RM 3), where 50 to 71 percent of the floodplain has been disconnected. The low entrenchment ratios resulting from road and levee constrictions have concentrated flood flow, increasing depth and velocity and therefore also increasing the potential for bank erosion, channel incision, and bed armoring. Exacerbating the issue is the channelization and straightening of the river adjacent to the highway and levees. The sinuosity of the channel decreases by more than 75 percent, to near 1.0 in several reaches. The loss of channel length associated with the decreased sinuosity also increases the gradient in the lower Lemhi River, which is already high compared to the upper Lemhi River.

Excessive bank erosion, cattle grazing, and runoff from roads, all-terrain vehicle trails, and mining operations have increased fine sediment inputs to the channel through sheet erosion. Dense riparian vegetation had historically stabilized banks composed of fine sand and silt, which are now eroding and contributing sediment to the river on an annual basis. Cattle grazing has disturbed the surface of the floodplain and compacted the soils, both of which lead to more fine sediment runoff. Heavy grazing in some areas has resulted in so much erosion that 2- to 3-foot-tall hummocks have formed from the loss of soil between each hummock (see Photograph 19). Such erosion is plainly visible from aerial photographs. Roads have been located adjacent to many of the tributaries, where they have altered the riparian vegetation composition, compacted soils, and provide conduits for concentrated sheet flows during snowmelt and thunderstorms. Mining operations have included placer mining and exploratory trenches, especially in the foothills and headwater areas along the Beaverhead Mountains from Gilmore to Salmon. The cumulative effects of these impacts have likely increased fine-sediment inputs entering the Lemhi River system, resulting in elevated fine sediment levels and siltation.

Data Gaps

Future analysis could be aided by the collection of additional data currently unavailable, including:

- Hydraulic modeling to confirm floodplain inundation timing and extent, sediment transport character, and appropriate channel geometry (i.e., width-to-depth ratio).
    - Data gaps necessary for hydraulic modeling include bathymetry data, frequent pebble counts, and an improved understanding of diversion withdrawals/returns, tributary inflows, and groundwater contributions.
- Riparian vegetation inventory, including health and successional stages within the low surface that directly influence lateral channel migration, force pool-riffle bedforms, sort and retain gravel, and provide bank stability.

Lemhi Valley Segments and Geomorphic Reaches

Valley segments, geomorphic reaches, and channel units are three hierarchically nested subdivisions of the drainage network (Frissell et al. 1986). Within the hierarchy of spatial scales, valley segments, geomorphic reaches, and channel units represent the largest physical subdivisions that can be directly altered by human activities. As such, it is useful to understand how they respond to anthropogenic disturbance, but to do so requires classification systems and quantitative assessment procedures that facilitate accurate, repeatable descriptions and convey information about biophysical processes that create, maintain, and destroy channel structure (Bisson et al. 2006).

Valley Segments

The Lemhi River occupies an alluvial valley that has varying discharge along its course due to flow and sediment inputs from major tributaries, classified using a 10th-field Hydrologic Unit Code (HUC 10). There are eight HUC 10 sub-watersheds that discharge to the Lemhi River (Table 9). Four valley segments were identified based on where the HUC 10 sub-watersheds interact with or are identified along the Lemhi River (Figure 44). These valley segments include the following:

1) The Lemhi Headwaters Valley Segment includes the Texas Creek, Eighteenmile Creek, and Hawley Creek HUC 10 sub-watersheds to where they combine to form the Lemhi River (Headwaters downstream to RM 63.3)
2) The Upper Lemhi Valley Segment includes the upstream extent of the Lemhi River to its confluence with Hayden Creek, including discharge from the Timber Creek HUC 10 sub-watershed and five other named tributaries (RM 63.3 to RM 32.7). The lower boundary of the Upper Lemhi Valley Segment includes the area of bedrock confinement that separates the upper and lower watershed based on groundwater influence. Upstream of this point, the hydrologic regime is primarily groundwater-influenced. Below this point and the confluence of Hayden Creek, the hydrologic regime is primarily surface-water/snowmelt-dominated.
3) The Middle Lemhi Valley Segment begins at the confluence of the Lemhi River and Hayden Creek, a HUC 10 sub-watershed, and continues downstream to the alluvial fan at the mouth of Kenney Creek. This valley segment includes discharges from four named tributaries (RM 32.7 to RM 19.6).
4) The Lower Lemhi Valley Segment begins at the confluence of the Lemhi River and Kenney Creek and collects discharges from six named tributaries before flowing into the Salmon River (RM 19.6 to RM 0.0).

Table 9. Lemhi River watershed valley segment delineations and sub-watersheds.

Valley Segments and Locations	Sub-watershed	HUC 10	Named Tributaries	River Miles	Square Miles
Lemhi Headwaters Valley Segment	Texas Creek	1706020401	6	Upstream of 63.3	97.38 mi^2
	Eighteenmile Creek	1706020403	9		158.13 mi^2
	Hawley Creek	1706204002	11		63.26 mi^2
Upper Lemhi Valley Segment	Upper Lemhi River	1706020405	31	63.3 – 32.7	333.35 mi^2
	Timber Creek	1706020404	12		81.54 mi^2
Middle Lemhi Valley Segment	Middle Lemhi River	1706020407	13	32.7 – 19.6	179.48 mi^2
	Hayden Creek	1706020406	28		143.55 mi^2
Lower Lemhi Valley Segment	Lower Lemhi River	1706020408	21	19.6 – 0	204.75 mi^2
	Total		**131**	**63.3**	**1261.44**

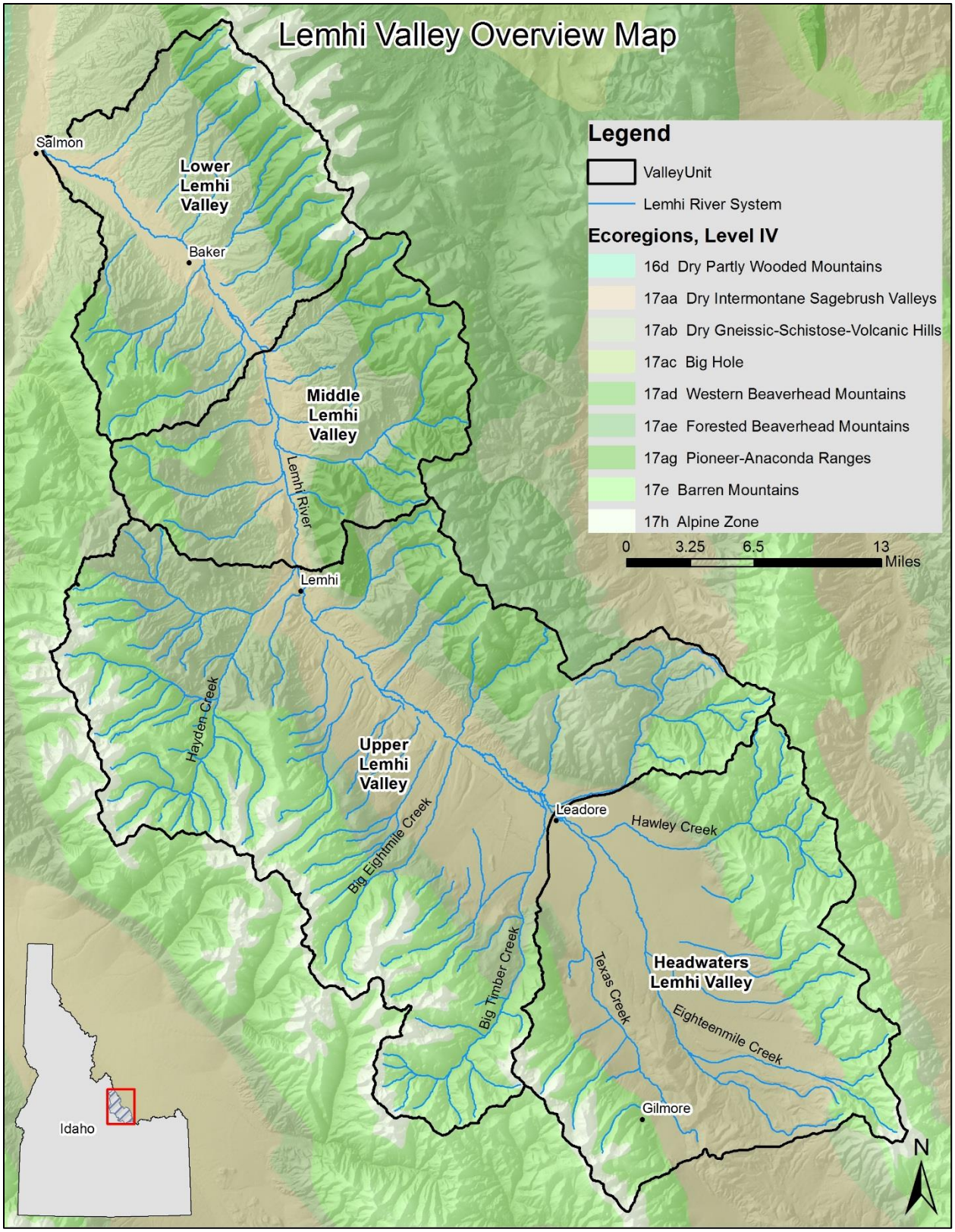

Figure 44. Lemhi River watershed valley segment locations.

Reach Characteristics

Reach characteristics are summarized per reach in Table 10 below.

Table 10. Summary of geomorphic reach characteristics for the Lemhi watershed.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-1	63.3 - 60.4	0.0075	526	558	0.0038	19	2.0	28	29	0%	Gaining	56%	44%	0%
VS-2	GR-2	60.4 - 52.6	0.0081	2050	2305	0.0038	29	2.2	71	80	6%	Gaining	53%	46%	1%
VS-2	GR-3	52.6 - 49.6	0.0075	1070	1053	0.0044	33	1.7	32	32	11%	Gaining	55%	38%	7%
VS-2	GR-4	49.6 - 46.5	0.0077	1235	1086	0.0057	37	1.4	33	29	7%	Losing	62%	29%	9%
VS-2	GR-5	46.5 - 43.2	0.0086	1675	1197	0.0060	34	1.4	49	35	8%	Losing	60%	22%	18%
VS-2	GR-6	43.2 - 41.1	0.0083	1342	676	0.0064	33	1.3	41	21	23%	Losing	62%	12%	26%
VS-2	GR-7	41.1 - 35.1	0.0080	2127	1338	0.0061	35	1.3	60	38	19%	Neutral	50%	25%	24%
VS-2	GR-8	35.1 - 32.7	0.0073	1393	805	0.0054	36	1.4	39	22	23%	Gaining	40%	4%	56%
VS-3	GR-9	32.7 - 30.3	0.0088	1488	1102	0.0077	54	1.1	28	20	6%	Gaining	13%	5%	81%
VS-3	GR-10	30.3 - 28	0.0093	1273	1063	0.0071	46	1.3	28	23	25%	Neutral	5%	28%	67%
VS-3	GR-11	28 - 25.4	0.0088	1158	518	0.0080	51	1.1	23	10	27%	Gaining	12%	10%	77%
VS-3	GR-12	25.4 - 19.6	0.0088	2813	2015	0.0076	54	1.1	53	38	32%	Gaining	27%	20%	53%
VS-4	GR-13	19.6 - 12.9	0.0084	2813	1492	0.0070	57	1.2	49	26	55%	Neutral	17%	34%	48%
VS-4	GR-14	12.9 - 8.1	0.0080	2217	1407	0.0065	62	1.2	36	23	64%	Neutral	13%	15%	72%
VS-4	GR-15	8.1 - 3.3	0.0080	1995	1657	0.0065	54	1.2	37	31	32%	Gaining	43%	30%	28%
VS-4	GR-16	3.3 - 0	0.0081	2480	1699	0.0072	62	1.1	40	27	20%	Gaining	38%	13%	49%

Lemhi Headwaters Valley Segment (VS-1)

The Lemhi Headwaters Valley Segment includes the headwater region of the Lemhi River watershed, and comprises the Texas Creek, Hawley Creek, and Eighteenmile Creek HUC 10 sub-watersheds (Figure 45). The individual sub-watersheds are described in the following sections.

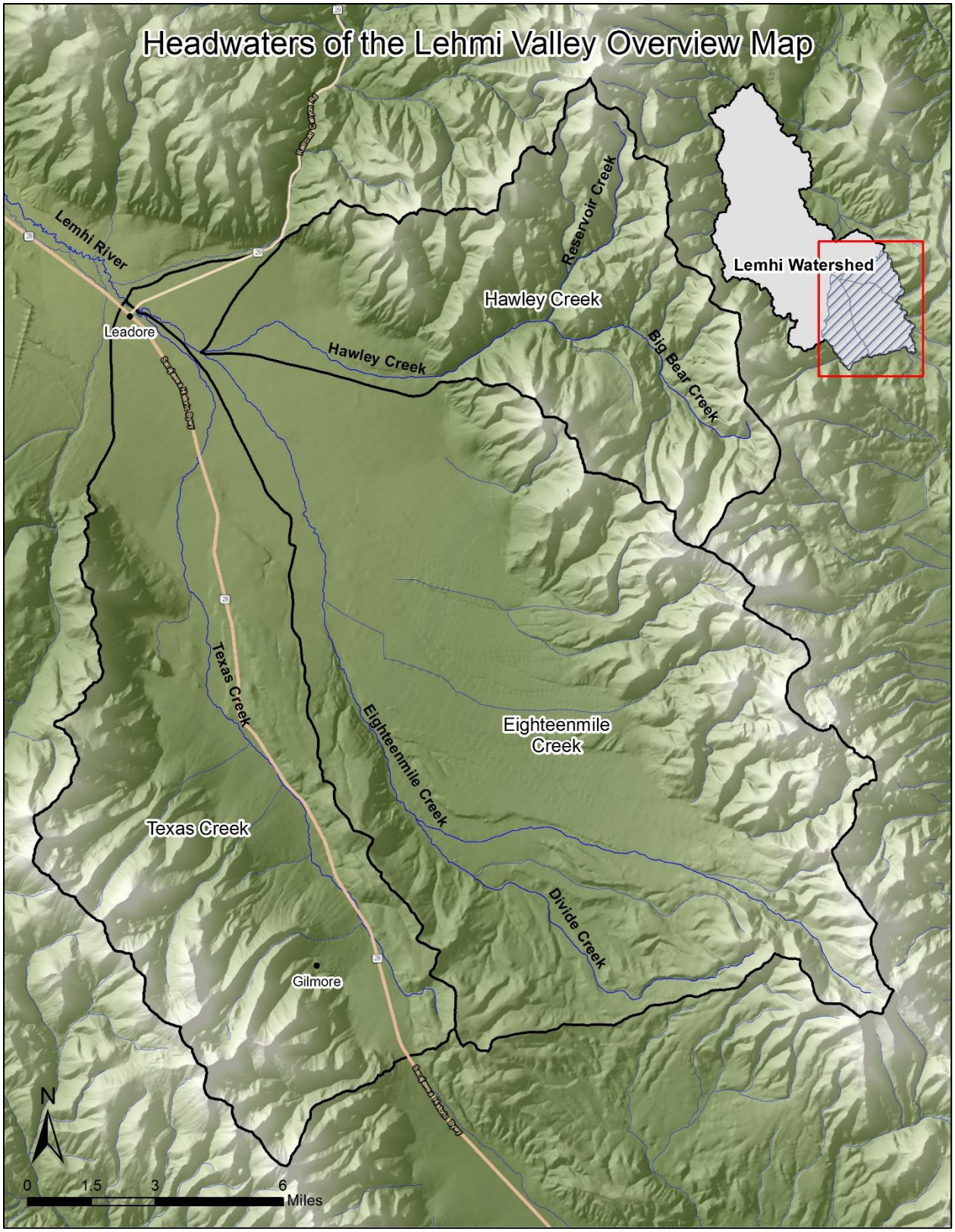

Figure 45. Location of Lemhi Headwaters Valley Segment (VS-1) comprising Hawley Creek, Eighteenmile Creek, and Texas Creek.

Texas Creek Sub-watershed

The Texas Creek sub-watershed (HUC 1706020401) covers 62,321 acres. Elevations range from about 5960 feet at the town of Leadore to more than 10000 feet along the Lemhi Range to the west. Gilmore Summit is an intrabasin divide that separates Texas Creek, which flows northward, from Birch Creek, which flows south. Center Ridge to the east separates the Texas Creek sub-watershed from the Eighteenmile Creek sub-watershed. The drainage pattern within the sub-watershed is dendritic, and the bedrock is predominantly limestone, dolomite, and quartzite. The higher-elevation, timbered lands are administered by the Salmon-Challis National Forest, lower-elevation slopes covered with shrub- and grasslands are administered by the Bureau of Land Management, and private holdings are predominantly located along the valley bottoms, covered with pastures and croplands.

Texas Creek begins as an ephemeral channel along Center Ridge and across an alluvial fan, with intermittent flows during snowmelt and thunderstorms. Allhands Spring, a tributary to Texas Creek, is impounded by an embankment dam. The creek becomes perennial where seeps and springs flowing out of alluvial fans along the foot of the Lemhi Range form wetland areas along an unconfined valley and coalesce to form Texas Creek (Figure 46). Pastureland and wetland meadows are heavily grazed, and livestock have direct access to Texas Creek. Two embankment dams (T14N and R26E) once impounded Texas Creek in the wetlands but have since been breached. Dunkin Lane, Timber Creek, and Eight Mile Roads are topographic highs that bisect the wetland meadows, interfering with surface water connectivity. A diversion at the confluence of Purcell Creek and Texas Creek flows along the base of Leadore Hill, collecting seepage and spring discharges from the alluvial fans. There are three cross-basin drainage diversions that flow from Timber Creek to Texas Creek. Highway 28, the Sacajawea Historic Byway and old railroad grade, crosses Texas Creek and runs south along the base of Middle Ridge, where it does not impact Texas Creek or the wetlands. About 0.6 miles downstream of the Highway 28 bridge crossing, Texas Creek dewaters due to diversions.

Summary

Texas Creek's flows are over-allocated for irrigation, resulting in dewatering about 0.6 miles downstream of the Highway 28 bridge crossing. The wetland meadows are heavily grazed by livestock, resulting in loss of riparian vegetation along Texas Creek, and thus, reduced shade and bank instability. Livestock have direct access to Texas Creek, resulting in bank erosion, channel widening, sedimentation, and nutrient loading.

The wetlands created by cold-water seeps and springs could provide a cold-water source to the Lemhi River if the wetlands were allowed to function naturally or were managed in a way that reestablishes the riparian vegetation, and flows were not over-allocated to maintain perennial flows along lower Texas Creek to the Lemhi River.

The cross-basin diversions from Timber Creek could have negative impacts to Timber Creek's flows.

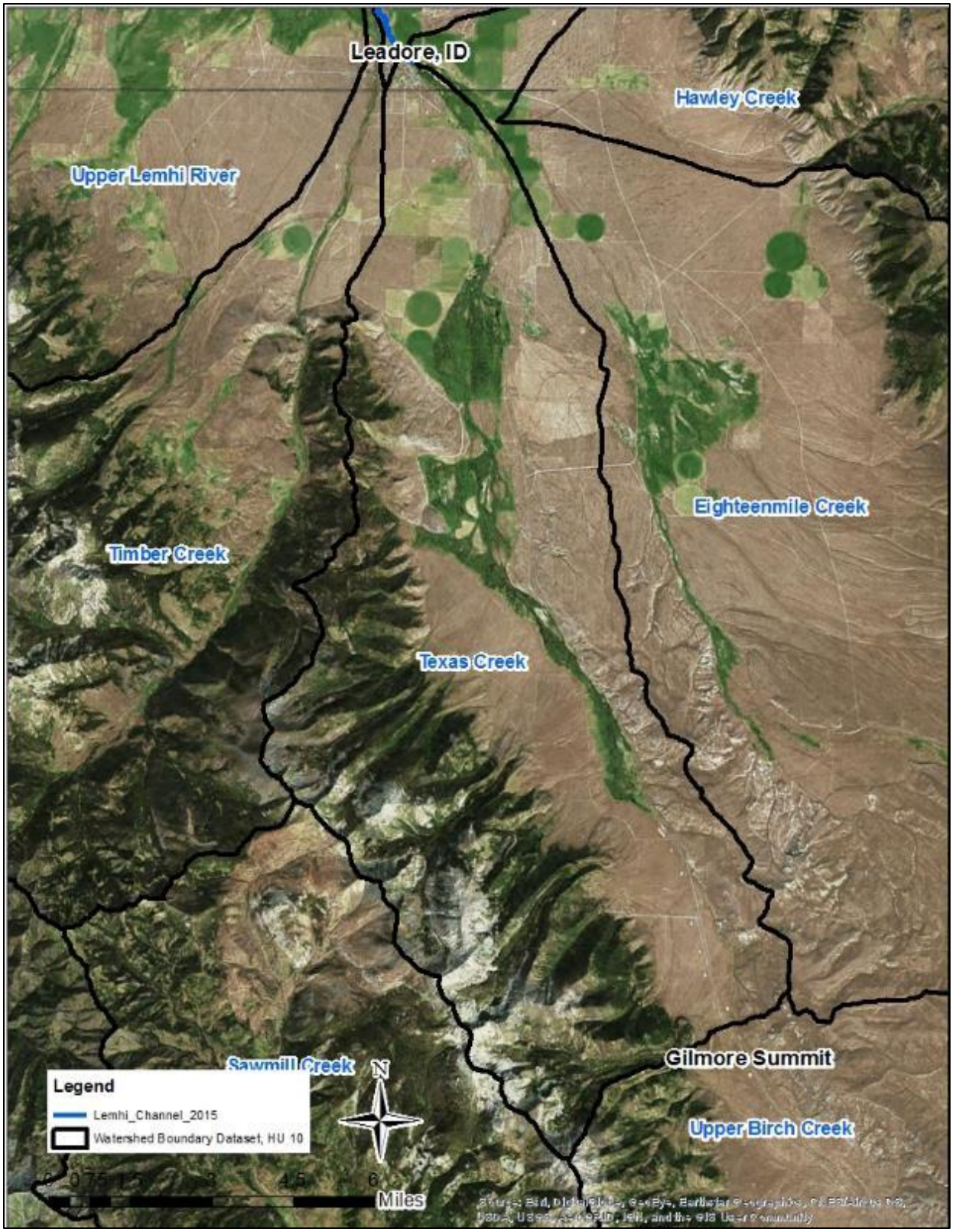

Figure 46. Location of Texas Creek sub-watershed with the Lemhi Range and alluvial fans along the west that have seeps and springs that drain into a wetland complex that maintains perennial flows in Texas Creek.

Hawley Creek Sub-watershed

The Hawley Creek sub-watershed (HUC 1706020402) covers 40,485 acres (Figure 47). Elevations range from about 6000 feet on the Lemhi Valley floor to more than 10000 feet along the Beaverhead Mountains to the east. A high ridge and alluvial fan separates the Hawley Creek sub-watershed from the Eighteenmile Creek sub-watershed. The drainage pattern within the sub-watershed is dendritic, and bedrock is predominantly limestone, dolomite, and quartzite. The higher-elevation, timbered lands are administered by the Salmon-Challis National Forest, lower-elevation slopes covered with shrub- and grasslands are administered by the Bureau of Land Management, and private holdings are predominantly along the valley bottoms, covered with pastures and croplands.

Hawley Creek begins in the Beaverhead Mountains at the confluence of Reservoir Creek and Big Bear Creek (T13S: R28E: Sect. 31). Reservoir Creek has been impounded with an embankment dam near its confluence with Short Creek (T13S: R28E: Sect. 16). Forest Service Road 275 parallels Hawley Creek from its junction with Hawley Creek Road and Forest Service Road 177, downstream about 1.6 miles to its junction with Cedar Canyon Loop Road. There are two irrigation diversions high on the Hawley Creek alluvial fan that divert most of Hawley Creek's flows. Downstream of the irrigation diversions and Cedar Creek Loop Road junction, Hawley Creek flows over its alluvial fan, where there are at least five ford crossings that have widened the channel. There are two additional irrigation diversions about midway down the alluvial fan, and at the base of the fan, Hawley Creek and irrigation return flows are ditched and again diverted, leaving little flow in the channel. Hawley Creek seasonally dewaters downstream of this lowest diversion. Any remaining flows are then discharged into the Eighteenmile Creek ditch, leaving the Hawley Creek and Eighteenmile Creek confluence area highly altered.

Summary

Reservoir Creek Dam and irrigation diversions have resulted in significant flow alterations in the Hawley Creek sub-watershed. Hawley Creek flows are essentially regulated by releases from Reservoir Creek Dam, a major tributary to Hawley Creek. Irrigation diversions along the Hawley Creek alluvial fan divert almost all of Hawley Creek flows, and then Hawley Creek and irrigation return flows are discharged into the Eighteenmile Creek ditch. Additionally, Forest Service roads adjacent to the creek and several ford crossings may increase fine sediment inputs to the Hawley Creek system.

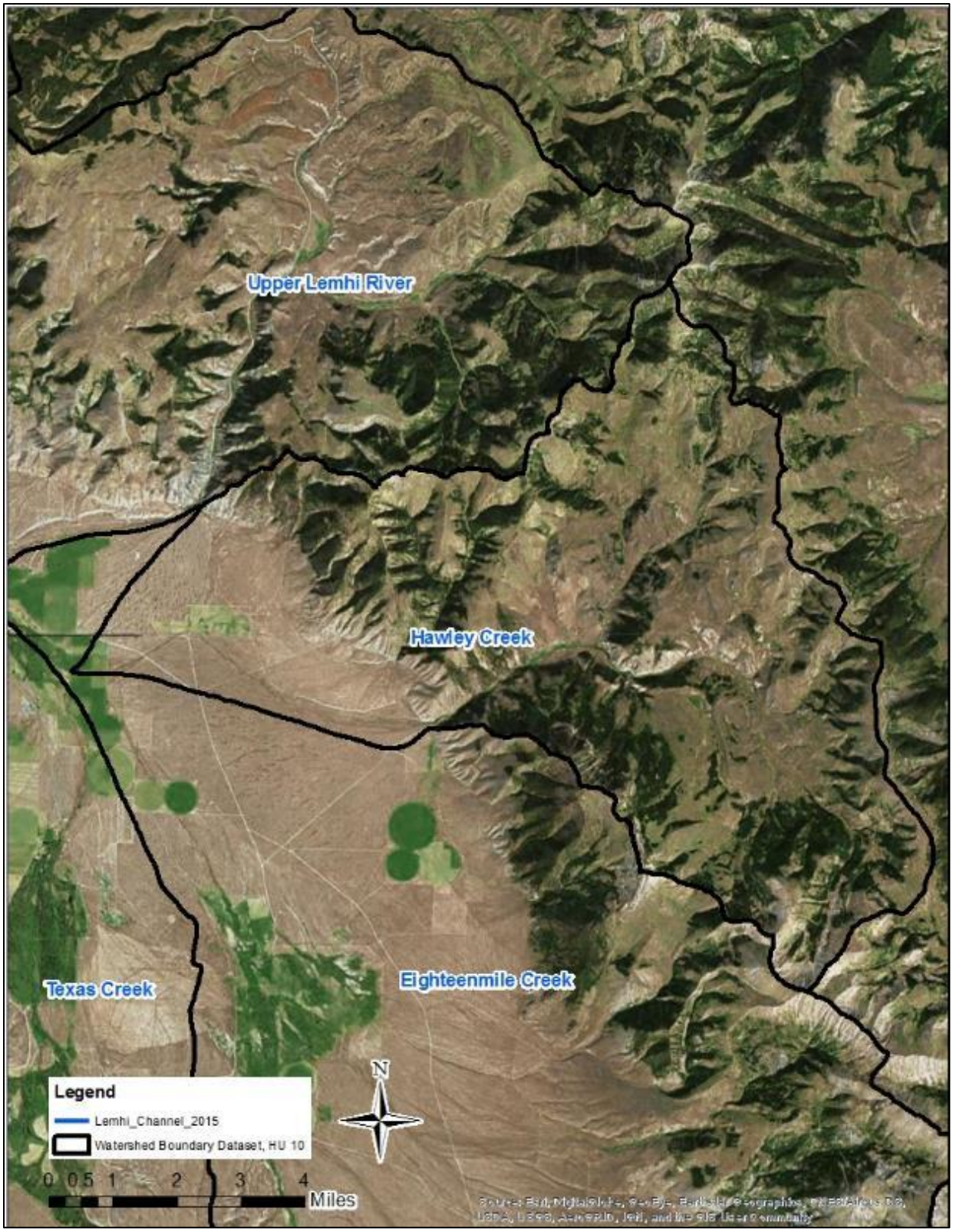

Figure 47. Location of the Hawley Creek sub-watershed.

Eighteenmile Creek Sub-watershed

The Eighteenmile Creek sub-watershed (HUC 1706020403) covers 101,200 acres (Figure 48). Elevations range from about 5960 feet at the town of Leadore to more than 11000 feet along the Beaverhead Mountains to the east. A ridge trending east from Gilmore Summit across Center Ridge to Eighteenmile Peak forms an intrabasin divide that separate the Eighteenmile Creek sub-watershed, which drains northward, from the Upper Birch Creek sub-watershed, which drains southward. The drainage pattern within the sub-watershed is dendritic, and bedrock is predominantly limestone, dolomite, and quartzite. The higher-elevation, timbered lands are administered by the Salmon-Challis National Forest, lower-elevation slopes covered with shrub- and grasslands are administered by the Bureau of Land Management, and private holding are located predominantly along the valley bottoms, covered with pastures and hay fields.

Eighteenmile Creek heads in a glacial cirque and trough on the northern aspect of Eighteenmile Peak (elevation 11142 feet). Several ephemeral tributaries coalesce along the glacial trough to form Eighteenmile Creek at about elevation 8699 feet. Eighteenmile Creek is a single-thread, sinuous channel in confined reaches and a multi-thread, island-braided channel along the unconfined meadows with dense willow species. Several avulsion paths are present through the grass and shrub areas, possibly forced by ice jams and/or beaver dams.

Where Eighteenmile Creek flows across the alluvial fan zone, it (a) loses surface water to groundwater through the porous sediments, (b) has more than a dozen irrigation diversions that divert surface water used to irrigate pastures, and (c) is intercepted by a cross-ditch (R15N: T27E: Sect. 32) that collects and diverts flows. About 4 miles of the historic Eighteenmile Creek was channelized and ditched along the northeast valley wall, where it no longer coalesces with Divide Creek in T15N, R27E, Sect. 29. Essentially, Divide Creek flows through this area, and Eighteenmile Creek no longer exists downstream of it. Below this section, the historic Eighteenmile Creek (now Divide Creek) flows down to T16N, R26E, Sect. 36, where it is ditched around pivot-irrigated crops, and then captures Hawley Creek before flowing into the Lemhi River near Leadore. A placer mining operation appears to be active in the Clear Creek drainage, and Clear Creek is fully diverted near a road crossing at the apex of the Clear Creek alluvial fan. Tenmile Creek and Bull Creek are fully diverted near the apexes of their alluvial fans.

Summary

Most of the tributaries in the Eighteenmile Creek sub-watershed enter the alluvial fan zone at the base of the mountains, where they go subsurface due to the porous alluvial materials. Eighteenmile Creek and Divide Creek (historic Eighteenmile Creek alignment) are the only perennial tributaries along the valley bottom. Irrigation diversions along these tributaries are used to irrigate pasturelands and hay fields. Livestock grazing has changed the native riparian vegetation through alteration and replacement, reducing the overall abundance of native willow and sedge species through consumption and soil compaction. Livestock also have direct access to tributaries resulting in bank instability, channel widening, sedimentation, and nutrient loading. An EPA-approved TMDL has been developed for Eighteenmile Creek for sedimentation and temperature (IDEQ 2011).

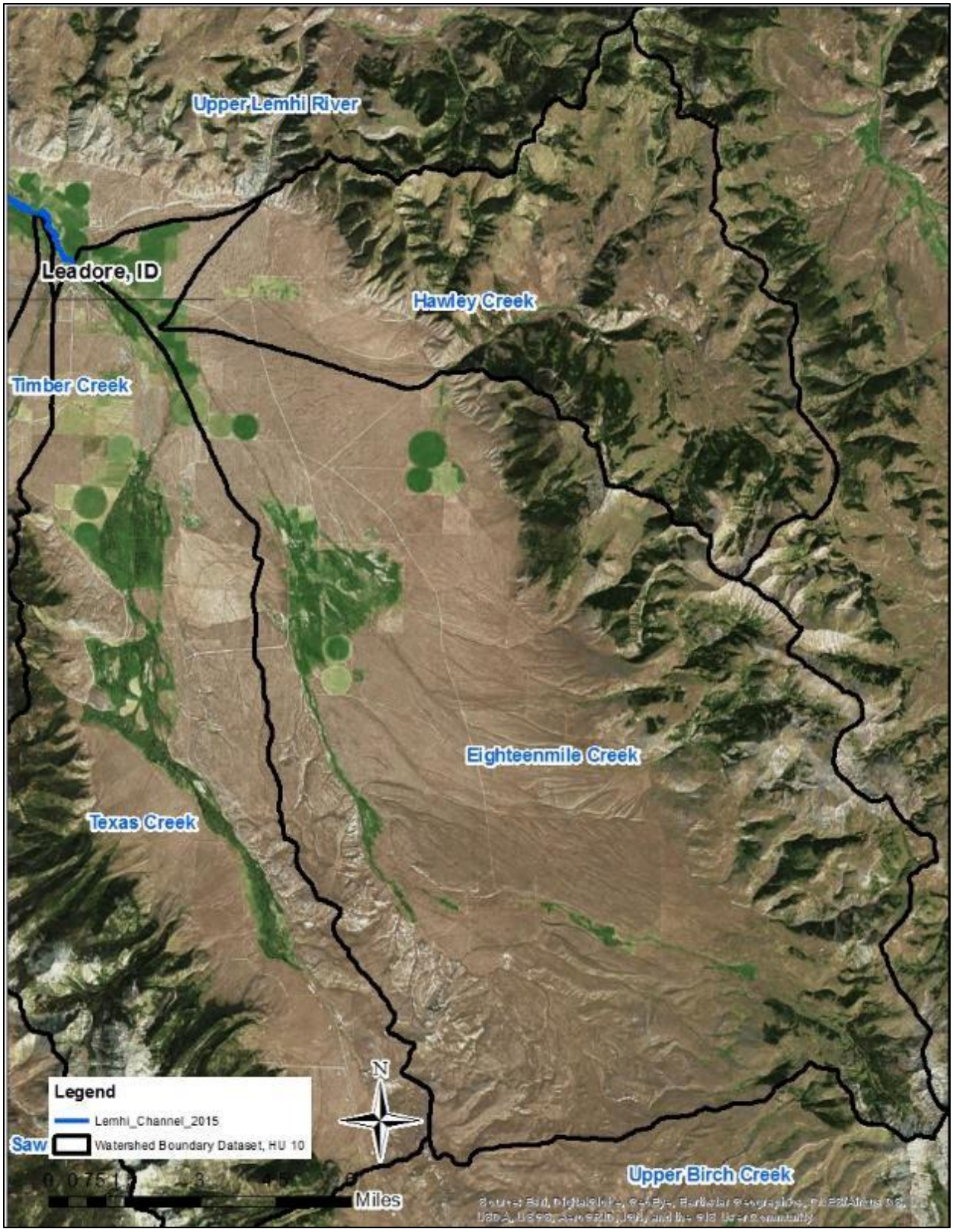

Figure 48. Location of the Eighteenmile Creek sub-watershed.

Upper Lemhi Valley Segment (VS-2)

The Upper Lemhi Valley Segment comprises the Upper Lemhi River watershed from RM 63.3 to RM 32.7. See Table 11 and Figure 49 below.

Table 11. Upper Lemhi Valley Segment watershed hydrologic units and areas.

Sub-watershed	HUC 10	Named Tributaries	Acreage	Square Miles
Upper Lemhi River	1706020405	31	213,346 acres	333.35 mi^2
Timber Creek	1706020404	12	52,188 acres	81.54 mi^2
Total		**43**	**265,534 acres**	**414.89 mi^2**

VS-2 Defining characteristics

Compared to the lower valley segments, VS-2 exhibits a groundwater/baseflow-dominated hydrology characterized by stable flows (consistent annual hydrograph) with significant groundwater inputs. Common characteristics include a low volume of coarse sediment bedload (sand, gravel, and cobble), low gradient, and broad valley/floodplain width.

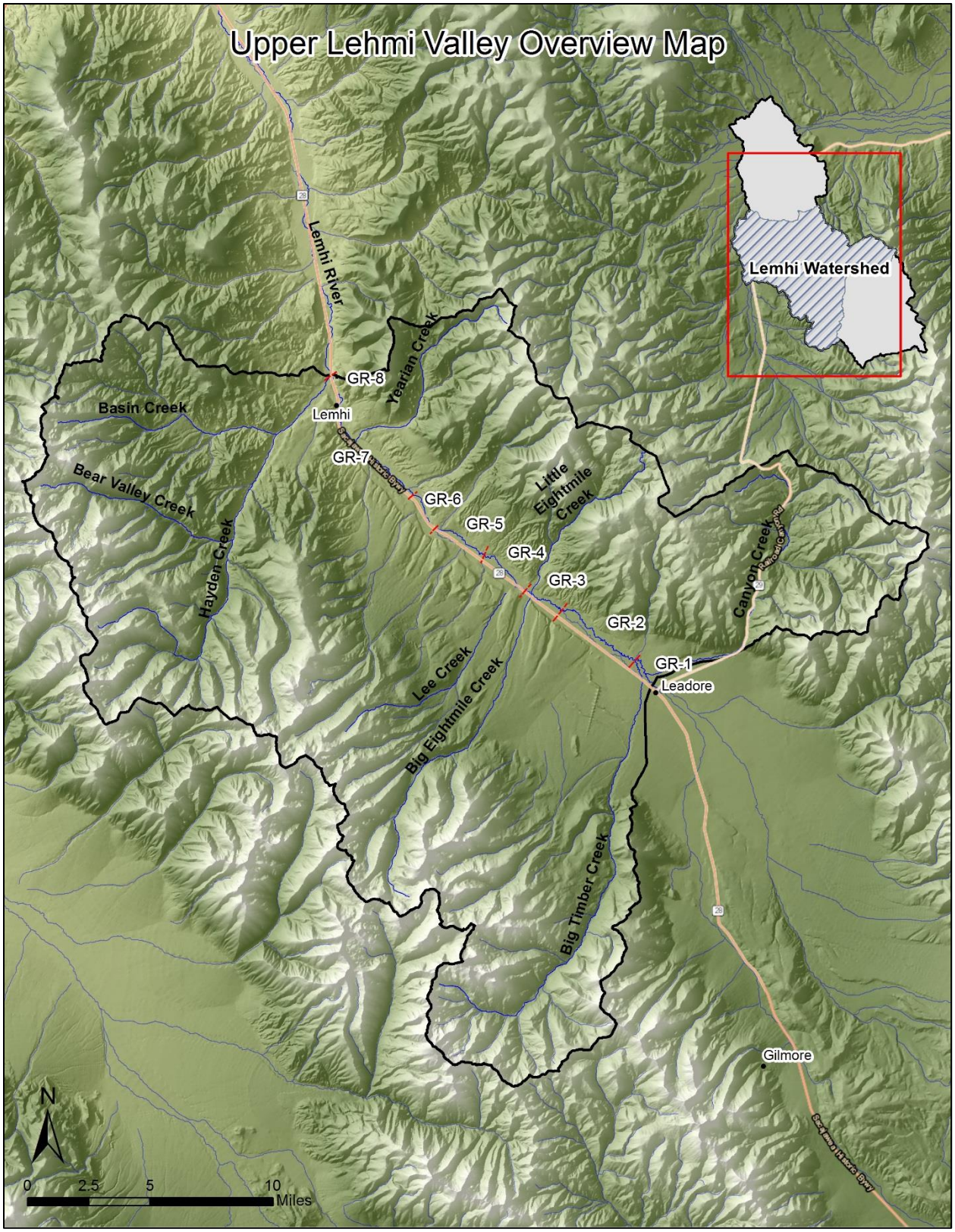

Figure 49. Upper Lemhi Valley Segment (VS-2) and associated geomorphic reaches (GR-2 through GR-8).

Timber Creek (Big Timber Creek) Sub-watershed

The Timber Creek sub-watershed (HUC 1706020404) covers 52,188 acres (Figure 50). Elevations range from about 5854 feet at the Lemhi River and Timber Creek confluence to more than 11000 feet along the Lemhi Range to the west. A ridge trending south from Leadore Hill to Sheephorn Peak separates the Timber Creek sub-watershed from the Texas Creek sub-watershed to the east. The drainage pattern within the sub-watershed is dendritic, and bedrock is predominantly limestone, dolomite, and quartzite. The higher-elevation, timbered lands are administered by the Salmon-Challis National Forest, lower-elevation slopes covered with shrub and grass species are administered by the Bureau of Land Management, and private holdings are predominantly along the valley bottoms, covered with pastures and croplands. The Timber Creek sub-watershed hydrology is snowmelt-dominated, with peak discharges capable of mobilizing and transporting coarse sediment.

Primary tributaries to Big Timber Creek include North Fork Little Timber Creek, Middle Fork Little Timber Creek (impounded to create Timber Creek Reservoir), Little Timber Creek, and Basin Creek.

Timber Creek heads in a glacial cirque and trough, where groundwater flows through glacial debris and colluvium and intermittently daylights at about elevation 9250 feet on the east aspect of the Lemhi Range, near Yellow Peak. From its headwaters to a half-mile downstream of its confluence with Falls Creek, Timber Creek occupies a channelized colluvial valley with a single-thread, fairly straight channel where confined, and a moderately sinuous channel where it is unconfined along wet meadows. Timber Creek then flows through a canyon section that opens up to a moderately confined valley, and instream flows appear to increase in the downstream direction, likely due to seeps and groundwater discharge. The channel is predominantly a single-thread, moderately sinuous to sinuous channel with pool-riffle morphology, likely forced by large woody material recruited through bank erosion and wind throw. Downstream from Trail Creek to Grove Creek, the channel has unconfined sections that have been impounded by beaver complexes in wet meadows with dense riparian vegetation (willow), and in the moderately confined sections between the beaver complexes, the channel reverts back to a single-thread, moderately sinuous channel with pool-riffle morphology. Downstream from Grove Creek, the unconfined sections have less riparian vegetation due to cattle grazing, with minor beaver activity in these sections. Where riparian vegetation is lacking, the channel has widened and shallowed. There is what appears to be a concrete irrigation diversion structure upstream of the junction where Big Timber Creek Road starts ascending the canyon that should be evaluated for fish passage. The structure also diverts surface water out-of-basin from Big Timber Creek to the Texas Creek sub-watershed. Downstream of the irrigation diversion to the Lemhi River confluence, Big Timber Creek has several irrigation diversions along its mainstem that reduce instream flows, and thus, the sediment transport capacity of the stream and the channel becomes moderately sinuous where dense riparian vegetation lines the banks with a predominantly pool-riffle morphology. Conversely, the channel tends to be fairly straight and wide where there is discontinuous or no riparian vegetation.

Summary

Big Timber Creek has a snowmelt-dominated hydrology capable of mobilizing and transporting coarse sediment. Irrigation diversions have attenuated peak flows in the stream, thus reducing the stream power and transport capacity. In addition, flows are impounded on the Middle Fork Little Timber Creek, and on Timber Creek, flows are diverted out-of-basin to the Texas Creek sub-watershed.

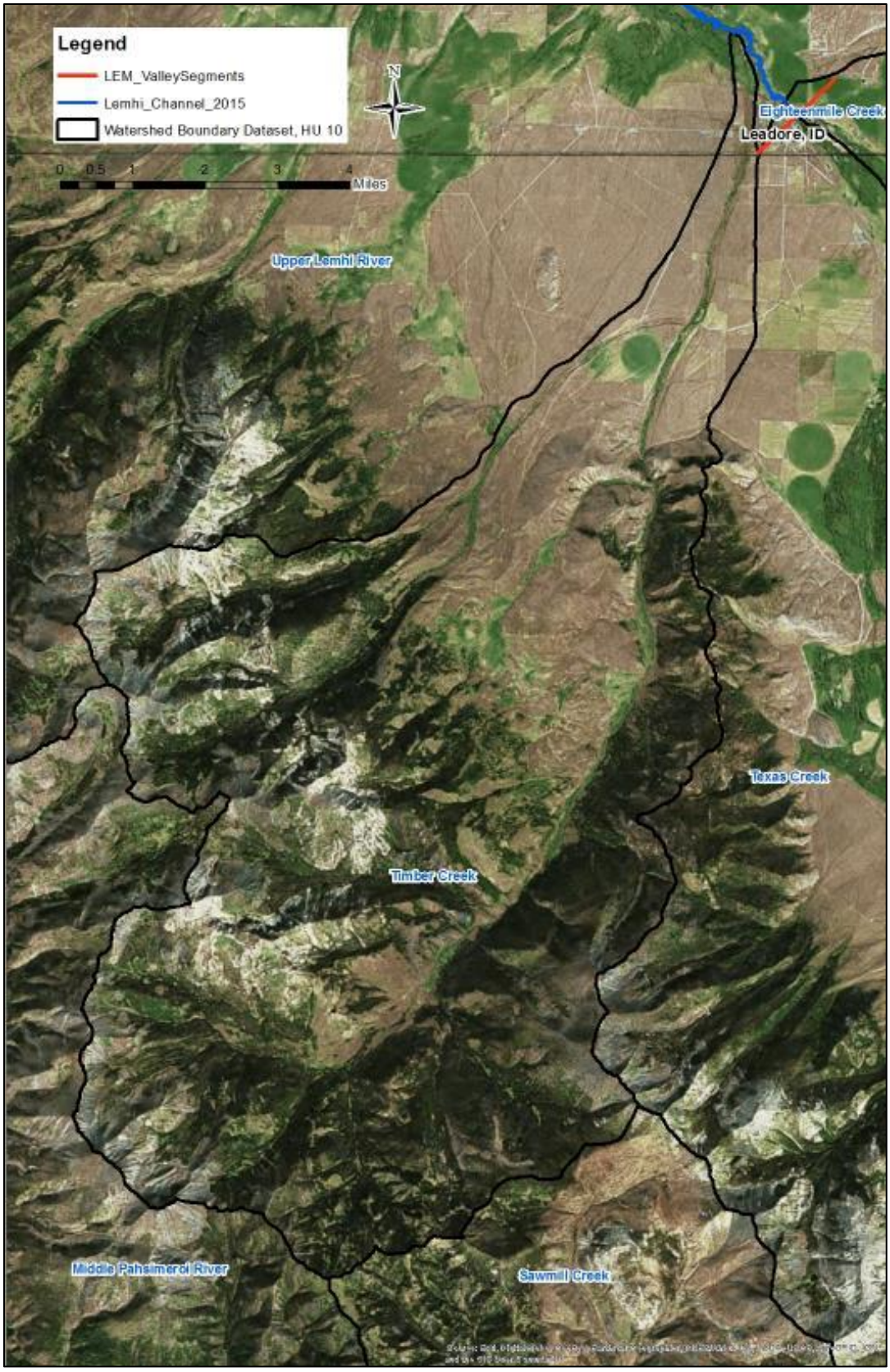

Figure 50. Location of the Timber Creek sub-watershed.

Geomorphic Reach GR-1 (RM 63.3 – 60.4)

Geomorphic Reach GR-1 is located along the Lemhi River between RM 63.3 and RM60.4 in an unconfined valley with minimal valley bottom constraints (Figure 51). Reach characteristics are summarized below in Table 12.

Table 12. Summary of attributes for Geomorphic Reach GR-1.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Avg. Valley Width (ft)	Avg. Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-1	63.3 - 60.4	0.0075	526	526	0.0038	19	2.0	28	28	0%	Gaining	56%	44%	0%

Forms

- Sinuous reach with little evidence of planform alterations not related to flow and sediment transport processes.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.
- Although unconfined, GR-1 has the narrowest average floodplain width measured on the Lemhi River.
- One of the lowest valley gradients of the Lemhi reaches.

Processes

- Observable channel widening where riparian vegetation is lacking.
- No point bar deposition suggests very low rates of channel migration (concurrent bank erosion on one bank and deposition on the other).
- Excessive fine sediment contributions resulting from increased erodibility of banks due to degraded riparian vegetation and livestock grazing leading to siltation and substrate embeddedness.

Human Impacts

- Patchy, discontinuous riparian corridor and associated bank instability, channel widening, plane-bed morphology, and lack of shade.
- Excessive fine sediment.
- Irrigation diversions.

Response Potential

- Groundwater-influenced hydrology, gaining reach (Donato 1998). Shallow groundwater supports riparian vegetation regeneration and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.
- Typical response to disturbances includes avulsion, side-channel formation, floodplain activation, and scour pool formation.

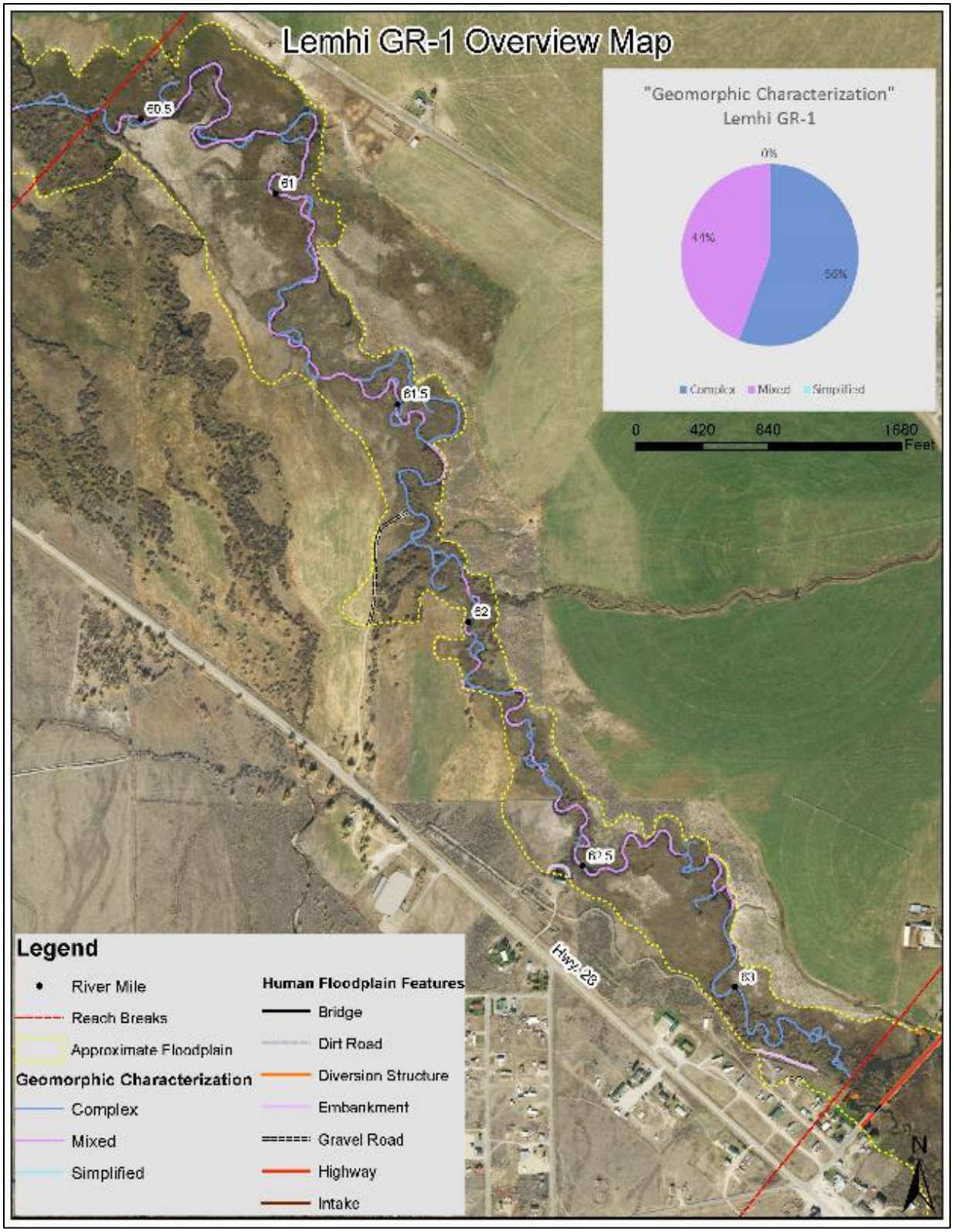

Figure 51. GR-1 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-2 (RM 60.4 – 52.6)

Geomorphic Reach GR-2 is located along the Lemhi River between RM 60.4 and RM 52.5 in an unconfined valley with few valley bottom constraints (Figure 52). The riverine system is geomorphically and hydrologically similar to Geomorphic Reach GR-1. Reach characteristics are summarized below in Table 13.

Table 13. Summary of attributes for Geomorphic Reach GR-2

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-2	60.4 - 52.6	0.0081	2050	1,785	0.0038	29	2.2	71	62	6%	Gaining	53%	46%	1%

Forms

- Sinuous reach with little evidence of planform alterations not related to flow and sediment transport processes
- Mix of plane-bed and pool-riffle morphology, with pool-riffle generally associated with areas of dense riparian vegetation.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.
- Expanded floodplain inundation area relative to upstream GR-1.

Processes

- Observable channel widening where riparian vegetation is lacking.
- No point bar deposition suggests very low rates of channel migration.
- Fine sediment deposition observed in over-widened areas.

Human Impacts

- Little evidence of possible artificial grade control influence
- Patchy, discontinuous riparian corridor and associated bank instability, channel widening, plane-bed morphology, and lack of shade.
- Excessive fine sediment contributions resulting from increased erodibility of banks due to degraded riparian vegetation and livestock grazing leading to siltation
- Irrigation diversions.

Response Potential

- Groundwater-influenced hydrology, gaining reach (Donato 1998). Shallow groundwater supports riparian vegetation regeneration and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.
- Typical response to disturbances includes avulsion, side-channel formation, floodplain activation, and scour pool formation.

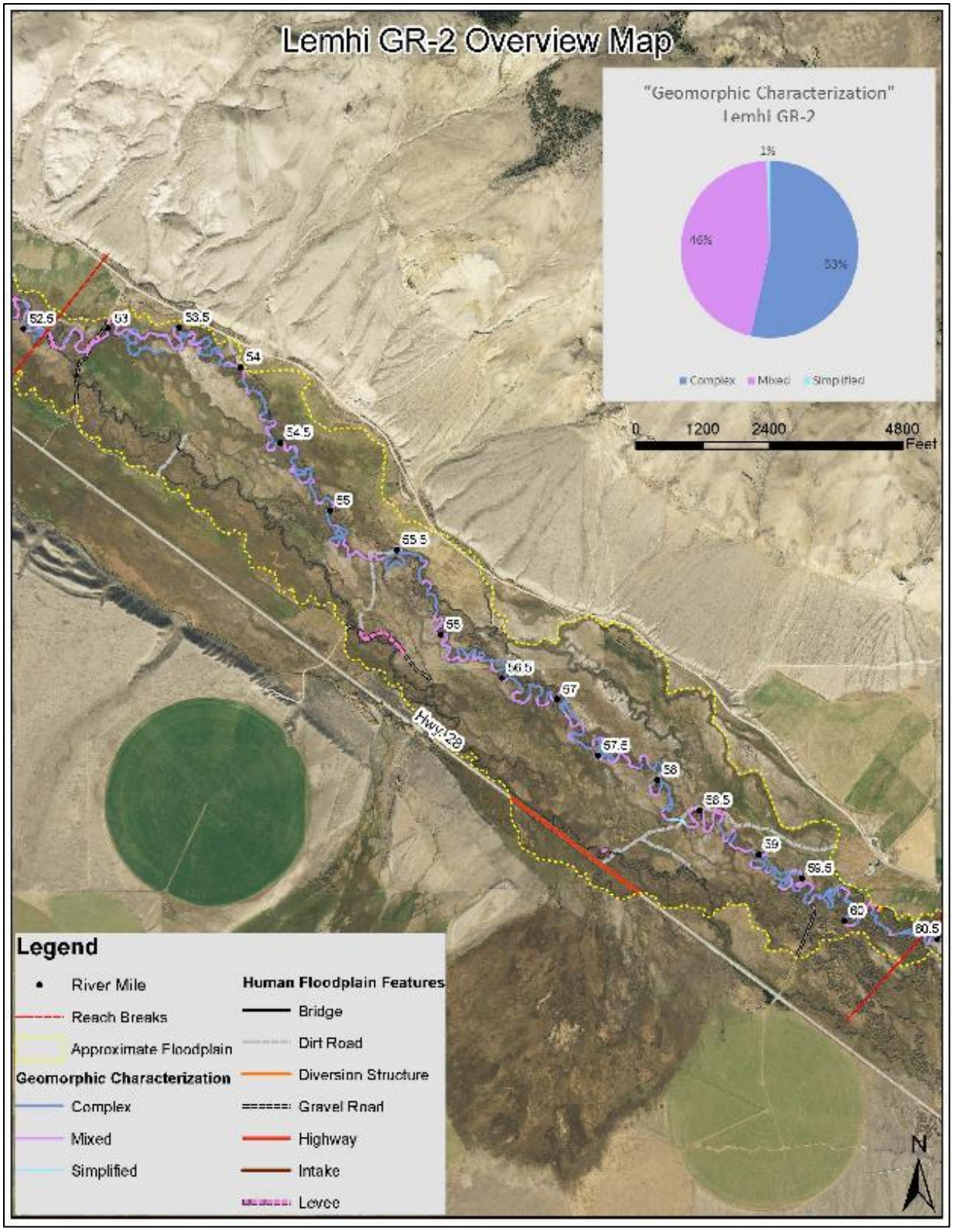

Figure 52. GR-2 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain

Geomorphic Reach GR-3 (RM 52.6 – 49.6)

Geomorphic Reach GR-3 is located along the Lemhi River between RM 52.6 and RM 49.6 in a mostly unconfined valley setting (Figure 53). The riverine system is beginning to transition to an increasingly simplified structure with less groundwater influence. Reach characteristics are summarized below in Table 14.

Table 14. Summary of attributes for Geomorphic Reach GR-3

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-3	52.6 - 49.6	0.0075	1070	960	0.0044	33	1.7	32	29	11%	Gaining	55%	38%	7%

Forms

- Sinuous, except minor channel straightening associated with roads and bridges in the downstream end of the reach.
- Mix of plane-bed and pool-riffle morphology, with pool-riffle generally associated with areas of dense riparian vegetation in the upper 75 percent of the reach.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Observable channel widening where riparian vegetation is lacking.
- Few point bars suggests low rates of channel migration.
- Fine sediment deposition observed in over-widened areas.

Human Impacts

- Patchy, discontinuous riparian corridor and associated bank instability, channel widening, plane-bed morphology, and lack of shade. Riparian conditions improve toward the downstream end of the reach.
- Areas of channel straightening and bridges may locally concentrate flow, causing incision and/or bed armoring.
- Excessive fine sediment filling interstitial space in the bed.
- Irrigation diversions, road embankments, bridges, and discontinuous levees altering in-channel and floodplain processes.

Response Potential

- Begins to transition from groundwater-influenced hydrology to more heavily peak-flow influenced, gaining reach (Donato 1998). Shallow groundwater supports riparian vegetation regeneration and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.

- Typical response to disturbances includes avulsion, side-channel formation, floodplain activation, and scour pool formation.

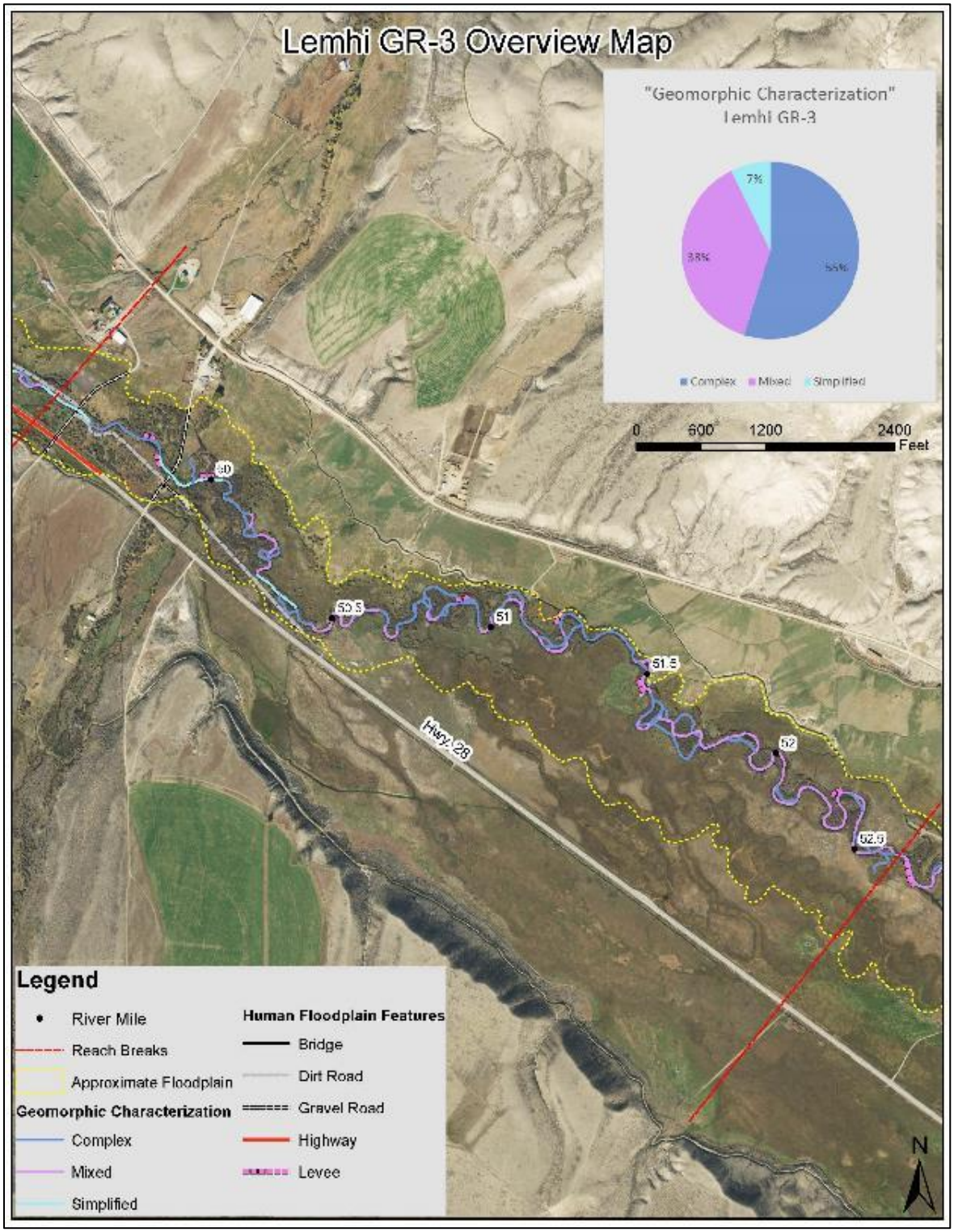

Figure 53. GR-3 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-4 (RM 49.6 – 46.5)

Geomorphic Reach GR-4 is located along the Lemhi River between RM 49.6 and RM 46.5 in an unconfined valley, with some valley bottom constraints resulting in the downstream disruption of flows and channel migration along the floodplain (Figure 54). Reach characteristics are summarized below in Table 15.

Table 15. Summary of attributes for Geomorphic Reach GR-4

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-4	49.6 - 46.5	0.0077	1235	1,236	0.0057	37	1.4	33	33	7%	Losing	62%	29%	9%

Forms

- Sinuous, except channel straightening associated with roads and bridges in the upper third of the reach.
- Multi-threaded form is prevalent in lower reach.
- Mix of plane-bed and pool-riffle morphology, with plane-bed generally associated with channel straightening, and pool-riffle associated with areas of dense riparian vegetation in the lower reach.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Observable, often significant, channel widening where riparian vegetation is lacking.
- Little to no point bar deposition suggests low rates of channel migration.
- Fine sediment deposition observed in over-widened areas.

Human Impacts

- Patchy, discontinuous riparian corridor and associated bank instability leading to channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening in the upper reach may increase local transport capacity, resulting in bed armoring.
- Excessive fine sediment filling interstitial space in the bed.
- Irrigation diversions, road embankments, bridges, and discontinuous levees altering in-channel and floodplain processes.

Response Potential

- Peak-flow-dominated hydrology; after irrigation season, it is a losing reach (Donato 1998). Shallow groundwater during summer months supports riparian vegetation and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.

- Typical response to disturbances includes avulsion, lateral channel migration, side-channel formation, floodplain activation, and scour pool formation.

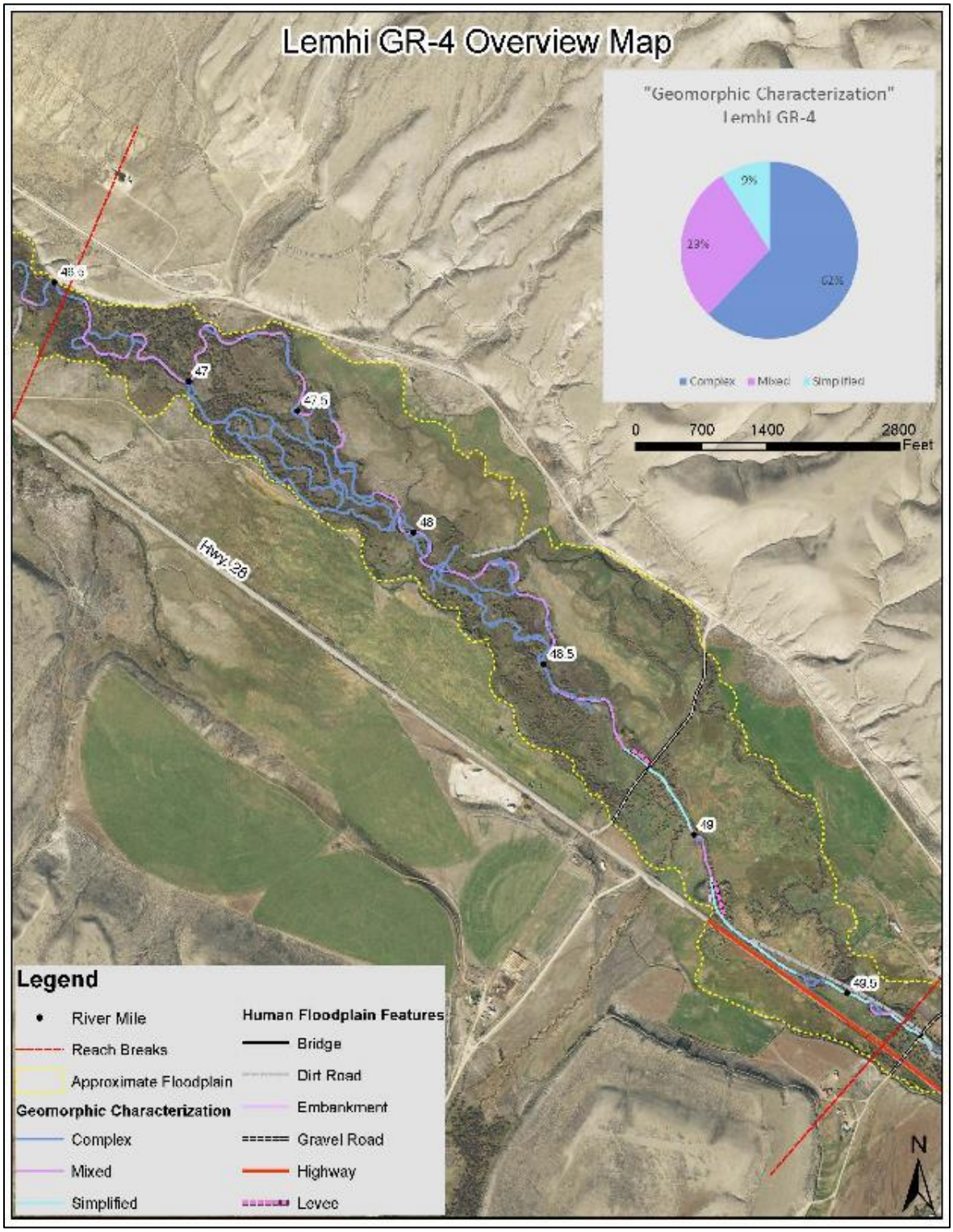

Figure 54. GR-4 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-5 (RM 46.5 – 43.2)

Geomorphic Reach GR-5 is located along the Lemhi River between RM 46.5 and RM 43.2 in an unconfined valley with significant constraints from Highway 28, resulting in the narrowing of the valley bottom by 30 percent and downstream disruption of flows and channel migration along the floodplain (Figure 55). Reach characteristics are summarized below in Table 16.

Table 16. Summary of attributes for Geomorphic Reach GR-5

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization	Geomorphic Characterization	Geomorphic Characterization "Simplified"
VS-2	GR-5	46.5 - 43.2	0.0086	1675	1,171	0.0060	34	1.4	49	34	8%	Losing	60%	22%	18%

Forms

- Sinuous, single-thread channel with significant side-channel development in the lower reach.
- Predominantly pool-riffle morphology generally associated with areas of mature riparian vegetation.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.
- Relatively high floodplain inundation area and valley gradient (similarities with GR-12 and GR-13)

Processes

- Observable channel widening where riparian vegetation is lacking.
- No point bar deposition suggests very low rates of channel migration.
- Fine sediment deposition observed in over-widened areas.

Human Impacts

- Discontinuous riparian corridor and associated bank instability and channel widening, and lack of shade.
- Highway 28 bisects the floodplain and artificially constrains the channel in the lower third of the reach, and channel confinement and straightening along the lower section may increase local transport capacity armoring the bed.
- Excessive fine sediment contributions resulting from increased erodibility of banks and floodplain due to degraded riparian vegetation and livestock grazing leading to siltation.
- Highway 28 road embankment, irrigation diversions, and bridges.

Response Potential

- Peak-flow-dominated hydrology; after irrigation season, it is a losing reach (Donato 1998). Fairly shallow groundwater during summer months supports riparian vegetation and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.

- Typical response to disturbances includes avulsion, side-channel formation, floodplain activation, and scour pool formation.

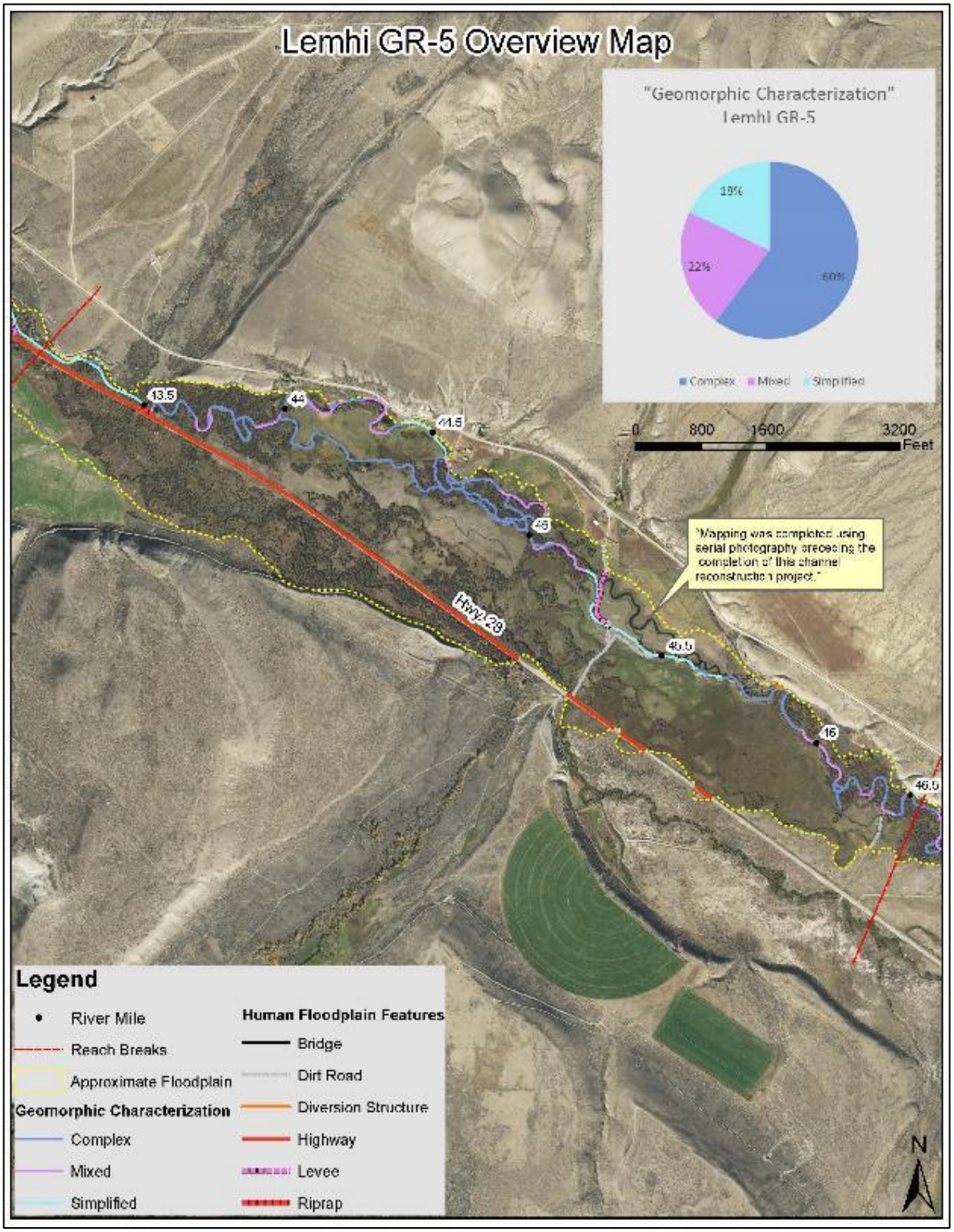

Figure 55. GR-5 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-6 (RM 43.2 – 41.1)

Geomorphic Reach GR-6 is located along the Lemhi River between RM 43.2 and RM 41.1 in an unconfined valley with significant human constraints from Highway 28, resulting in the narrowing of the valley bottom by about 50 percent, disrupting floodplain connection and channel migration (Figure 56). Reach characteristics are summarized below in Table 17.

Table 17. Summary of attributes for Geomorphic Reach GR-6

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-6	43.2 - 41.1	0.0083	1342	663	0.0064	33	1.3	41	20	23%	Losing	62%	12%	26%

Forms

- Sinuous, except minor channel straightening associated with roads and bridges in the upstream and downstream ends of the reach.
- Mix of plane-bed and pool-riffle morphology, with pool-riffle generally associated with areas of dense riparian vegetation in the middle section of the reach.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Observable channel widening where riparian vegetation is lacking.
- No point bar deposition suggests very low rates of channel migration.
- Fine sediment deposition observed in over-widened areas.

Human Impacts

- Patchy, discontinuous riparian corridor and associated bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and minor straightening may increase local transport capacity, armoring the bed predominantly in the upstream quarter of the reach.
- Excessive fine sediment filling interstitial space in the bed.
- Highway 28 road embankment, bridges, irrigation diversions, and discontinuous levees.

Response Potential

- Peak-flow-dominated hydrology; after irrigation season, it is a losing reach (Donato 1998). Fairly shallow summer groundwater supports riparian vegetation regeneration and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.
- Typical response to disturbances includes avulsion, side-channel formation, floodplain activation, and scour pool formation.

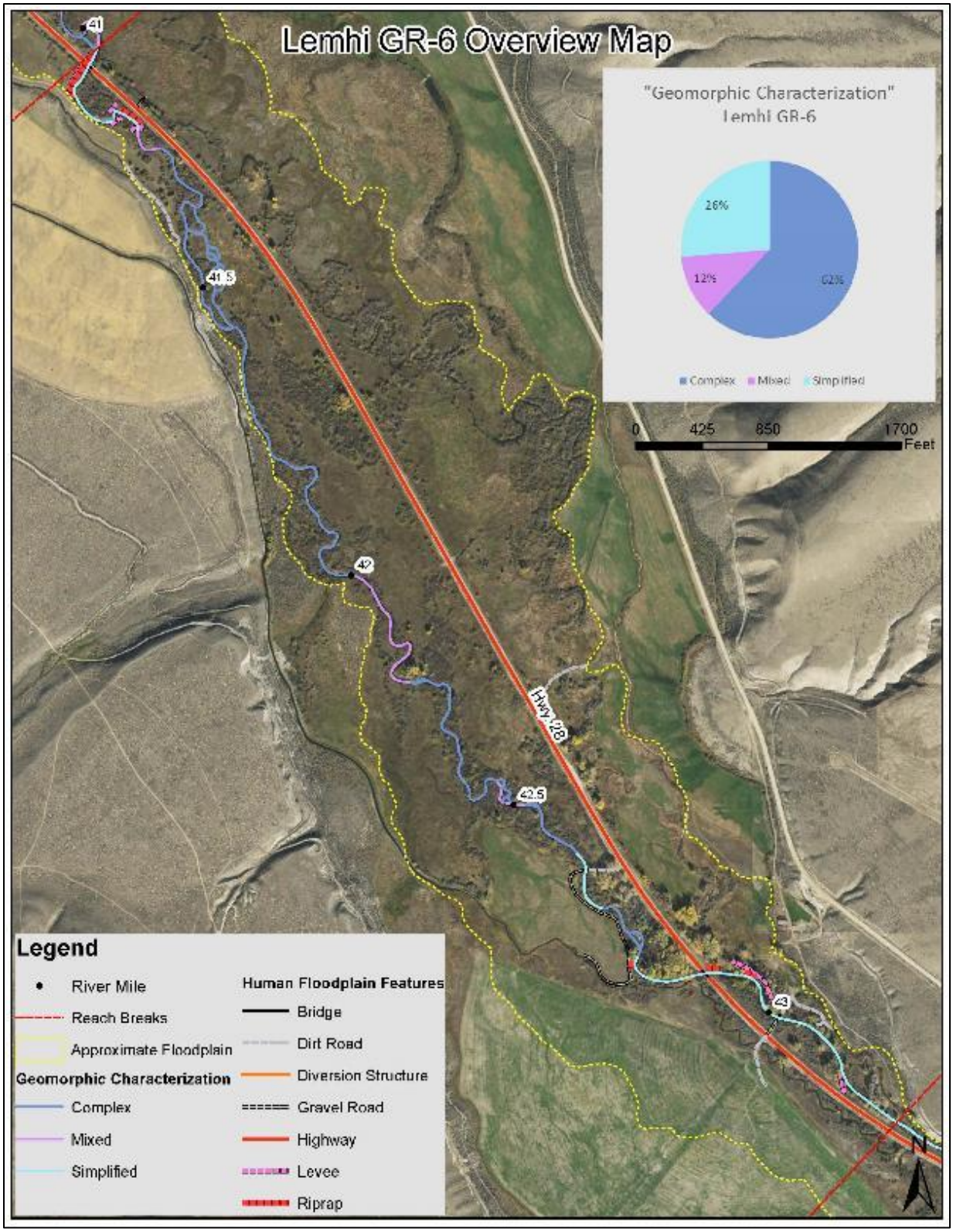

Figure 56. GR-6 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-7 (RM 41.1 – 35.1)

Geomorphic Reach GR-7 is located along the Lemhi River between RM 41.1 and RM 35.1 in an unconfined valley with significant valley bottom constraints, resulting in the narrowing of the valley bottom by about 40 percent (Figure 57). Reach characteristics are summarized below in Table 18.

Table 18. Summary of attributes for Geomorphic Reach GR-7

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-7	41.1 - 35.1	0.0080	2127	1,204	0.0061	35	1.3	60	34	19%	Neutral	50%	25%	24%

Forms

- Sinuous, except major channel straightening associated with roads, bridges, and discontinuous levees primarily in the upstream half of the reach.
- Mix of plane-bed morphology generally associated with channel straightening, and pool-riffle morphology generally associated with areas of dense riparian vegetation.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Observable channel widening where riparian vegetation is lacking.
- Little to no point bar deposition suggests low rates of channel migration.
- Fine sediment deposition observed in over-widened areas.

Human Impacts

- Patchy, discontinuous riparian corridor resulting in bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity, armoring the bed.
- Highway 28 artificially constrains the floodplain from RM 37.7 to 36.5.
- Excessive fine sediment filling interstitial space in the bed.
- Road embankments, bridges, irrigation diversions, and discontinuous levees.

Response Potential

- This reach gains from groundwater discharge during the irrigation season and then loses to the aquifer following irrigation season (Donato 1998). Shallow bedrock forces groundwater flows toward the surface at the downstream end of the reach and supports an area of dense, mature riparian vegetation.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.
- Typical response to disturbances includes avulsion, side-channel formation, floodplain activation, and scour pool formation.

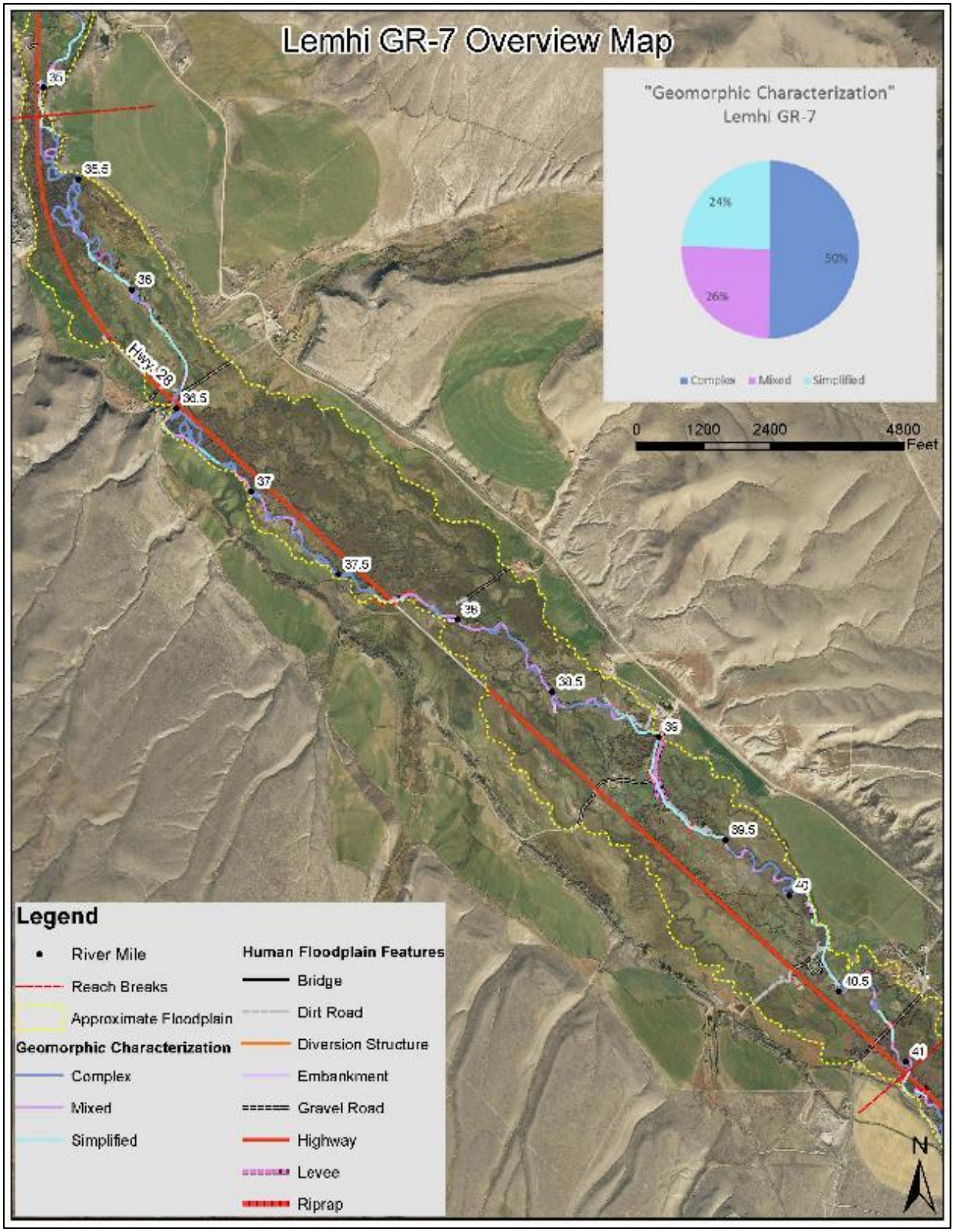

Figure 57. GR-7 overview map illustrating approximate floodplain, geomorphic characterization, and human alterations to floodplain.

Geomorphic Reach GR-8 (RM 35.1 – 32.7)

Geomorphic Reach GR-8 is located along the Lemhi River between RM 35.1 and RM 32.7 in a naturally unconfined valley with significant valley bottom constraints, resulting in narrowing of the valley bottom by about 40 percent due to Highway 28 (Figure 58). The reach is located immediately upstream of the confluence with Hayden Creek. Reach characteristics are summarized below in Table 19.

Table 19. Summary of attributes for Geomorphic Reach GR-8.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-8	35.1 - 32.7	0.0073	1393	781	0.0054	36	1.4	39	22	23%	Gaining	40%	4%	56%

Forms

- Sinuous, except for major channel straightening along Highway 28 in the downstream third of the reach.
- Predominantly plane-bed morphology generally associated with a lack of instream structure and channel straightening.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Observable channel widening where riparian vegetation is lacking.
- No point bar deposition suggests very low rates of channel migration.
- Fine sediment deposition observed in over-widened areas.

Human Impacts

- Narrow, discontinuous riparian corridor resulting in bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity armoring the bed.
- Highway 28 artificially constrains the floodplain throughout the reach.
- Excessive fine sediment filling interstitial space in the bed.
- Road embankments, bridges, irrigation diversions, and discontinuous levees.

Response Potential

- Groundwater/baseflow-dominated hydrology, predominantly a gaining reach (Donato 1998). Shallow bedrock has raised the groundwater table, supporting riparian vegetation and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow). Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.
- Typical response to disturbances includes avulsion, side-channel formation, floodplain activation, and scour pool formation. Incision and bed armoring occur in straightened and confined areas.

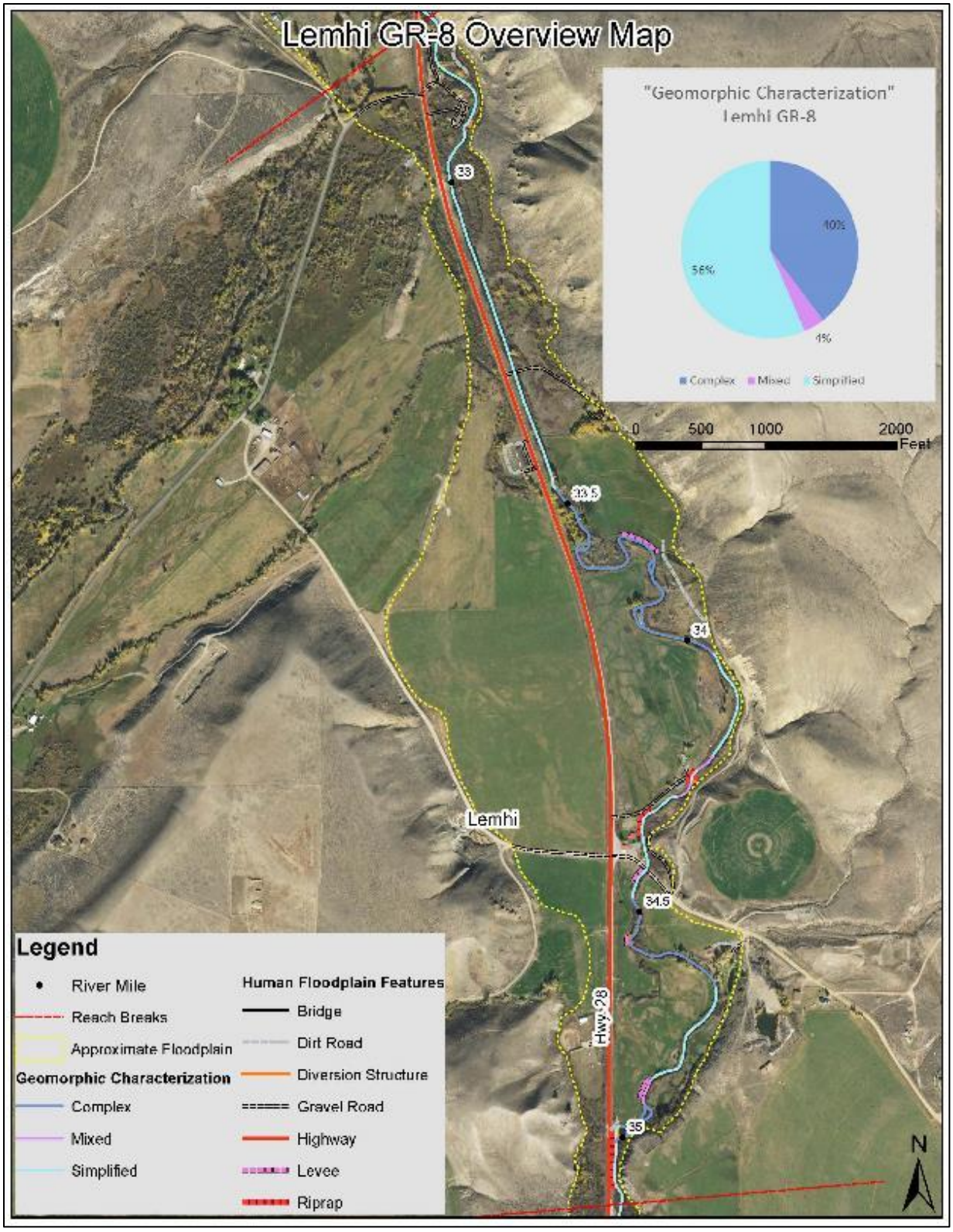

Figure 58. GR-8 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Middle Lemhi Valley Segment (VS-3)

Middle Lemhi River Valley Segment comprises the Middle Lemhi River watershed and the Hayden Creek watershed (Table 20, Table 21, Figure 59). The Hayden Creek watershed contributions nearly double the flows in the Lemhi River.

RM 32.73– RM 19.55

Table 20. Lemhi watershed hydrologic units and areas

Sub-watershed	HUC 10	Named Tributaries	Acreage	Square Miles
Hayden Creek	1706020406	28	91,873 acres	143.55 mi^2
Middle Lemhi River	1706020407	13	114,868 acres	179.48 mi^2
Total		**41**	**206,741 acres**	**323.03 mi^2**

Table 21. Middle Lemhi sub-watershed tributaries

Tributary	Flow Regime	Drainage	Connectivity	Other
Kenney Creek (RM 19.6)	Perennial	Beaverhead Mountains	Direct connection	EPA-approved TMDL (Category 4a); Tributaries include East Fork Kenney Creek
Pattee Creek (RM 23.22)	Perennial	Beaverhead Mountains	Direct connection	Tributaries include Cherry Creek, High Creek, and Wade Creek
Agency Creek (RM 24.76)	Perennial	Beaverhead Mountains	Direct connection	Blue Bird – Gold Flint Copper Queen Consolidated Lodes, (Mineral Survey #993), Aug. 27, 1892, T19N – R25E, 58.65 acres; Mine T19N – R25E, Sect. 15, Quarry; Mine T19N –R25E, Sect. 9, Quarry; Tributaries include Cow Creek, Sharkey Creek, White Creek, Flume Creek, and Horseshoe Bend Creek; Lewis and Clark Pass
McDevitt Creek (RM 25.85)	Perennial	Lemhi Range	Indirect connection	Dewaters on alluvial fan; EPA-approved TMDL (Category 4)
Muddy Creek (RM 26.75)	Ephemeral	Lemhi Range	Direct connection	Channelized due to railroad/road grade
Hayden Creek (RM 32.66)	Perennial	Lemhi Range	Direct connection	HUC 10 sub-watershed; See Table 20.

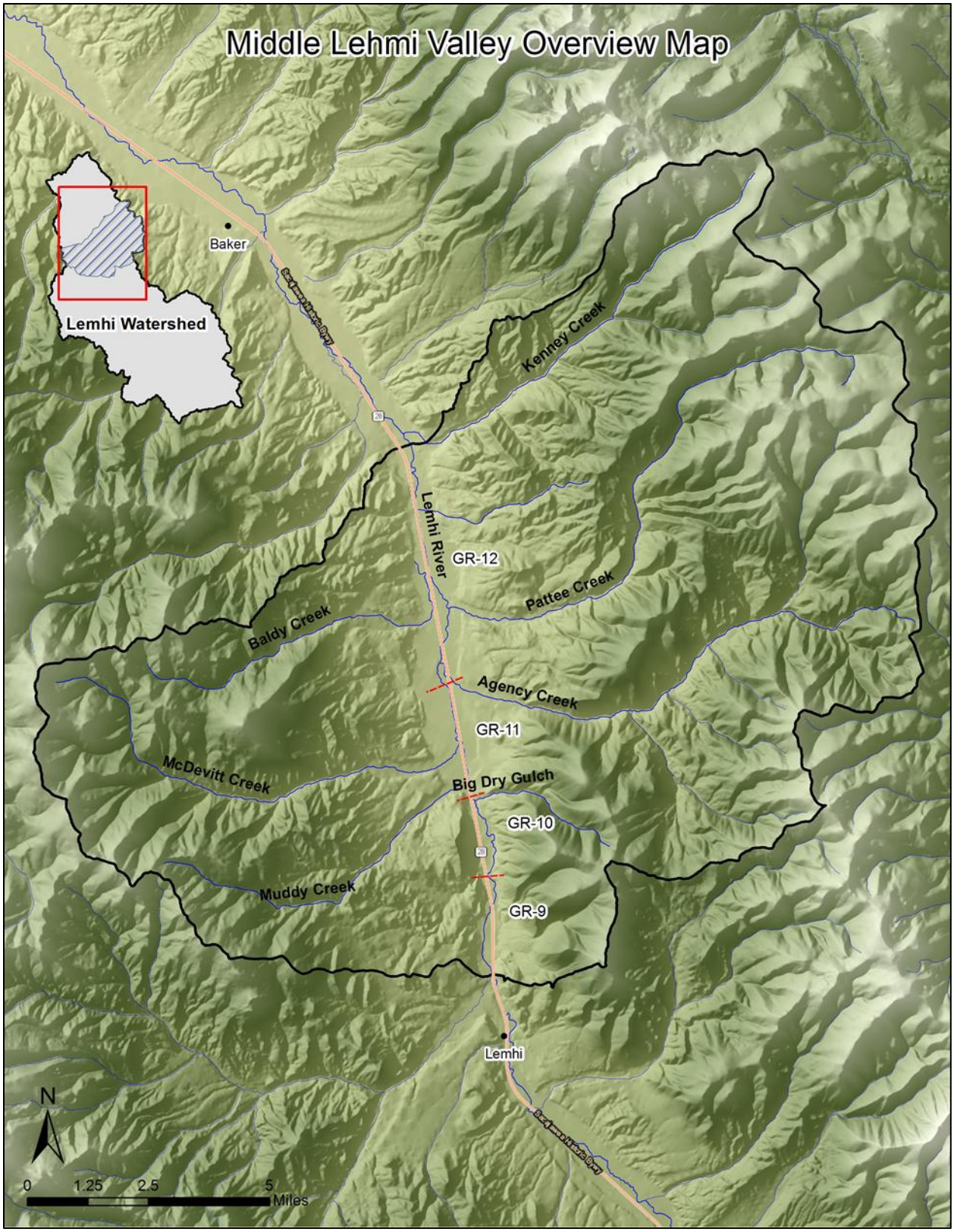

Figure 59. Middle Lemhi Valley Segment (VS-3) and geomorphic reaches (GR-9 through GR-12).

Hayden Creek Sub-watershed

The Hayden Creek sub-watershed (HUC 1706020406) covers 91,873 acres (Figure 60). Elevations range from about 5140 feet at the confluence of the Lemhi River and Hayden Creek to more than 10000 feet along the Lemhi Range. The Lemhi Range has several alpine lakes and tarns within glacial cirques. The drainage pattern within the sub-watershed is dendritic, and bedrock is predominantly limestone, dolomite, and quartzite. The higher-elevation, timbered lands are administered by the Salmon-Challis National Forest, lower-elevation slopes covered with shrub- and grasslands are administered by the BLM, and private holdings are predominantly along the valley bottoms in Hayden Creek and Basin Creek, and at the Hayden Creek and Lemhi River confluence. The Hayden Creek sub-watershed hydrology is snowmelt-dominated, with peak discharges capable of mobilizing and transporting coarse bedload from its confluence with Paradise Creek downstream through the canyon section to the Lemhi River.

Primary tributaries to Hayden Creek include West Fork Hayden Creek, Mogg Creek, East Fork Hayden Creek, Bear Valley Creek, and Basin Creek. Along the base of the Lemhi Range ridge, the West Fork Hayden Creek, Bear Valley Creek, and Basin Creek watersheds head in several alpine lakes and unnamed tarns. Named alpine lakes include Bear Valley Lakes and Buck Lakes in the Bear Valley Creek watershed, and Basin Lake in the Basin Creek watershed.

Hayden Creek heads in a glacial cirque where groundwater flows through glacial debris and colluvium, and intermittently daylights at about elevation 8240 feet on the east aspect of Long Mountain in the Lemhi Range. In the headwaters area to its confluence with Paradise Creek, Hayden Creek has a channelized colluvial valley with a single-thread, moderately sinuous channel with likely step-pool morphology, where forced by instream structure, and possibly multi-thread, island-braided channel where unconfined along wet meadows with dense willow and grass species. Hayden Creek then flows through a canyon section as a single-thread, fairly straight channel with sediment inputs from landslides and debris flows, and significant large wood recruitment that likely forces a step-pool to pool-riffle morphology. As the valley bottom opens up and the channel is no longer confined, log jams begin to accumulate upstream of the Hayden Creek and Meadow Creek confluence, likely forcing a pool-riffle morphology. From about the end of Tonsmeire Ranch Road, several irrigation diversions reduce instream flows, thereby reducing the stream's transport capacity to move wood downstream. There is a significant reduction in instream wood, likely due to removal from the channel through the populated sections to reduce the threat of flooding. In this area, the channel has adjusted to a single-thread, moderately sinuous channel with a likely pool-riffle morphology. Here, dense riparian vegetation (willows and cottonwoods) and log jams still force flow convergence and bed scour, as well as a likely plane-bed channel in widened areas where riparian vegetation has been replaced with pasturelands for grazing, which is causing bank recession.

Summary

Hayden Creek has a snowmelt-dominated hydrology capable of mobilizing and transporting large wood and coarse sediment. However, peak flows have been attenuated by irrigation diversions taking water out of Hayden Creek and reducing stream power and transport capacity. In addition, the visible reduction of instream wood near populated areas suggests wood has been removed from the system to reduce the threat of flooding.

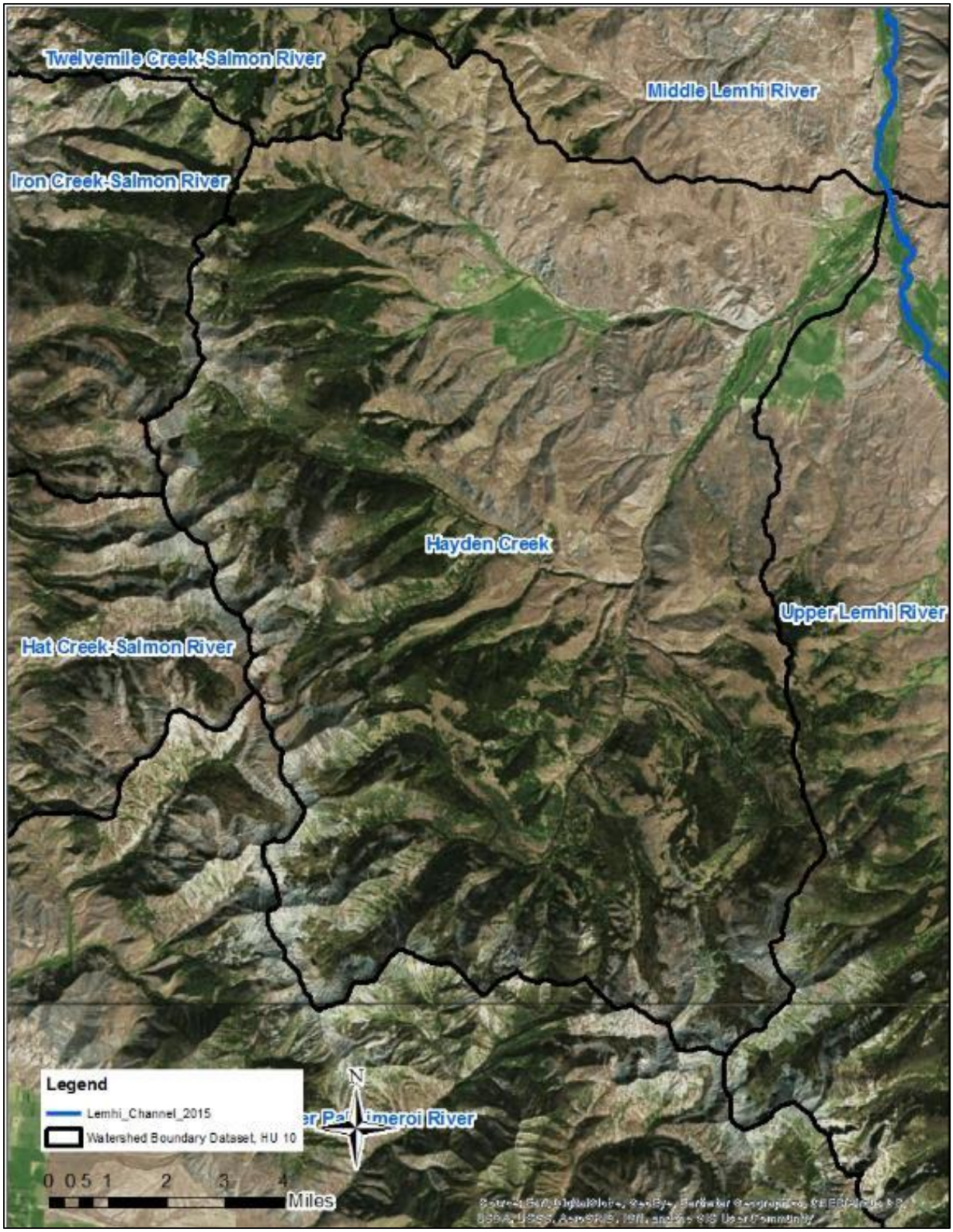

Figure 60. Aerial image of Hayden Creek sub-watershed.

Geomorphic Reach GR-9 (RM 32.7 – 30.3)

Geomorphic Reach GR-9 is located along the Lemhi River between RM 32.7 and RM 30.3, in an unconfined valley with moderate valley bottom constraints resulting in the narrowing of the valley bottom by about 25 percent (Figure 61). The reach is located immediately below the confluence with Hayden Creek and is significantly influenced by the peak-flow hydrology and coarse sediment inputs from Hayden Creek. Reach characteristics are summarized below in Table 22.

Table 22. Summary of attributes for Geomorphic Reach GR-9

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-9	32.7 - 30.3	0.0088	1488	1,074	0.0077	54	1.1	28	20	6%	Gaining	13%	5%	81%

Forms

- Low to moderate sinuosity; much of the channel appears to have been mechanically altered and straightened.
- Predominantly plane-bed morphology generally associated with a lack of instream structure, low sinuosity, and likely channel alteration.
- Many banks lacking riparian vegetation.

Processes

- Possible incision and/or bed armoring associated with channel alterations and straightening.
- No point bar deposition suggests very low rates of channel migration.
- Bank recession and widening observed in areas lacking mature riparian vegetation.
- Disturbance regime supports cottonwood riparian vegetation from this point downstream.

Human Impacts

- Patchy, discontinuous riparian corridor resulting in bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity incising and/or armoring the bed.
- Highway 28 artificially constrains the floodplain throughout the reach.
- Road embankments, bridges, and irrigation diversions.

Response Potential

- Snowmelt-dominated hydrology driven by discharge from Hayden Creek with groundwater inputs. Shallow groundwater supports riparian vegetation and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow and cottonwood) in addition to coarse sediment and large wood inputs from Hayden Creek. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.

- Typical response to disturbances includes channel migration, floodplain activation, pool and riffle formation, and island braiding associated with instream obstruction. Incision and bed armoring in straightened and confined areas.

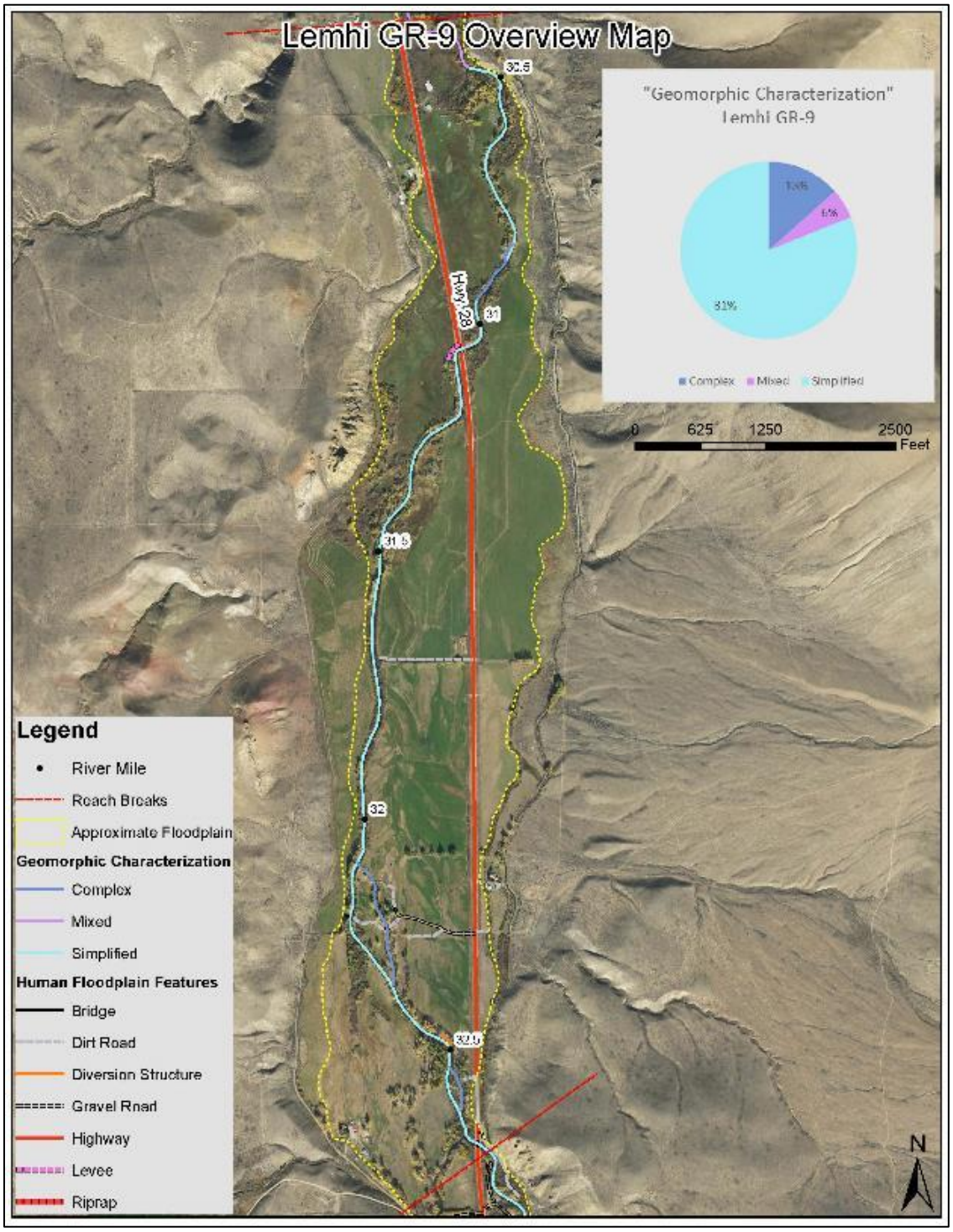

Figure 61. GR-9 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-10 (RM 30.3 – 28)

Geomorphic Reach GR-10 is located along the Lemhi River between RM 30.3 and RM 28.0, in an unconfined valley with moderate valley bottom constraints, resulting in the narrowing of the valley bottom by about 35 percent (Figure 62). Reach characteristics are summarized below in Table 23.

Table 23. Summary of attributes for Geomorphic Reach GR-10.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-10	30.3 - 28	0.0093	1273	816	0.0071	46	1.3	28	18	25%	Neutral	5%	28%	67%

Forms

- Sinuous channel may have been repositioned along the right valley wall, at least in the upper half of the reach, if not most of the reach.
- Predominantly plane-bed morphology
- Narrow (about 30 feet wide) riparian corridor.
- Many banks lacking riparian vegetation.

Processes

- Possible incision and/or bed armoring associated with channel alterations and straightening.
- No point bar deposition suggests very low rates of channel migration.
- Bank recession and widening observed in areas lacking mature riparian vegetation.

Human Impacts

- Patchy, discontinuous riparian corridor resulting in bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity armoring the bed.
- Highway 28 artificially constrains the floodplain, predominantly in the downstream third of the reach.
- Road embankments, bridges, irrigation diversions, discontinuous levees, and riprap.

Response Potential

- Snowmelt surface-water-dominated hydrology driven by discharge from Hayden Creek, with groundwater inputs during irrigation season and losses to aquifer after irrigation season. Shallow groundwater during the summer supports riparian vegetation and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (primarily willow and cottonwood) in addition to coarse sediment and large wood inputs from Hayden Creek. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.
- Typical response to disturbances includes channel migration, floodplain activation, pool and riffle formation, and island braiding associated with instream obstruction. Incision and bed armoring in straightened and confined areas.

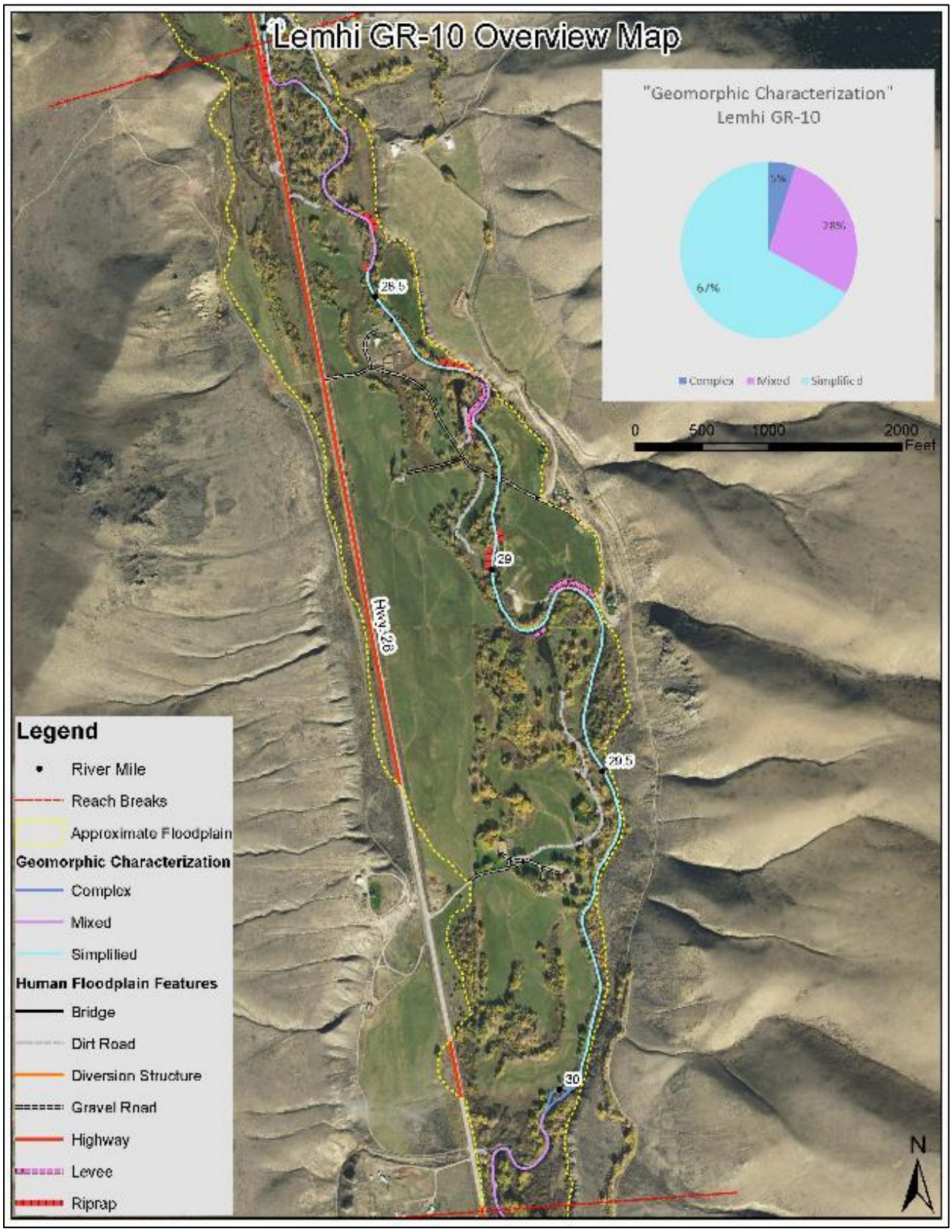

Figure 62. GR-10 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-11 (RM 28 – 25.4)

Geomorphic Reach GR-11 is located along the Lemhi River between RM 28.0 and RM 25.4 in a naturally unconfined valley with significant valley bottom constraints resulting from narrowing of the valley bottom by about 55 percent due to Highway 28 (Figure 63). Reach characteristics are summarized below in Table 24.

Table 24. Summary of attributes for Geomorphic Reach GR-11

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-11	28 - 25.4	0.0088	1158	490	0.0080	51	1.1	23	10	27%	Gaining	12%	10%	77%

Forms

- Sinuous channel may have been repositioned along the right valley wall, at least in the upper half of the reach, if not most of the reach.
- Predominantly plane-bed morphology
- Narrow (about 30 feet wide) riparian corridor.
- Many banks lacking riparian vegetation.

Processes

- Possible incision and/or bed armoring associated with channel alterations and straightening.
- No point bar deposition suggests very low rates of channel migration.
- Bank recession and widening observed in areas lacking mature riparian vegetation.

Human Impacts

- Patchy, discontinuous riparian corridor resulting in bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity armoring the bed.
- Highway 28 artificially constrains the floodplain throughout the reach.
- Road embankments, bridges, irrigation diversions, discontinuous levees, and riprap.

Response Potential

- Snowmelt surface-water-dominated hydrology driven by discharge from Hayden Creek with groundwater inputs. Shallow groundwater during the summer supports riparian vegetation and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (willow and cottonwood) in addition to coarse sediment and large wood recruitment. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation versus channel widening.
- Typical response to disturbances includes channel migration, floodplain activation, pool and riffle formation, and island braiding associated with instream obstruction. Incision and bed armoring in straightened and confined areas.

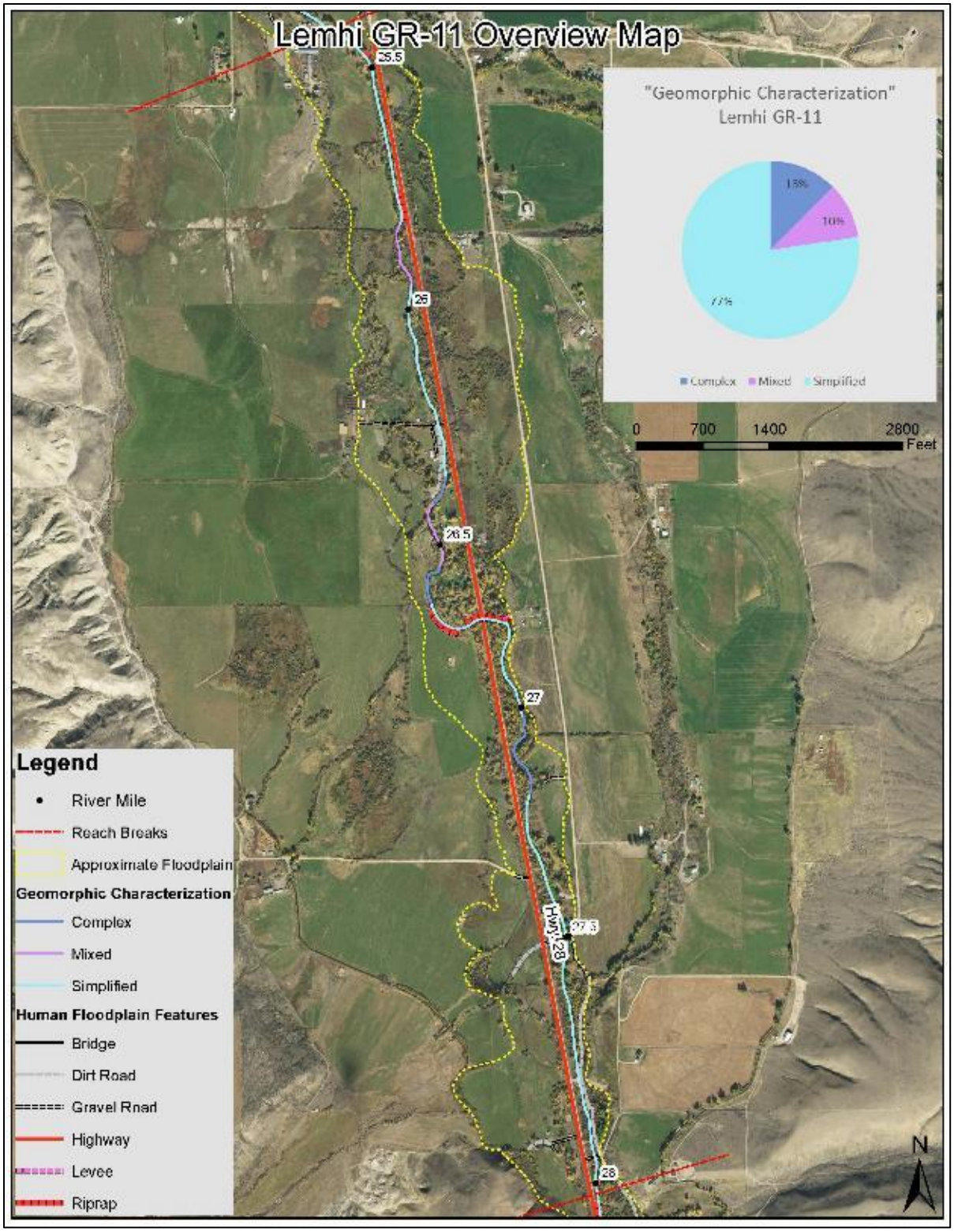

Figure 63. GR-11 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-12 (RM 25.4 – 19.6)

Geomorphic Reach GR-12 is located along the Lemhi River between RM 25.4 and RM 19.6 in a naturally unconfined valley with significant valley bottom constraints associated with Highway 28, resulting in the narrowing of the valley bottom by about 30 percent (Figure 64). Reach characteristics are summarized below in Table 25.

Table 25. Summary of attributes for Geomorphic Reach GR-12.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-12	25.4 - 19.6	0.0088	2813	1,917	0.0076	54	1.1	53	36	32%	Gaining	27%	20%	53%

Forms

- Low to moderate sinuosity with major channel straightening along Highway 28 and levees in the downstream half of the reach.
- Floodplain constrained by Highway 28 along the entire reach.
- Predominantly plane-bed morphology generally associated with a simplified and straightened channel.
- Many banks lacking riparian vegetation.
- Over-widened channel, primarily where riparian vegetation is lacking.

Processes

- No point bar deposition suggests very low rates of channel migration.
- Evidence of large wood recruitment on bends in lower reach initiating small-scale island braiding (near RM 20.5).

Human Impacts

- Patchy, discontinuous riparian corridor resulting in bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity armoring the bed.
- Highway 28 artificially constrains the floodplain throughout the reach.
- Road embankments, bridges, irrigation diversions, discontinuous levees, and riprap.

Response Potential

- Snowmelt surface-water-dominated hydrology with groundwater inputs. Shallow groundwater during the summer supports riparian vegetation and associated bank stability.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (willow and cottonwood) in addition to coarse sediment and large wood recruitment. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation.

- Typical response to disturbances includes channel migration, floodplain activation, pool and riffle formation, and island braiding associated with instream obstruction. Incision and bed armoring in straightened and confined areas.

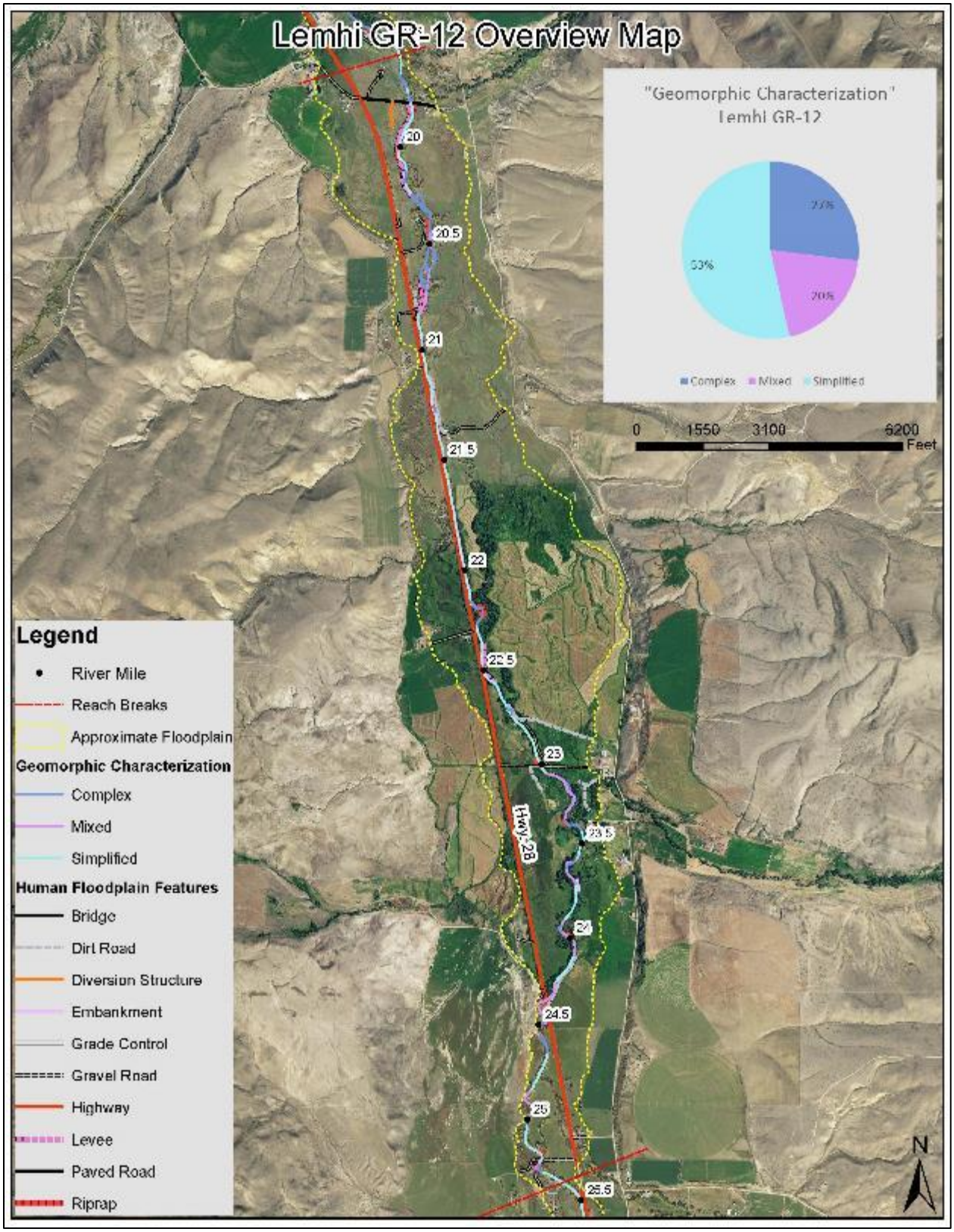

Figure 64. GR-12 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Lower Lemhi Valley Segment (VS-4)

Includes the mainstem Lemhi River from RM 0 to RM 19.55.

The Lower Lemhi River Valley Segment comprises the Lower Lemhi River watershed (Table 26, Table 27, Figure 65), gaining from groundwater inputs in August and October (Donato 1998).

Table 26. Lemhi watershed hydrologic units and areas.

Sub-watershed	HUC 10	Named Tributaries	Acreage	Square Miles
Lower Lemhi River	1706020408	21	131,037 acres	204.75 mi^2
Total		**21**	**131,037 acres**	**204.75 mi^2**

Table 27. Lower Lemhi sub-watershed tributaries.

Tributary	Flow Regime	Drainage	Connectivity	Other
Kirtley Creek (RM 2.55)	Ephemeral	Beaverhead Mountains	Indirect Connection	Dewaters on alluvial fan; EPA-approved TMDL (Category 4a); Tributaries include North Fork Kirtley Creek, East Fork Kirtley Creek, and four unnamed tributaries; No. 3 Placer, No. 2 Placer, and No. 1 Placer (Mineral Survey #990), approved June 23, 1892, T21N – R22E/T22N – R22E, 3.8 miles of valley bottom.
Geertson Creek (~RM 8.4)	Perennial	Beaverhead Mountains	Indirect connection	Dewaters on alluvial fan; heads in tarn; EPA-approved TMDL (Category 4a); tributaries include Gary Creek
Bohannon Creek (RM 10.9)	Perennial	Beaverhead Mountains	Direct connection	Heads in tarn; EPA-approved TMDL (Category 4a); Marengo, Durango, and Red Bluff Consolidated Placers, (Mineral Survey #1202), Nov. 6, 1896, T21N- R23E, 360 acres; Red Bluff Placer (Mineral Survey #2585), 8/10/1911, T21N – R23E, 70.12 acres; tributaries include East Fork Bohannon Creek; tributaries include East Fork Bohannon Creek, 3 miles of valley bottom.
Wimpey Creek (RM 12.8)	Perennial	Beaverhead Mountains	Direct connection	EPA-approved TMDL (Category 4a); tributaries include East Fork Wimpy Creek, and West Fork Wimpey Creek
Withington Creek (RM 13.15)	Perennial	Lemhi Range	Indirect connection	Disconnected near Old Baker Highway; Harmony Millsite (Mineral Survey #3121B), Nov. 12, 1926, T20N – R22E, 4.44 acres; tributaries include Cheney Creek and Joe Moore Creek; Eli Creek with Pope Shenon Group (Mineral Survey #2952) Cancelled, Sept. 20, 1922, T20N – R22E, NA acres

Tributary	Flow Regime	Drainage	Connectivity	Other
Pratt Creek (~RM 14.3)	Perennial	Beaverhead Mountains	Indirect connection	Dewaters on alluvial fan
Kadletz Creek (RM 14.95)	Ephemeral	Lemhi Range	Direct connection	
Sandy Creek (~RM 17.8)	Perennial	Beaverhead Mountains	Indirect connection	Dewaters on alluvial fan; heads in tarn; Lone Star, Lone Star Extension, and Walcott Consolidated Lodes, (Mineral Survey #1591), Jan. 4, 1901, T21N – R24E, 61.9 acres; Grizzly Bear Group (Mineral Survey #2473A), March 23, 1910, T20N – R24E/T21N – R24E, 61.22 acres; Gem Group (Mineral Survey #2531), July 29, 1910, T21N – R24E, 70.12 acres; Grizzly Bear Millsite (Mineral Survey #2473B), March 23, 1910, T21N – R24E, 4.98 acres; tributaries include West Fork Sandy Creek
Haynes Creek (RM 19.02)	Perennial	Lemhi Range	Direct connection	Dewaters on alluvial fan; Haynes Creek Reservoir (T19S – R23E, Sect. 10)

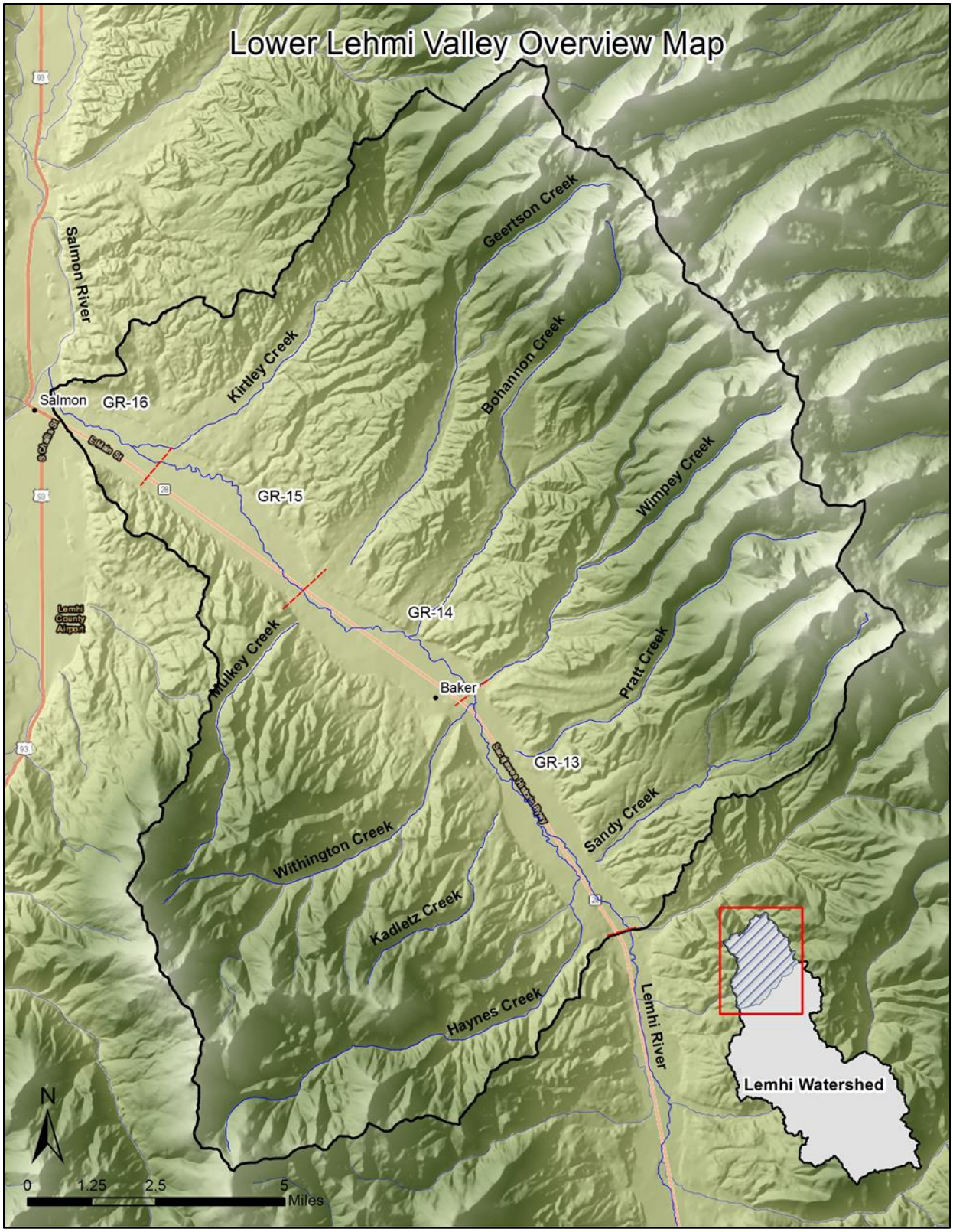

Figure 65. Lower Lemhi Valley Segment (VS-4) and geomorphic reaches (GR-13 through GR-16).

Geomorphic Reach GR-13 (RM 19.6 – 12.9)

Geomorphic Reach GR-13 is located along the Lemhi River between RM 19.6 and RM 12.9 in an unconfined valley with significant valley bottom constraints, resulting in the narrowing of the valley bottom by about 65 percent (Figure 66). Reach characteristics are summarized below in Table 28.

Table 28. Summary of attributes for Geomorphic Reach GR-13.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-4	GR-13	19.6 - 12.9	0.0084	2813	919	0.0070	57	1.2	49	16	55%	Neutral	17%	34%	48%

Forms

- Low to moderate sinuosity; minor channel straightening and alteration, especially near bridges, irrigation diversions, and levees throughout the reach.
- Floodplain constrained by Highway 28 along the entire reach.
- Predominantly plane-bed morphology generally associated with mechanical channel alterations and lack of instream structure.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Observable channel widening where riparian vegetation is lacking.
- Areas of point bar deposition with low to moderate rates of channel migration
- Evidence of large wood recruitment in few places where instream structure is present, including irrigation diversions and at the head of islands.

Human Impacts

- Patchy, discontinuous riparian corridor resulting in bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity, causing incision and bed armoring.
- Road embankments, bridges, discontinuous levees, riprap, and irrigation diversions.

Response Potential

- Snowmelt surface-water-dominated hydrology with groundwater inputs during the irrigation season and groundwater losses after the irrigation season. Shallow groundwater during the summer supports riparian vegetation consisting of willow and cottonwood.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (willow and cottonwood) in addition to coarse sediment and large wood recruitment. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation.
- Typical response to disturbances includes channel migration, floodplain activation, pool and riffle formation, and island braiding associated with instream obstruction. Incision and bed armoring in straightened and confined areas.

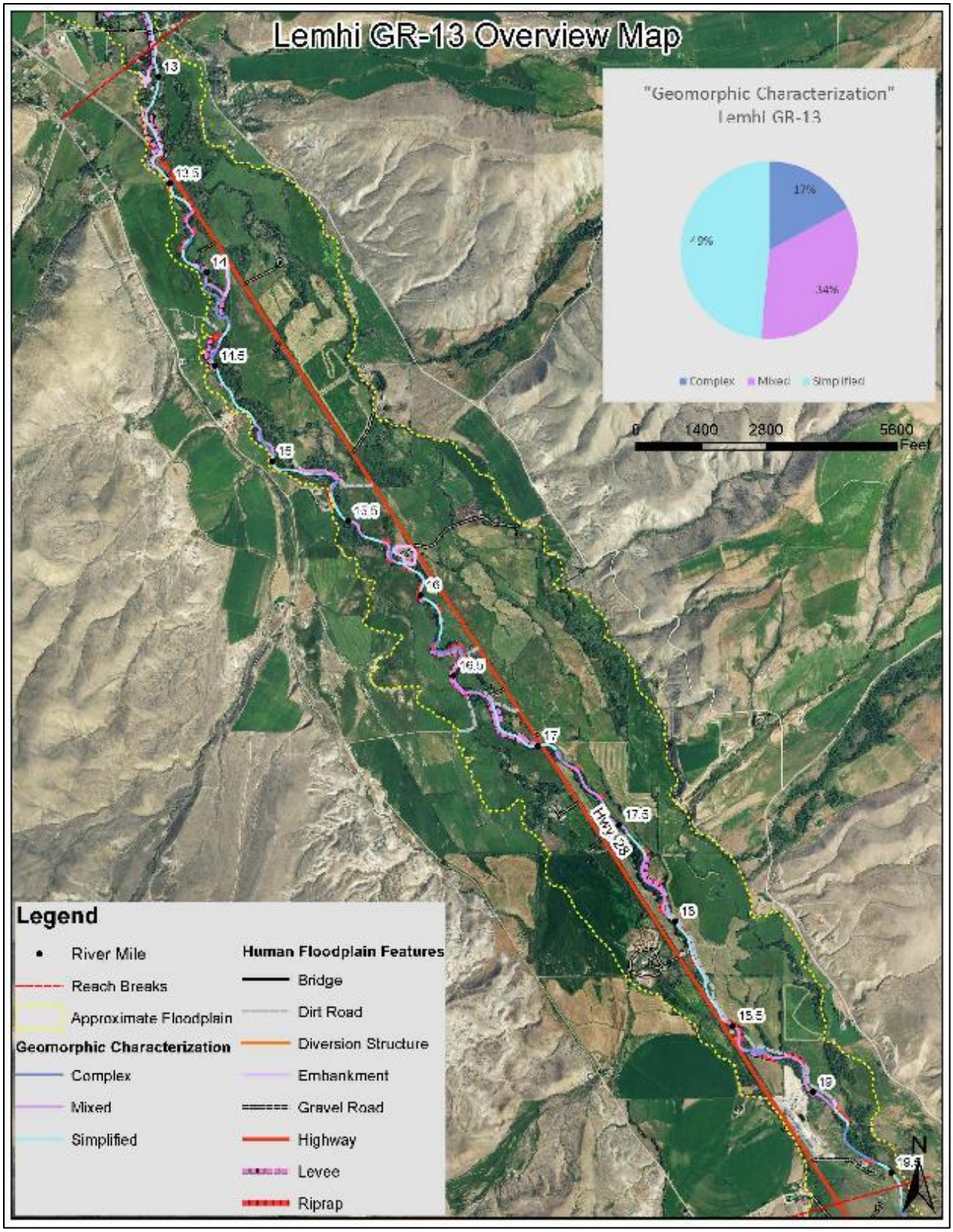

Figure 66. GR-13 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-14 (RM 12.9 – 8.1)

Geomorphic Reach GR-14 is located along the Lemhi River between RM 12.9 and RM 8.1 in an unconfined valley with significant valley bottom constraints, resulting in the narrowing of the valley bottom by about 65 percent (Figure 67). Reach characteristics are summarized below in Table 29.

Table 29. Summary of attributes for Geomorphic Reach GR-14.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-4	GR-14	12.9 - 8.1	0.0080	2217	640	0.0065	62	1.2	36	10	64%	Neutral	13%	15%	72%

Forms

- Low to moderate sinuosity.
- Significant channel alterations, simplification, and straightening.
- Floodplain constrained by Highway 28 along the downstream half of the reach.
- Predominantly plane-bed morphology generally associated with channel alterations and lack of instream structure.
- Many banks lacking riparian vegetation.

Processes

- Minimal point bar deposition suggests low rates of channel migration.
- Large wood recruitment associated with limited instream obstructions, including irrigation diversions and islands.

Human Impacts

- Patchy, discontinuous riparian corridor contributing to bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity armoring the bed.
- Discontinuous levees, road embankments, bridges, riprap, and irrigation diversions.

Response Potential

- Snowmelt surface-water-dominated hydrology with groundwater inputs during the irrigation season and groundwater losses after the irrigation season. Shallow groundwater during the summer supports riparian vegetation consisting of willow and cottonwood.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (willow and cottonwood) in addition to coarse sediment and large wood recruitment. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation.
- Typical response to disturbances includes channel migration, floodplain activation, pool and riffle formation, and island braiding associated with instream obstruction.

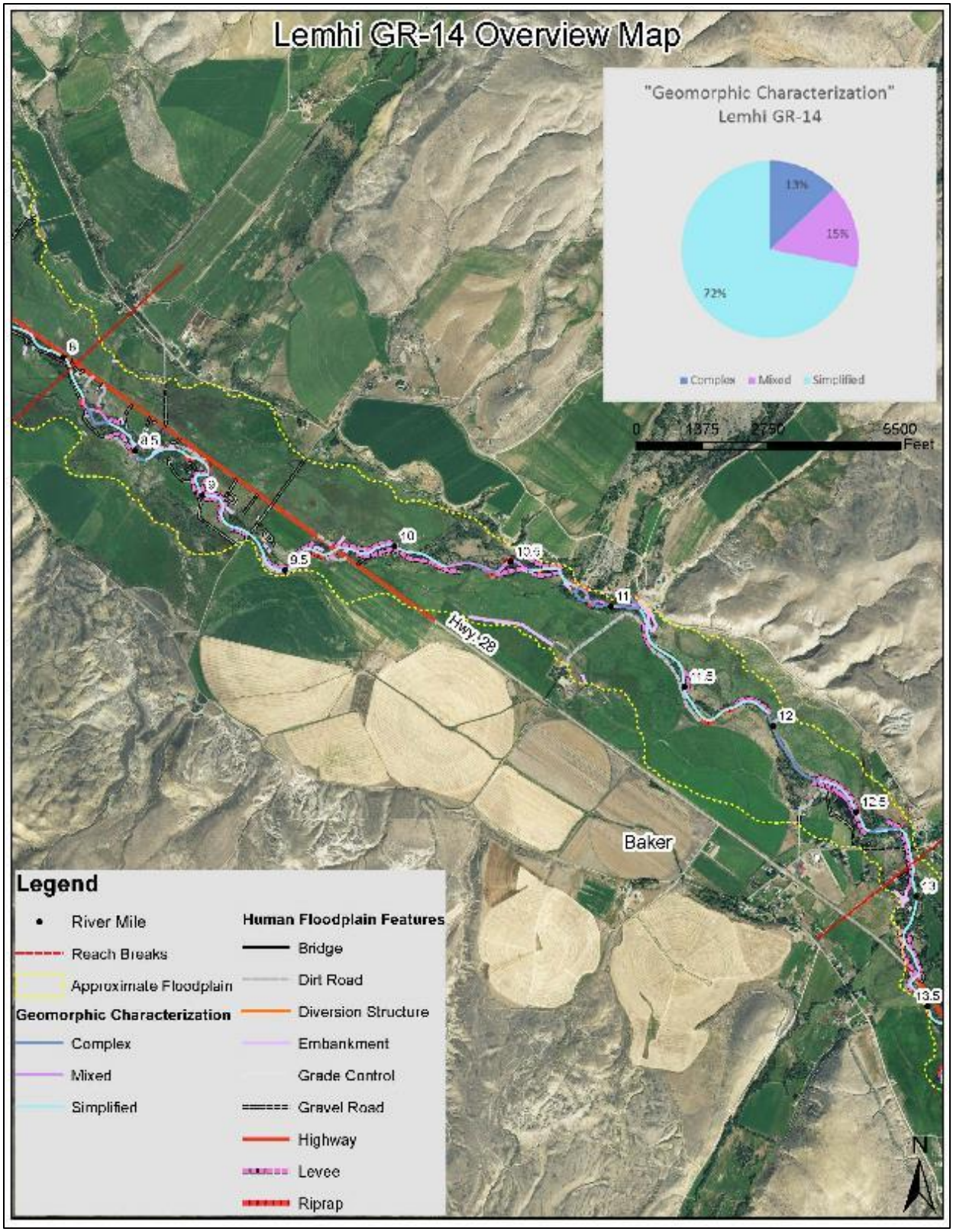

Figure 67. GR-14 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-15 (RM 8.1 – 3.3)

Geomorphic Reach GR-15 is located along the Lemhi River between RM 8.1 and RM 3.3 in an unconfined valley with significant valley bottom constraints, resulting in the narrowing of the valley bottom by about 50 percent (Figure 68). Reach characteristics are summarized below in Table 30.

Table 30. Summary of attributes for Geomorphic Reach GR-15

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-4	GR-15	8.1 - 3.3	0.0080	1995	991	0.0065	54	1.2	37	18	32%	Gaining	43%	30%	28%

Forms

- Low to moderate sinuosity.
- Minor channel straightening, alterations, and simplification throughout reach.
- Floodplain constrained by Highway 28 along the upstream third of the reach.
- Mixed morphology. Pool-riffle morphology generally associated with higher-sinuosity areas of dense riparian vegetation. Plane-bed morphology generally associated with low-sinuosity, altered areas.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Point bar deposition suggests low to moderate rates of channel migration, increasing where riparian vegetation is lacking.
- Large woody debris recruitment and retention in areas with instream channel obstructions, including islands and irrigation diversions (especially between RM 3.5 and RM 4.6).
- Island braiding and avulsion occurring where unconfined and associated with instream structure (wood recruitment).

Human Impacts

- Patchy, discontinuous riparian corridor contributing to bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement and straightening may increase local transport capacity armoring the bed.
- Discontinuous levees, road embankments, bridges, riprap, and irrigation diversions.

Response Potential

- Snowmelt surface-water-dominated hydrology with groundwater inputs throughout the year. Shallow groundwater during the summer supports riparian vegetation consisting of willow and cottonwood.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (willow and cottonwood) in addition to coarse sediment and large wood recruitment. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation.
- Typical response to disturbances includes channel migration, floodplain activation, pool and riffle formation, and island braiding associated with instream obstruction.

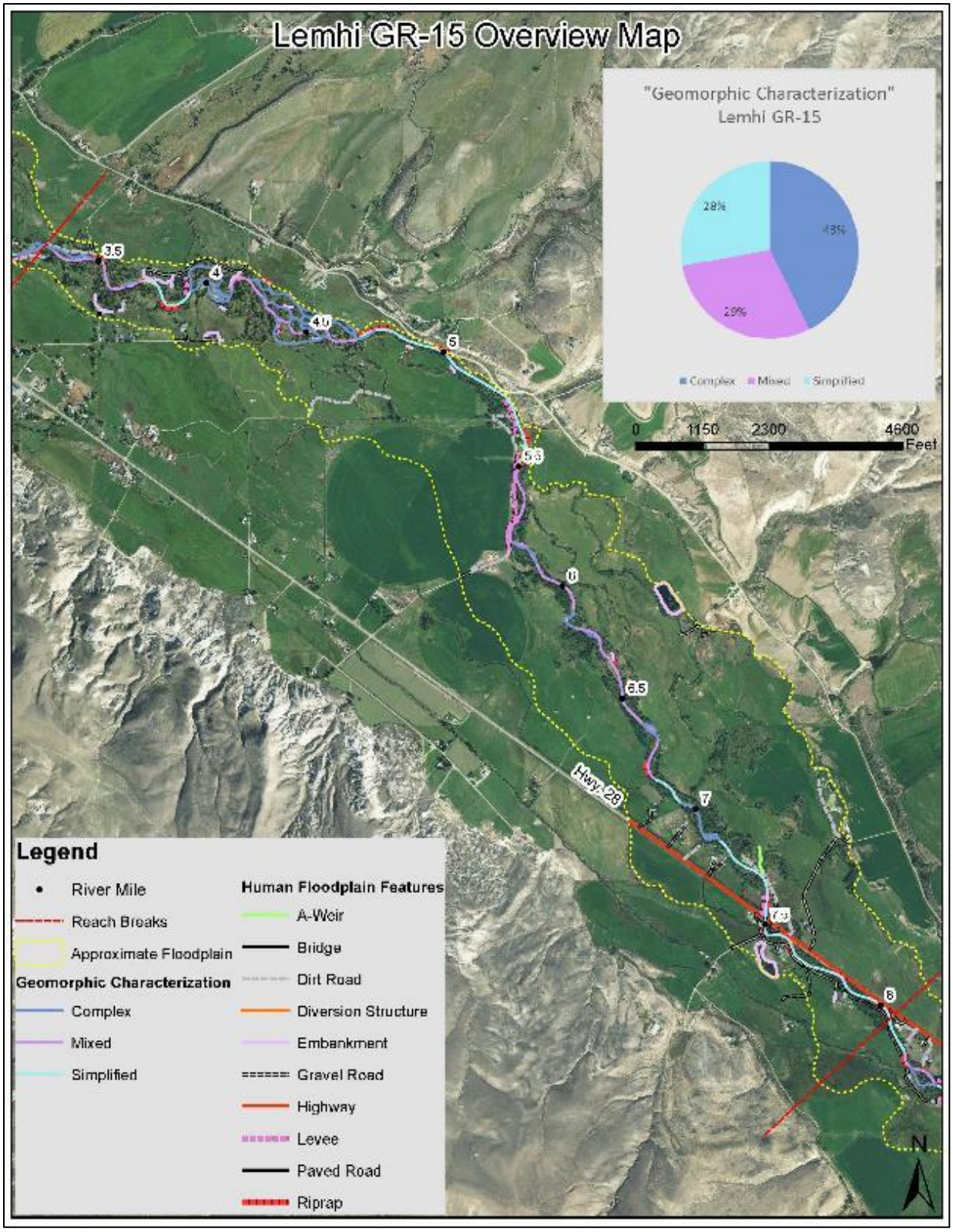

Figure 68. GR-15 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-16 (RM 3.3 – 0)

Geomorphic Reach GR-16 is located along the Lemhi River between RM 3.3 and RM 0 in an unconfined valley with significant valley bottom constraints associated with roads and levees, resulting in the narrowing of the valley bottom by about 65 percent (Figure 69). Reach characteristics are summarized below in Table 31.

Table 31. Summary of attributes for Geomorphic Reach GR-16

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-4	GR-16	3.3 - 0	0.0081	2480	821	0.0072	62	1.1	40	13	20%	Gaining	38%	13%	49%

Forms

- Low to moderate sinuosity.
- Major channel straightening, alterations, and simplification throughout reach, especially in the lower half.
- Floodplain constrained by levees in the lower reach.
- Mixed morphology. Pool-riffle morphology generally associated with higher-sinuosity areas of dense riparian vegetation. Plane-bed morphology generally associated with low-sinuosity, altered areas.
- Many banks lacking riparian vegetation.
- Over-widened channel in areas lacking riparian vegetation.

Processes

- Point bar deposition in upper reach suggests low to moderate rates of channel migration, increasing where riparian vegetation is lacking. Channel confinement in lower reach prevents deposition.
- Channel straightening, confinement, and bank armoring likely increase sediment transport, resulting in incision and bed armoring.
- Minimal floodplain connection.

Human Impacts

- Patchy, discontinuous riparian corridor contributing to bank instability, channel widening, plane-bed morphology, and lack of shade.
- Channel confinement, straightening, and bank armoring may increase local transport capacity, incision, and bed armoring.
- Discontinuous levees, road embankments, bridges, riprap, and irrigation diversions.

Response Potential

- Snowmelt surface-water-dominated hydrology with groundwater inputs throughout the year. Shallow groundwater during the summer supports riparian vegetation consisting of willow and cottonwood.
- Channel form (especially width and bedform) and processes are driven by the presence or absence of mature riparian vegetation (willow and cottonwood) in addition to coarse sediment and large wood recruitment. Dense riparian vegetation maintains a narrow width-to-depth ratio, stabilizes banks, and promotes scour pool formation.

- Typical response to disturbances includes incision and bed armoring in the lower reach; channel migration and point bar deposition associated with instream obstruction and sinuosity in the upper reach.

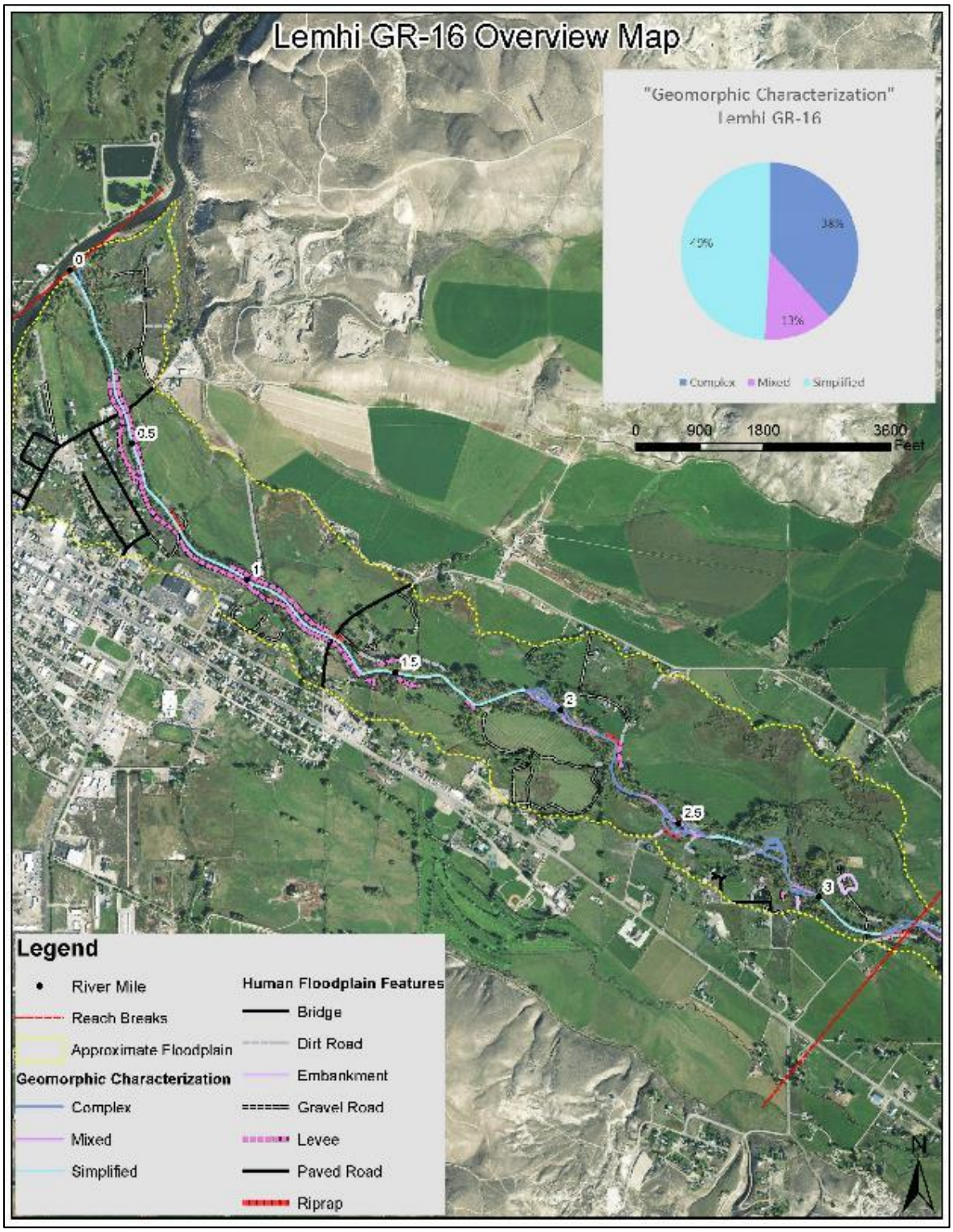

Figure 69. GR-16 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Temperature and Climate Change Assessment

Chinook salmon

Under current conditions, winter and early-spring modeled water temperatures are generally below optimum values for Chinook salmon for the following life-stages: egg incubation, fry emergence, juvenile winter rearing, and spring smolt emigration (Figure 70). This is likely to reduce or cease presmolt growth during winter months. Modeled spring temperature values vary widely and can include periods of both below-optimum and above-optimum temperature ranges. Alternatively, summer temperatures exceed optimum values at times, potentially increasing spawner stress and elevating food requirements for summer parr. Under an assumed 3° C water temperature increase scenario, conditions improve somewhat for winter and spring life stages (incubation and emergence, winter rearing, spring emigration; Figure 71). Conditions worsen for summer parr and spawners, though, with conditions across much of the watershed exceeding maximum temperature criteria in excess of 50 percent of the time.

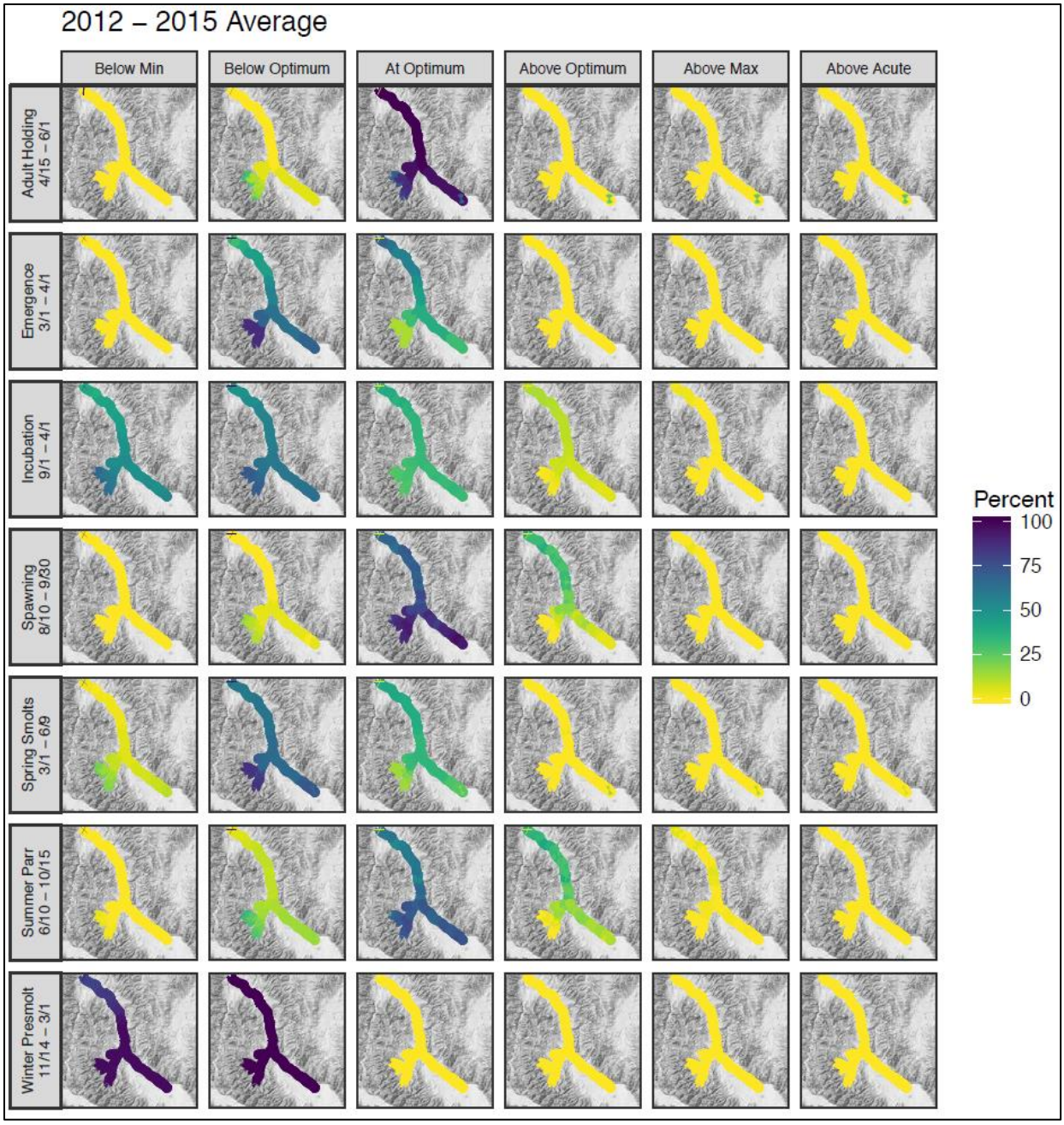

Figure 70. The percentage of time that Lemhi River watershed water temperatures were below, within, or above a given temperature threshold (Carter 2005) for seven Chinook salmon life stages. Water temperatures were averaged across years for which complete modeled temperature data were available (2012-2015).

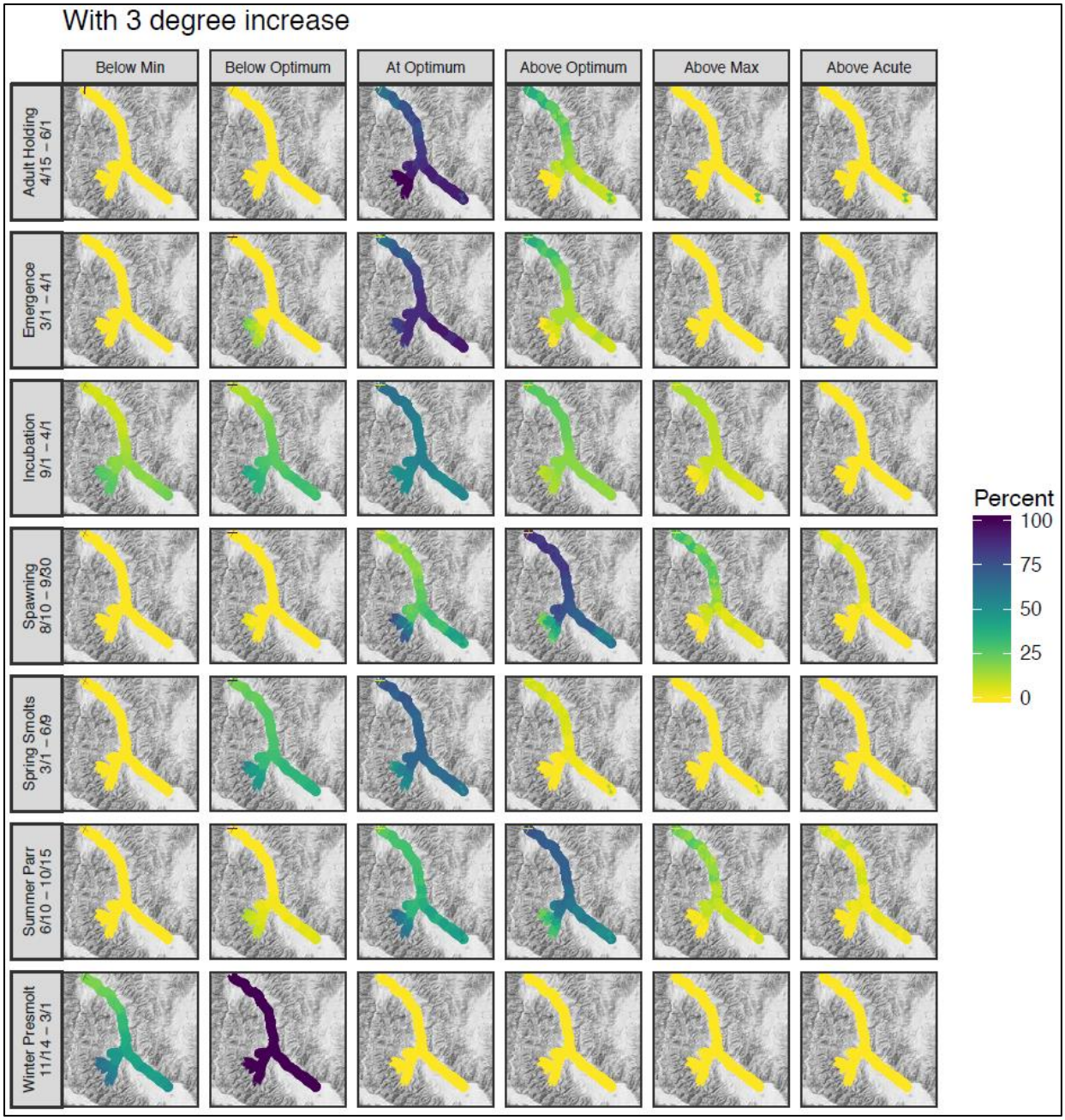

Figure 71. The percentage of time that Lemhi River watershed water temperatures may potentially be below, within, or above a given temperature threshold (Carter 2005) for seven Chinook salmon life stages, assuming a potential climate change scenario.

Steelhead

Under current conditions, winter and early-spring modeled water temperatures are generally below optimum values for steelhead juvenile winter rearing and spring emigration (Figure 72). This is likely to reduce or cease presmolt growth during winter months. Alternatively, summer temperatures exceed optimum values during late incubation and emergence for steelhead; however, it is unclear to what degree late incubation and emergence might overlap with early summer high temperatures in the Lemhi River.

Under an assumed 3° C water temperature increase scenario, conditions improve somewhat for winter and spring life stages (winter rearing and spring emigration; Figure 73). Conditions worsen for late-spring and summer life stages (late spawning, incubation/emergence, summer rearing), though, with conditions exceeding maximum temperature criteria during incubation/emergence and summer juvenile rearing across much of the watershed.

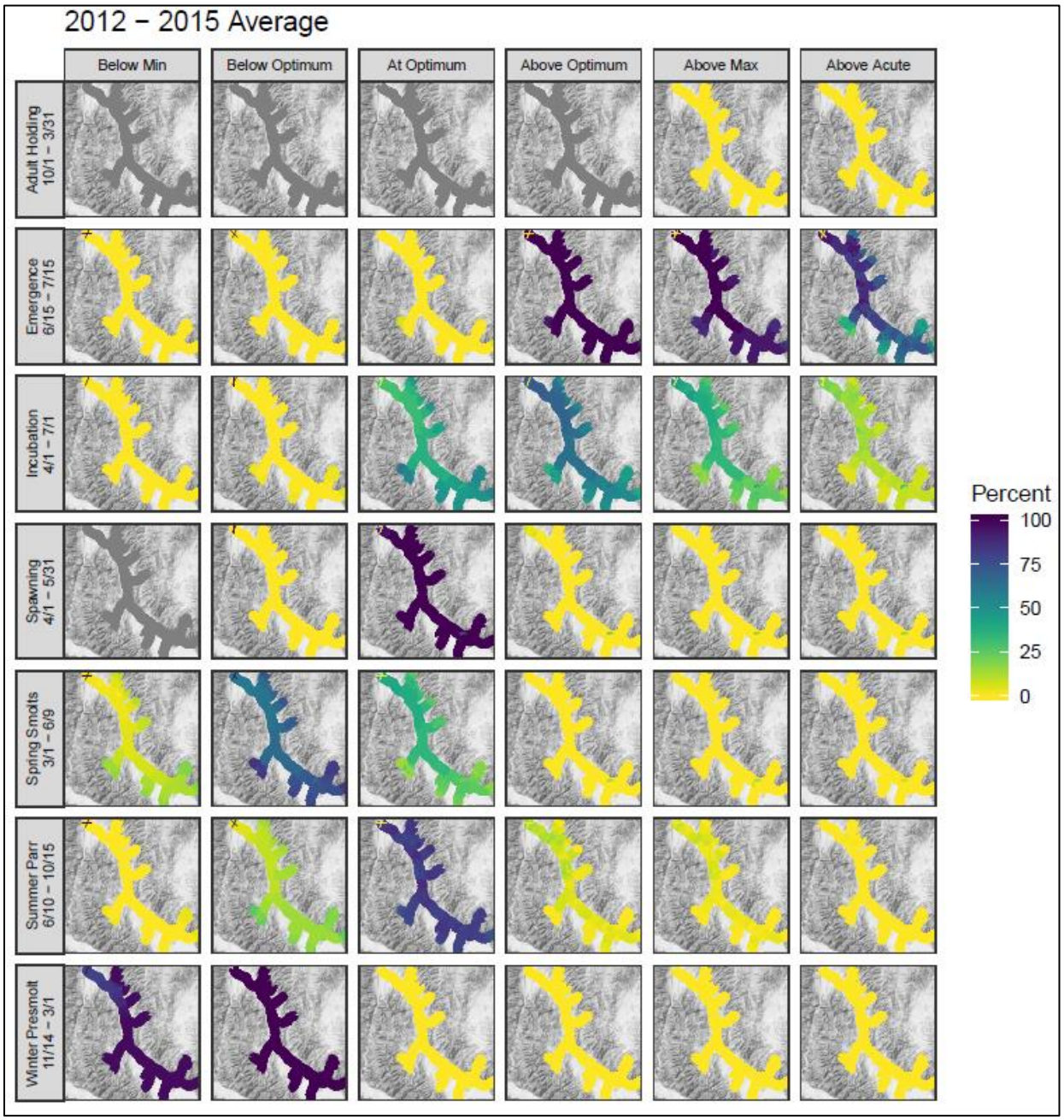

Figure 72. The percentage of time that Lemhi River watershed water temperatures were below, within, or above a given temperature threshold (Carter 2005) for seven steelhead life-stages. Water temperatures were averaged across years for which complete modeled temperature data were available (2012-2015).

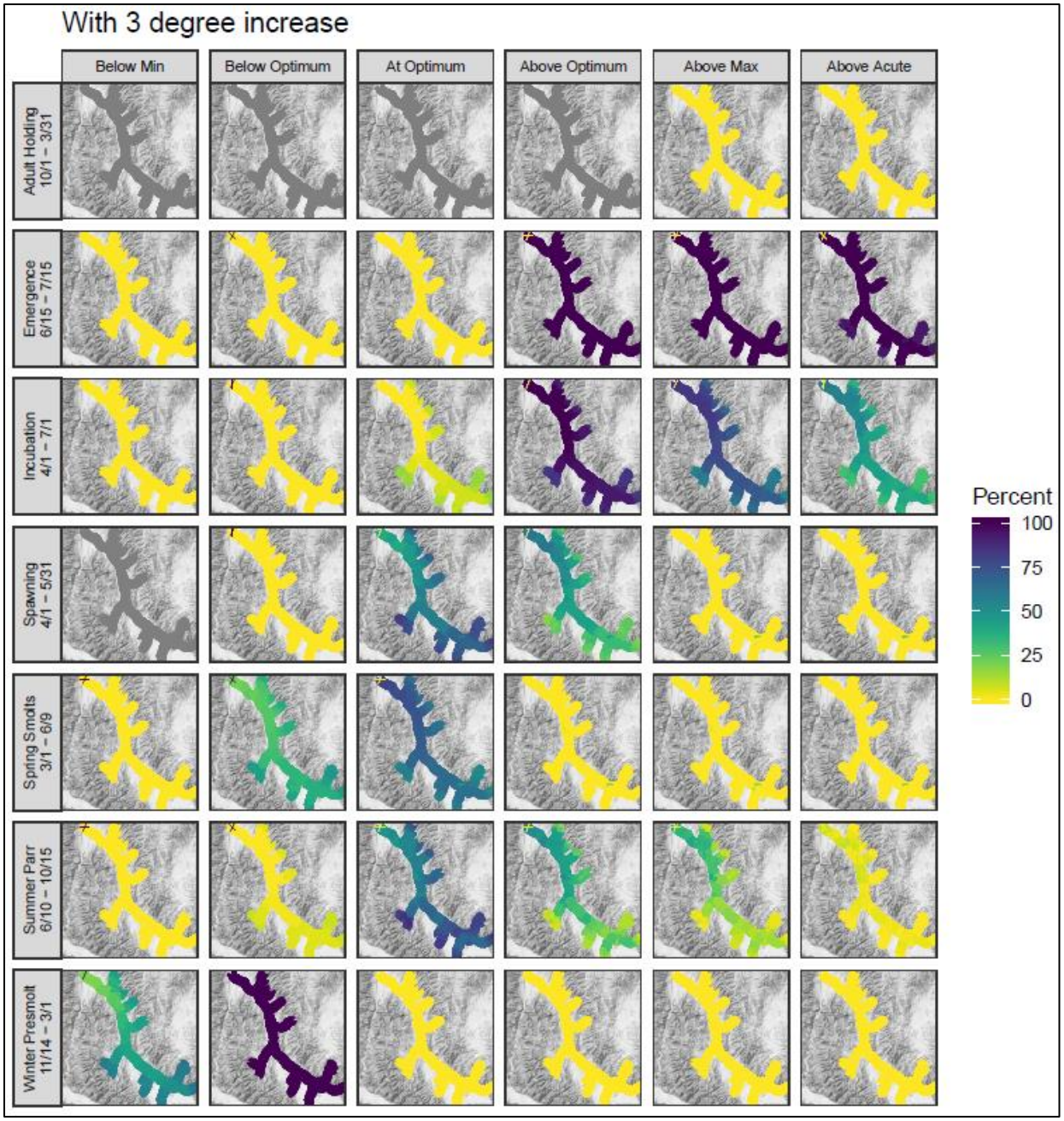

Figure 73. The percentage of time that Lemhi River watershed water temperatures may potentially be below, within, or above a given temperature threshold (Carter 2005) for seven steelhead life stages, assuming a potential climate change scenario.

Results and Discussion

In the Lemhi River Biological Assessment, the lack of quantity and quality juvenile rearing habitat during summer and winter months was identified as the highest-priority limiting PBF for Chinook salmon. Assuming recent mean adult Chinook salmon escapement, habitat capacity does not appear to limit the production of summer parr or winter presmolts (Table 2). However, currently available rearing habitat (summer and winter) is likely not sufficient to support recent high escapements or support escapements

necessary for ESA delisting (Table 3). Juvenile rearing habitat during summer and winter does not appear to be a limiting PBF for *O. mykiss* in the Lemhi River. Finally, redd capacity (i.e., available spawning habitat) does not appear to be limiting for Chinook salmon or steelhead in the Lemhi River.

Limiting Physical and Biological Features

The lack of quality juvenile rearing habitat during summer (parr) and winter (presmolt) life stages appears to be the highest-priority PBF limiting Chinook salmon in the Lemhi River. Assuming mean contemporary adult Chinook salmon escapement in the Lemhi River from 2010 to 2015, habitat does not appear to limit the production of summer parr or winter presmolts. However, estimates of carrying capacity given current habitat for summer parr (357,948) and winter presmolts (173,375) fall short of capacity required for adult escapement in 2015 and are approximately one-fourth of the juvenile capacity needed to support an annual escapement of 2,000 adult Chinook salmon required for delisting (Table 2, Table 3). The lack of quantity and quality overwinter rearing habitat is further supported by recent data showing that, on average, 72 percent of juvenile emigrants from the Lemhi River emigrate as parr or presmolts prior to the winter. This suggests that winter rearing habitat is insufficient or unsuitable to support a large portion of juvenile production. The lack of overwinter capacity requires increased juvenile emigration during the critical winter period, which can lead to increased survival risk in mainstem corridor habitats.

- Summer (parr) and winter (presmolt) juvenile rearing capacity were each identified as high-priority PBF limiting Chinook salmon production in the Lemhi River.

Priority Areas

To address both PBFs limiting Chinook salmon production in the Lemhi River (overwinter and summer rearing habitat), rehabilitation to reaches within the Lemhi River should be considered in the following order:

- **First priority: mainstem Lemhi River downstream of Hayden Creek.** This section does not currently support Chinook salmon spawning but provides key summer and winter rearing for fish spawned in the upper Lemhi River and Hayden Creek.
- **Second priority: mainstem Lemhi River upstream of Hayden Creek.** This is the section of the Lemhi River watershed where about two-thirds of the spawning occurs, on average.
- **Third priority: Hayden Creek.** This is the section where about one-third of the spawning occurs, on average.

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Chapter 2 – Pahsimeroi River Watershed

Location and Watershed Description

The Pahsimeroi River watershed is located in the Northern Rocky Mountain System physiographic region that comprises extensive parallel mountain ranges, intermontane valleys, and plateaus (Figure 74). Elevations in the watershed range from about 4600 to 12000 feet, with the lowest elevations along the Pahsimeroi valley floor and the highest elevations along the bounding Lemhi Range to the north and Lost River Range to the south. It is in the Dry Intermontane Sagebrush Valleys Ecoregion (17AA), characterized by stream terraces, floodplains, saline areas, and alluvial fans. Water availability and potential for cropland agriculture are low because the Ecoregion is in the rain shadow of high mountains, receives little mountain runoff, and is underlain by highly permeable valley fill deposits. Its deep gravels are unlike the basalts of Ecoregion 12. Sagebrush grassland is widespread and contrasts with the open-canopied forests of the more-rugged and higher Ecoregion 17e. Shadscale and greasewood grow on alkaline soils that receive less than 8 inches of precipitation annually. Grazing is the dominant land use (McGrath et al. 2002).

The Pahismeroi River watershed is a hydrologic unit code (HUC) 8th field basin (HUC 8 – 17060202), within the Salmon River subbasin within the Columbia River Basin. The watershed covers about 839 square miles (536,960 acres) in east-central Idaho and is located in Lemhi and Custer Counties. About 90 percent of the land is owned by the Federal government and administered by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM). Federal lands are located primarily in the higher elevations, whereas private lands are typically located in lower elevations along the valley bottoms.

The Pahsimeroi River is an alluvial stream flowing over gravel and cobble originating at the confluence of the East Fork and West Fork Pahsimeroi Rivers near the base of Leatherman Peak. The river flows generally to the northwest along the Pahsimeroi Valley for about 64 miles, where it discharges into the Salmon River near Ellis, Idaho.

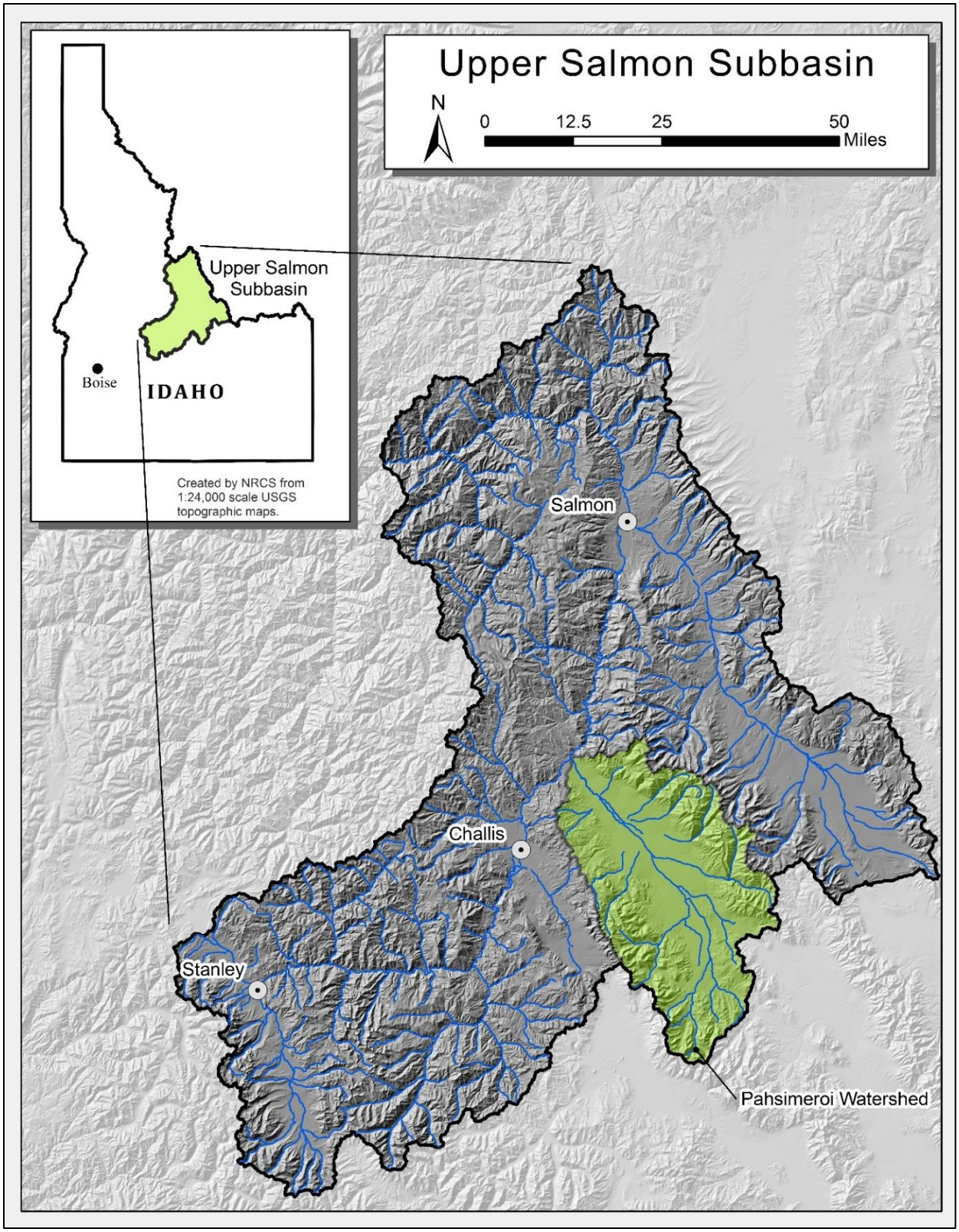


Figure 74. Location map of the Pahsimeroi River watershed.

Biological Assessment

The Pahsimeroi River maintains populations of three fish species listed under the ESA including Chinook salmon, steelhead, and bull trout. The watershed also supports westslope cutthroat trout, which has been petitioned for listing under the ESA. The Pahsimeroi River is a snowmelt-dominated tributary to the mainstem Salmon River, with a drainage area of approximately 840 mi^2. Similar to the Lemhi River, agricultural diversions have significantly reduced the connection of Pahsimeroi River tributaries and have truncated access to the mainstem Pahsimeroi River from RM 26.4 to RM 17.8 (NOAA 2017). The remaining lower mainstem reach available to Chinook salmon and steelhead is a low-gradient, sinuous, groundwater-dominated channel with high primary productivity (Copeland and Venditti 2009). NOAA (2017) classifies the Pahsimeroi River Chinook salmon population as Large and the Pahsimeroi River steelhead population as Intermediate.

Despite the moderate- to high-quality habitat available in the lower mainstem Pahsimeroi River, the Chinook salmon population has declined dramatically from historical escapement estimates (2,500 adults) and is currently considered at high risk of extinction (NOAA 2017). Between 2000 and 2015, the Pahsimeroi River has a mean escapement of 402 adult Chinook salmon, with a maximum escapement of 822 adults in 2003. Pahsimeroi River Chinook salmon are unique for the Upper Salmon River Major Population Group (MPG) because they exhibit a summer run timing. Pahsimeroi River steelhead have been identified as being maintained (i.e., 6 to 25 percent risk of extinction; NOAA 2017), but that listing is tentative due to insufficient data for Pahsimeroi River steelhead. Between 2011 and 2015, the Pahsimeroi River had an estimated mean escapement of 1,156 adult steelhead, with a maximum escapement of 1,614 adults in 2015 (see Stark et al. 2017 and references therein). The Idaho Power Company funds the operation of a production hatchery on the Pahsimeroi River, which is operated by the Idaho Department of Fish and Game; however, no hatchery-origin adults have been placed above the hatchery weir located in the lowermost Pahsimeroi River since 2005.

Habitat Capacity

Chinook salmon

Current Conditions

Contemporary estimates of life-stage-specific capacity requirements were generated based on the mean (402) and maximum (822) adult Chinook salmon escapement observed in the Pahsimeroi River from 2000 to 2015. Those adult escapements were then propagated through to four additional life stages to estimate life-stage-specific capacity requirements for Chinook salmon in the Pahsimeroi River; capacity requirements were then compared to available habitat capacity estimated using QRF models (Table 32).

Table 32. Estimated current life-stage-specific capacity requirements versus estimated available capacity for Chinook salmon in the Pahsimeroi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	Mean	Max		
Escapement	402	822		
Redd	197	403	1,886	0
Eggs	1,041,496	2,129,424		
Summer Parr	302,034	617,533	311,530	306,003

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	Mean	Max		
Winter Presmolt	122,375	250,206	103,977	146,229

Under current habitat conditions, and using contemporary escapement estimates, habitat capacity does not appear to limit the production of redds in the Pahsimeroi River; however, it does appear that juvenile rearing capacity is limited during both summer (parr) and winter (presmolt) months (Table 32). Given current habitat conditions, it appears that the Pahsimeroi River watershed can support roughly half of the required juvenile capacity, assuming recent maximum escapement. These findings are supported by the fact that, on average, 39 percent of total Chinook salmon juveniles emigrate from the Pahsimeroi River as fry or parr prior to or during the summer rearing period. Further, approximately 48 percent of total Chinook salmon juveniles leave the Pahsimeroi River as presmolts prior to the winter rearing period, suggesting that winter habitat capacity is limited. Only 12 percent of total Chinook salmon juvenile emigrants have left at the spring smolt (age 1) life stage in recent years.

Chinook salmon have lost access to approximately 33 percent of mainstem stream length available prior to agricultural development. Therefore, it is possible that a large fraction of fry emigration from the Pahsimeroi River is partially a function of the proximity of spawning habitat to the mainstem Salmon River.

Desired Conditions

NOAA (2017) delisting requirements include a minimum annual escapement (i.e., MAT) of 1,000 Chinook salmon adults to the Pahsimeroi River. Based on this requirement, life-stage-specific capacity requirements were recalculated consistent with 1,000 adults (MAT) and 1,250 adults (MAT + 25%). Those capacity requirements were also compared to estimates of currently available habitat capacity to identify potential habitat limitations if delisting is desired (Table 33). Potential limitations (capacity deficit) were calculated as the life-stage-specific capacity requirements needed to achieve a MAT of 1,000 plus a 25 percent buffer minus available capacity.

Table 33. Estimated life-stage-specific capacity requirements to accommodate ESA de-listing and estimated available capacity for Chinook salmon in the Pahsimeroi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	MAT	MAT + 25%		
Escapement	1,000	1,250		
Redd	490	613	1,886	0
Eggs	2,592,100	3,240,125		
Summer Parr	751,709	939,636	311,530	628,106
Winter Presmolt	304,570	380,712	103,977	276,735

There appears to be sufficient redd capacity in the Pahsimeroi River to support 1,250 adult Chinook salmon. However, the available juvenile rearing capacity during summer (311,530) and winter (103,977) are far from sufficient to support the potential parr and presmolt production from 1,250 adult Chinook salmon (Table 33). Therefore, to achieve delisting of Chinook salmon in the Pahsimeroi River, both summer and winter juvenile rearing capacity would need to be increased.

Summary

There appears to be sufficient spawning (redd) capacity in the Pahsimeroi River to support contemporary escapement and escapement required to achieve delisting criteria for Chinook salmon (

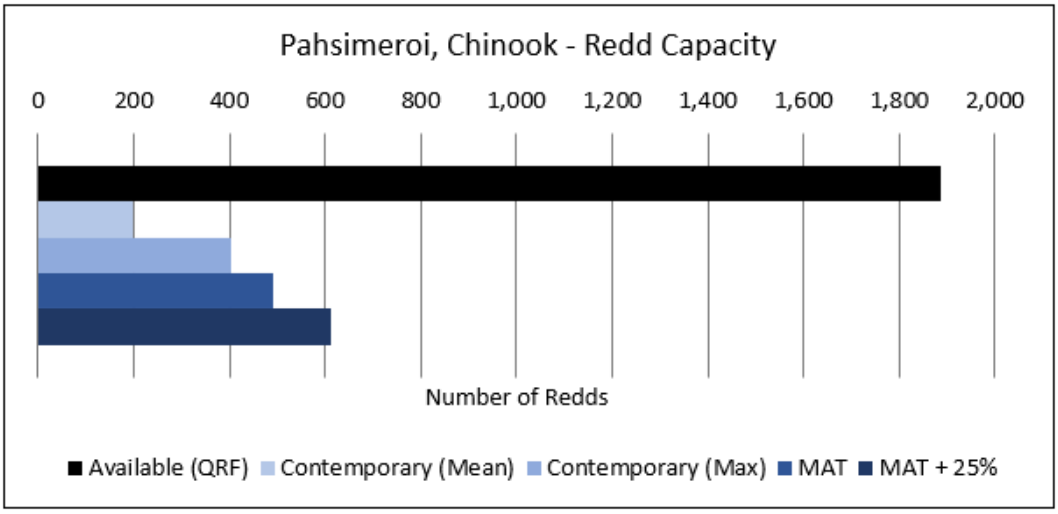
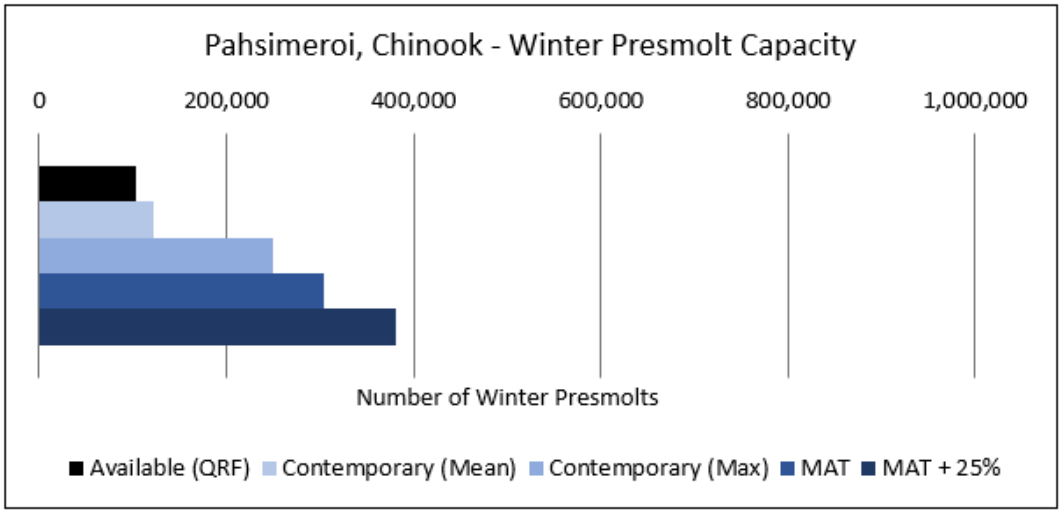


Figure 75). However, juvenile rearing habitat appears to be limiting to support both recent escapements and escapements required to achieve delisting (NOAA 2017) for Pahsimeroi River Chinook salmon



(Figure 76 and Figure 77).

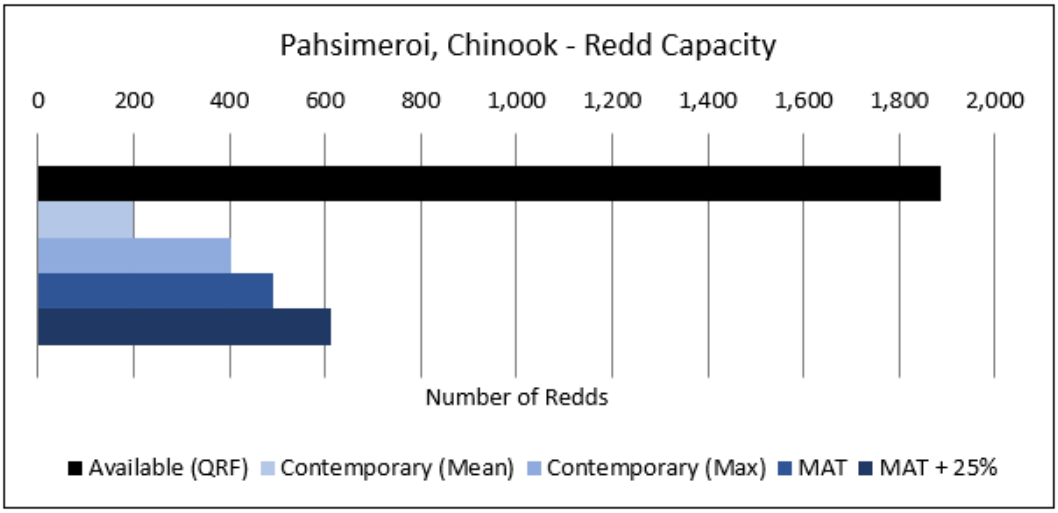


Figure 75. Estimates of available spawning (redd) capacity given current habitat conditions for Chinook salmon in the Pahsimeroi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

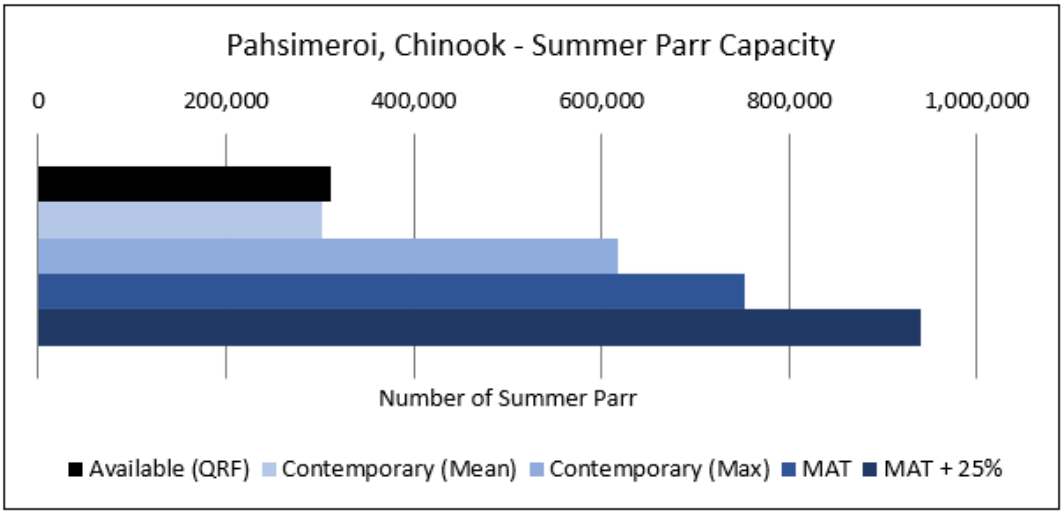


Figure 76. Estimates of available summer juvenile (parr) rearing capacity given current habitat conditions for Chinook salmon in the Pahsimeroi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

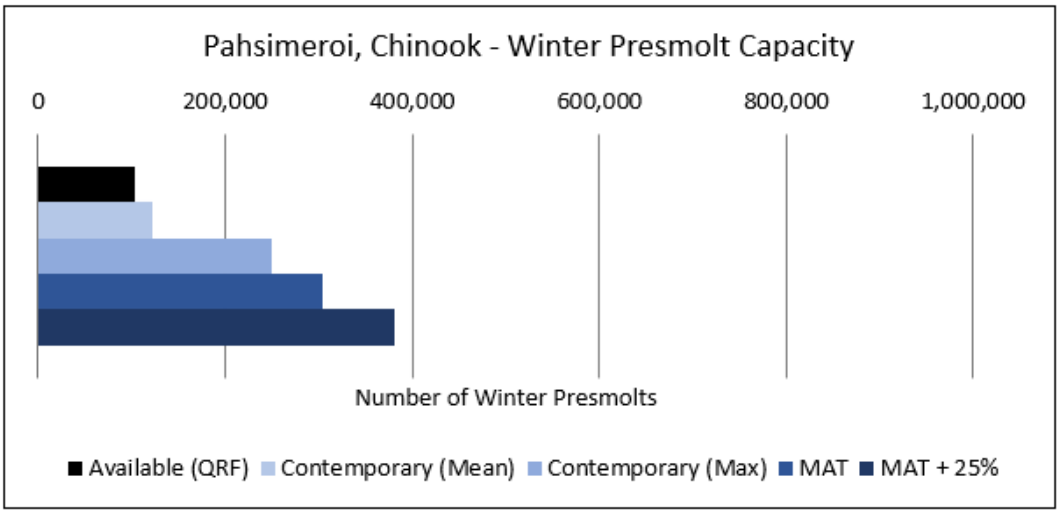


Figure 77. Estimates of available winter juvenile (presmolt) rearing capacity given current habitat conditions for Chinook salmon in the Pahsimeroi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

Steelhead

Available habitat capacity estimates from QRF are considered preliminary for steelhead in the Pahsimeroi River due to unknown spatial extents of available habitat for steelhead spawning and rearing. The IRA team will work with local biologists and experts to more appropriately identify the extents of habitat in the Pahsimeroi River available to steelhead. Available habitat capacity estimates can be improved in future reach assessments or as needed with local groups.

Current Conditions

Contemporary estimates of life-stage-specific capacity requirements were generated based on the mean (1,156) and maximum (1,614) adult steelhead escapements estimated in the Pahsimeroi River from 2011 to 2015. Those adult escapements were then propagated through to four additional life stages to estimate life-stage-specific capacity requirements for steelhead in the Pahsimeroi River; capacity requirements were then compared to available habitat capacity estimated using QRF models (Table 34).

Table 34. Estimated current life-stage-specific capacity requirements versus estimated available capacity for steelhead in the Pahsimeroi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	Mean	Max		
Escapement	1,156	1,614		
Redd	641	896	1,228	0
Eggs	3,159,649	4,412,245		
Summer Parr	424,183	592,344	264,740	327,604
Winter Presmolt	152,124	212,431	166,936	45,495

Under current habitat conditions, and using contemporary escapement estimates (e.g., Stark et al. 2017), habitat capacity does not appear to limit the production of steelhead redds in the Pahsimeroi River; however, it does appear that juvenile rearing capacity is limited during both summer (parr) and winter

(presmolt) months (Table 34). Given current habitat conditions, it appears that the Pahsimeroi River watershed can support roughly half of the required juvenile steelhead capacity during summer (parr) rearing months. Available winter (presmolt) capacity is sufficient to support recent mean adult steelhead escapements, but not numbers estimated during recent high escapements.

Desired Conditions

NOAA (2017) delisting requirements include a minimum annual escapement (i.e., MAT) of 1,000 steelhead adults to the Pahsimeroi River. Based on this requirement, life-stage-specific capacity requirements were recalculated consistent with 1,000 adults (MAT) and 1,250 adults (MAT + 25%). Those capacity requirements were also compared to estimates of currently available habitat capacity to identify potential habitat limitations if delisting is desired (Table 35). Potential limitations (capacity deficit) were calculated as the life-stage-specific capacity requirements needed to achieve a MAT of 1,000 plus a 25 percent buffer minus available capacity.

Table 35. Estimated life-stage-specific capacity requirements to accommodate ESA de-listing and estimated available capacity for steelhead in the Pahsimeroi River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	MAT	MAT + 25%		
Escapement	1,000	1,250		
Redd	555	694	1,228	0
Eggs	2,733,733	3,417,166		
Summer Parr	367,004	458,755	264,740	194,015
Winter Presmolt	131,618	164,522	166,936	0

There appears to be sufficient redd capacity and juvenile rearing capacity during winter months to support 1,250 adult steelhead (Table 35). However, the available juvenile rearing capacity during summer (264,740) is insufficient to support the potential parr production from 1,250 adult steelhead. Therefore, to achieve delisting of steelhead in the Lemhi River, summer juvenile rearing capacity would likely need to be increased.

Summary

There appears to be sufficient spawning (redd) capacity in the Pahsimeroi River to support contemporary escapement and escapement required to achieve delisting criteria for steelhead (

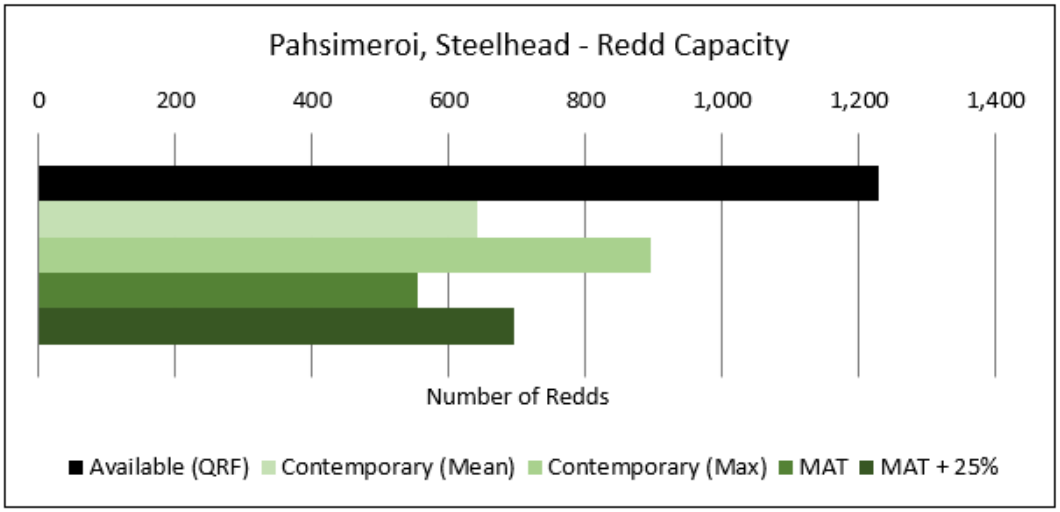


Figure 78). Moreover, juvenile rearing capacity during winter (presmolt) months may be sufficient within the Pahsimeroi River to support delisting criteria for steelhead (

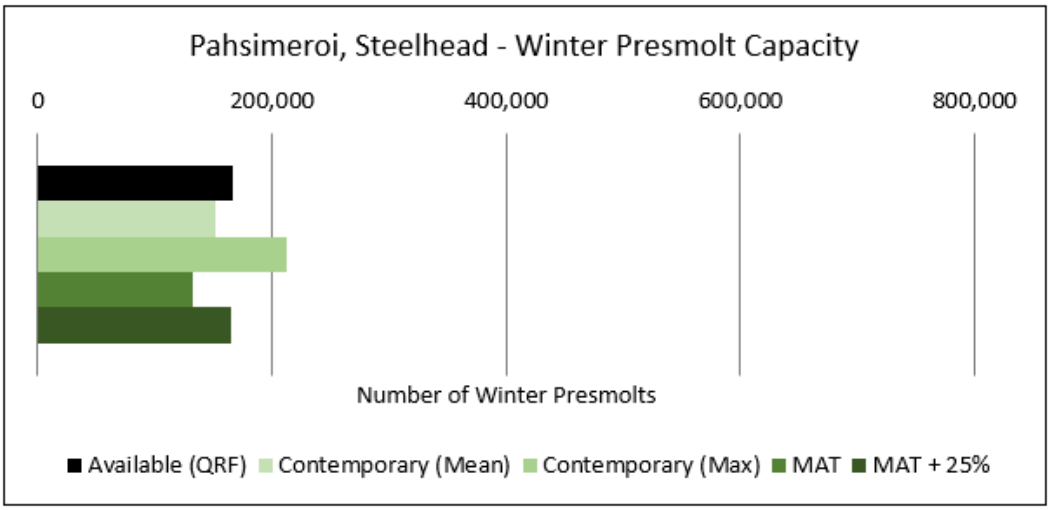


Figure 80). However, juvenile rearing habitat during summer (parr) months appears to be limiting for recent escapements and for escapements necessary to achieve delisting criteria (NOAA 2017) for Pahsimeroi River steelhead (Figure 79).

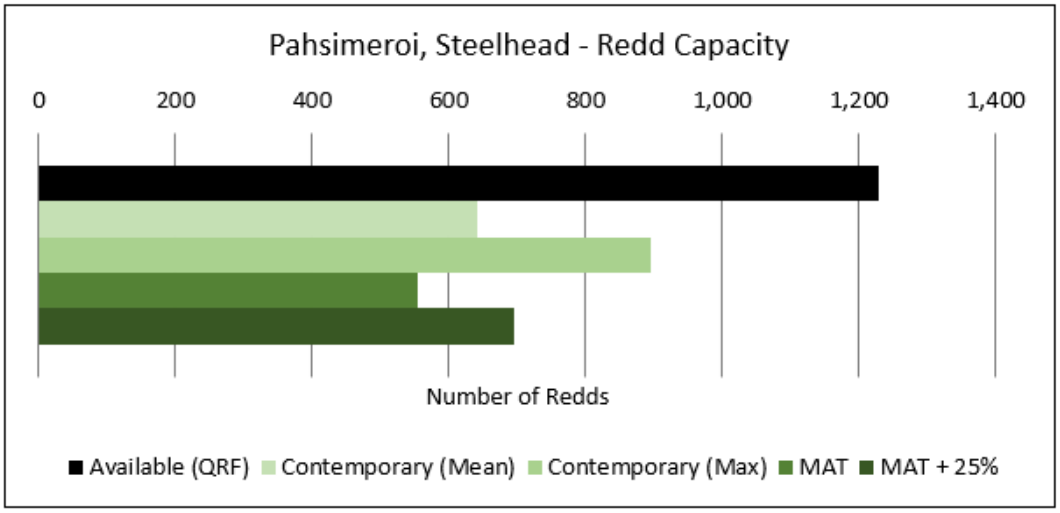


Figure 78. Estimates of available spawning (redd) capacity given current habitat conditions for steelhead in the Pahsimeroi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

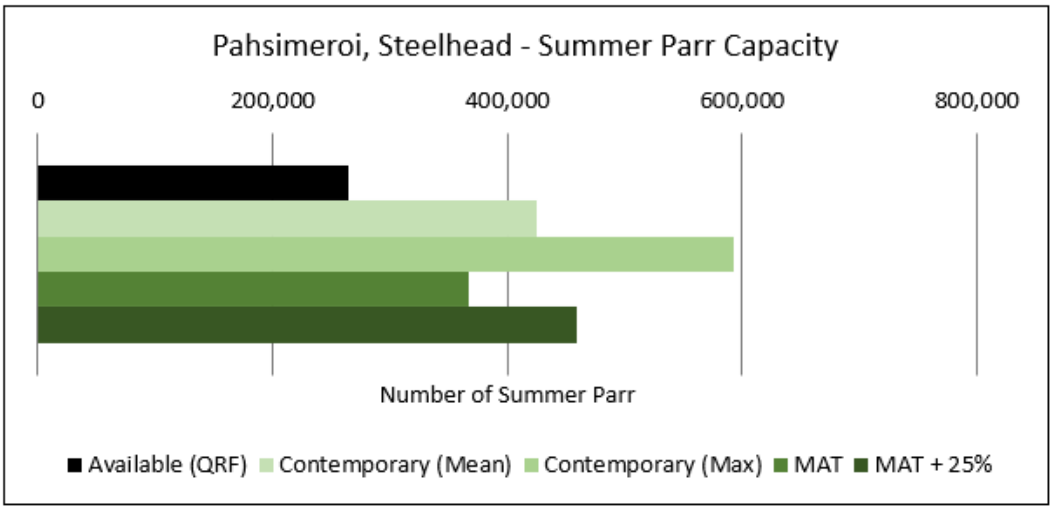


Figure 79. Estimates of available summer juvenile (parr) rearing capacity given current habitat conditions for steelhead in the Pahsimeroi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

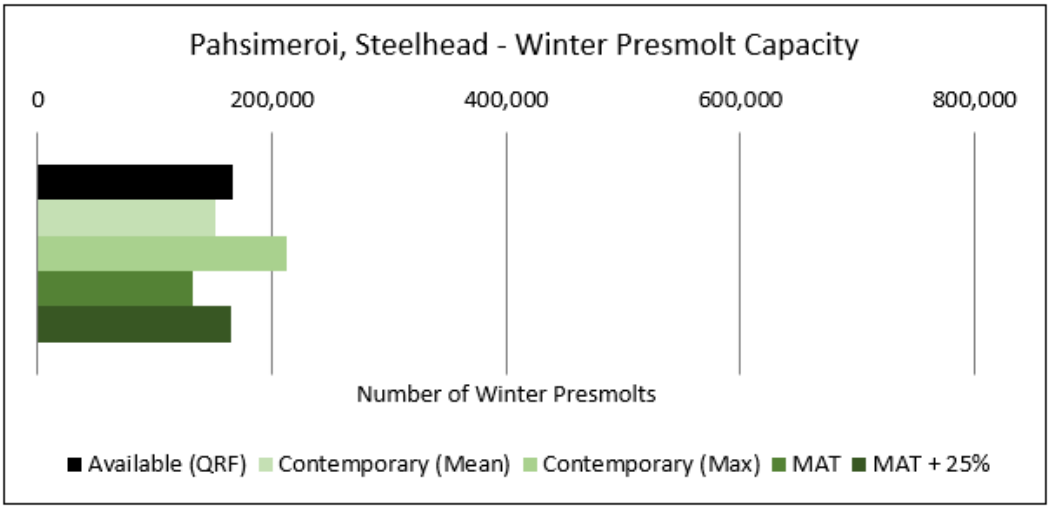


Figure 80. Estimates of available winter juvenile (presmolt) rearing capacity given current habitat conditions for steelhead in the Pahsimeroi River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

Geomorphic Assessment

Much of the geomorphic assessment in this report has been compiled in an effort to help paint a better picture of historical and potential target conditions (qualitative), recognizing that detailed (quantitative) target conditions will be generated as part of the MRA for select reaches in the future.

Historical Watershed Conditions

The Pahsimeroi River is located in a north/northwest-trending valley between the Pahsimeroi Mountains and the Lost River Range to the southwest, the Donkey Hills to the south, and the Lemhi Range to the northeast. The mountains consist of volcanic, metamorphic, and marine sedimentary rocks. The oldest metamorphic and sedimentary rocks were thrust up onto the continental crust roughly 60 million years ago during the formation of the ancestral Rocky Mountains (Link and Janecke 1999). The volcanic rocks are part of the Challis Volcanic Group that erupted onto the surface roughly 45 million years ago (Moye et al. 1988). Over the past several million years, the continental crust has expanded in this area due to the nearby Yellowstone hotspot (Simpson and Anders 1992; Pierce et al. 2007). Normal faulting associated with the expansion has lowered some blocks of the crust, creating valleys and raising others, forming mountain ranges. The Pahsimeroi Valley is one of these lowered blocks that has now partially filled with deep deposits of alluvial sediment. Valley fill sediment includes multiple episodes of significant alluvial fan deposition that occurred over several million years (Ungate 1988). During the last ice age (between 1.8 million years and 10,000 years ago), glaciers were present in the Lemhi and Lost River Ranges, contributing additional outwash sediment to the Pahsimeroi Valley, although no glacial ice is believed to have reached the valley bottom (Meinzer 1924; Ungate 1988). Since the last ice age, over-bank river deposits have added a thin additional layer of sediment to the valley bottom.

Geophysical data suggest the valley fill sediment is deepest (approximately 3,000 feet deep) near Furey Lane, between Big Creek and Goldberg Creek, and generally shallows to about 30 feet deep at the northern end of the basin (Young and Harenberg 1973). These sediments were determined to be coarse-

grained (Meinzer 1924; Ungate 1988) and capable of sustaining a robust aquifer. Areas where the aquifer intercepts the surface produce reaches that gain flow from groundwater, while areas where the aquifer is below the surface generally lose flow to the aquifer. Although modern measurements of surface/groundwater exchange are influenced by irrigation practices, seepage runs measured after the irrigation season in 2005 provide an estimate of historic groundwater conditions. These measurements suggest that historically, the upper Pahsimeroi River was largely losing flow to groundwater, the lower Pahsimeroi River was largely gaining flow from groundwater, and the middle Pahsimeroi River was mixed (Williams et al. 2006) (Figure 81). The historic conditions of the Pahsimeroi channel and floodplain were influenced greatly based on the spatial variability of surface-to-groundwater interactions in the valley.

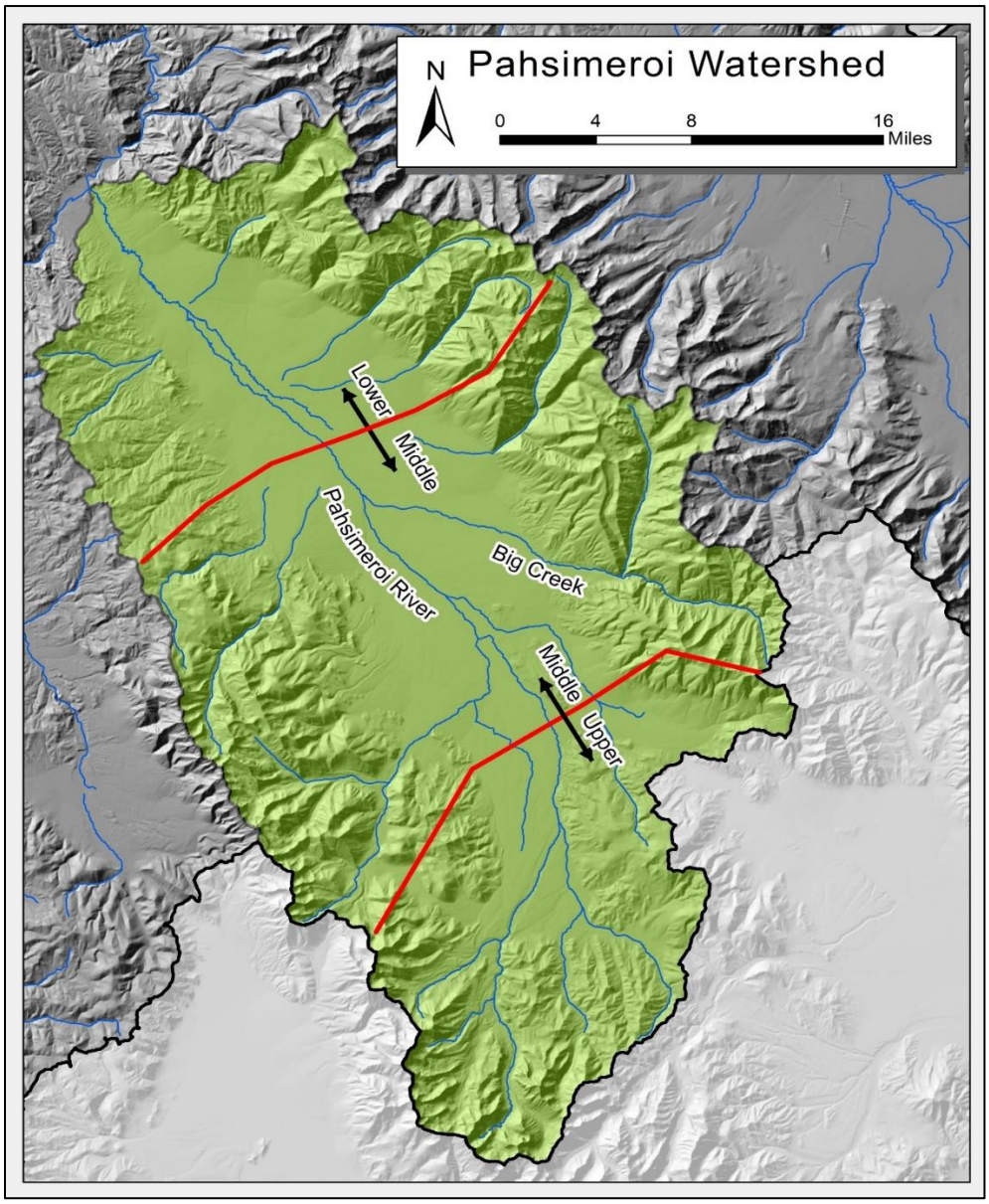


Figure 81. Map of the Pahsimeroi River watershed illustrating the approximate boundary between the upper, middle, and lower valleys.

The character of the upper Pahsimeroi River and other areas that lose flow to groundwater was largely driven by the snowmelt-dominated (i.e., peak-flow) hydrology in those areas. The upper Pahsimeroi River was primarily transport-dominated, with sufficient gradient and discharge to mobilize sediment and slowly incise its bed over thousands of years, creating a narrow, inset floodplain bound by relic terraces. The single-threaded channel within the terraces was characterized by a low sinuosity and a predominantly plane-bed morphology, although a forced pool-riffle morphology may have formed over small areas, given sufficient structure and/or woody debris loading (based on Montgomery and Buffington 1998). The snowmelt-dominated, losing reaches of the middle Pahsimeroi River were lower gradient than the upper Pahsimeroi River and had a depositional character (i.e., transport-limited), enabling the formation of a broad floodplain. The sinuous channel in these areas was likely characterized by a pool-riffle morphology (based on Montgomery and Buffington 1998) driven by abundant coarse-sediment deposition.

Flashy, snowmelt-dominated hydrology provided a disturbance regime suitable for the establishment and propagation of cottonwood and aspen trees, in addition to willow and other shrubs. The roots of the riparian vegetation provided bank stability and instream structure. Bank erosion into densely vegetated riparian areas provided a source of large wood recruitment that likely enhanced and/or forced pool-riffle morphology and may have created localized areas of island braiding. Large floods and debris torrents from tributaries may have transported large wood from the uplands episodically, but research suggests that wood is unlikely to transport through such small streams with low channel width and depth (Braudrick and Grant 2001).

In contrast to the losing reaches, the character of the lower Pahsimeroi River and other areas gaining flow from the groundwater was largely driven by their groundwater-influenced (i.e., baseflow) hydrology. These reaches were characterized by a fairly stable, multi-threaded (anastomosing), highly sinuous channel, with multiple side channels and spring-fed tributary channels all occupying the same broad floodplain. Channel morphology was likely pool-riffle, where sufficient gradient and coarse sediment (gravel) were available, or dune-ripple within low-gradient areas dominated by fine sediment (sand) deposition (Montgomery and Buffington 1998). Although the low gradient and unconfined channel created a depositional character, much of the available incoming sediment was likely deposited within losing/dry reaches and/or alluvial fans prior to reaching the lower Pahsimeroi River, except during large floods, promoting a fairly stable channel with episodic response to large disturbance.

Historical riparian conditions in the lower Pahsimeroi River likely reflected a consistent groundwater-influenced hydrology and associated high water table punctuated by periods of extended flooding associated with beaver activity. Relic topographic variation from occasional avulsions, beaver dams, and disturbance from grazing animals (bison, elk, and deer) likely created a mosaic of open water, emergent wetland, floodplain, and upland. The riparian community would have mirrored this diversity with areas of wetland meadow (rushes and sedges), floodplain shrubs (willow) and upland vegetation (sagebrush and grass). Most riparian vegetation had to tolerate fine, poorly draining soils and extended periods of submergence. Few, sporadic stands of cottonwood or aspen trees may have established on well-draining soils, particularly near the mouth of snowmelt-dominated tributaries that could occasionally produce the disturbance (i.e., sand and gravel deposition) required for germination and establishment. The inconsistent source of coarse sediment to the channel likely severely limited rates of point bar development and channel migration, suggesting the banks were fairly stable and able to maintain a deep/narrow channel. A first-hand account of the historic Pahsimeroi from W. A. Ferris, 1830-1835 (Journal entry taken on June 28, 1831) supports this characterization, stating that the river:

> *…though only ten or twelve feet wide, was yet so deep as to be unfordable, except at occasional points. Some of our men, ignorant of its depth, attempted to ford it, but only escaped drowning, by clinging to the branches which were interlaced and bound together by wild vines, forming a complete canopy over the stream. Their horses were carried some distance down by the impetuosity of the current before we could reach and rescue them.*

Another first-hand account from W. A. Ferris in 1832 states that the Pahsimeroi Valley:

> *…is thirty miles long, and twelve broad; it is intersected by willowed streams, and large bottoms, covered with rich pasturage, hence it is a favourite resort for both deer and buffalo. The only trees are a few orchard-like groves in the head of the valley, and pines of every variety, on the abrupt sides of the surrounding mountains.*

Notably, Ferris and his compatriots were fur trappers, and over the course of 5 years of traversing the region, did not document significant trapping of beaver in the Pahsimeroi River valley, nor did they document passing extended periods of time there, suggesting that beaver populations may have been relatively low in the Pahsimeroi compared to neighboring watersheds. Given the likely vegetation assemblages and physical conditions of the historic river, it is likely that beaver were present, but in lower numbers compared with other areas due to isolation and/or previous trapping. Regardless, it is highly likely that beaver had an impact on the Pahsimeroi River, particularly in the lower-gradient, gaining reaches.

Prior to Euro-American settlement, the Salmon River Mountains region was most likely inhabited by a group of Northern Shoshone known as the *Tu'kudeka*, or Sheepeaters, who wintered in the mountains, where they hunted mountain sheep (Rossillon 1980). Given the Shoshone's subsistence cycles and seasonal movements across central and southern Idaho, their impacts on the land were likely confined to their encampments, where tribes from the region would congregate and trade their goods. Reports from Lewis and Clark and others on the abundance of fur-bearing animals west of the divide spurred the business of fur trade. Independent fur trappers, as well as several companies (including the Hudson Bay Company and the American Fur Company) made their way into the northwest to explore and exploit the region. By the early 1840s, local beaver populations were brought to the brink of extinction, and bison had disappeared from the Salmon River region (Albers et al. 1998).

The discovery of gold in California in 1848 began a western mining craze, leading to an influx of prospectors into Idaho and the discovery of gold there. Mining in the area consisted of placer mining along some tributaries and some hard-rock mining. Miners and other settlers were interested in acquiring the Shoshone Tribe's lands and waterways to support their growing agrarian and mining enterprises, and homesteads sprang up across the lower-elevation lands (Albers et al. 1998). Beginning in the 1880s, irrigation development and associated water rights were established in the mainstem Pahsimeroi River and its tributaries (ISCC 1995). Irrigation ditches withdrew water from the river and drained wetlands, redistributing the captured water across the floodplain. Such a redistribution of water had significant impacts on the hydrology of the river, increasing losses in the upper river and enhancing gains in the lower river.

Presently, irrigated and dryland agriculture and livestock grazing are the major land uses in the valley. Livestock grazing is the predominant ongoing activity that occurs on both private and public lands. Grazing on public lands provides a substantial feed base for cattle in the Pahsimeroi River watershed. Generally, cattle graze on public lands from May to October and then return to private lands along the valley bottoms for the remainder of the year (ISCC 1995). Historical agricultural and grazing practices

resulted in riparian vegetation clearing and associated streambank destabilization, as well as increased surface-water runoff and erosion.

Existing Watershed Conditions

The modern Pahsimeroi River has changed as a result of human influence relative to its historical condition. The physical and ecological processes in the Pahsimeroi River have been impacted through irrigation diversions that alter instream flows, reducing the timing and magnitude of seasonal channel-forming flows associated with the spring freshet. Livestock grazing and agriculture along the mainstem Pahsimeroi River and its tributaries have caused a loss of woody riparian vegetation, leading to bank instability, bank erosion, and sedimentation. Road embankments, fine sediment from dirt and gravel roads, and dispersed campsites throughout the drainage network have a cumulative effect on siltation in the mainstem Pahsimeroi River.

Hydrology/floods

The Pahsimeroi River flow regime differs from a traditional snowmelt-dominated stream. The upper basin experiences peak flows in May or June, which is consistent with snowmelt-dominated stream flows. In contrast, the lower Pahsimeroi River experiences peak flows in November, with flow remaining high through the winter, then dropping to lower-than-normal base flow from May through September, indicating a highly modified hydrograph (Arthaud et al. 2010). Overall, the hydrology in the Pahsimeroi River basin is largely driven by groundwater influences (bedrock depth and alluvium) and irrigation practices. Diversions direct water from the Pahsimeroi River and its tributaries to irrigate about 38,000 acres of cropland and to water livestock. While agricultural diversion locations and volumes are regulated by local water authorities and the Idaho Department of Water Resources, exact withdrawal rates on a seasonal and daily basis are unknown.

Flood frequency peaks were estimated at two operational United States Geological Survey (USGS) gages using the PeakFQ program, and at 12 ungaged locations (including two locations in the headwaters), applying methods from Berenbrock (2002). Flow uncertainties are especially high in the middle of the Pahsimeroi River basin (between RM 41.7 and RM 52.4), where sites are located too far away from the gages to adhere to the assumptions of the drainage area ratio method, resulting in a large range of possible discharges. Using the USGS gage data, it appears that discharge does not regularly increase with distance downstream. Discharge decreases from the upper valley to the middle valley, likely due to groundwater influences and irrigation withdrawals (Table 36).

Table 36. Pahsimeroi River hydrology.

River Mile [1]	Drainage area (sq. mi.)	Valley Segment	Estimated Flood-Frequency Values (cfs)						
			1.5	2	5	10	25	50	100
2.1	824	Lower	308	350	459	535	634	712	792
35.7	331	Middle[2]	149	169	221	258	306	343	382
55.9	56	Upper	302	361	506	600	715	798	880

[1]The river mile location is near the downstream end of the valley segment.
[2]High uncertainty exists for flow estimates in the middle of the Pahsimeroi Valley.

Surface and Groundwater Interactions

Irrigation diversions and groundwater pumping have altered the surface water/groundwater interchange along the Pahsimeroi River. Many tributaries are naturally disconnected from the mainstem Pahsimeroi

River during low flow and are disconnected by irrigation diversions at high flow. Surface flow is also ephemeral in many parts of the upper Pahsimeroi River. Water diverted for irrigation or lost to the aquifer returns to the river in many locations as springs along the valley floor, providing the lower river with year-round flow and high connectivity to the Salmon River (NOAA 2017). Detailed seepage runs were conducted in the Pahsimeroi River in 2005 to measure gains and losses to surface flow to and from the local aquifer. Results of the study suggest the upper Pahsimeroi River (upstream of RM 42) is largely losing surface water to the aquifer, while the lower Pahsimeroi River (downstream of RM 23) is largely gaining surface water from the aquifer (Figure 82) (Williams et al. 2006). The middle Pahsimeroi River is mixed, with some areas gaining and some areas losing.

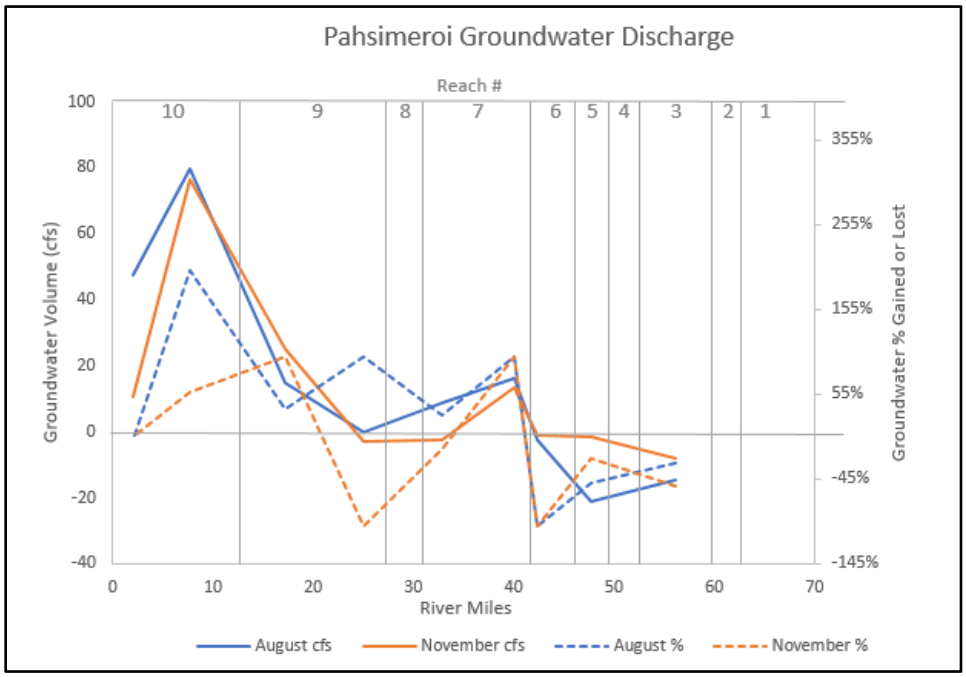


Figure 82. Representative Pahsimeroi River groundwater discharge, as interpreted from Williams et al (2006).

Results represent 1 year of data collected via seepage runs measured in August and November 2005. Surface water flows went dry at the time of measurement in Reaches 5, 6, and the upper portion of Reach 9; therefore, measurements in these areas reflect the minimum volumes lost. Surface water lost to groundwater may be significantly higher in these reaches during years with greater overall discharge. Where discharge increased from 0 cubic feet per second (cfs) to a measurable volume between two reaches, percent gain calculations were not possible (divide by 0). A standard value of 100 percent has been used to graphically represent these gains (RM 40.05 Aug. and Nov.; RM 25.05 Aug.; RM 17.2 Nov.).

A detailed water budget was prepared for the Pahsimeroi River basin by Whittier for water years 2006 and 2007 to calculate where the majority of the groundwater originated (Whittier 2010). The results of the analysis conclude that nearly all of the groundwater contributions to the Pahsimeroi originate from the west (Lost River Range and Pahsimeroi Mountains) and south (Donkey Hills), with negligible contributions from the east (Lemhi Range). The study further concludes that 67 percent of the water discharged at the mouth of the Pahsimeroi River originated from the Lost River Range as a combination of surface water and groundwater.

Icing and Surface Water Interactions

Ice and ice-related channel response may play a minor role in defining the channel morphology in the perennial headwaters of the upper Pahsimeroi River, but the thermal buffering provided by significant groundwater inputs generally prevents large ice accumulations and associated channel response in the gaining reaches of the middle and lower Pahsimeroi River.

Hydraulics

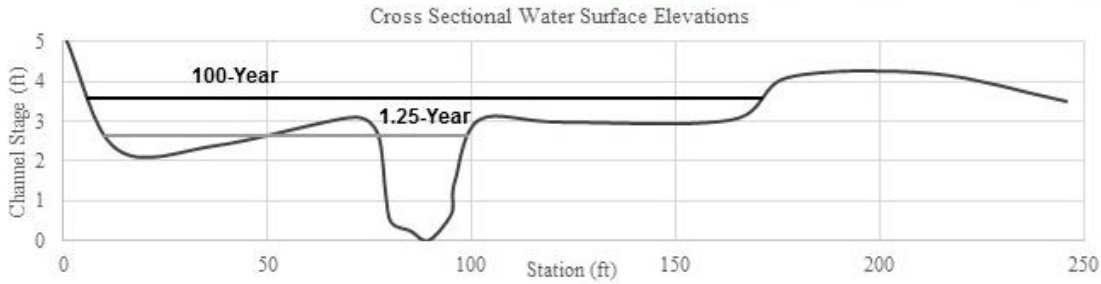
Coarse, at-a-station hydraulic analyses were completed from three representative locations within the watershed to provide context for the geomorphic conditions discussed below. More-detailed two-dimensional hydraulic modeling will be completed as part of the future MRA process for select reaches. Three typical cross-sections located in the lower Pahsimeroi River watershed were measured and evaluated to assess existing hydraulic characteristics and to determine if any generalizations could be inferred from the calculations. Cross-sections were measured at RM 25.6 (Valley Segment 3, Geomorphic Reach 11, Figure 83), RM 11.8 (Valley Segment 3, Geomorphic Reach 12, Figure 84), and RM 2.1 (Valley Segment 3, Geomorphic Reach 12, Figure 85).

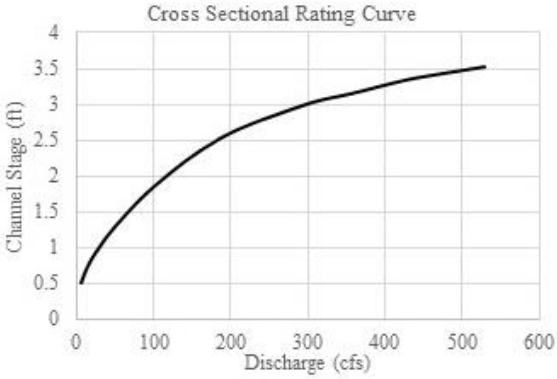
At a Station Hydraulic Calculations Summary Sheet

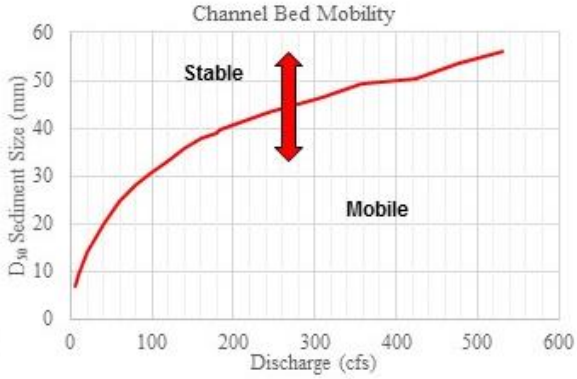
River:	Pahsimeroi
Rivermile:	25.6
Valley Segment:	3
Geomorphic Reach:	11
Reach Slope:	TBD
Localized Slope:	0.0062
n-value (range):	0.035 - 0.045

Local Sediment Size (mm)

D_{16}: 15 D_{50}: 35 D_{84}: 66







Recurrence Event:	1.25-Year	100-Year
Discharge (cfs):	184	530
Stage (ft):	2.7	3.6
Top Width (ft):	24	164
Ave. Velocity (ft/s):	4.1	5.2
Ave. Shear (lb/ft^2):	0.6	0.9
Ave. St. Power (lb/ft*s):	2.6	4.6
D_{50} Mobilized (mm):	48	69

Entrenchment Ratio (ft/ft):	6.8[1]
Discharge to Mobilize D_{50} (cfs):	> 530
Bed Armored (yes/no):	Yes

Notes: 1. Entrenchment Ratio based off main channel width not including side channel.

Pahsimeroi River–Upper Section

Integrated Rehabilitation Assessment

Idaho Governor's Office of Species Conservation Date Exported: 03/23/2017

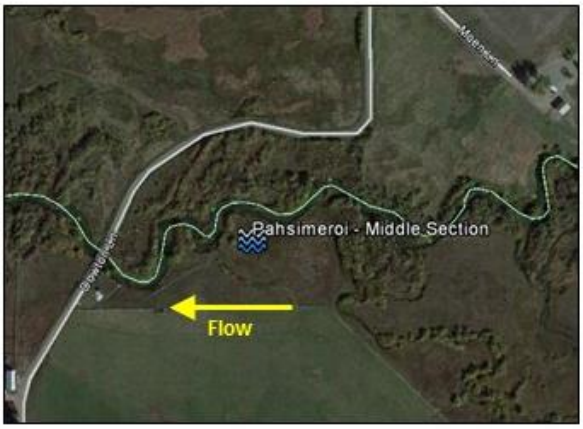
Figure 83. Summary of representative hydraulic conditions at Site 1.

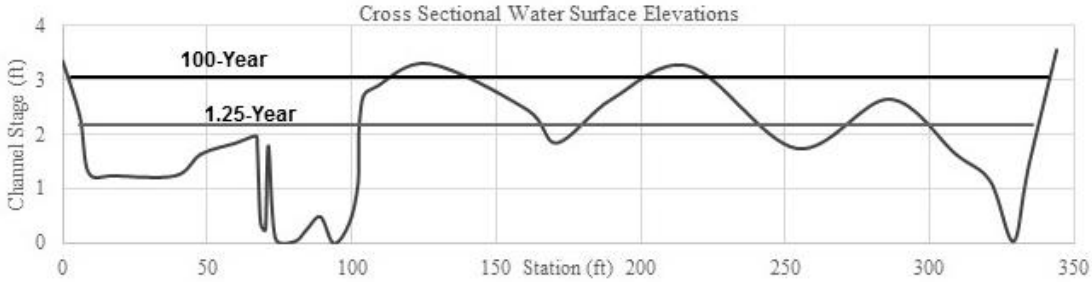
At a Station Hydraulic Calculations Summary Sheet

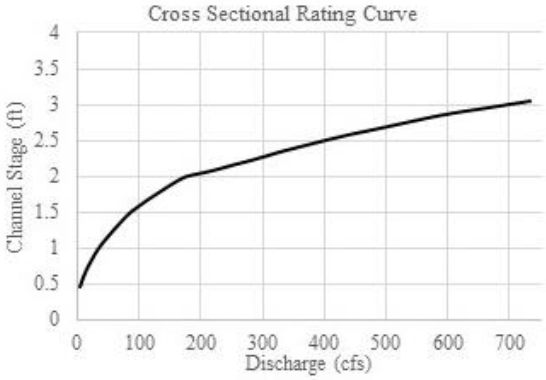
River:	Pahsimeroi
Rivermile:	11.8
Valley Segment:	3
Geomorphic Reach:	12
Reach Slope:	TBD
Localized Slope:	0.0027
n-value (range):	0.035 - 0.045

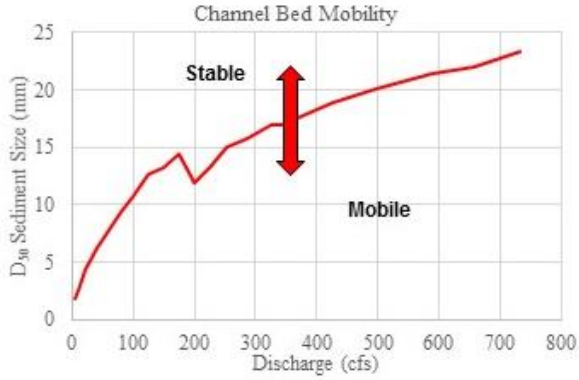
Local Sediment Size (mm)

D_{16}:	14	D_{50}:	29	D_{84}:	56









Recurrence Event:	1.25-Year	100-Year
Discharge (cfs):	254	733
Stage (ft):	2.2	3.1
Top Width (ft):	36	306
Ave. Velocity (ft/s):	2.5	3.3
Ave. Shear (lb/ft^2):	0.2	0.4
Ave. St. Power (lb/ft*s):	0.6	1.2
D_{50} Mobilized (mm):	15	23

Entrenchment Ratio (ft/ft):	8.5[1]
Discharge to Mobilize D_{50} (cfs):	> 733
Bed Armored (yes/no):	Yes

Notes: 1. Entrenchment Ratio based off main channel width not including side channels.

Pahsimeroi River–Middle Section

Integrated Rehabilitation Assessment

Idaho Governor's Office of Species Conservation Date Exported: 03/23/2017

Figure 84. Summary of representative hydraulic conditions at Site 2.

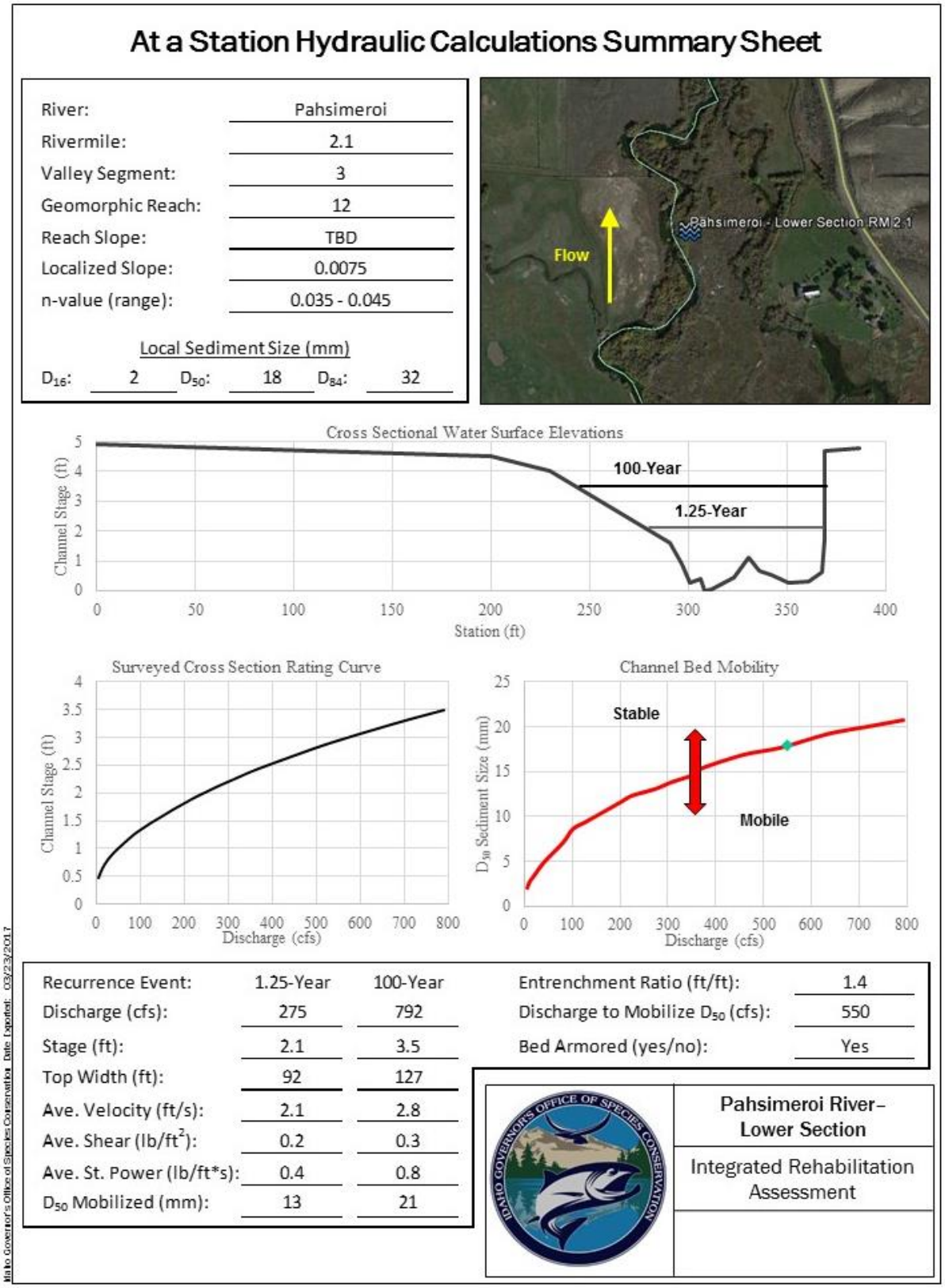


Figure 85. Summary of representative hydraulic conditions at Site 3.

The upstream-most section is located at the upstream end of a gaining area, based on previous groundwater studies. The section modeled shows the 1.25-year discharge contained primarily within the main channel banks, with overtopping occurring near the 1.25-year discharge. The entrenchment ratio is 6.8, which relates to a well-activated floodplain. The sediment size was showing bed mobilization beginning at less than the 1.25-year event, which allows the channel to scour and maintain pools. Average channel velocities varied from 4.1 feet per second at the 1.25-year event up to 5.2 feet per second at the 100-year event. Shear stresses varied from 0.6 to 0.9 lb/ft^2 between these two events. The estimated discharges and resultant hydraulic forces associated with this cross-section result in the potential for bed and bank movement at high-frequency return intervals (yearly).

The middle section is located a short distance upstream of Dowton Lane in a predominantly multi-threaded channel. The channel geometry is such that the 1.25-year event is slightly out of bank, with active, flowing side channels. The 100-year event accesses a good portion of its floodplain, with an entrenchment ratio of approximately 8.5, assuming that the floodplain actively conveys flow downstream. Local sediment sizes show that the bed begins to mobilize at flows higher than 733 cfs, which is greater than the 100-year event, suggesting a heavily armored bed. Channel velocities range from 2.5 ft/sec to upwards of 3.3 ft/sec. Depending on how and when the channel accesses a large portion of its floodplain (side channel network) at this section, there is a lot potential variation in flood hydraulics, and further study would be required to assess those characteristics to determine if all side channels were active. Given the multi-thread pattern of this cross-section, dispersion of flow between these channels could be affecting the armoring of the channel bed. If these side channels are not active and all flows are concentrated toward the main channel bed, armoring might be less than estimated in this analysis.

The lower section is located approximately 1 mile upstream of the lower hatchery. At this section, the waterway is channelized by high ground on each river bank, reducing the entrenchment ratio to 1.4. Channel velocities range between 2 and 3 ft/sec for the 1.25- and 100-year discharge events, respectively. Shear stresses vary from 0.2 to 0.3 lb/ft^2 for the same two flow events. The channel appears to be armored through this section of river, with D_{50} mobilization occurring between the 10- and 25-year events. Upon additional review of LiDAR data, it appears the lower section was taken in a locally confined area with limited floodplain connectivity and likely does not represent the overall reach accurately. It is anticipated that adjacent areas do not contain the 100-year flow, based on similar stage estimates and likely increases in both the entrenchment ratio and the effect of bed armoring.

Among these three cross-sections, the floodplain is accessible to flood waters at the upper two sections, and perhaps artificially limited by the downstream section. The channel bed appears to become more armored farther downstream. This could be caused by distributary and multi-thread channels reducing stream energy in the upper sections or increasing influence of groundwater versus peak-flow hydrology. Armoring could limit potential scour depths and pool development at these locations. Results from the lower Pahsimeroi River cross-section hydraulics do not appear to be representative of the lower valley segment. The cross-section was taken at a location with high ground on the floodplain (approximately 1 to 2 feet higher than surrounding areas), yielding a lower entrenchment ratio than is believed to be representative of the area. Alterations to the peak hydrograph from irrigation withdrawals, and possibly minor channel incision, may also affect the hydraulic calculations, resulting in lower entrenchment ratios than those interpreted from aerial photos. More-detailed hydraulic modeling is required to confirm actual floodplain inundation timing and associated entrenchment.

Water Quality

Surface water quality standards apply to a waterbody depending on its designated uses and/or existing uses. Pursuant to the Clean Water Act (CWA), Idaho recognizes existing uses, which are uses present or attained in a water body on or after November 28, 1975. When water bodies do not have designated beneficial uses, they are assigned a presumed use protection. All water bodies are classified for more than one beneficial use and must meet the fishable/swimmable intent of the CWA.

Under Idaho's water quality standards, beneficial uses are categorized as aquatic life, recreation, water supply, wildlife habitat, and aesthetics. For the Lemhi River watershed, the beneficial uses that are not fully supported are: (1) aquatic life, which includes salmonid spawning and cold-water aquatic life beneficial uses, and (2) and contact recreation that includes primary and secondary contact recreation.

The Idaho Department of Environmental Quality completed a subbasin assessment for the Pahsimeroi River watershed in 1999 (IDEQ 2013). Total maximum daily loads (TMDLs) were developed for water bodies not supporting their beneficial uses and impaired by a pollutant. In Idaho's 2002 Integrated Report (IDEQ 2005), streams were converted from water-quality-limited segments to assessment units (AUs) based on Strahler Stream Order within a Waterbody ID.

Additional AUs identified by IDEQ's Beneficial Use Reconnaissance Program monitoring were added to the 2008 and 2010 Integrated Reports. Further investigation by IDEQ determined that some listed AUs are ephemeral and therefore should not be listed as water-quality-limited (Section 5: TMDL needed) but rather placed in Section 4C (impaired but not due to a pollutant). Under the CWA, lack of flow is not considered pollution, and no TMDL can be calculated. The 2012 Addendum updated water bodies and pollutants for which TMDLs have been developed (Table 37).

Table 37. Streams and pollutants for which TMDLs were developed

Waterbody	2001	2013 Addendum
Pahsimeroi River	Sediment, Temperature	Bacteria
North Fork Lawson Creek		Sediment
East Fork Pahsimeroi River		Temperature
Short Creek		Sediment

Source: IDEQ 2013

Basin Geometry

Domains within a watershed can be characterized as zones that are governed by sediment supply, alluvial fan formation, sediment transfer, or deposition (Figure 86). The headwaters and upper reaches of the Pahsimeroi River are generally classified as sediment supply zones dominated by weathering and erosion of steep slopes, where tributaries collect and transport sediment downslope to the alluvial fan zone. The alluvial fan zone is where coarse sediment has accumulated across broad alluvial fans and piedmont belts at the valley head and margins. Here, the basin-fill sediments are porous and the river loses surface water to the aquifer and commonly goes dry. During high flow, even losing reaches of the Pahsimeroi River convey surface flow, episodically transporting and depositing sediment through the transfer zone.

Below the alluvial fan and ephemeral transfer zones, tributaries flow across the broad, low-gradient valley bottom, where they are unable to consistently transport a coarse sediment load, creating a pronounced deposition zone characterized by fine sediment and a highly sinuous, commonly multi-threaded channel. A longitudinal profile of the channel from RM 60 to the mouth of the river (RM 0) shows a concave

profile, with the highest gradient in the upper valley and a generally decreasing slope in the downstream direction (Figure 87).

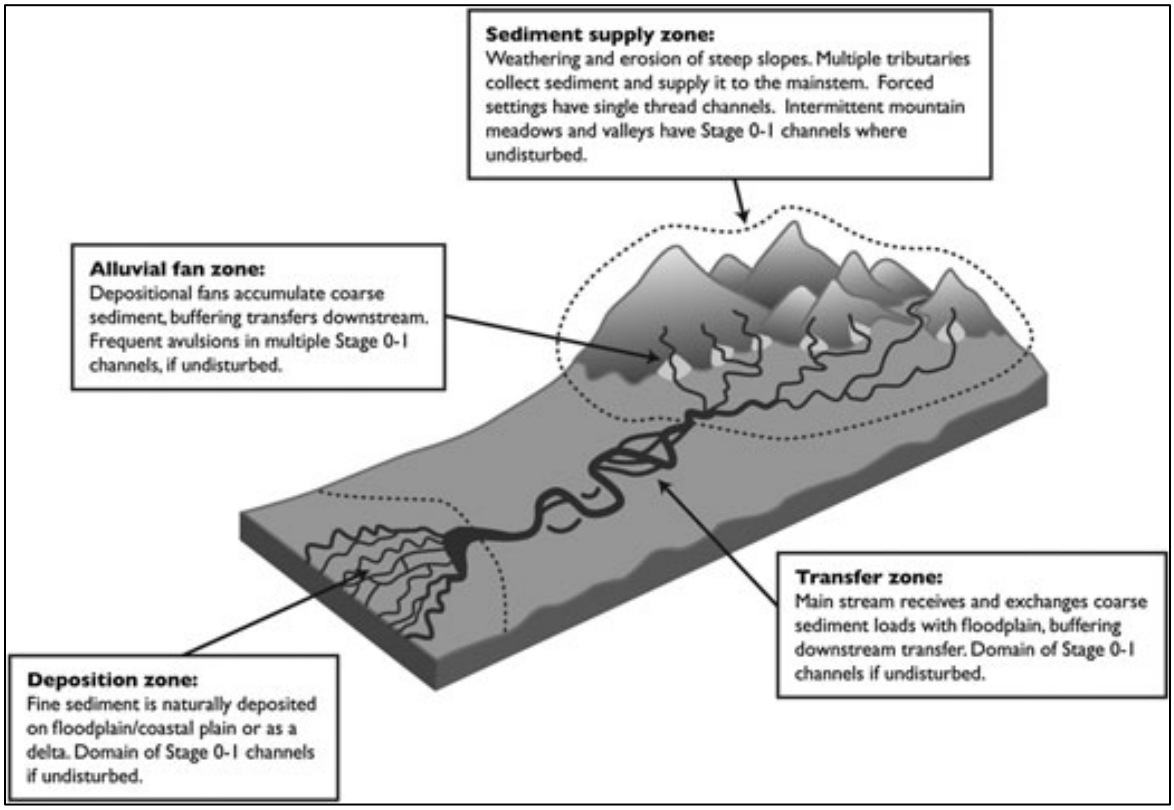


Figure 86. Locations of sediment domains within a typical watershed (Cluer and Thorne 2013).

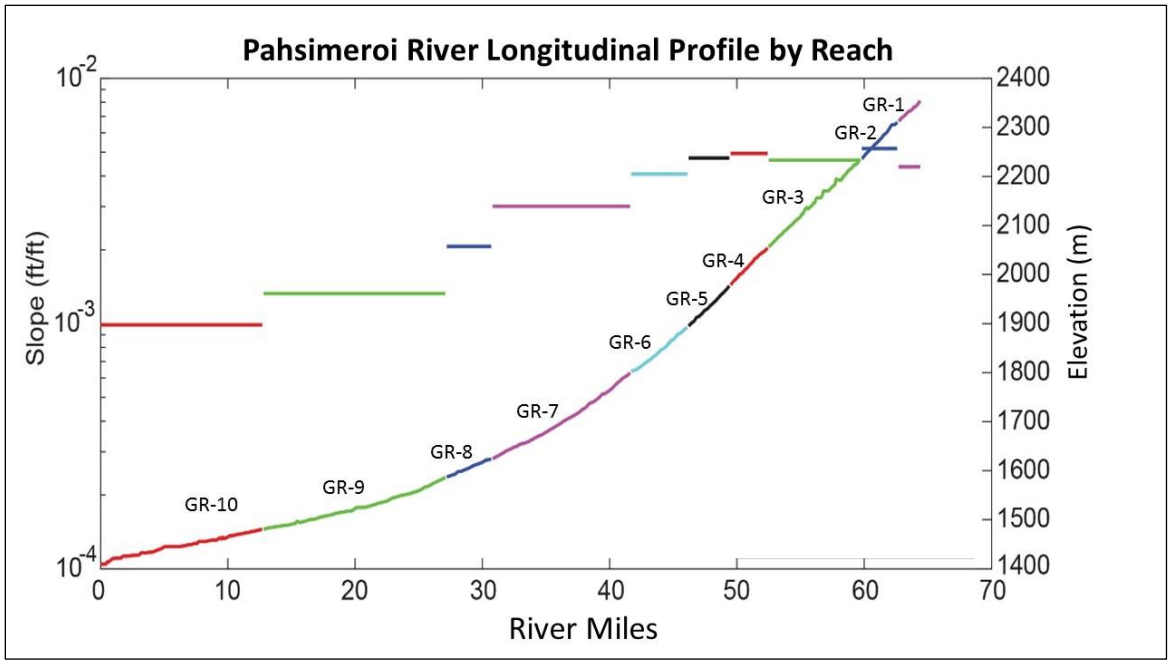


Figure 87. Pahsimeroi River longitudinal profile by geomorphic reach. The channel exhibits a typical concave curve with generally decreasing slopes in the downstream direction.

The width of the Pahsimeroi River floodplain, as defined by the location of confining terraces and/or valley margin, is narrow in the upper valley and wide in the lower valley. Dividing the width of the floodplain by the width of the bankfull channel produces a result called the entrenchment ratio. A small entrenchment ratio means the channel has less accessible floodplain area and therefore less ability to dissipate flood energy on the floodplain. This results in deeper, higher-velocity, more-forceful flood flows, increasing the potential for erosion and/or incision (i.e., transport reach). Large entrenchment ratios are representative of channels with broadly accessible floodplains that can dissipate flood energy outside the banks of the channel, resulting in less-forceful flood flows and a tendency for deposition (i.e., response reach).

Large portions of the upper and middle Pahsimeroi River are naturally confined by terraces and exhibit relatively low entrenchment ratios. Measurements of entrenchment in the lower Pahsimeroi River were highly variable, but lower than expected, possibly due to a highly altered hydrograph from irrigation and/or minor incision and channel widening (i.e., larger cross-sectional area). The middle Pahsimeroi River is mixed, exhibiting both high and low entrenchment ratios. Human features such as levees, road embankments, and other obstructions appear to have had minimal large-scale impact on entrenchment in the Pahsimeroi River. More-detailed hydraulic modeling is required to confirm floodplain inundation timing and extent and associated entrenchment.

Soils

Geomorphic features in the Pahsimeroi River valley bottom include the active channel, floodplains, alluvial fans and stream terraces, and outwash fans and fan terraces. Soils that have formed on these features are described in Table 38. Soil descriptions are based on the NRCS detailed soil maps and the Detailed Soil Map Units section in the report (NRCS 2003).

Table 38. Geomorphic features along the valley bottoms and margins, and associated soils

Geomorphic Feature	Soil Description and Other Information
Active Channel	Water. Soils that have formed adjacent to or in the channel (gravel bars and islands) are described in the Floodplains soil description.
Floodplains	Soil description: a very deep, very poorly drained to moderately well drained soil that is dark-colored, silty loam to very cobbly sandy loam, and on floodplains and old stream channels. Slope range: 0 to 4 percent; Elevation range: 3700 to 7400 feet; Average annual precipitation: 8 to 18 inches; Average annual air temperature: 34 to 45° F; Frost-free season: 5 to 90 days; Depth class: very deep; Drainage class: very poorly drained to moderately well drained; Permeability: moderately slow to very rapid; Available water capacity: 1 to 12 inches; Effective rooting depth: 10 inches to more than 60 inches; Runoff: slow; Hazard of water erosion: slight; Range site: basin big sagebrush, western wheatgrass, black cottonwoods, willows, and sedges
Alluvial Fans and Stream Terraces	Soil description: a very deep, poorly drained to well-drained soil the is light-colored silt loam over silty clay to very gravely loamy silt, and on alluvial fans and stream terraces Slope range: 0 to 6 percent; Elevation range: 3800 to 6600 feet; Average annual precipitation: 8 to 12 inches; Average annual air temperature: 37 to 45° F; Frost-free season: 25 to 100 days; Depth class: very deep; Drainage class: poorly drained to well drained; Permeability: moderate in the upper part to very rapid in the lower part to moderately slow; Available water capacity: 2 to 11 inches; Effective rooting depth: 10 inches to more than 60 inches; Runoff: slow to medium; Hazard of water erosion: slight to moderate; Range site: Wyoming big sagebrush, bluebunch wheatgrass, threetip sagebrush, and Idaho fescue
Outwash Fans and Fan Terraces	Soil description: a very deep, well drained to somewhat excessively drained soil that is a darker-colored, gravely loam, and on outwash fans and fan terraces. Slope range: 1 to 20 percent; Elevation range: 4500 to 7100; Average annual precipitation: 6 to 12 inches; Average annual air temperature: 35 to 44° F; Frost-free season: 30 to 90 days; Depth class: very deep; Drainage class: well drained; Permeability: moderate in upper part and very rapid in lower part to moderately slow; Available water capacity: 3.5 to 5.5 inches; Effective rooting depth: 40 inches to more than 60 inches; Runoff: slow; Hazard of water erosion: slight; Range site: mountain big sagebrush, Idaho fescue, Wyoming big sagebrush, and bluebunch wheatgrass

Land Use

The Pahsimeroi River watershed covers about 839 square miles, and about 90 percent of the land is owned by the Federal government and administered by the USFS and BLM. Private lands are primarily located along the more-fertile valley bottoms. The primary land uses are livestock grazing, irrigated pasturelands and hay fields, developed and dispersed recreation, and timber harvest. Livestock grazing

occurs on both public and private lands across much of the middle and lower elevations in the watershed. Livestock are grazed on public lands from May to October and then return to private lands for the remainder of the year. Irrigated pasturelands and hay fields are on private lands along the Pahsimeroi valley bottom and margins. The effects of irrigation and grazing in the valley bottom include diversion of flows from the mainstem Pahsimeroi River, diversion of tributaries away from the mainstem Pahsimeroi River, stream alterations, and native vegetation replacement.

Developed and dispersed recreation, several small mining claims, and small timber harvests are additional land uses that are believed to have minimal impact on the modern Pahsimeroi River.

Land Cover and Riparian Conditions

More than half of the drainages in the Pahsimeroi River watershed have less-than-satisfactory riparian conditions, based on stream functionality and plant community-type assessments. Most of these altered riparian communities are in the lower portions of the watershed (NPCC 2004). Degradation of riparian conditions is due to both livestock grazing and reduced streamflows from irrigation withdrawals (NOAA 2017). Agricultural development and livestock grazing have altered the riparian vegetation through clearing and soil compaction, resulting in the replacement of native sedge and willow species with grass and other species that do not have the bank-stabilizing and shade-providing effects that natural woody riparian vegetation provides.

Channel Migration

Meander bend channel migration involves erosion of the outside bank of a bend, coupled with concurrent deposition of sediment along the inside bank of the same bend, resulting in the lateral movement of the channel while maintaining consistent channel shape and width. This process is driven by and dependent on concurrent deposition and erosion. Bank erosion without deposition results in channel widening. Deposition without bank erosion results in aggradation and possible avulsion. There are very few active depositional point bars within the entire Pahsimeroi River, suggesting that channel migration is not a dominant process. Observable bank erosion and bank recession are common, especially in the lower Pahsimeroi River, where riparian vegetation has been cleared and bank stability compromised (Photograph 22). These areas of bank erosion do not show evidence of deposition on the opposite bank, resulting in channel widening, rather than channel migration. Where bank erosion has occurred in areas with dense riparian vegetation, rates of bank recession are so slow that active point-bar deposition is not readily observable. The sinuous channel pattern observed on the lower Pahsimeroi River is likely the result of episodic avulsion and very low rates of channel migration, largely undetectable over the span of available historical photos for the area.

Photograph 22. Example of eroding bank in the Lower Pahsimeroi. This bank has subsequently been improved with multiple rootwad structures to reduce excessive bank erosion, reduce the over-widened width-to-depth ratio of the channel, and to provide habitat and cover for juvenile salmonids.

Large Wood Recruitment and Retention

Other than a handful of cottonwood trees that appear to have been planted or otherwise associated with human disturbance, no large trees were observed in the lower Pahsimeroi River riparian area (downstream of RM 24), and no buried wood was observed in the banks or bed of the lower Pahsimeroi River during 2016 field work. A high groundwater table and limited coarse sediment disturbance (overbank sand and gravel deposition) suggest few large trees historically occupied the banks of the lower Pahsimeroi River. Additionally, large depositional zones, ephemeral surface flow, and small tributary drainages upstream of the lower Pahsimeroi River likely precluded frequent large wood recruitment from upstream sources. Historically and currently, mature riparian vegetation (willow clumps) provide structure to the lower Pahsimeroi River channel, forcing flow convergence and stabilizing banks where present, providing a function similar to large wood (Photograph 23). Rehabilitation projects may consider using large woody material to emulate willow clumps as a temporary surrogate for mature riparian vegetation on otherwise barren banks until mature vegetation can be established.

Photograph 23. Mature willow clump providing instream structure and splitting flow in a groundwater-influenced channel (Big Springs Creek in the Lemhi watershed).

Historically and currently, most of the upper Pahsimeroi River (upstream of RM 24) had/has a greater influence from snowmelt hydrology and tributary-derived coarse sediment than the lower Pahsimeroi River. These conditions have created a disturbance regime more suitable for the establishment and propagation of cottonwood trees, in addition to willows and other shrubs. It is likely that large woody material has been recruited to the upper Pahsimeroi River via local windfall for thousands of years. It is unlikely that large floods and debris torrents commonly transported large wood from the uplands, given the distance of transport required and the small size of tributaries in the upper Pahsimeroi River. Reports suggest that wood is unlikely to transport through such small streams with low channel width and depth (Braudrick and Grant 2001).

Channel Planform and Morphology

Channel planform on the Pahsimeroi River is moderately to highly sinuous. In an alluvial valley, sinuosity is typically inversely proportional to gradient, with lower sinuosity in areas of steeper gradient. This is the case on the Pahsimeroi River, where reach-averaged sinuosity ranges between 1.1 and 1.3 in the high-gradient upper Pahsimeroi River and between 1.3 and 1.8 in the lower-gradient lower Pahsimeroi River, where the hydrology also tends to be more groundwater-influenced. The upper Pahsimeroi River, with lower sinuosity, greater sediment supply, higher gradient, and more pronounced peak flows, likely has been and remains a predominantly single-threaded system. In the lower Pahsimeroi River, low gradients, high sinuosity, groundwater-influenced hydrology, dense riparian vegetation, and beaver activity likely led to a historically multi-threaded channel system. Over the past 100+ years, the removal of riparian vegetation and loss of beaver, along with irrigation diversions and channel manipulation, have created a largely single-threaded system. Where riparian vegetation has been removed, the bankfull width of the channel has increased significantly.

Channel morphology, as defined by Montgomery and Buffington (1998), is determined by bedform features associated with slope, discharge, sediment supply, bedrock lithology, and disturbance history. The channel morphology of the Pahsimeroi River has not significantly changed since historic times, with

the upper Pahsimeroi River characterized by a predominant plane-bed morphology, and the lower Pahsimeroi River characterized by a predominant pool-riffle morphology. Channel obstructions and bank structure-associated riparian vegetation and woody debris may increase areas of flow contraction within the channel, locally driving otherwise plane-bed morphology toward a forced pool-riffle morphology (Photograph 24). Alternatively, where a lack of riparian vegetation has resulted in bank recession and channel widening, flow divergence reduces local transport competence and the development of scour pools, driving a pool-riffle morphology toward a plane-bed morphology (Photograph 25 and Photograph 26). The significant lack of riparian vegetation on the lower mainstem Pahsimeroi River, and to an even larger extent on tributaries within the valley bottom, has likely resulted in many more linear feet of plane-bed as opposed to pool-riffle morphology, relative to historic conditions. Detailed reach-scale mapping will be required to quantify this claim.

Photograph 24. Forced pool-riffle morphology due to riparian plant structure on the bank of the lower Pahsimeroi River.

Photograph 25. Photograph illustrating a straightened channel and plane-bed morphology in the lower Pahsimeroi River.

Photograph 26. Plane-bed morphology in Big Creek in the upper Pahsimeroi River valley.

The upper Pahsimeroi River loses so much flow to groundwater and irrigation withdrawals that near RM 40, the channel not only goes dry but is reduced to such infrequent surface flow that it does not have recognizable banks or a specific morphology. The valley bottom in this area reveals many small, dry channels similar to the surface of an alluvial fan, but no well-defined primary channel, suggesting this

condition to be natural, although likely exacerbated by irrigation withdrawals. Many springs originate at the toe of the Doublesprings alluvial fan immediately downstream of this point, reestablishing a multi-thread network of surface channels by RM 38, which have coalesced into a primary single-thread channel by RM 33. Many irrigation ditches and ponds intercept flow, influencing the morphology of the channel(s) in this area.

Beaver

The existing influence from beavers has been severely limited as a result of legacy fur trapping. Limited evidence of beaver activity on the Pahsimeroi River was observed during 2016 field work, suggesting that population numbers remain extremely low. As discussed previously, beaver activity likely played a significant role in modifying and developing the historic Pahsimeroi River morphology. Beavers generally require 40 to 60 percent tree/shrub canopy closure and shrub height greater than 6.6 feet within a broad/intact riparian corridor (Slough and Sadleir 1977). Beavers also require trees less than 6 inches in diameter for food source, preferring aspen, willow, cottonwood, alder (in that order) (Denney 1952). These conditions are present in discontinuous patches throughout the valley and suggest beaver reestablishment is possible.

Watershed Impacts

The higher-elevation areas along the Lemhi Range and the Lost River Range are on public lands that are administered by the Salmon-Challis National Forest. The middle and lower elevation areas along the foothills and piedmont belts are on public lands administered by the BLM Challis Field Office. The valley bottoms of the Pahsimeroi Valley are predominantly private lands.

Forested, higher-elevation areas along the Lemhi Range and Lost River Range have been minimally impacted by human activities. Road density, timber harvests, and dispersed recreation have had minor impacts on the watershed. However, at middle and lower elevations, there are significant, localized human impacts that have negatively affected riverine processes. These impacts include, but are not limited to, flow alteration from irrigation diversions, loss of riparian vegetation on tributaries, channel and floodplain alteration from roads, and increased fine-sediment deposition.

Irrigation diversions significantly reduce instream flows by diverting tributaries away from and out of the mainstem Pahsimeroi River. The many irrigation diversions reduce the frequency and magnitude of peak flows, as well as the quantity of instream habitat available through isolation (i.e., disconnected tributaries) and volume (i.e., linear feet of stream with adequate surface water). Another effect of irrigation diversions is an alteration of the timing and spatial distribution of groundwater recharge. Diversions redistribute river water onto the floodplain during the summer months, artificially increasing groundwater levels in those locations.

The loss of dense riparian vegetation (primarily willow, and especially in the lower Pahsimeroi River) has resulted in an over-widened and homogenous channel. Dense riparian vegetation on the outside of bends stabilizes the bank and obstructs flow, forcing contraction and resulting in pool scour and a narrow width-to-depth ratio, often with undercut banks. Dense riparian vegetation also promotes channel response via side-channel formation and avulsion around the structure provided by the vegetation, rather than bank erosion and widening when vegetation is lacking. A reduction in the amounts of bank structure and instream structure has resulted in a simplified, homogenous channel exemplified by an over-widened, predominantly plane-bed morphology. The over-widened condition also expands the cross-sectional area of the channel between the banks, enabling more water to pass between the banks during floods, reducing

floodplain connection frequency and duration. Finally, in all areas where woody riparian vegetation has been lost, the channel is exposed to greater solar radiation and thermal heating from the loss of shade.

Channel and floodplain alterations from roads are most prevalent in the lower Pahsimeroi River valley. Several roads span the valley bottom, with culverts and bridges passing the stream beneath the road, concentrating flow at each crossing location. It is unclear to what extent these crossings have impacted physical and biological conditions on the Pahsimeroi River. Undersized crossings can obstruct flow, promoting upstream flooding and deposition (for better or worse). Crossings often also provide grade control that can impact (positively or negatively) the stream gradient.

Loss of riparian vegetation, cattle grazing, and to a lesser extent, runoff from roads, all-terrain vehicle trails, and mining operations, have increased fine sediment inputs to the channel through sheetwash and wind erosion. Dense riparian vegetation had historically stabilized banks composed of fine sand and silt, which are now eroding and contributing sediment to the river on an annual basis. Cattle grazing has disturbed the surface of the floodplain and compacted the soils, both of which lead to greater fine-sediment runoff. Roads have been located adjacent to or drain into many of the tributaries, where they have altered the riparian vegetation composition, compacted soils, and provided conduits for concentrated sheet flows during snowmelt and thunderstorms. Mining operations have included placer mining and exploratory trenches, especially in the foothills and headwater areas along the Lemhi Range by the Patterson Creek drainage. The cumulative effects of these impacts have likely increased fine sediment inputs entering the Pahsimeroi River system, resulting in elevated fine-sediment levels and siltation.

Data Gaps

Future analysis could be aided by the collection of additional data currently unavailable, including:

- Hydraulic modeling to confirm floodplain inundation timing and extent, sediment transport character, and appropriate channel geometry (i.e., width-to-depth ratio).
    - Data gaps necessary for hydraulic modeling include bathymetry data, frequent pebble counts, and an improved understanding of diversion withdrawals/returns, tributary inflows, and groundwater contributions.
- Riparian vegetation inventory, including health and successional stages within the low surface that directly influence lateral channel migration, force pool-riffle bedforms, sort and retain gravel, and provide bank stability.

LiDAR upstream of RM 30 will aid assessment and design efforts in the mid- and upper Pahsimeroi River if and when regular surface flow can be extended upstream to this area.

Pahsimeroi Valley Segments and Geomorphic Reaches

Valley segments, geomorphic reaches, and channel units are three hierarchically nested subdivisions of the drainage network (Frissell et al. 1986). Within the hierarchy of spatial scales, valley segments, geomorphic reaches, and channel units represent the largest physical subdivisions that can be directly altered by human activities. As such, it is useful to understand how they respond to anthropogenic disturbance, but to do so requires classification systems and quantitative assessment procedures that facilitate accurate, repeatable descriptions and convey information about biophysical processes that create, maintain, and destroy channel structure (Bisson, Buffington, and Montgomery 2006).

Valley Segments

The Pahsimeroi River occupies an alluvial valley that has varying discharge along its course due to flow and sediment inputs from major tributaries classified using a 10th field Hydrologic Unit Code (HUC-10). There are four HUC 10 sub-watersheds that discharge to the Pahsimeroi River (Table 39). Four valley segments were identified based on the location of where the Pahsimeroi River begins and where the HUC 10 sub-watersheds interact with or are identified along the Pahsimeroi River (Figure 88).

(1) The Pahsimeroi Headwaters Valley Segment includes the East and West Forks of the Pahsimeroi River downstream to where they combine to form the Pahsimeroi River (Headwaters to RM 64.4)

(2) The Upper Pahsimeroi Valley Segment includes the upstream extent of the Pahsimeroi River to a point estimated to represent an average location where perennial surface flow becomes ephemeral. The entire Upper Pahsimeroi has been shown to lose significant volumes of flow to the aquifer (Williams et al. 2006)/ (RM 64.4 to 52.5)

(3) The Middle Pahsimeroi Valley Segment includes the majority of the Pahsimeroi River that is considered ephemeral due to surface water losses to groundwater and irrigation. There are sections of the Middle Valley Segment that gain flow from groundwater sources (along the toe of the Doublesprings alluvial fan), but the stream is generally ephemeral above and below these locations. The hydrologic regime is considered mixed, with most of the Middle Valley Segment characterized by surface-water/snowmelt discharge, with the exception of the groundwater-influenced section identified above. (RM 52.5 – 30.9)

(4) The Lower Pahsimeroi Valley Segment includes the majority of the Pahsimeroi River that is considered perennial due in large part to significant groundwater gains throughout this valley segment. (RM 30.9 – 0).

Table 39. Pahsimeroi River watershed valley segments delineations and sub-watersheds

Valley Segments and Locations	Sub-watershed	HUC 10	Named Tributaries	River Miles	Square Miles
Pahsimeroi Headwaters Valley Segment (Headwaters to RM 64.55)	West Fork Pahsimeroi River	Sub-watershed in HUC 1706020201	0	Upstream of 64.5	12.9
	East Fork Pahsimeroi River	Sub-watershed in HUC 1706020201	0		17.5
Upper Pahsimeroi Valley Segment (RM 64.55 to 52.50)	Upper Pahsimeroi River	1706020201	3	64.5 – 52.5	90.1
Middle Pahsimeroi Valley Segment (RM 52.50 to 30.92)	Middle Pahsimeroi River	1706020202	2	52.5 – 30.9	342.7
Lower Pahsimeroi Valley Segment (RM 30.92 to 0)	Lower Pahsimeroi River	1706020203	12	30.9 – 0	367.2
	Total		**15**	**64.5**	**830.4**

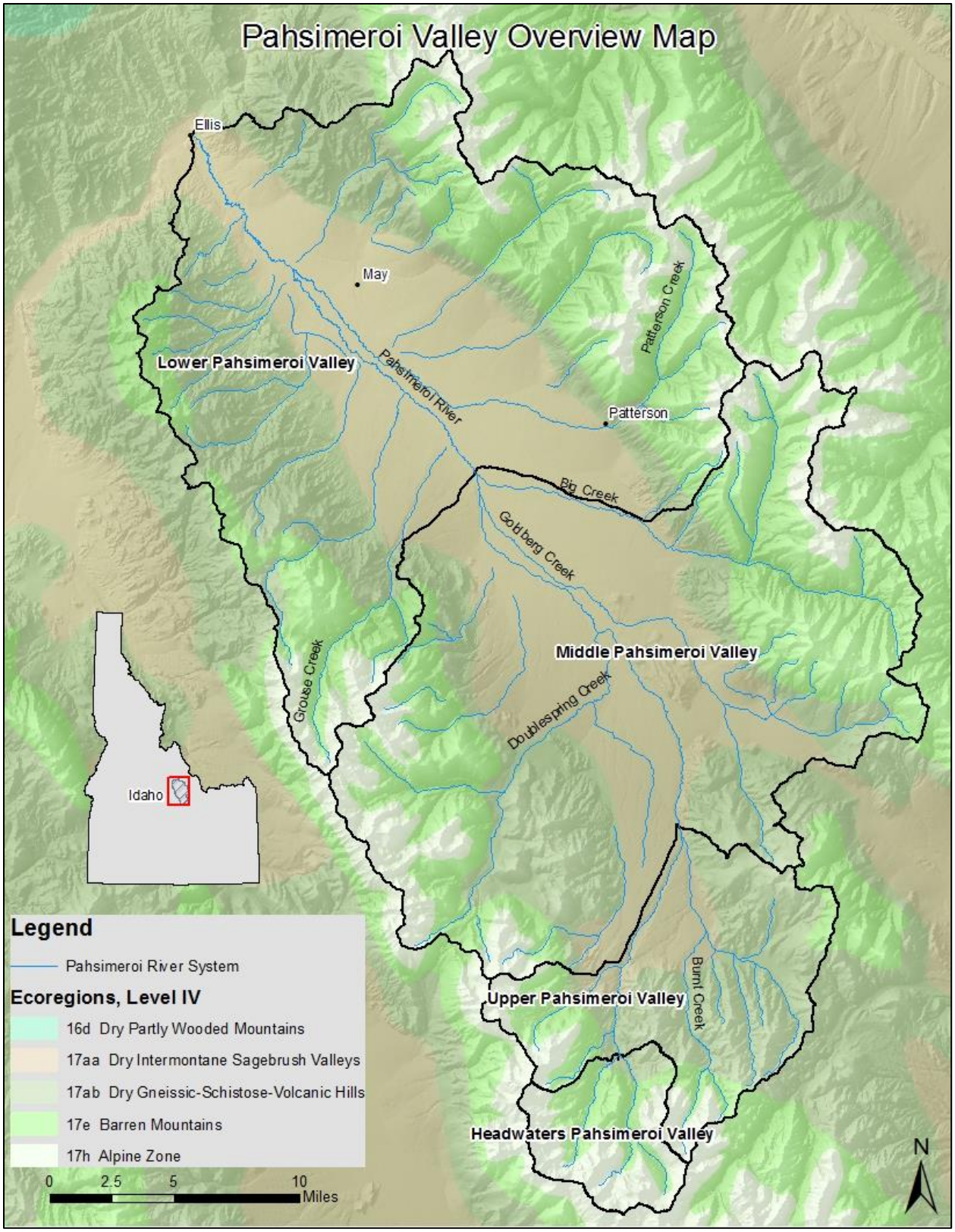


Figure 88. Pahsimeroi River watershed valley segment locations.

Reach Characteristics

Reach characteristics are summarized by reach in Table 40 below.

Table 40. Summary of geomorphic conditions for the Pahsimeroi River watershed

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-1	64.5 - 62.6	0.0185	391	-	0.0145	23	1.3	17	-	0%	-	19%	81%	0%
VS-2	GR-2	62.6 - 59.8	0.0194	204	-	0.0169	23	1.1	9	-	0%	-	20%	61%	19%
VS-2	GR-3	59.8 - 52.5	0.0168	290	-	0.0152	28	1.1	10	-	1%	Losing	13%	87%	0%
VS-3	GR-4	52.5 - 49.5	0.0182	389	-	0.0155	23	1.2	17	-	1%	Losing	30%	70%	0%
VS-3	GR-5	49.5 - 46.1	0.0188	208	-	0.0164	18	1.1	11	-	1%	Losing	41%	56%	2%
VS-3	GR-6	46.1 - 41.6	0.0165	594	-	0.0128	18	1.3	33	-	3%	Losing	57%	43%	0%
VS-3	GR-7	41.6 - 30.9	0.0124	3187	-	0.0098	13	1.3	243	-	3%	Losing	15%	14%	7%
VS-4	GR-8	30.9 - 27.2	0.0089	315	-	0.0069	17	1.3	19	-	3%	Neutral	59%	27%	13%
VS-4	GR-9	27.2 - 12.8	0.0075	3672	-	0.0045	19	1.7	195	-	2%	Gaining	60%	33%	7%
VS-4	GR-10	12.8 - 0	0.0057	1510	-	0.0032	34	1.8	44	-	7%	Gaining	54%	44%	2%

- No constraints exist within the approximated floodplain.

Pahsimeroi Headwaters Valley Segment (VS-1)

The Pahsimeroi Headwaters Valley Segment comprises the West Fork Pahsimeroi River (West Fork) and the East Fork Pahsimeroi River (East Fork) drainages (Figure 89). Both the West Fork and East Fork drain the Lost River Range, an uplifted mountainous region that has been sculpted by alpine glaciers. Along the eastern ridgeline, there are several glacial cirques that are still occupied by lakes (tarns) in which the East Fork and West Fork begin their journeys and then coalesce to form the Pahsimeroi River at RM 64.55. Both the West Fork and East Fork drainages are within the larger Upper Pahsimeroi River sub-watershed (HUC 1706020201). The entire drainage is administered by the Salmon-Challis National Forest.

This valley segment is within the sediment supply zone of the upper Pahsimeroi River watershed. The supply zone provides sediment through the weathering and erosion of bedrock and colluvium that is transported downslope to the mainstem Pahsimeroi River through a dendritic (branching) network of coalescing tributaries. These tributaries generally have single-thread, sinuous channels. Channel segments that are unconfined have evidence of beaver activity where the tributary has been impounded and sediment has accumulated to form mountain meadows. Nearly all beavers have been removed from this region, based on interpretation of 2015 aerial photographs. Livestock grazing occurs along tributaries and has altered the riparian vegetation along some channel segments.

The West Fork drainage includes about 8,275 acres, with elevations ranging from about 7950 feet at the confluence of the West Fork and East Fork to more than 12000 feet along the Lost River Range, between Mount Borah and Leatherman Peak. The historically glaciated Lost River Range has several tarns in the

glacial cirques along the eastern slopes. The West Fork begins in Pass Lake at 10600 feet in elevation and has ephemeral flows for about 1 mile until it intercepts several seeps and springs before becoming perennial. About 4 river miles downstream, the West Fork intercepts additional flows from the outlet flows of Merriam Lake at about 9800 feet.

The East Fork drainage includes 11,230 acres, with elevations ranging from about 7950 feet at the confluence of the West Fork and East Fork to more than 12000 feet along the Lost River Range, between Leatherman Peak and Mount Breitenbach. The historically glaciated Lost River Range has several tarns in the glacial cirques along the eastern slopes. The East Fork begins in a glacial cirque and has ephemeral flows into a tarn at 9800 feet in elevation and has perennial flows to the East Fork and West Fork confluence. The East Fork has EPA-approved TMDLs for water temperature and sediment/siltation (IDEQ 2011).

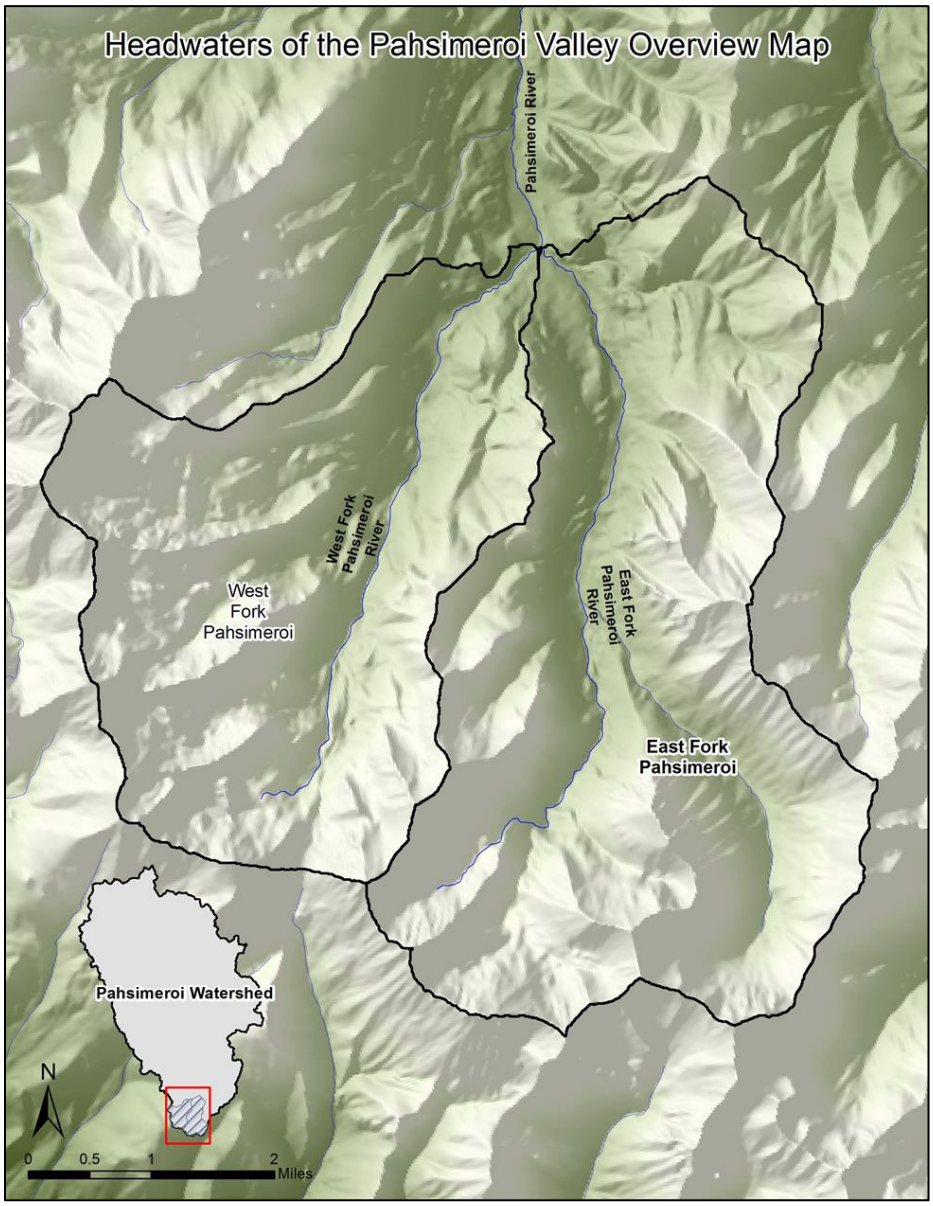


Figure 89. Location of Pahsimeroi Headwaters Valley Segment, comprising the West Fork and the East Fork drainages.

Upper Pahsimeroi Valley Segment (VS-2)

The Upper Pahsimeroi Valley Segment comprises the Upper Pahsimeroi River sub-watershed, excluding the West Fork and East Fork drainages, covering about 57,637 acres (Figure 90). The valley segment is along the Pahsimeroi River from about RM 64.55 to 52.50, and contains Geomorphic Reaches GR-1, GR-2, and GR-3. This valley segment is within the alluvial fan zone, where coarse sediment accumulates across broad alluvial fans and piedmonts before entering the transfer zone. Here, the basin-fill sediments are permeable, and the Pahsimeroi River loses water to the groundwater system.

Groundwater flow from the Lost River Range is an important component to the Pahsimeroi Valley aquifer. Geochemical analysis of underground flow found the Lost River Range to be the largest contributor to the Pahsimeroi Valley aquifer, and that underlying geologic structures influence gaining and losing reaches along the Pahsimeroi River (Whittier 2009). For example, an extension of the Goldburg Fault follows the Pahsimeroi River through this valley segment and could be providing a conduit through permeable, fractured rock, thereby exacerbating the surface water losses to the aquifer.

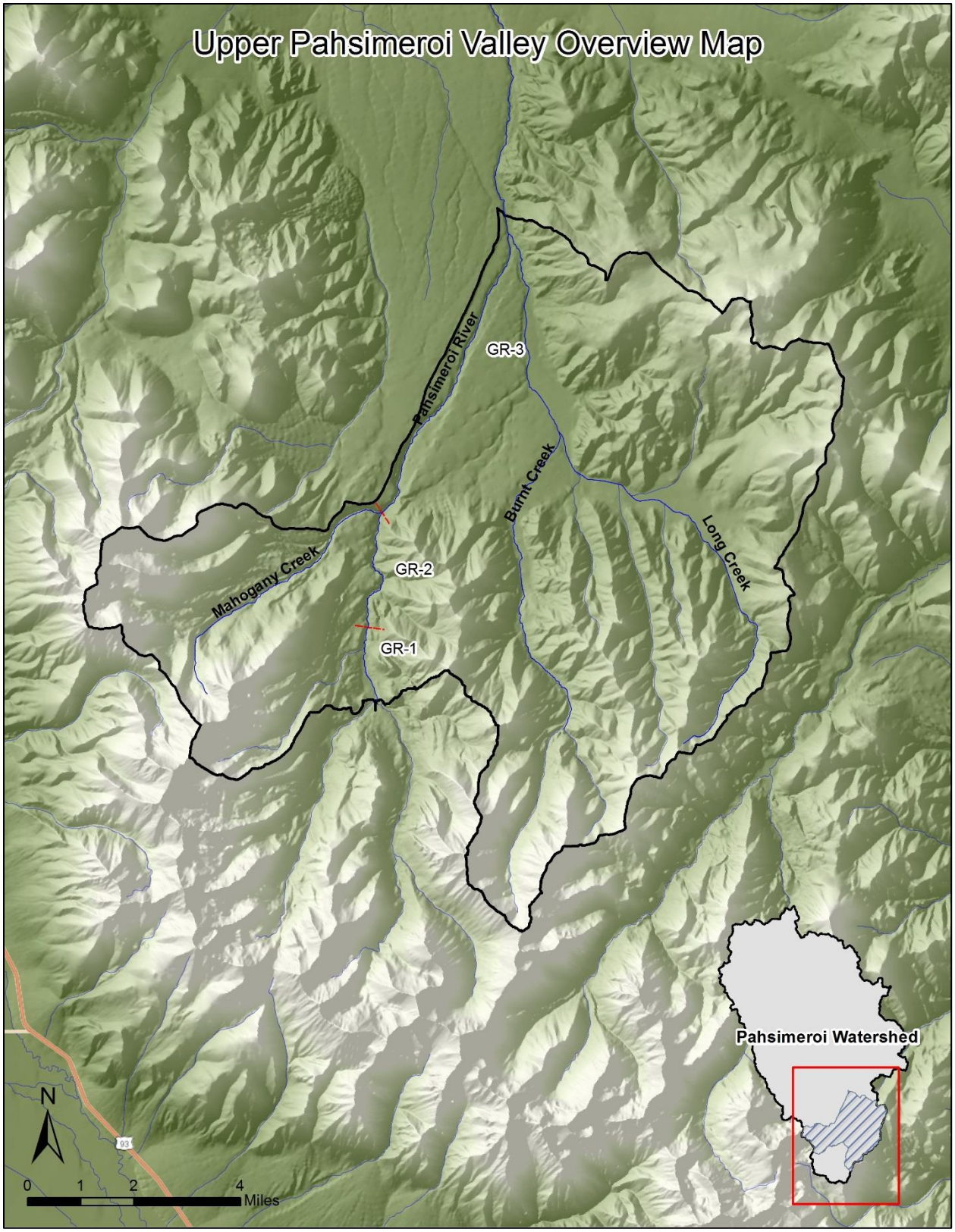


Figure 90. The Upper Pahsimeroi Valley Segment and associated geomorphic reaches (GR-1 through GR-3).

Geomorphic Reach GR-1 (RM 64.5 – 62.6)

Geomorphic Reach GR-1 is located along the Pahsimeroi River between RM 64.5 and RM 62.6 in a moderately confined valley with no valley bottom constraints (Figure 91). Reach characteristics are summarized below in Table 41.

Table 41. Summary of attributes for Geomorphic Reach GR-1.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-1	64.5 - 62.6	0.0185	391	391	0.0145	23	1.3	17	17	0%	-	19%	81%	0%

Forms

- Moderate sinuosity (little to no channel straightening) single-thread channel.
- Primarily pool-riffle morphology.
- Dense riparian vegetation consisting primarily of willow and other shrubs.
- Areas of bank erosion associated with lost riparian vegetation and cattle grazing.

Processes

- Relatively stable banks; minimal channel migration; some widening observed where riparian vegetation is lacking.
- Historical photos reveal periods of impounded water, suggesting beaver activity.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.

Human Impact

- Minimal human impact.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations.
- Fine sediment from roads.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams).
- Channel avulsion associated with instream obstruction (beaver dams, debris flows).
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

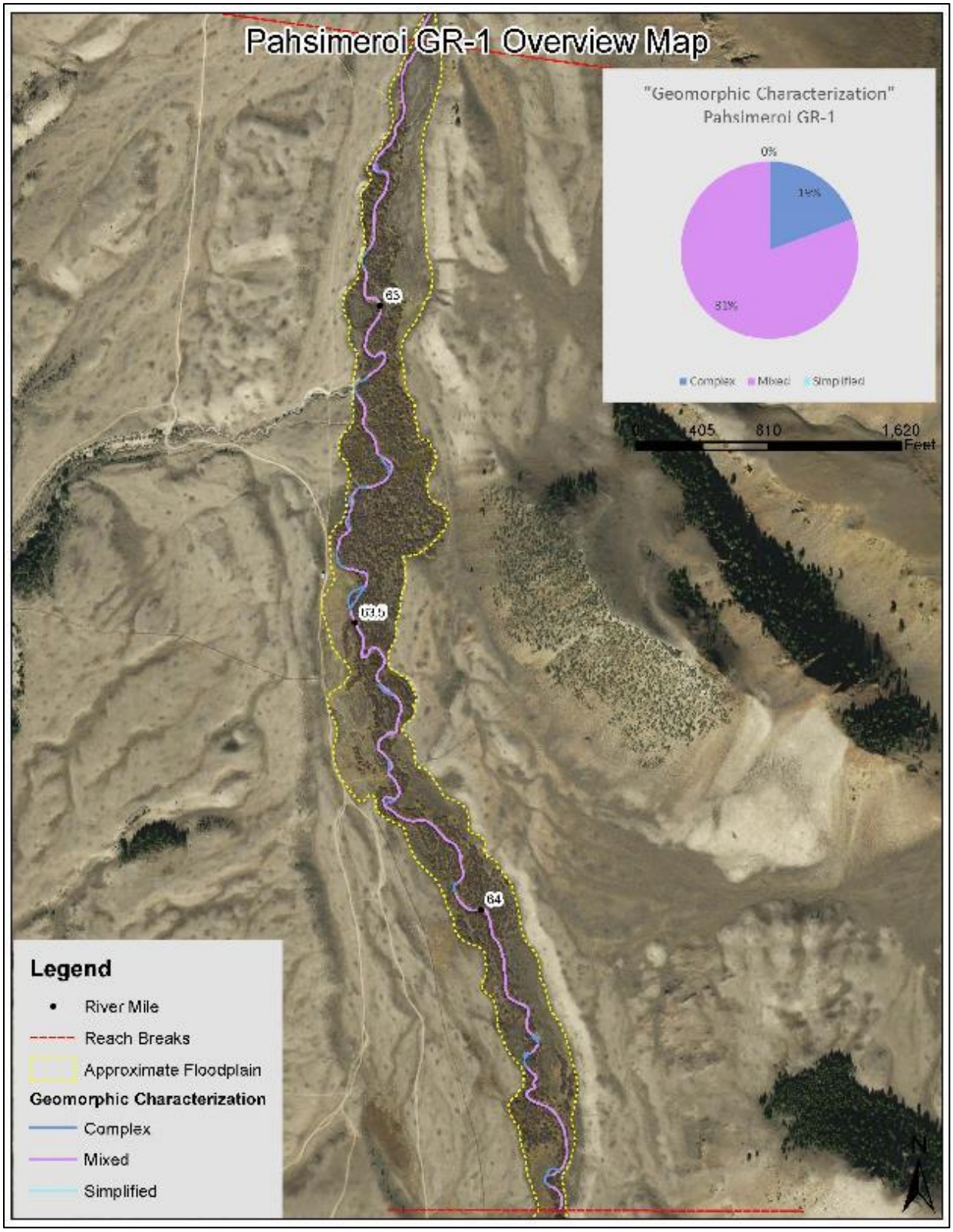


Figure 91. GR-1 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-2 (RM 62.6 – 59.8)

Geomorphic Reach GR-2 is located along the Pahsimeroi River between RM 62.6 and RM 59.8 in an unconfined valley with no valley bottom constraints (Figure 92). Reach characteristics are summarized below in Table 42.

Table 42. Summary of attributes for Geomorphic Reach GR-2.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-2	62.6 - 59.8	0.0194	204	204	0.0169	23	1.1	9	9	0%	-	20%	61%	19%

Forms

- Moderately sinuous (little to no channel straightening) single-thread channel.
- Primarily pool-riffle morphology.
- Narrow band of dense riparian vegetation consisting primarily of willow and other shrubs.
- Channel is largely confined by bedrock and/or terraces.

Processes

- Relatively stable banks; minimal channel migration.
- Three bedrock channel segments provide vertical grade control.
- Channel migration is limited but appears to be more downstream than lateral where observed.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.

Human Impacts

- Minimal human impact.
- Fine sediment from roads.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams).
- Bed armoring within confined sections.
- Minimal incision anticipated due to bedrock grade controls.

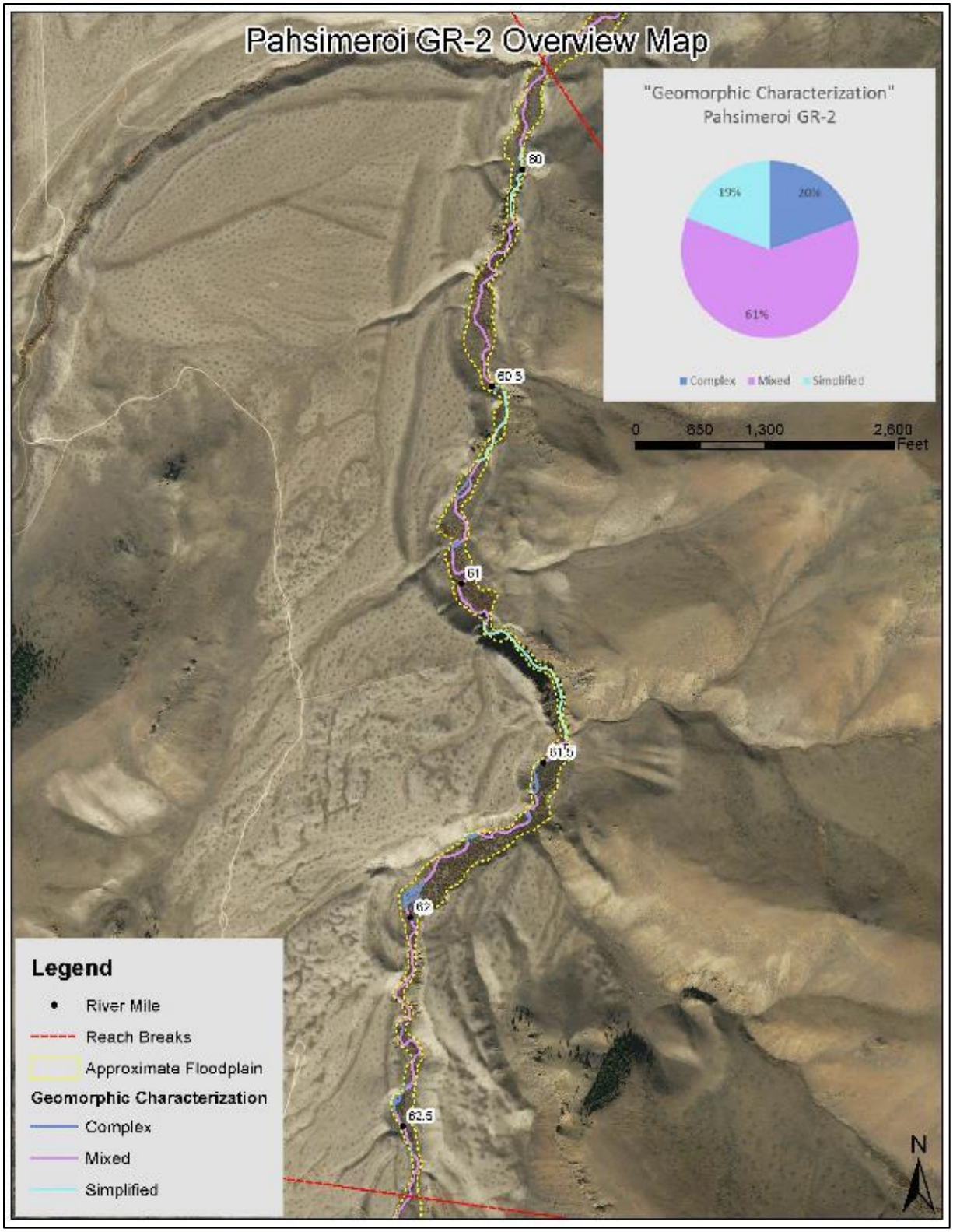


Figure 92. GR-2 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-3 (59.8 – 52.5)

Geomorphic Reach GR-3 is located along the Pahsimeroi River between RM 59.8 and RM 52.5 in an unconfined valley with minimal valley bottom constraints (Figure 93). Reach characteristics are summarized below in Table 43.

Table 43. Summary of attributes for Geomorphic Reach GR-3.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-3	59.8 - 52.5	0.0168	290	290	0.0152	28	1.1	10	10	1%	Losing	13%	87%	0%

Forms

- Low to moderate sinuosity (little to no channel straightening) single-thread channel.
- Primarily plane-bed morphology with limited pool-riffle associated with instream structure.
- Narrow band of dense riparian vegetation consisting primarily of willow and other shrubs.
- Channel and floodplain naturally confined by relic terraces.

Processes

- Relatively stable banks.
- Little to no channel migration (only in unconfined sections of the upper reach).
- Sediment transport dominated.

Human Impacts

- Minor human impacts from single road crossing with culvert, dispersed campsites, and limited cattle grazing.
- Fine sediment from roads.

Response Potential

- Forced pool-riffle formation associated with instream structure.
- Episodic channel avulsion associated with debris and/or ice jams.
- Surface water flows over porous alluvium and is lost to the groundwater system (losing reach).

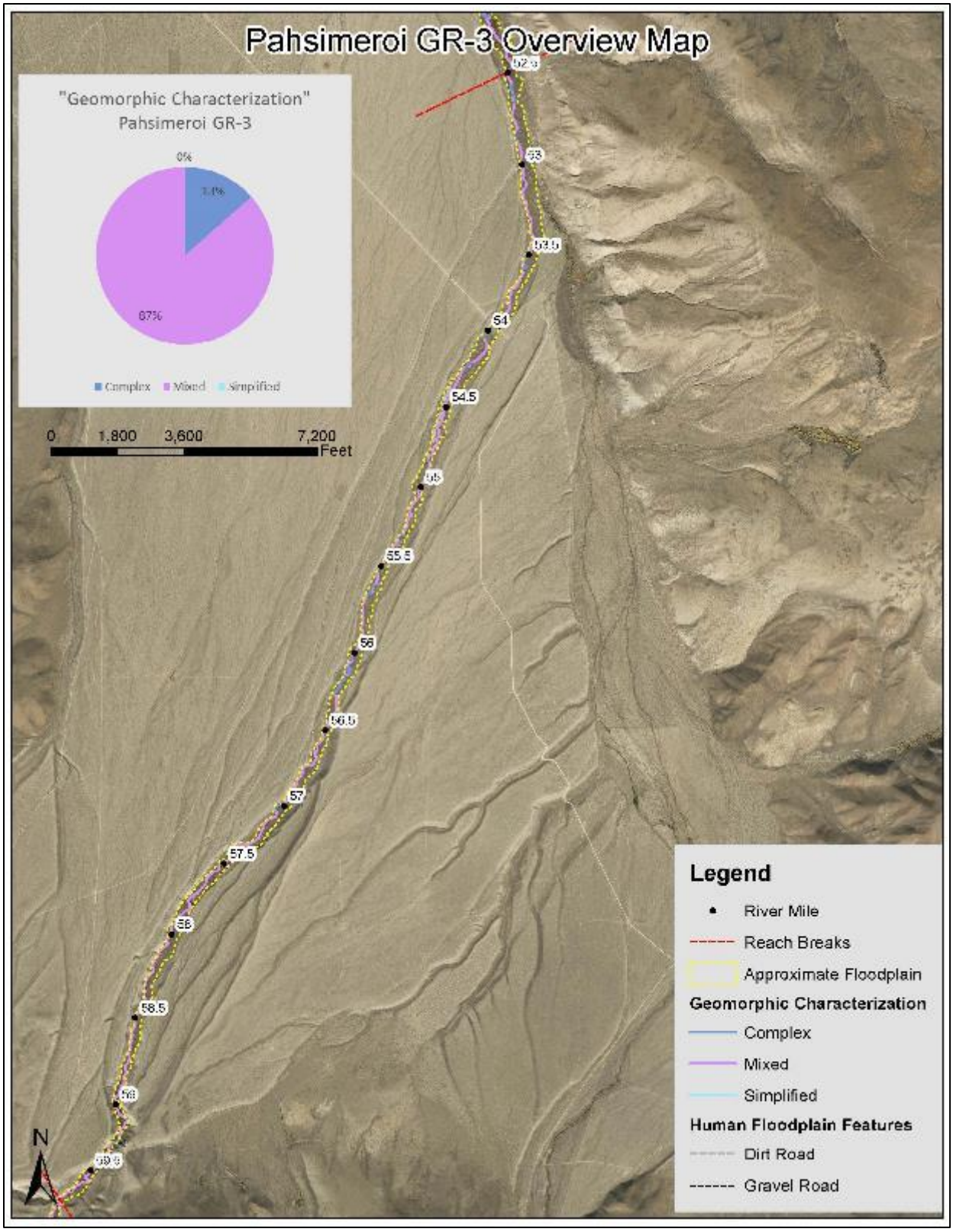


Figure 93. GR-3 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Middle Pahsimeroi Valley Segment

The Middle Pahsimeroi Valley Segment comprises the Middle Pahsimeroi River sub-watershed (HUC 10 – 1706020202) covering about 219,335 acres (Figure 94). The valley segment is along the Pahsimeroi River from about RM 52.5 to RM 30.9 and contains Geomorphic Reaches GR-4, GR-5, GR-6, and GR-7. This valley segment includes the alluvial fan zone and transfer zone, where coarse sediment accumulates across broad alluvial fans and then is exchanged with the floodplain through channel-floodplain interactions. In the alluvial fan zone, the basin-fill sediments are permeable and the Pahsimeroi River loses water to the groundwater system through GR-6. The Pahsimeroi River is dewatered from about RM 41 to RM 34 in GR-7.

Flows daylight near RM 34 along a poorly defined channel and the Pahsimeroi River continues to gain flows through seeps and springs where a northwest bend along the Goldburg Fault creates a subsurface barrier and forces groundwater to surface (Whittier 2009).

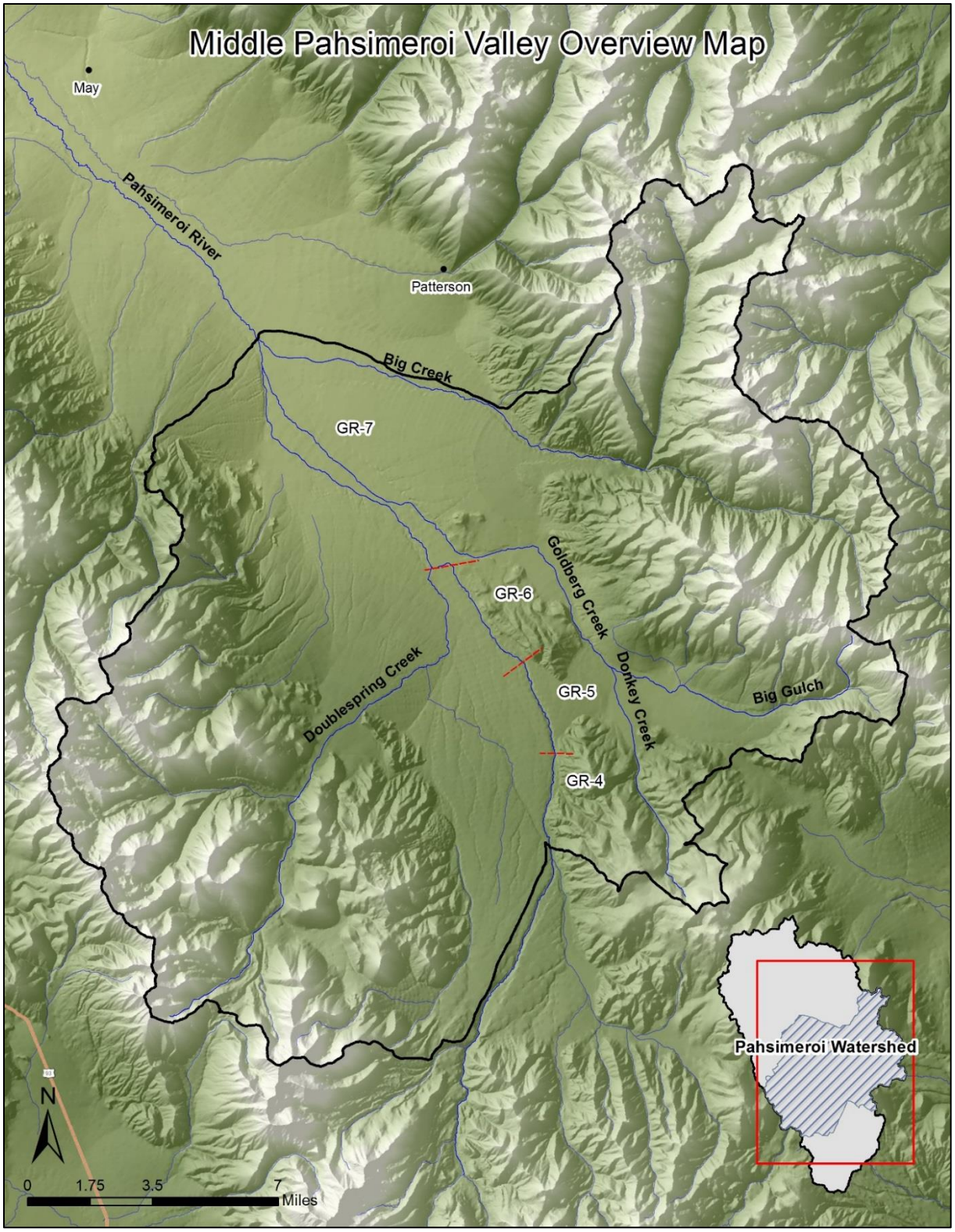


Figure 94. Middle Pahsimeroi Valley Segment and associated geomorphic reaches (GR-4 through GR-7).

Geomorphic Reach GR-4 (52.5 – 49.5)

Geomorphic Reach GR-4 is located along the Pahsimeroi River between RM 52.5 and RM 49.5 in an unconfined valley, with no valley bottom constraints (Figure 95). Reach characteristics are summarized below in Table 44.

Table 44. Summary of attributes for Geomorphic Reach GR-4

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-4	52.5 - 49.5	0.0182	389	389	0.0155	23	1.2	17	17	1%	Losing	30%	70%	0%

Forms

- Low to moderate sinuosity (little to no channel straightening); single-thread channel.
- Primarily pool-riffle morphology with large plane bed sections where sinuosity is low.
- Visible point bars in several locations.
- Narrow band of dense riparian vegetation consisting of willow and other shrubs, with some small patches of cottonwood.
- Several abandoned avulsion channels present within the inset floodplain bound by terraces.

Processes

- Relatively stable banks where vegetation is present.
- Low to moderate occurrence of channel migration in unconfined areas.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.

Human Impacts

- Significant human impact primarily from three irrigation diversions.
- Channel commonly dewaters due to irrigation withdrawals and natural losses to groundwater.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations.
- Fine sediment from roads.

Response Potential

- Returning diverted flows to the Pahsimeroi River could seasonally connect the upper Pahsimeroi River to the lower Pahsimeroi River when discharge is greater than 50 cfs (Meinzer 1924).
- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams).
- Channel avulsion associated with instream obstruction (beaver dams, debris and ice jams).
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

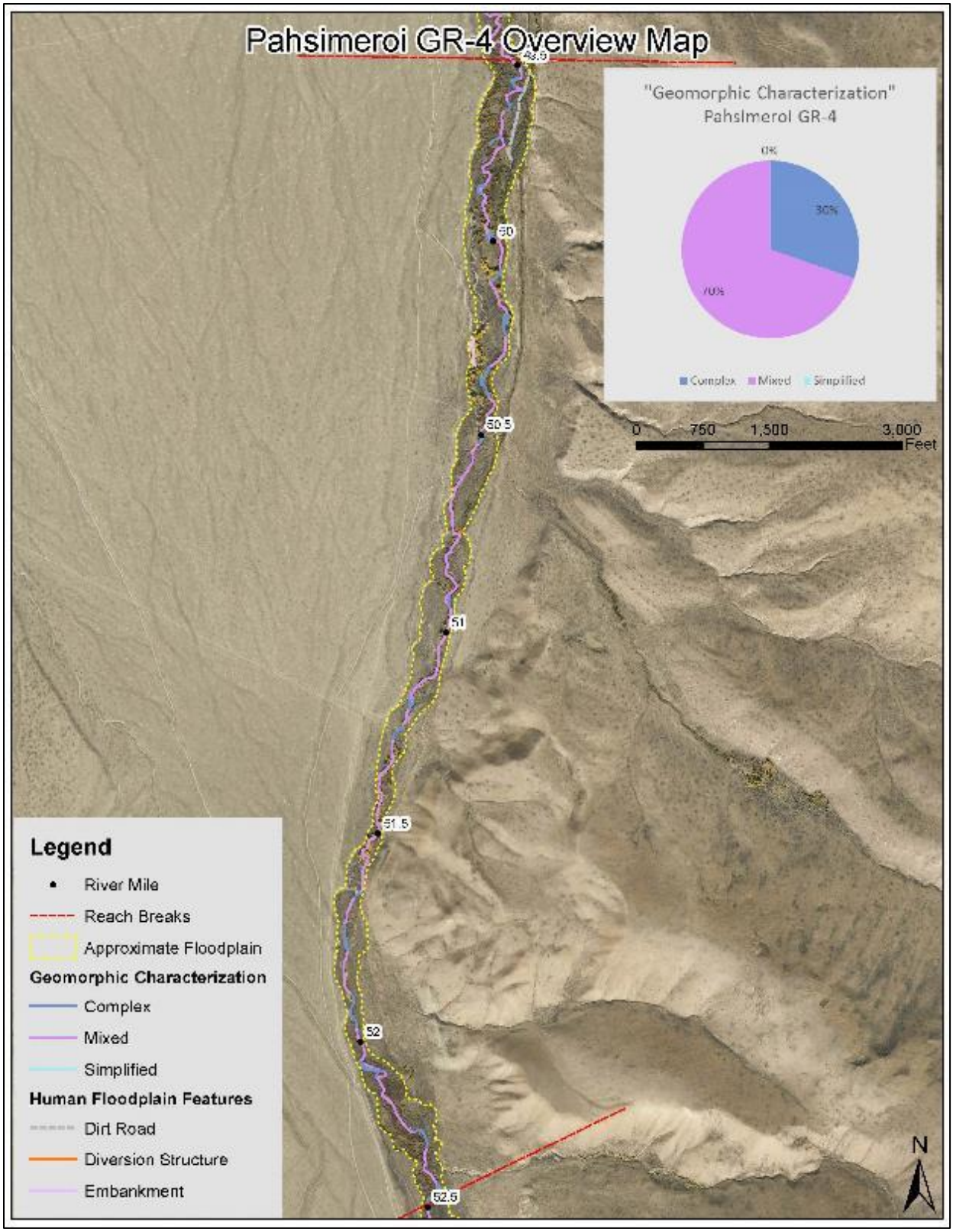


Figure 95. GR-4 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-5 (49.5 – 46.1)

Geomorphic Reach GR-5 is located along the Pahsimeroi River between RM 49.5 and RM 46.1 in an unconfined valley with no significant valley bottom constraints (Figure 96). Reach characteristics are summarized below in Table 45.

Table 45. Summary of attributes for Geomorphic Reach GR-5.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-5	49.5 - 46.1	0.0188	208	208	0.0164	18	1.1	11	11	1%	Losing	41%	56%	2%

Forms

- Low to moderate sinuosity (little to no channel straightening); single-thread channel.
- Primarily pool-riffle morphology.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs, with small patches of cottonwood; channel dewatering limits riparian growth.
- Areas of bank erosion associated with areas lacking riparian vegetation.

Processes

- Channel migration and some widening observed where riparian vegetation is lacking.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.

Human Impacts

- Channel seasonally dewaters or has significantly reduced surface water flows due to upstream irrigation diversions and natural infiltration through porous alluvium.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations.
- Fine sediment from roads.

Response Potential

- Returning diverted flows to the Pahsimeroi River could provide seasonal surface water flows through this reach.
- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction.
- Channel avulsion associated with instream obstruction (debris and ice jams).
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

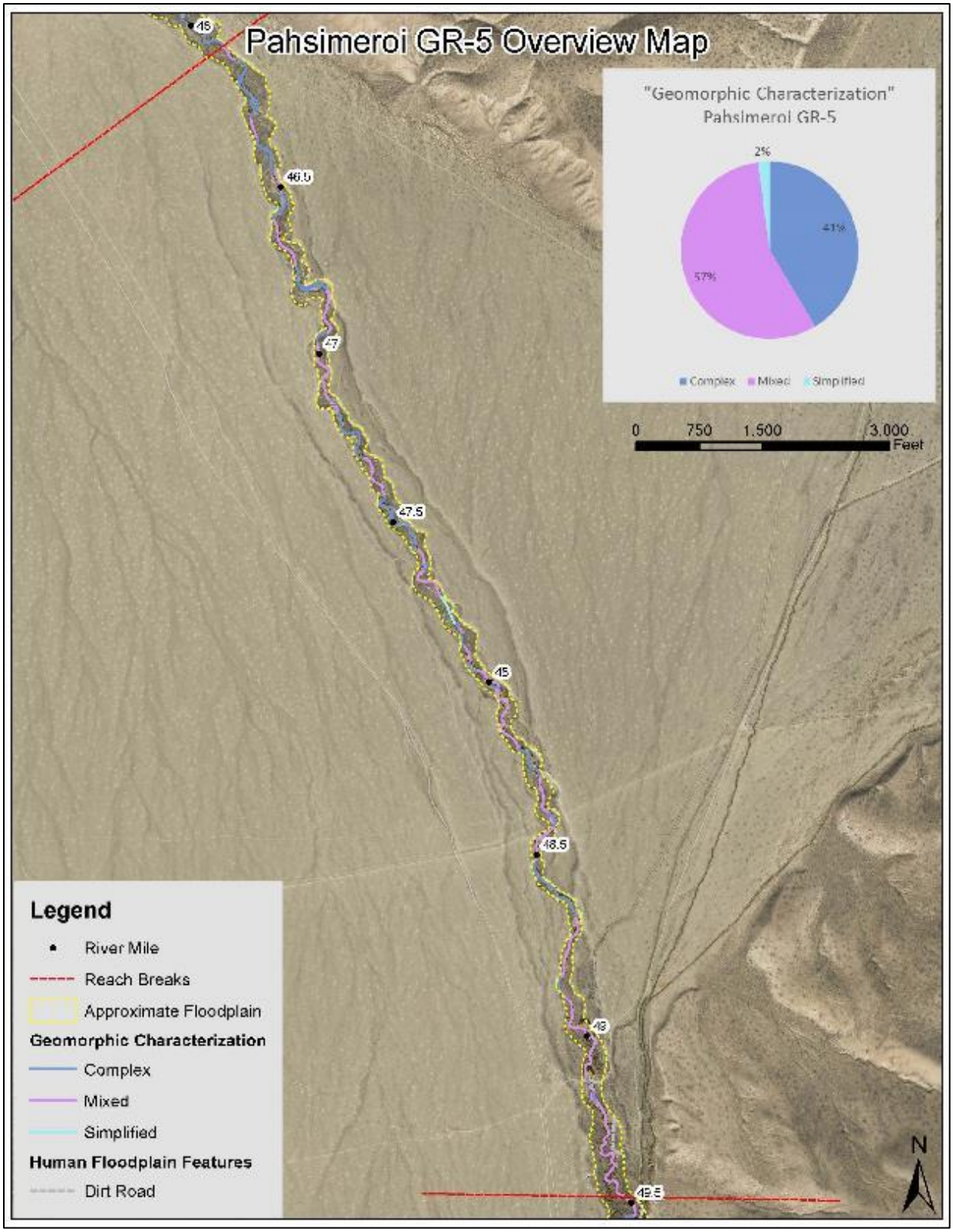


Figure 96. GR-5 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-6 (RM 46.1 – 41.6)

Geomorphic Reach GR-6 is located along the Pahsimeroi River between RM 46.1 and RM 41.6 in an unconfined valley with minimal valley bottom constraints (Figure 97Figure 97. GR-6 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

). Reach characteristics are summarized below in Table 46.

Table 46. Summary of attributes for Geomorphic Reach GR-6.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-6	46.1 - 41.6	0.0165	594	594	0.0128	18	1.3	33	33	3%	Losing	57%	43%	0%

Forms

- Moderately sinuous (little to no channel straightening); primarily single-thread channel.
- Primarily pool-riffle morphology.
- Discontinuous riparian vegetation consisting of primarily willow and other shrubs, with cottonwood patches. Seasonally dry channel limits riparian growth.
- Areas of bank erosion associated with areas lacking riparian vegetation.

Processes

- Channel migration and some widening observed where riparian vegetation is lacking.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.

Human Impacts

- Channel seasonally dewaters or has significantly reduced surface water flows due to irrigation diversions and natural infiltration through porous alluvium.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations.
- Fine sediment from roads.

Response Potential

- Returning diverted flows to the Pahsimeroi River could provide seasonal surface water flows through this reach.
- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction.
- Channel avulsion associated with instream obstruction (aggradation of coarse sediment, debris, and ice jams).
- Channel widening and simplification where lacking riparian vegetation.

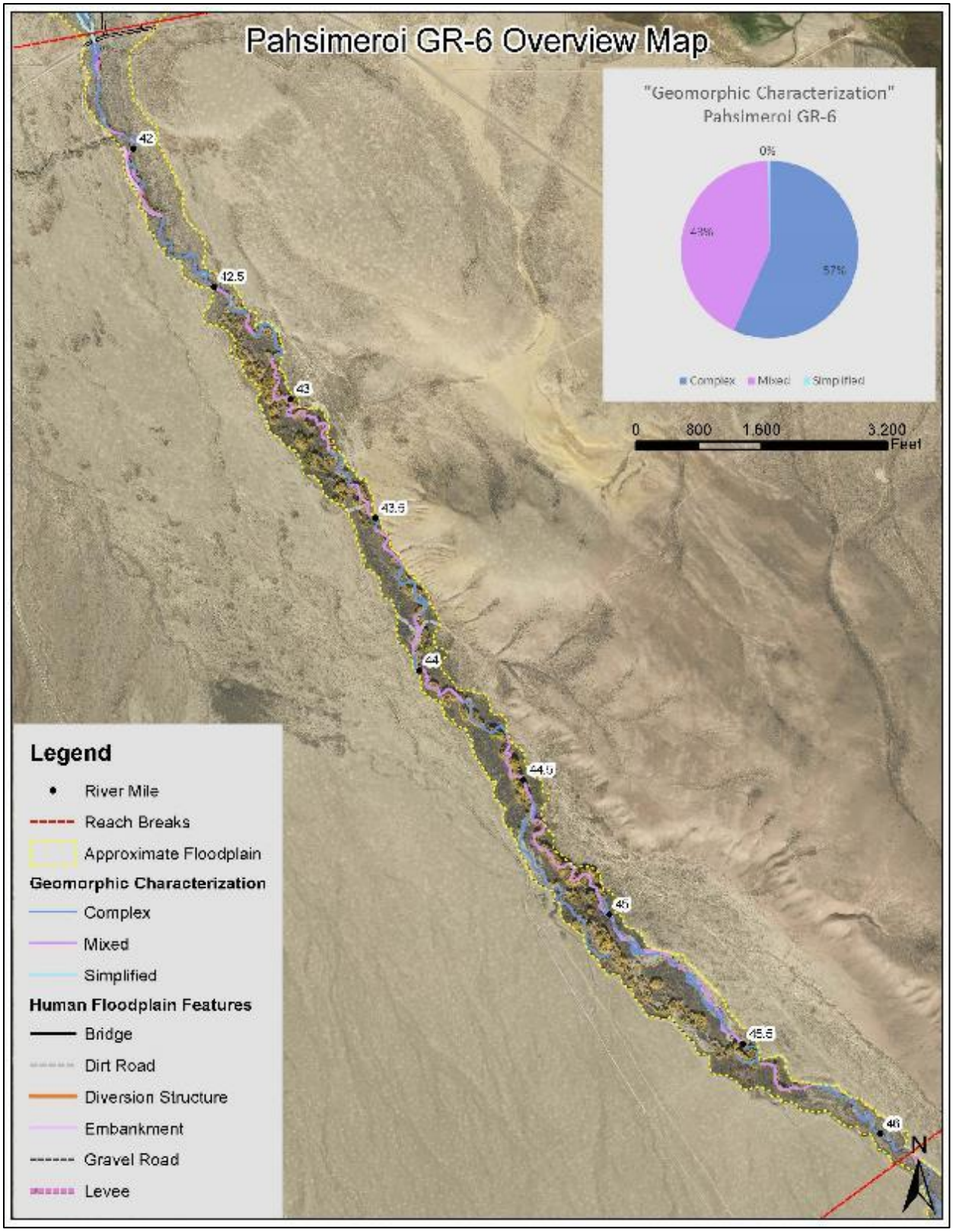


Figure 97. GR-6 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-7 (RM 41.6 – 30.9)

Geomorphic Reach GR-7 is located along the Pahsimeroi River between RM 41.6 and RM 30.9 in a naturally unconfined valley with significant valley bottom constraints associated with roads and irrigation infrastructure (Figure 98). Reach characteristics are summarized below in Table 47.

Table 47. Summary of attributes for Geomorphic Reach GR-7.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-3	GR-7	41.6 - 30.9	0.0124	3187	-	0.0098	13	1.3	243	-	3%	Losing	15%	14%	7%

Forms

- Moderate sinuosity (little to no channel straightening); split flow (north and south channel).
- Dewatered from about RM 40.95 to RM 33.75 with no definitive channel morphology.
- Primarily pool-riffle morphology where the channel is well-defined.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs, with cottonwood patches.
- Areas of bank erosion associated with lost riparian vegetation and cattle grazing.

Processes

- The north channel loses flow while the south channel gains flow from groundwater.
- Springs discharge groundwater to the south channel from the Doublesprings alluvial fan, and the Pahsimeroi River starts flowing intermittently.
- Sediment regime is dominated by deposition with episodic transport during large floods.

Human Impacts

- The Pahsimeroi River dewaters between RM 40.95 and RM 33.75 due to infiltration through porous alluvium and multiple irrigation diversions.
- Cattle grazing impacts downstream of the dewatered section include bank erosion and lost riparian vegetation in several locations.
- Fine sediment from roads.
- Ditching, impoundments, irrigation diversions, airstrip, dirt roads, cattle grazing, and bridges.

Response Potential

- Returning diverted flows could provide seasonal surface water through this reach.
- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction.
- Channel avulsion associated with instream obstruction (coarse sediment deposition, debris, and ice jams).
- Channel widening and simplification associated with lost bank vegetation.

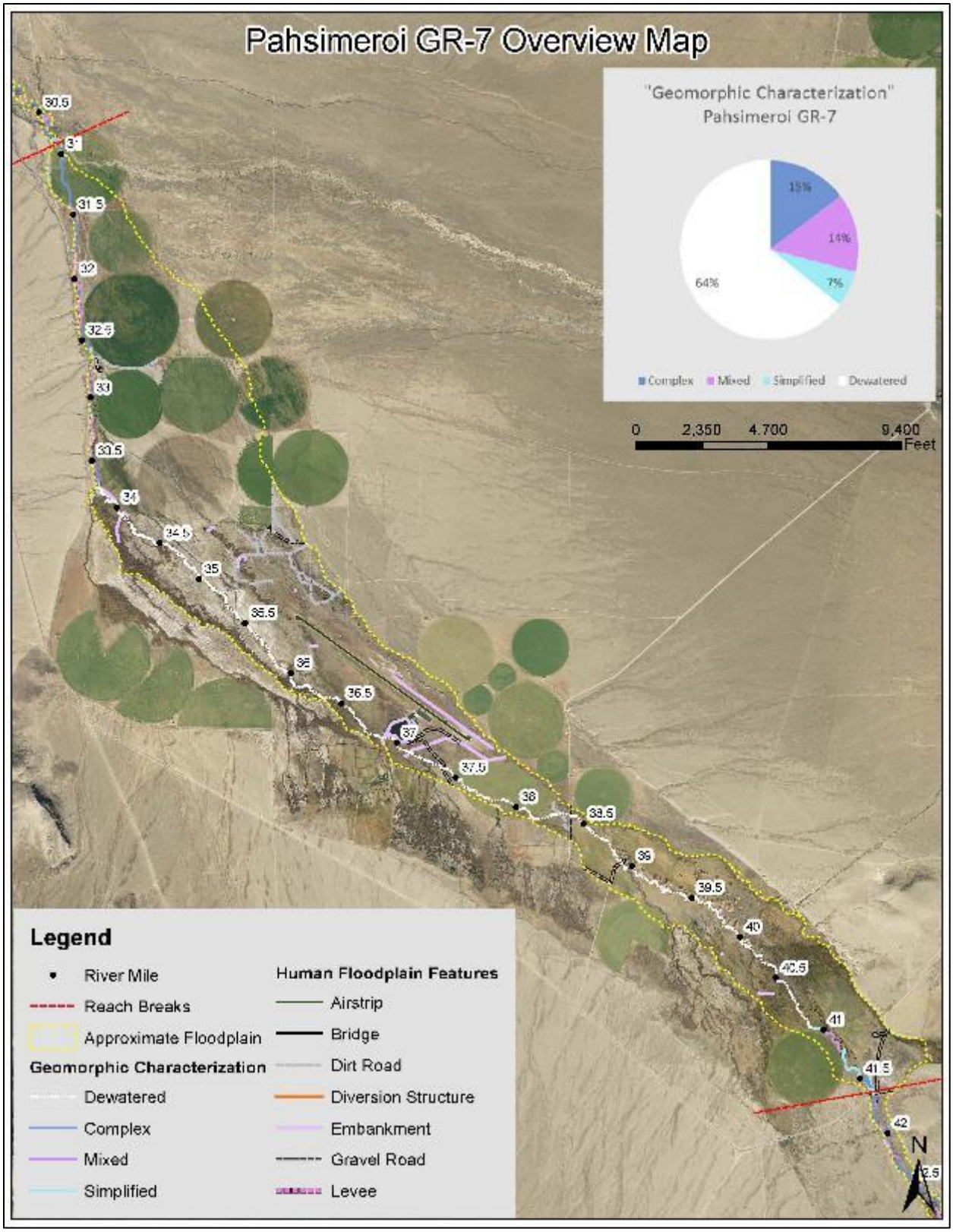


Figure 98. GR-7 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Lower Pahsimeroi Valley Segment

The Lower Pahsimeroi Valley Segment comprises the Lower Pahsimeroi River sub-watershed (HUC 10 – 1706020203) covering about 234,993 acres (Figure 99). The valley segment is along the Pahsimeroi River from about RM 30.9 to RM 0 and contains Geomorphic Reaches GR-8, GR-9, and GR-10. This valley segment is within the transfer zone and deposition zones, where sediment is exchanged with the floodplain through channel-floodplain interactions and deposited in low-gradient areas.

Along GR-8, the Pahsimeroi River loses water to the groundwater system and can intermittently run dry due to highly porous surficial geology, irrigation diversions, groundwater recharge, or a combination of all three. The Pahsimeroi River gains flows from groundwater through GR-9 and GR-10 as the bedrock shallows near the confluence with the Salmon River. These two lower geomorphic reaches are highly groundwater-influenced and maintain perennial flows (Whittier 2009).

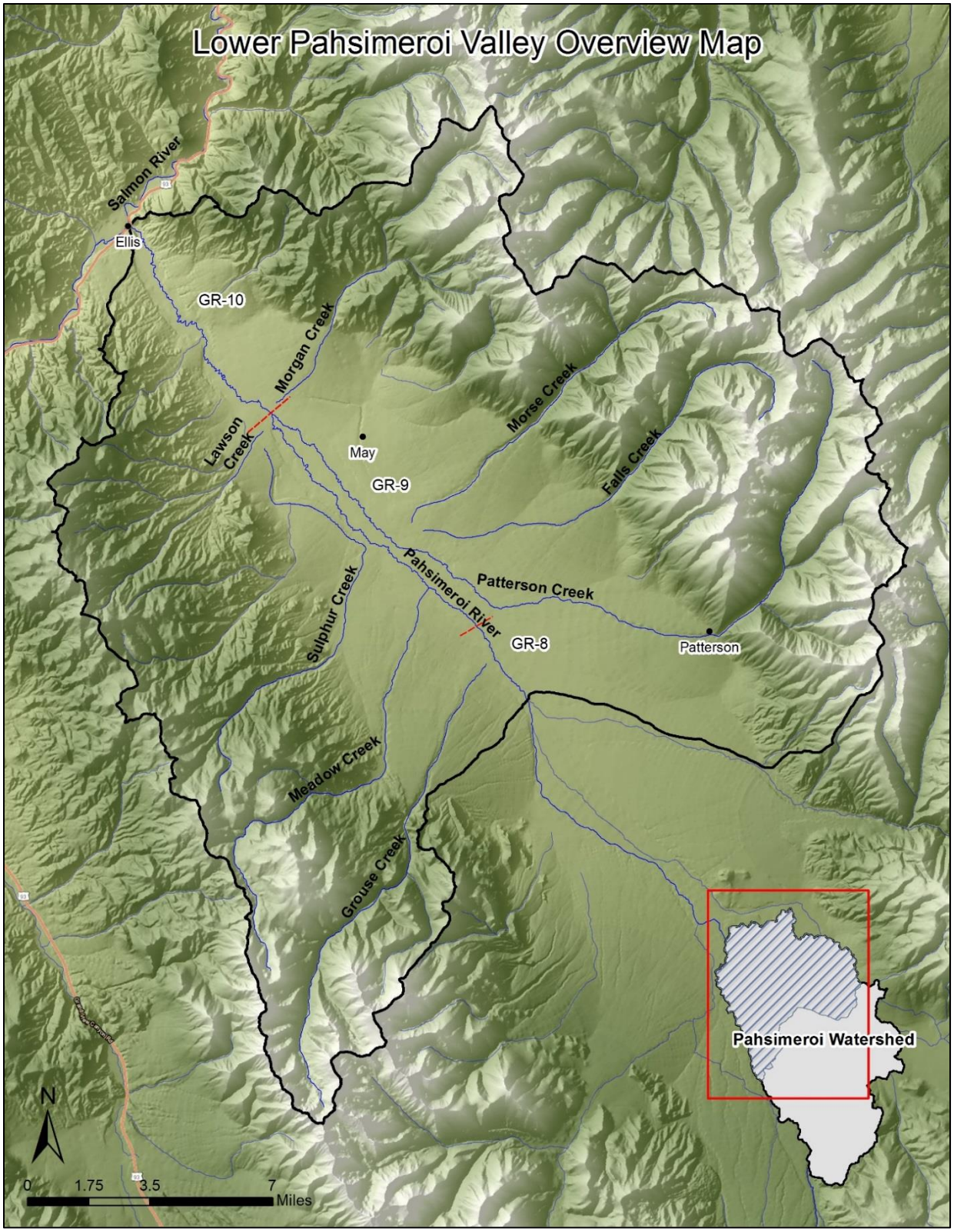


Figure 99. Lower Pahsimeroi Valley Segment and associated geomorphic reaches (GR-8 through GR-10).

Geomorphic Reach GR-8 (RM 30.9 – 27.2)

Geomorphic Reach GR-8 is located along the Pahsimeroi River between RM 30.9 and RM 27.2 in a naturally unconfined valley with some valley bottom constraints associated with human features (Figure 100). Reach characteristics are summarized below in Table 48.

Table 48. Summary of attributes for Geomorphic Reach GR-8.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-4	GR-8	30.9 - 27.2	0.0089	315	-	0.0069	17	1.3	19	-	3%	Neutral	59%	27%	13%

Forms

- Moderately sinuous (minor channel straightening) single-thread channel.
- Large portions of the reach are seasonally dry due to irrigation diversions and natural losses to groundwater.
- Primarily pool-riffle morphology.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs, with some cottonwood; poor riparian growth where the channel is seasonally dry.
- Areas of bank erosion associated with lost riparian vegetation and cattle grazing.

Processes

- Poor bank stability and areas of channel migration/widening where riparian vegetation is lacking.
- Mixed sediment-transport regime, including primarily deposition with periods of transport during large floods.

Human Impacts

- Irrigation diversions contribute to surface water losses and a seasonally dry channel.
- Fine sediment from roads.
- Irrigation diversions, cattle grazing, dirt roads, fords and bridges.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstructions, primarily in response to large floods when surface water has sufficient capacity to mobilize sediment.
- Channel avulsion associated with in-stream obstruction (coarse sediment deposition, debris, and ice jams).
- Channel widening and simplification associated with lost bank vegetation.

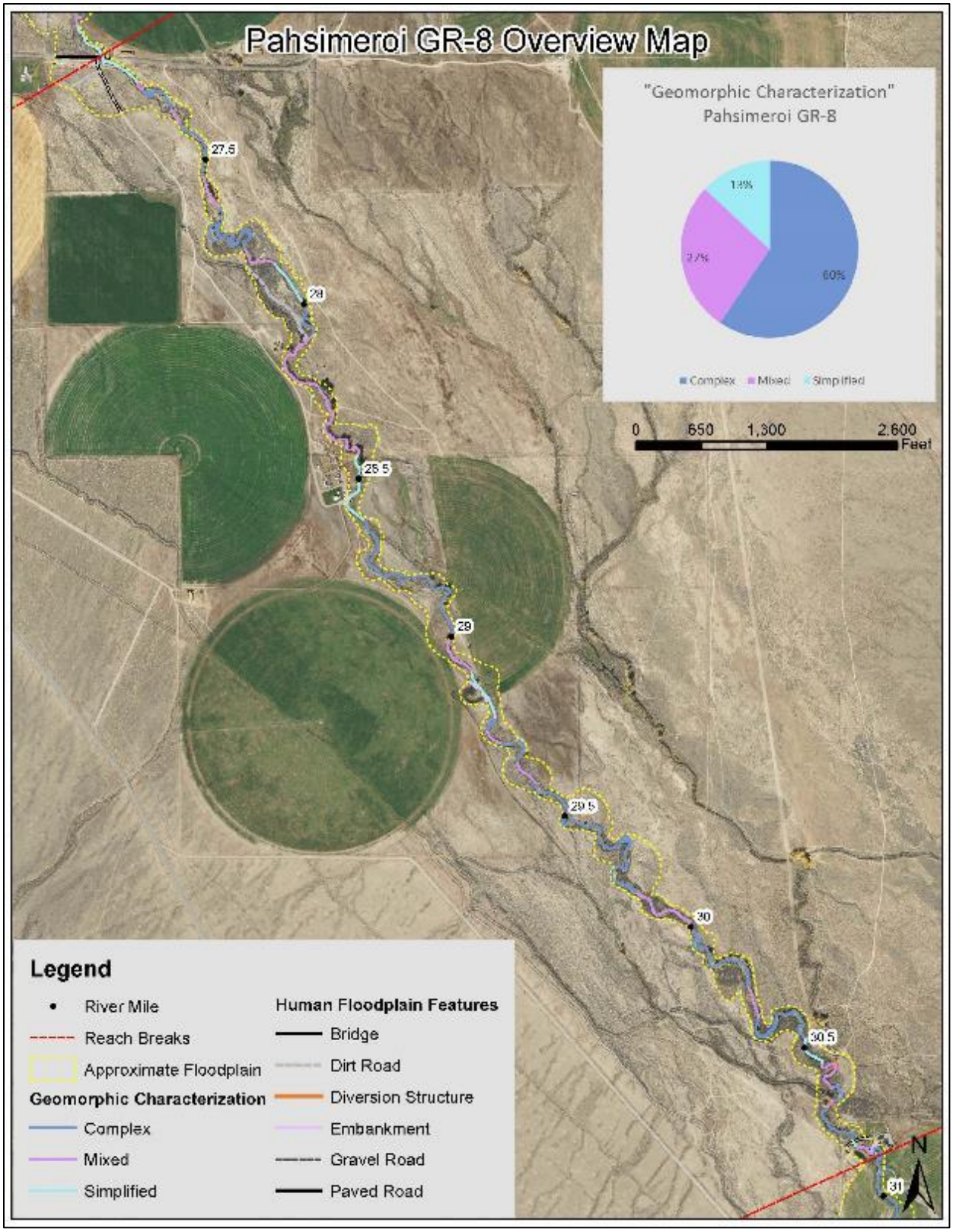


Figure 100. GR-8 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-9 (RM 27.2 – 12.8)

Geomorphic Reach GR-9 is located along the Pahsimeroi River between RM 27.2 and RM 12.8 in a naturally unconfined valley with some valley bottom constraints associated with human features, such as bridges and roads (Figure 101). Reach characteristics are summarized below in Table 49.

Table 49. Summary of attributes for Geomorphic Reach GR-9.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-4	GR-9	27.2 - 12.8	0.0075	3672	-	0.0045	19	1.7	195	-	2%	Gaining	60%	33%	7%

Forms

- Moderate to high sinuosity, single-thread channel with many spring-fed tributary channels.
- Primarily pool-riffle morphology.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs; significant areas of riparian vegetation clearing, especially in the floodplain.
- Areas of bank erosion associated with lost riparian vegetation.

Processes

- Relatively stable banks; minimal channel migration; some widening observed where riparian vegetation is lacking.
- Pools and riffles forced by flow interactions with woody material and riparian vegetation.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport during large floods.

Human Impacts

- Cattle grazing impacts include bank erosion and lost riparian vegetation in several locations.
- Fine sediment from roads, floodplain erosion, and bank erosion.
- Irrigation diversions, ditching, cattle grazing, channel straightening, dirt roads, fords, and bridges.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstructions.
- Channel avulsion associated with instream obstruction (sediment deposition especially in the upper reach, beaver dams, and debris).
- Potential for channel incision where confined and/or straightened.
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

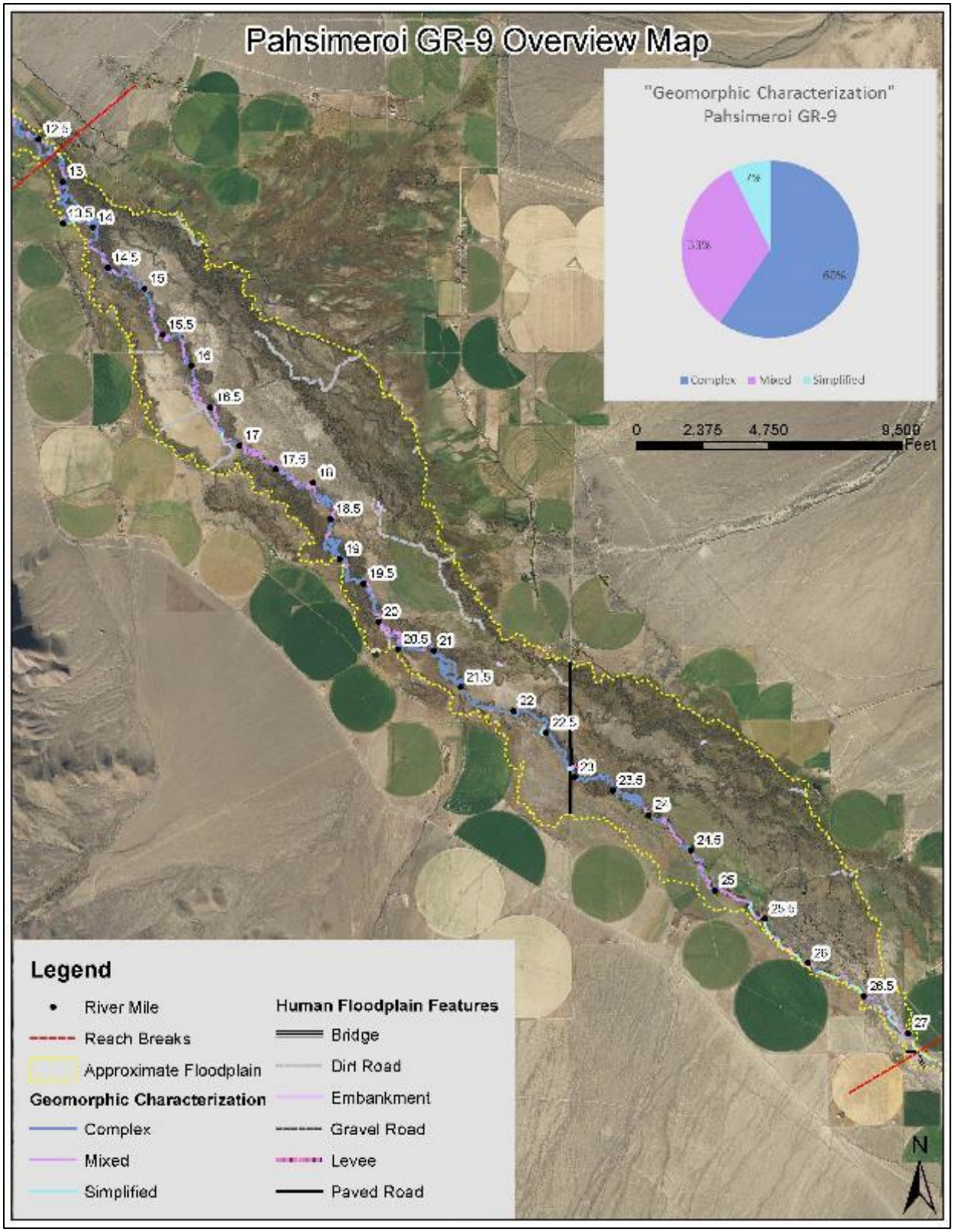


Figure 101. GR-9 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-10 (RM 12.8 – 0)

Geomorphic Reach GR-10 is located along the Pahsimeroi River between RM 12.8 and RM 0.0 in a naturally unconfined valley with some valley bottom constraints associated with human features, such as bridges and roads (Figure 102). Reach characteristics are summarized below in Table 50.

Table 50. Summary of attributes for Geomorphic Reach GR-10.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-4	GR-10	12.8 - 0	0.0057	1510	-	0.0032	34	1.8	44	-	7%	Gaining	54%	44%	2%

Forms

- Moderate to high sinuosity, single-thread channel with numerous spring-fed side channels and oxbows.
- Primarily pool-riffle morphology.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs; significant areas of riparian vegetation clearing, especially in the floodplain.
- Areas of bank erosion associated with lost riparian vegetation.

Processes

- Relatively stable banks; minimal channel migration; some widening observed where riparian vegetation is lacking.
- Pools and riffles forced by flow interactions with woody material and riparian vegetation.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport during large floods.

Human Impacts

- Cattle grazing impacts include bank erosion and lost riparian vegetation in several locations.
- Three roads that bisect the floodplain may inhibit dynamic channel-floodplain interactions.
- Flow diversions to two fish hatcheries.
- Fine sediment from roads, floodplain erosion, and bank erosion.
- Irrigation diversions, ditching, cattle grazing, channel straightening, dirt roads, fords, and bridges.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstructions.
- Channel avulsion associated with instream obstruction (beaver dams and debris).
- Spring-fed tributary channel formation or augmentation.
- Potential for channel incision where confined and/or straightened.
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

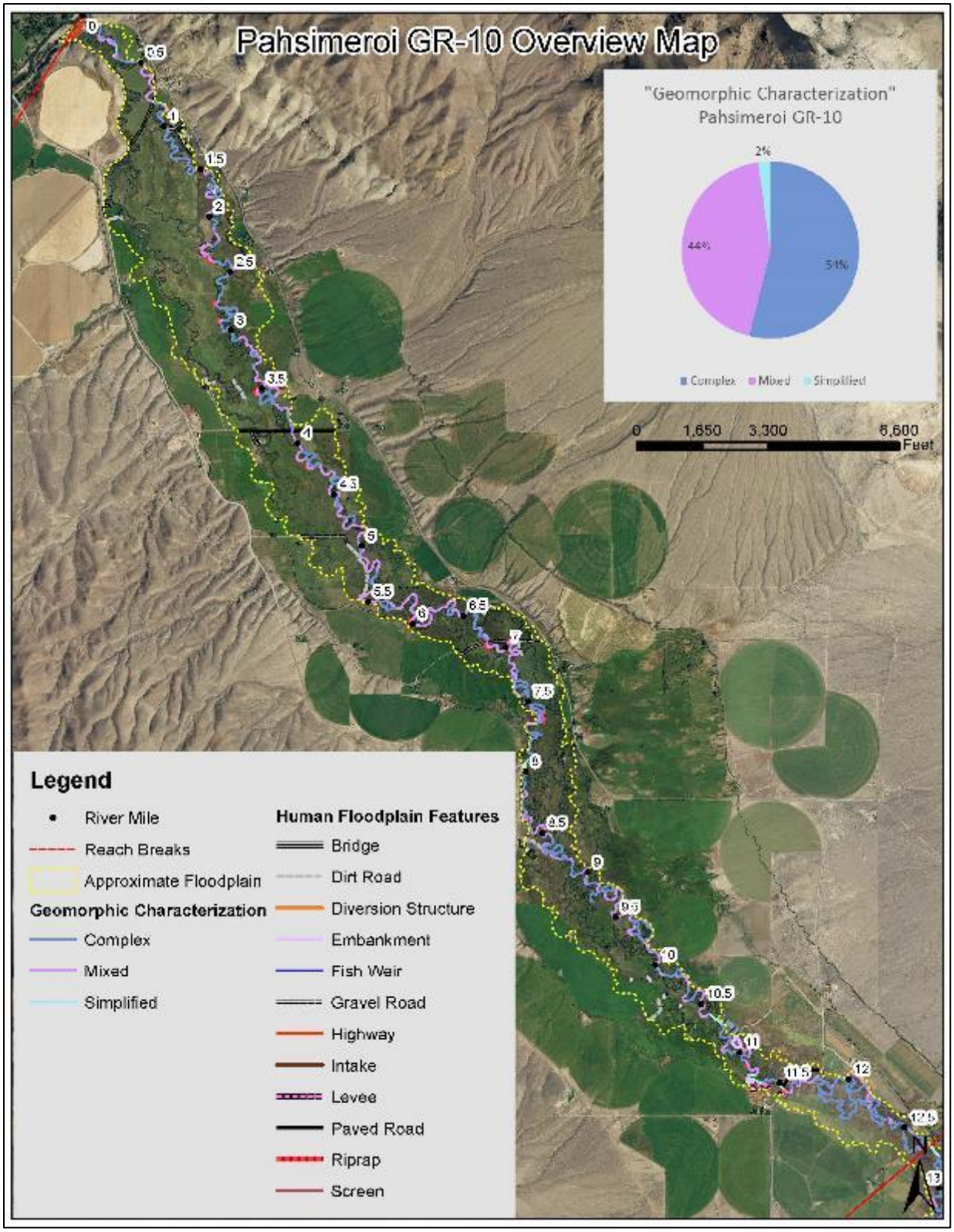


Figure 102. GR-10 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Temperature and Climate Change Assessment

Chinook salmon

Under current conditions, water temperatures in the Pahsimeroi River are rarely to never below minimum or above maximum values for Chinook salmon (Figure 103). Only in brief periods during the spring (smolts) and summer (parr) are water temperatures below optimum conditions for Chinook salmon. Alternatively, spring and summer temperature tend to exceed optimum values for extended periods. Elevated temperatures potentially increase stress on adults during the staging (holding) and spawning periods, decrease survival during incubation/emergence, and increase food requirements for spring smolts and summer parr. Under an assumed 3° C water temperature increase scenario, conditions worsen for all five life stages evaluated (Figure 104). For both adults (holding and spawning) and juveniles (emergence, summer parr, spring smolts), water temperatures are above optimum for a majority of the time. Moreover, acute (lethal) temperatures may be expected during the summer for both holding and spawning adults.

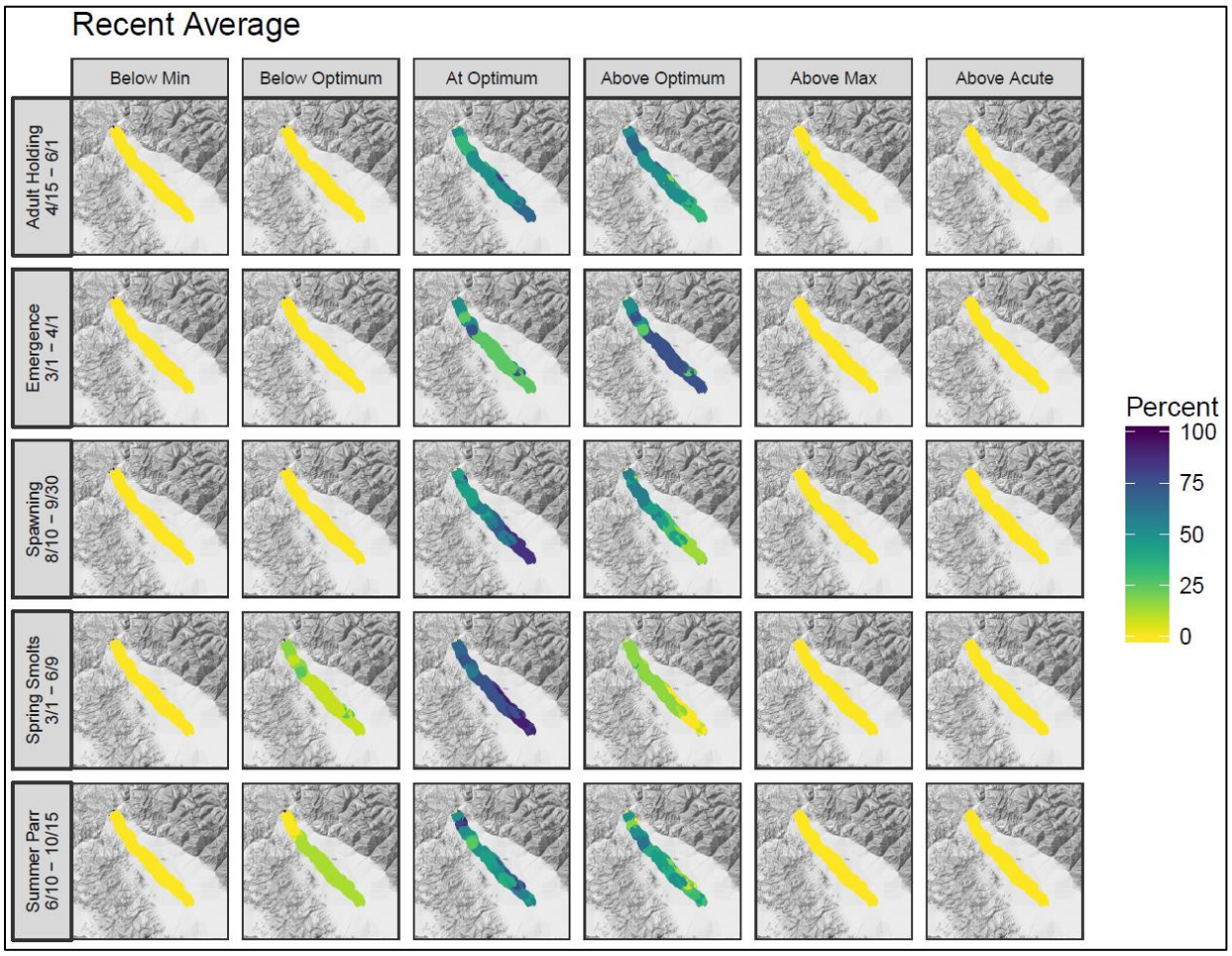


Figure 103. The percentage of time that Pahsimeroi River watershed water temperatures were below, within, or above a given temperature threshold (Carter 2005) for five Chinook salmon life stages. Water temperatures were averaged across years for which complete modeled temperature data were available (2011 and 2013).

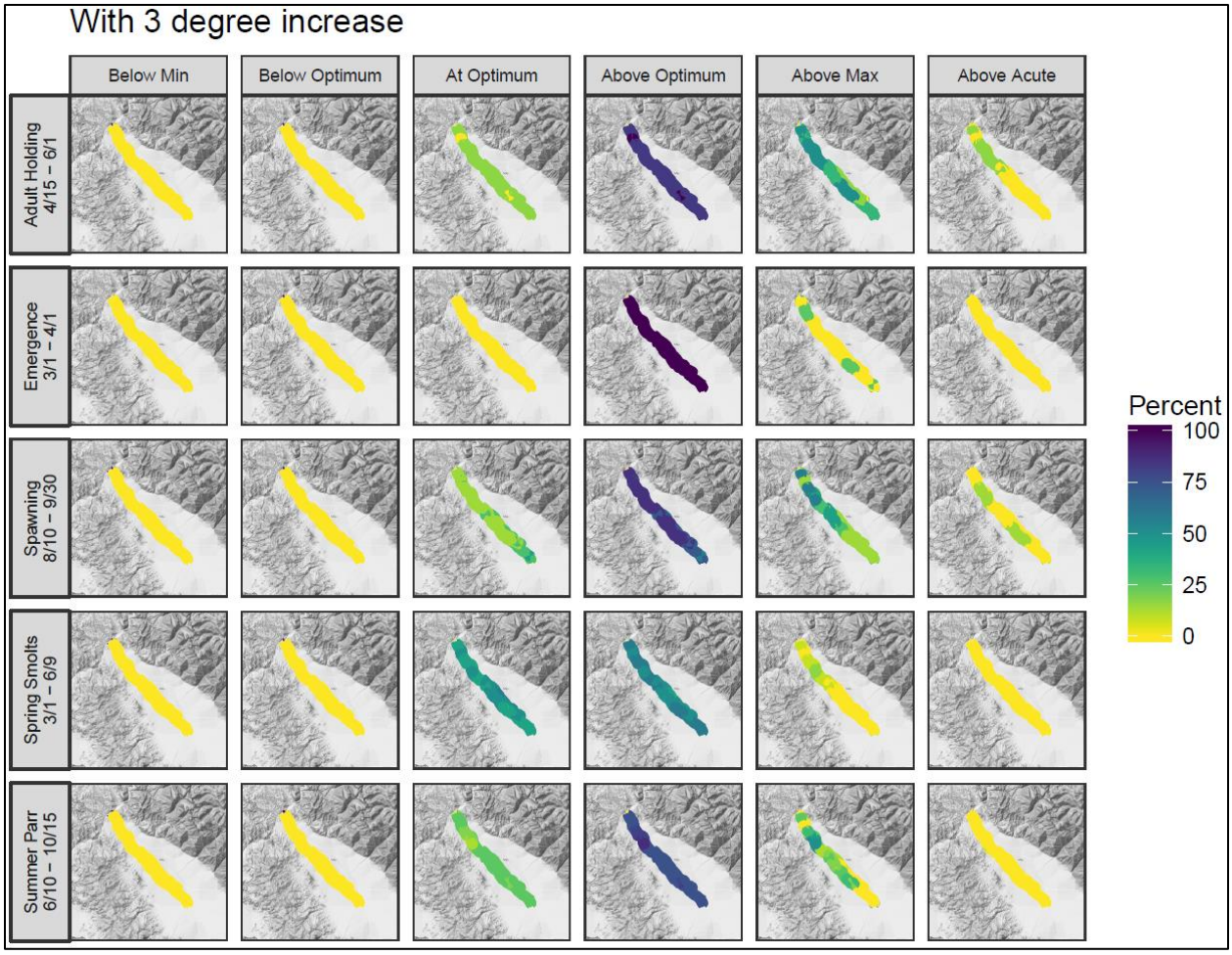


Figure 104. The percentage of time that Pahsimeroi River watershed water temperatures may potentially be below, within, or above a given temperature threshold (Carter 2005) for five Chinook salmon life-stages assuming a potential climate change scenario.

Steelhead

Under current conditions, water temperatures in the Pahsimeroi River are rarely below optimum values for steelhead (Figure 105) except during brief periods in the late spring and early summer. Water temperatures are largely within optimal values during spring and early summer during periods of spawning, spring smolt emigration, and early-summer parr rearing. Alternatively, summer temperatures exceed optimum and acute values during late incubation and emergence for steelhead; however, it is unclear to what degree late incubation and emergence timings might overlap with summer high temperatures in the Pahsimeroi River. Under an assumed 3° C water temperature increase scenario, conditions worsen for all steelhead life stages evaluated (Figure 106). Modeled water temperatures became above optimum, maximum, or acute temperature thresholds for steelhead for the entire duration of the spawning and incubation/emigration life stages. Further, water temperatures tend to move above optimum, and in some cases maximum, temperature thresholds for the summer parr rearing and spring smolt emigration steelhead life stages during portions of the season.

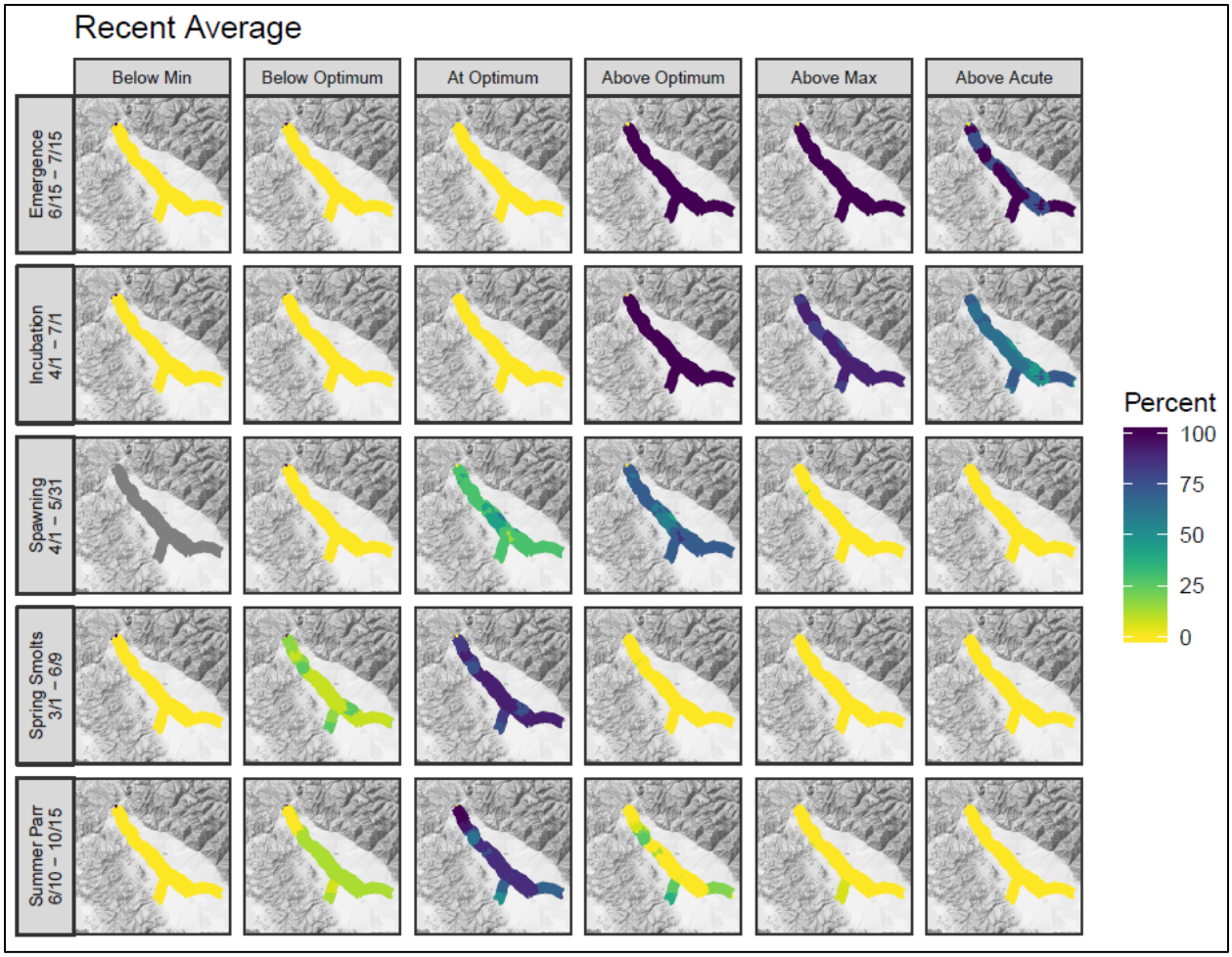


Figure 105. The percentage of time that Pahsimeroi River watershed water temperatures in 2013 were below, within, or above a given temperature threshold (Carter 2005) for five steelhead life stages. Water temperatures were averaged across years for which complete modeled temperature data were available (2011 and 2013).

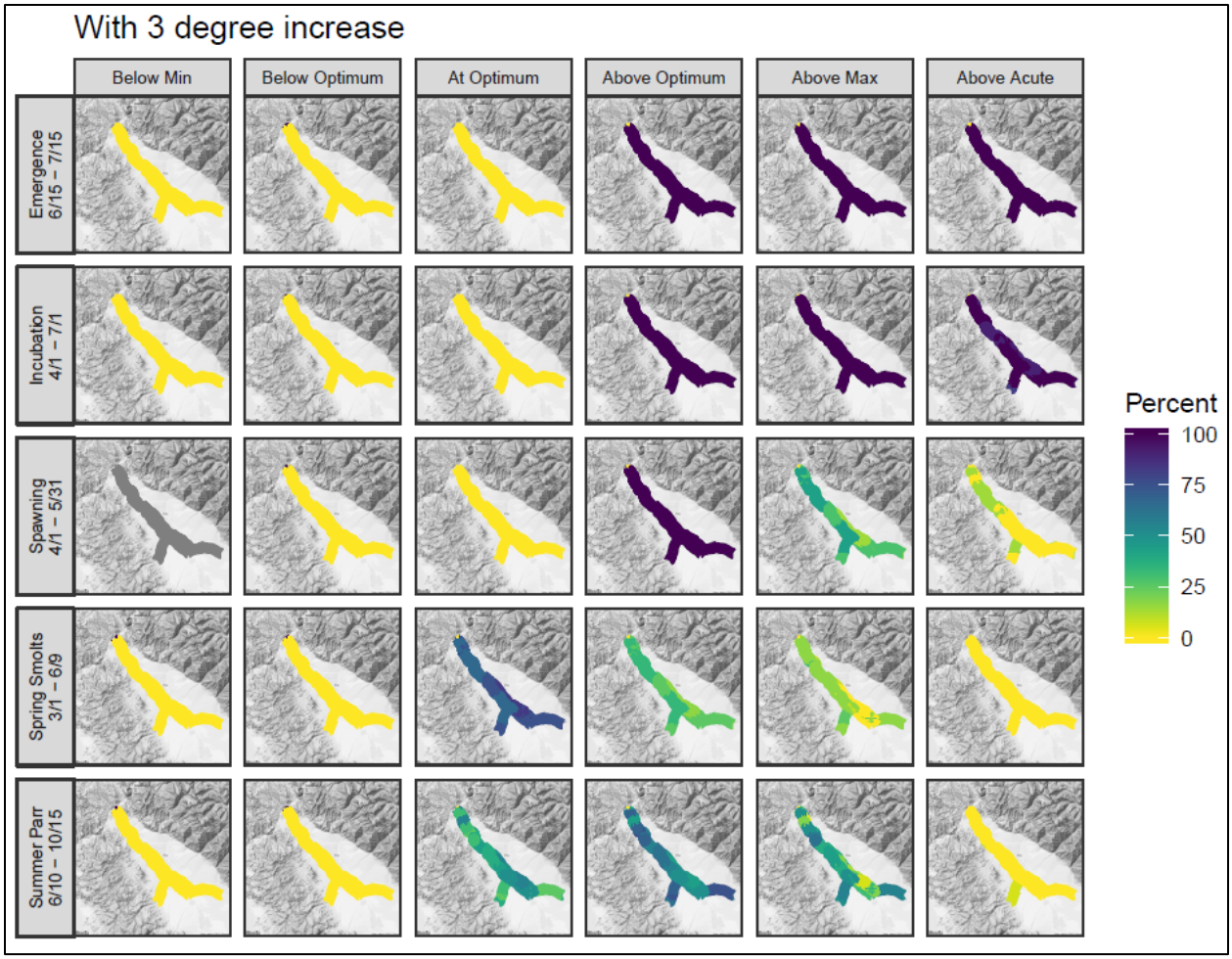


Figure 106. The percentage of time that Pahsimeroi River watershed water temperatures may potentially be below, within, or above a given temperature threshold (Carter 2005) for five steelhead life-stages, assuming a potential climate change scenario.

Results and Discussion

In the Pahsimeroi River Biological Assessment, the lack of quantity and quality juvenile rearing habitat was identified as the highest-priority limiting PBF. Assuming recent mean adult Chinook salmon escapement, habitat capacity does not appear to limit production of summer parr (Table 32). However, currently available juvenile rearing habitat (summer and winter) likely is not sufficient to support recent high escapements or escapements necessary for ESA delisting of Chinook salmon (Table 33). For steelhead in the Pahsimeroi River, winter (presmolt) juvenile rearing habitat may be sufficient to support ESA delisting (Table 34), but available summer (parr) rearing habitat appears to be limiting if ESA delisting is desired (Table 35). Redd capacity (i.e., available spawning habitat) does not appear to be limiting for Chinook salmon or steelhead in the Lemhi River.

Limiting Physical and Biological Features

The lack of quality summer (parr) and overwinter (presmolt) rearing habitat downstream of spawning habitat were identified as high-priority PBFs in the Pahsimeroi River. In recent years, only 12 percent of

the total Chinook salmon juvenile production from the Pahsimeroi River have emigrated at the spring smolt (age 1) life stage; the remaining 88 percent have emigrated prior to the spring as fry, parr, or presmolts, suggesting limited rearing habitat. Estimates of currently available summer and winter rearing capacity (via QRF models) suggest that the Pahsimeroi River provides only roughly 50 percent of the juvenile parr or presmolt production required for recent high escapements (Table 32) and is far short of juvenile habitat required for ESA delisting (Table 33). Both summer and winter rearing habitat appear to be insufficient or unsuitable to support a large portion of juvenile production in the Pahsimeroi River. The lack of rearing capacity requires increased juvenile emigration during the critical periods and leads to increased survival risk in mainstem corridor habitats.

The lack of quality summer (parr) rearing habitat downstream of current spawning habitat was also identified as a PBF for steelhead in the Pahsimeroi River. The Pahsimeroi River was the only watershed of the three evaluated in this assessment identified as having PBFs limiting production of steelhead. Estimated available summer rearing habitat for steelhead in the upper Salmon River is approximately 50 percent of that required to support recent high escapements (Table 34) and is short of habitat required to support ESA delisting criteria (Table 35). Estimated available winter (presmolt) rearing habitat in the Upper Salmon River is below required habitat for recent high escapements but appears to be sufficient to support ESA delisting (NOAA 2017).

- Summer (parr) and winter (presmolt) juvenile rearing capacity were each identified as high-priority PBF limiting Chinook salmon production in the Pahsimeroi River.
- Summer (parr) juvenile rearing capacity was identified as a medium-priority PBF limiting steelhead production in the Pahsimeroi River.

Priority Areas

Priority areas within the Pahsimeroi River watershed include the mainstem Pahsimeroi River and (Patterson) Big Springs Creek.

- **First priority: Pahsimeroi River from the mouth to Hooper Lane.** Hooper Lane is currently the upstreammost extent of Chinook salmon spawning and rearing, except for Big Springs Creek.
- **Second priority: (Patterson) Big Springs Creek.** The portion of the creek within the Pahsimeroi valley bottom.

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Chapter 3 – Upper Salmon River Watershed (Above Redfish Lake Creek)

Location and Watershed Description

The Upper Salmon River watershed is located in the Northern Rocky Mountains System physiographic region that comprises extensive parallel mountain ranges, intermontane valleys, and plateaus (Figure 107). Elevations in the watershed range from a low of about 6190 to a high of 10750 feet. It is also in the High Glacial Drift-Filled Valleys Ecoregion (16G), characterized by terraces, outwash plains, moraines, wetlands, and hills that are much less rugged and less forested than Ecoregion 16k. Originally, sedges and rushes were common on wet soils, bunchgrasses and mountain big sagebrush occurred on drier soils, and lodgepole pine and ponderosa pine grew on valley floors. Winters are cold and snowy. Ecoregion 16g receives large amounts of spring runoff from mountain snowpack. It is summer pasture for large numbers of livestock; cropland and growing residential and recreational developments also occur. Flood irrigation and grazing have raised sediment and phosphorus levels in streams (McGrath et al. 2002).

The Upper Salmon River watershed is defined as the Salmon River and its headwaters upstream from the confluence of Redfish Lake Creek. The watershed includes two hydrologic unit code (HUC) 10th field basins: Pole Creek – Salmon River (HUC 10 – 1706020102) and Alturas Lake Creek (HUC 1706020103). The watershed covers more than 305 square miles in east-central Idaho and is within Blaine and Custer Counties, Idaho. More than 90 percent of the land is owned by the Federal government and administered by the USFS. Federal lands are primarily in the higher elevations, whereas private lands are typically located in lower elevations along the valley bottoms.

The Upper Salmon River is predominantly an alluvial stream that originates high in the Sawtooth Range at about 9800 feet. The river flows about 6 miles through a U-shaped valley eroded by an alpine glacier with steep valley walls. It then flows for another 32 miles across a broad floodplain that has developed within the glacial outwash plain to a canyon section, where it flows about another half-mile to its confluence with Redfish Lake Creek.

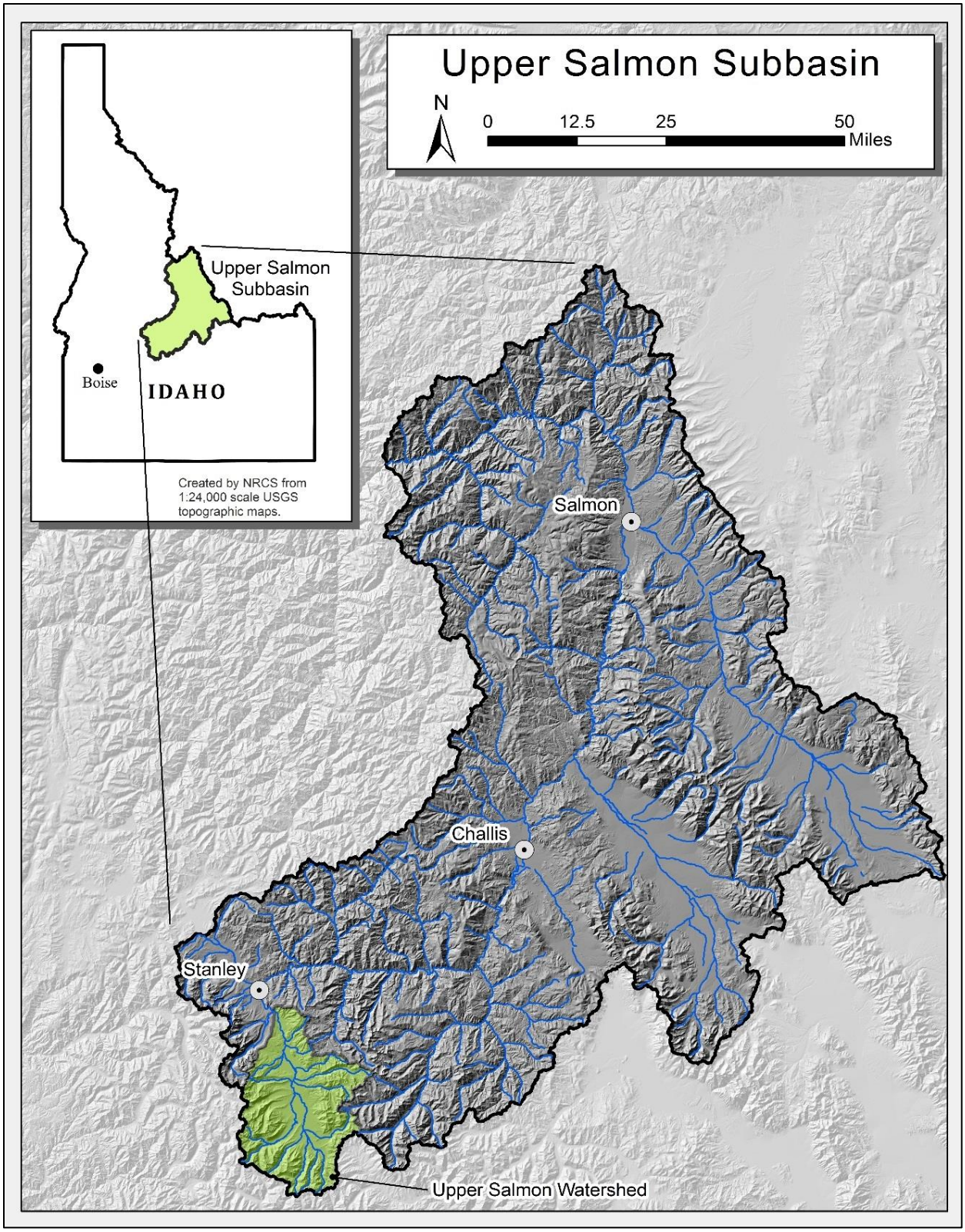


Figure 107. Map of location of the Upper Salmon River subbasin.

Biological Assessment

The Upper Salmon River maintains populations of three fish species listed under the ESA: Chinook salmon, steelhead, and bull trout. The watershed also supports westslope cutthroat trout, which has been petitioned for listing under the ESA. The headwaters of the Upper Salmon River are dominated by roadless wilderness areas, although the valley floor has been developed for agriculture. Timber harvest, grazing, and recreation activities occur within the watershed.

The mainstem Salmon River is estimated to provide 56 percent of the spawning habitat and 34 percent of the rearing habitat for this Chinook salmon population, with the remainder supported by tributary habitat, of which Alturas Lake Creek is the largest contributor (NOAA 2017). The Upper Salmon River Chinook salmon population inhabits the mainstem Salmon River and tributaries upstream from the confluence with Redfish Lake Creek, including Redfish Lake Creek. Since 2000, the Upper Salmon River has a mean escapement of 656 adult Chinook salmon, with a maximum escapement of 1,419 in 2002. NOAA (2017) classifies this population as Large and at a high risk of extinction.

The Upper Salmon River steelhead population includes the mainstem Salmon River and all of its tributaries (including Yankee Fork Salmon, Valley Creek, Upper Salmon) upstream from the confluence of the East Fork Salmon River. In the steelhead section here, we focus on the portion of the population that inhabits the mainstem Salmon River and tributaries upstream from the confluence with Redfish Lake Creek, including Redfish Lake Creek. Since 2010, the Upper Salmon River has a mean escapement of 92 adult steelhead, with a maximum escapement of 154 in 2010. NOAA (2017) classifies the entire Upper Salmon River steelhead population as Intermediate with a maintained (i.e., 6 to 25 percent chance) risk of extinction.

Habitat Capacity

Chinook salmon

Current Conditions

Contemporary estimates of life-stage-specific capacity requirements were generated based on the mean (656) and maximum (1,419) adult Chinook salmon escapement observed in the Upper Salmon River from 2000 to 2016. Those adult escapements were then propagated through to four additional life stages to estimate life-stage-specific capacity requirements for Chinook salmon in the Upper Salmon River; capacity requirements were then compared to available habitat capacity estimated using QRF models (Table 51).

Table 51. Estimated current life-stage-specific capacity requirements versus estimated available capacity for Chinook salmon in the Upper Salmon River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	Mean	Max		
Escapement	656	1,419		
Redd	321	695	4,909	0
Eggs	1,700,372	3,678,497		
Summer Parr	493,108	1,066,764	721,873	344,891
Winter Presmolt	199,793	432,221	220,838	211,383

Under current habitat conditions and using contemporary escapement estimates, the productivity of the Upper Salmon River Chinook salmon population does not appear to be limited by redd capacity; however, it does appear that juvenile rearing capacity may be limited during both summer (parr) and winter (presmolt) months (Table 51). Available summer and winter juvenile rearing habitat for Chinook salmon seems adequate to support parr and presmolt capacity requirements given contemporary mean escapement, but available habitat may support only roughly 70 percent of summer (parr) and 50 percent of winter (presmolt) production from the recent max escapement in 2002. In other words, considering the mean of recent escapements, it appears that required capacity is below the predicted available capacity, suggesting zero deficit. However, during large escapements, required capacity likely exceeds available capacity during summer and winter months (Table 51). These findings appear to be supported by the fact that 57 percent of total Chinook salmon juvenile production from this reach emigrate as fry (26 percent) or parr (31 percent); however, this could be due, in part, to the fact that the majority of redds are enumerated within roughly 6 river miles upstream of the rotary screw trap. Further, on average, 33 percent of total Chinook salmon juveniles emigrate as presmolts, prior to the winter rearing period, suggesting that winter habitat capacity in upper reaches of the Upper Salmon River is limited.

Desired Conditions

NOAA (2017) delisting requirements include a minimum annual escapement (i.e., MAT) of 1,000 Chinook salmon adults to the Upper Salmon River. Based on this requirement, life-stage-specific capacity requirements were recalculated consistent with 1,000 adults (MAT) and 1,250 adults (MAT + 25%). Those capacity requirements were also compared to estimates of currently available habitat capacity to identify potential habitat limitations if delisting is desired (Table 52). Potential limitations (capacity deficit) were calculated as the life-stage-specific capacity requirements needed to achieve a MAT of 1,000 plus a 25 percent buffer minus available capacity. There appears to be sufficient redd capacity in the Upper Salmon River to support 1,250 adult Chinook salmon. However, the available juvenile rearing capacity during summer (721,873) and winter (220,838) are far from sufficient to support the potential parr and presmolt production from 1,250 adult Chinook salmon (Table 52). Therefore, to achieve delisting of Chinook salmon in the Lemhi River, both summer and winter juvenile rearing capacity would need to be increased.

Table 52. Estimated life-stage-specific capacity requirements to accommodate ESA de-listing and estimated available capacity for Chinook salmon in the Upper Salmon River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	MAT	MAT + 25%		
Escapement	1,000	1,250		
Redd	490	613	4,909	0
Eggs	2,592,100	3,240,125		
Summer Parr	751,709	939,636	721,873	217,763
Winter Presmolt	304,570	380,712	220,838	159,874

Summary

Sufficient spawning (redd) capacity is available in the Upper Salmon River to support contemporary escapement and escapement required to achieve delisting criteria for Chinook salmon (Figure 108). Predicted available juvenile rearing capacity during summer (parr) and winter (presmolt) months appears sufficient to support recent mean escapements, but perhaps not high escapements in recent years (Figure

109 and Figure 110); juvenile rearing capacity for Chinook salmon in both summer and winter months would likely need to be increased to achieve delisting.

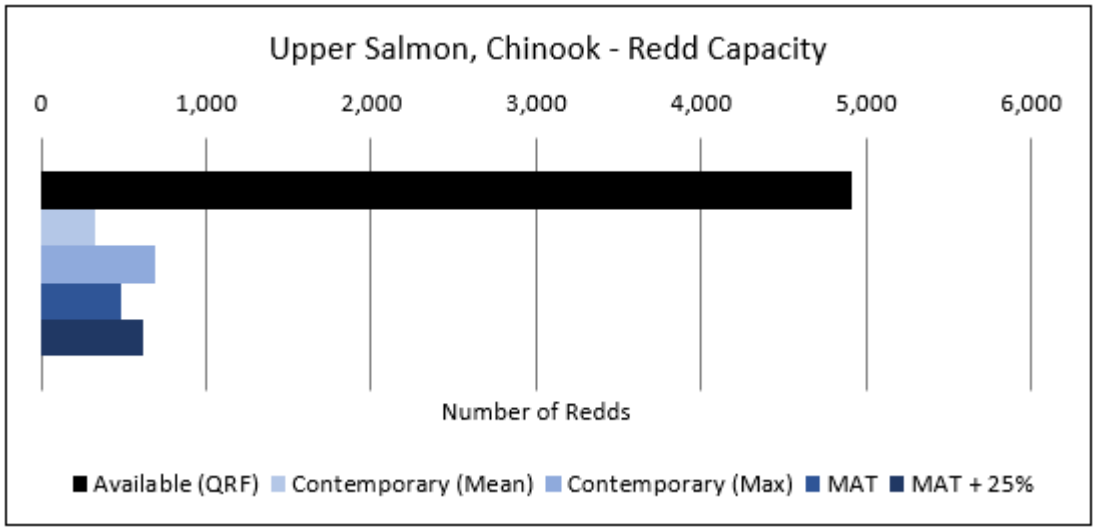


Figure 108. Estimates of available spawning (redd) capacity given current habitat conditions for Chinook salmon in the Upper Salmon River watershed, made using quantile regression forest models (black bars), versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

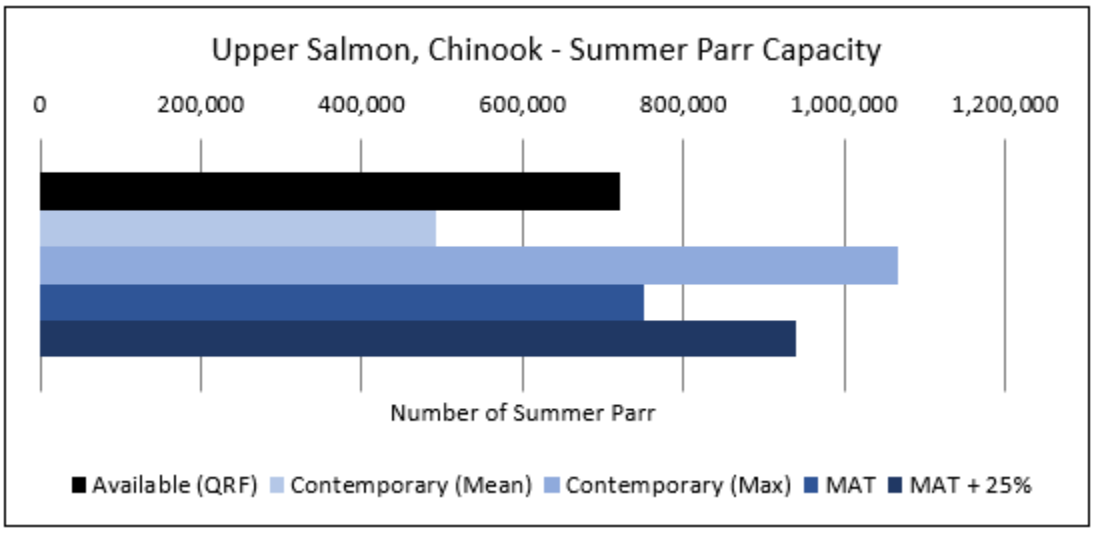


Figure 109. Estimates of available summer juvenile (parr) rearing capacity given current habitat conditions for Chinook salmon in the Pahsimeroi River watershed, made using quantile regression forest models (black bars), versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

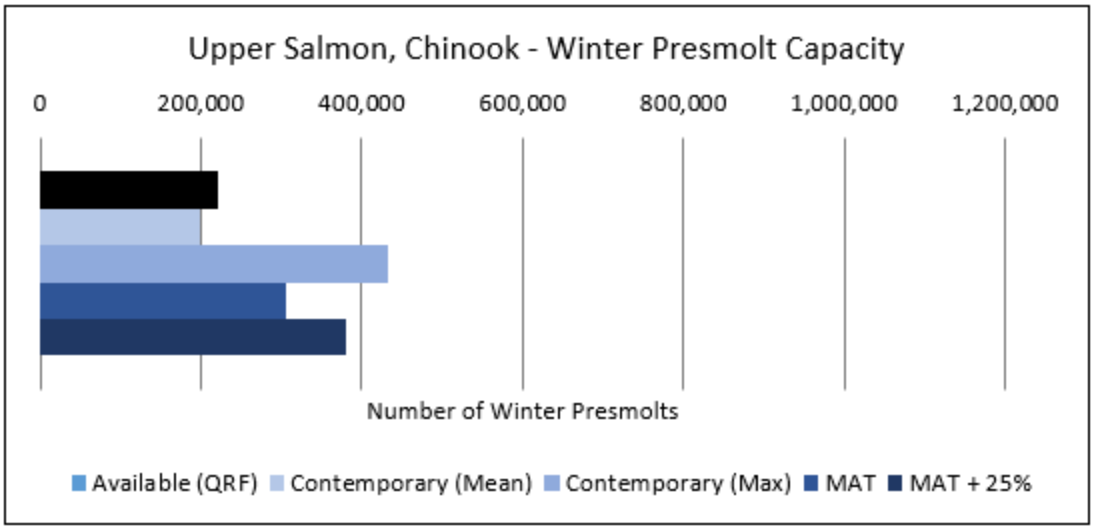


Figure 110. Estimates of available winter juvenile (presmolt) rearing capacity given current habitat conditions for Chinook salmon in the Pahsimeroi River watershed, made using quantile regression forest models (black bars), versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (blue bars).

Steelhead

Available habitat capacity estimates from QRF models are considered preliminary for steelhead in the Upper Salmon River due to unknown spatial extents of available habitat for steelhead spawning and rearing. The IRA team will work with local biologists and experts to more appropriately identify the extents of habitat in the Upper Salmon River available to steelhead. Available habitat capacity estimates can be improved in future reach assessments or as needed with local groups.

Current Conditions

Contemporary estimates of life stage-specific capacity requirements were generated based on the mean (92) and maximum (154) adult steelhead escapements estimated in the Upper Salmon River from 2010 to 2015. Those adult escapements were then propagated through to four additional life stages to estimate life-stage-specific capacity requirements for steelhead in the Upper Salmon River; capacity requirements were then compared to available habitat capacity estimated using QRF models (Table 53).

Table 53. Estimated current life-stage-specific capacity requirements versus estimated available capacity for steelhead in the Upper Salmon River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	Mean	Max		
Escapement	92	154		
Redd	51	85	2,475	0
Eggs	251,959	420,995		
Summer Parr	33,826	56,519	470,009	0
Winter Presmolt	12,131	20,269	473,201	0

Under current habitat conditions, and using contemporary escapement estimates, habitat capacity does not appear to limit spawning (redd) or juvenile rearing for steelhead in the Lemhi River.

Desired Conditions

NOAA (2017) delisting requirements include a minimum annual escapement (i.e., MAT) of 1,000 steelhead adults to the Upper Mainstem Salmon River steelhead population that includes the mainstem Salmon River and all tributary habitats upstream of its confluence with the East Fork Salmon River. For this Biological Assessment, we are only interested in the portion of the population that inhabits the mainstem Salmon River and tributaries upstream from the confluence with Redfish Lake Creek, including Redfish Lake Creek. To determine a relative MAT for this portion of the population, we first compared the available stream length within the steelhead domain in the Upper Salmon River above Redfish Lake Creek (195.3 km) to available stream length within the steelhead domain in Valley Creek (99.9 km) and the Yankee Fork Salmon River (111.3 km) and determined that about 48 percent of the available habitat in the Upper Mainstem Salmon River steelhead population lies within our area of interest. Therefore, we multiplied the total MAT (1,000) by 48 percent to establish a relative MAT of 480 adult steelhead. Based on this requirement, life-stage-specific capacity requirements were recalculated consistent with 480 adults (MAT) and 601 adults (MAT + 25%) using the same methods as above. Those capacity requirements were also compared to estimates of currently available habitat capacity to identify potential habitat limitations if delisting is desired (Table 54). Potential limitations (capacity deficit) were calculated as the life-stage-specific capacity requirements needed to achieve an abundance of 601 minus available capacity.

There appears to be sufficient redd and juvenile rearing capacity for steelhead to support 601 adult steelhead in the Upper Salmon River above Redfish Lake (Table 54).

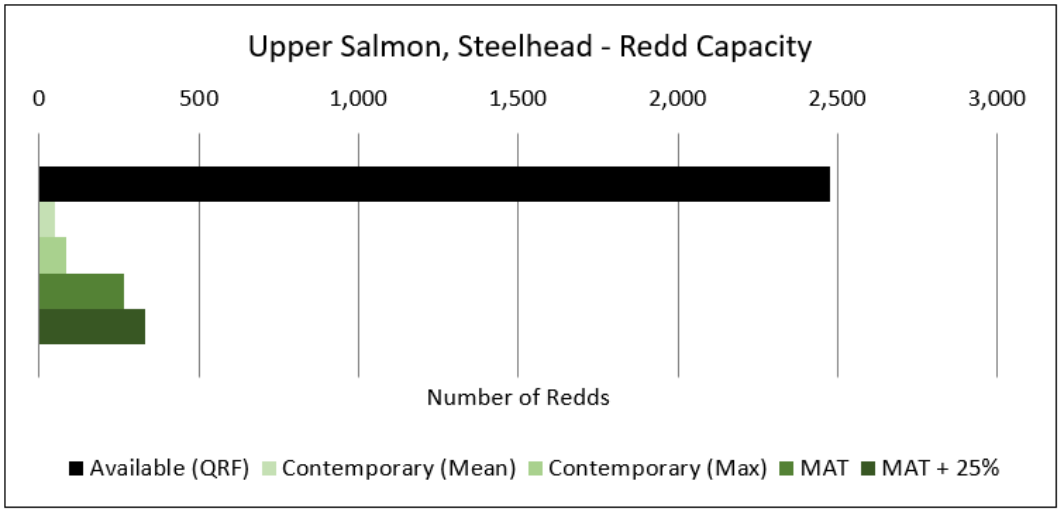
Table 54. Estimated life-stage-specific capacity requirements to accommodate ESA de-listing and estimated available capacity for steelhead in the Upper Salmon River.

Life-Stage	Required Capacity		Available Capacity	Capacity Deficit
	MAT	MAT + 25%		
Escapement	480	601		
Redd	267	333	2,475	0
Eggs	1,313,402	1,641,753		
Summer Parr	176,324	220,405	470,009	0
Winter Presmolt	63,235	79,043	473,201	0

Summary

There appears to be sufficient spawning (redd) and juvenile rearing capacity for steelhead in the Upper Salmon River (above Redfish Lake) to support contemporary escapement and escapement required to

achieve delisting criteria for steelhead (



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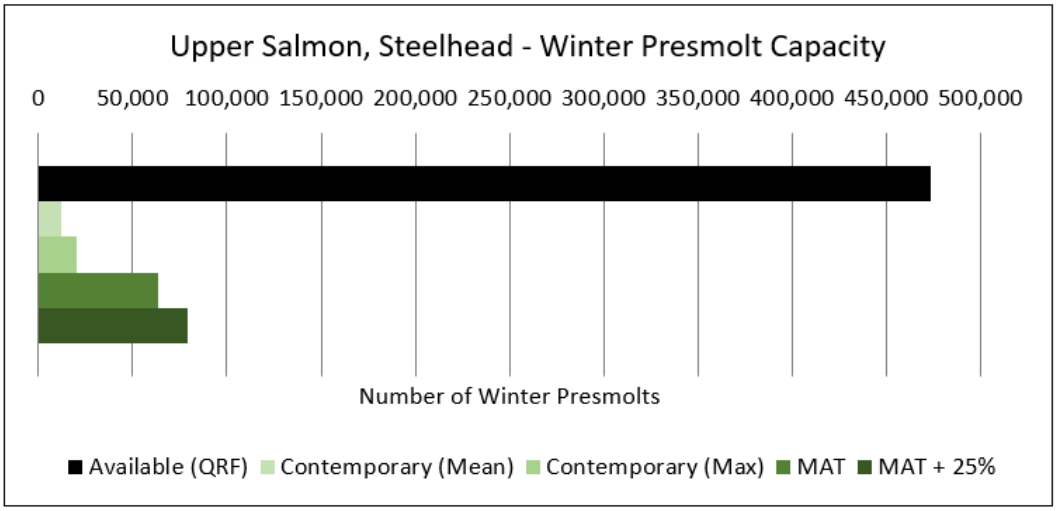

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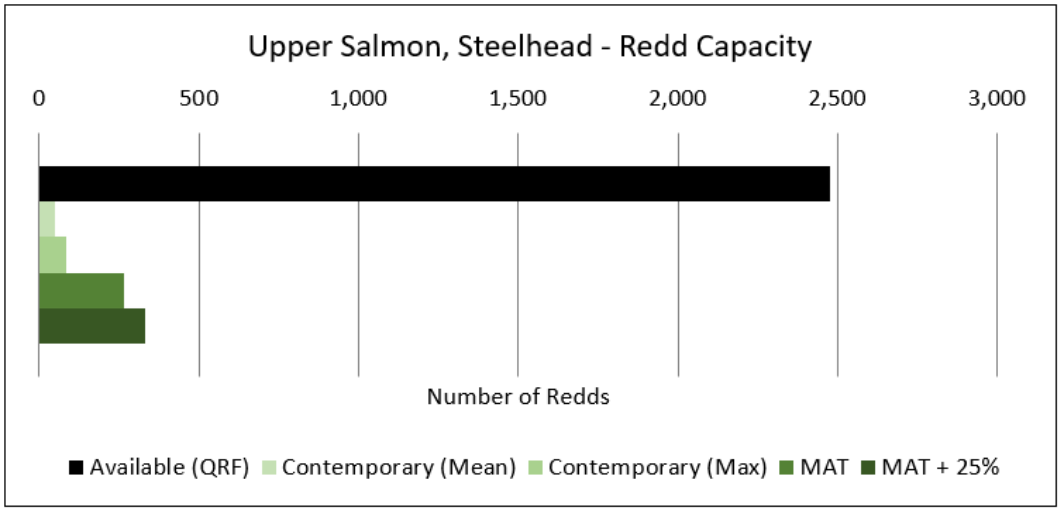


Figure 111. Estimates of available spawning (redd) capacity given current habitat conditions for steelhead in the Upper Salmon River watershed, made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

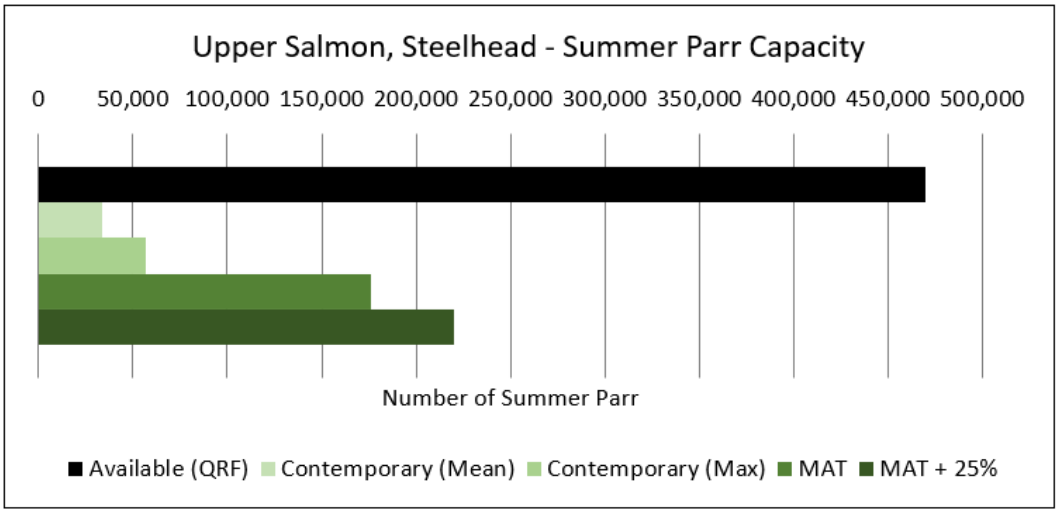


Figure 112. Estimates of available summer juvenile (parr) rearing capacity given current habitat conditions for steelhead in the Upper Salmon River watershed made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

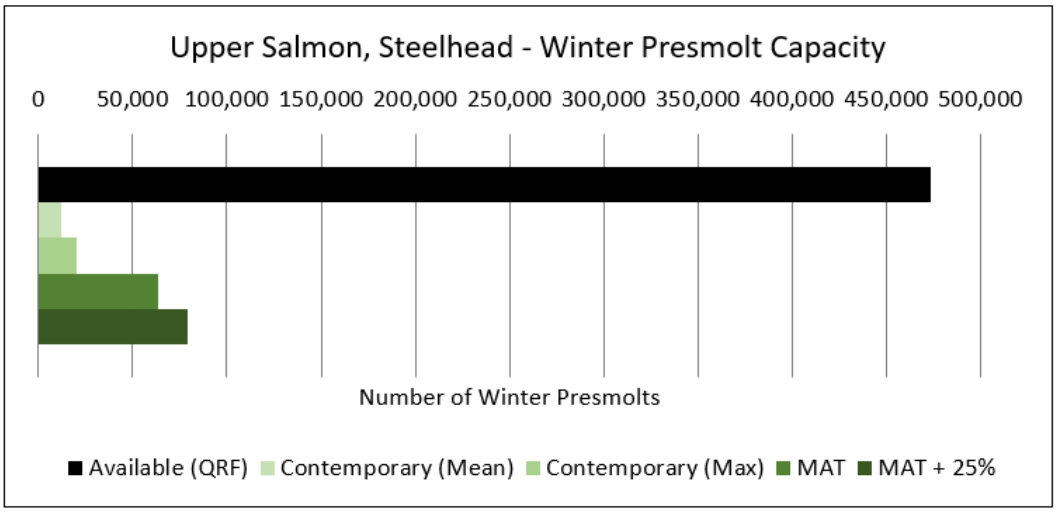


Figure 113. Estimates of available winter juvenile (presmolt) rearing capacity given current habitat conditions for steelhead in the Upper Salmon River watershed made using quantile regression forest models (black bars) versus the capacity required to support contemporary abundance and minimum abundance thresholds (MATs) needed for ESA de-listing (green bars).

Geomorphic Assessment

Much of the geomorphic assessment in this report has been compiled in an effort to help paint a better picture of historical and potential target conditions (qualitative), recognizing that detailed (quantitative) target conditions will be generated as part of the MRA for select reaches in the future.

Historical Watershed Conditions

The Upper Salmon River occupies a broad north/northwest-trending valley bound by the granitic Sawtooth Mountains to the west and the granitic and sedimentary White Cloud Mountains to the east. The valley formed through a sequence of mountain building, faulting, and valley-fill sedimentation over millions of years. Some of the oldest rocks in the area were deposited more than 100 million years ago as marine sediments that were subsequently thrust up onto the continental crust about 60 million years ago, during the formation of the ancestral Rocky Mountains (Link and Janecke 1999). At roughly the same time, the subduction of the ancestral oceanic tectonic plate beneath the continental tectonic plate resulted in the emplacement of the granitic Idaho batholith, a large body of igneous granitic rock that comprises much of central Idaho, including the Sawtooth Mountains and portions of the White Clouds (Johnson et al. 1988). Over the past several million years, the continental crust has expanded in this area due to the nearby Yellowstone hotspot. Normal faulting associated with the expansion has lowered some blocks of the crust, creating valleys and raising others, forming mountain ranges (Pierce et al. 2007). The Idaho batholith was faulted along a roughly northwest-trending normal fault (Sawtooth Fault), forming the Salmon River Valley (lowered block) and Sawtooth Mountains (raised block) (Simpson and Anders 1992).

During the last ice age that ended approximately 10,000 years ago, the temperatures in the area were estimated to be 6 to 10° C colder than today (Pierce and Scott 1982). Lower temperatures resulted in more snow accumulation and less evaporation, which formed glaciers in the Sawtooth and White Cloud Mountains and is estimated to have increased stream flow by at least an order of magnitude relative to

modern hydrology (Pierce and Scott 1982). Glaciers and streams with much-higher-than-modern discharge transported large volumes of sediment to the valley bottom, where they were deposited in thick layers. Glacial ice from the Sawtooth Mountains extended onto the Sawtooth Valley, forming substantial moraine deposits grading in sequence to fan and outwash gravels that occupy much of the valley floor (Breckenridge et al. 1988) (Figure 114). Outlet glaciers from the White Cloud Mountains are believed to have reached the margin of the Sawtooth Valley but did not coalesce with glaciers from the Sawtooth Range (Breckenridge et al. 1988). Ten thousand years of subsequent erosion into the glacial sediment has resulted in the formation of large terraces that, along with remnant glacial moraines, confine the otherwise broad valley.

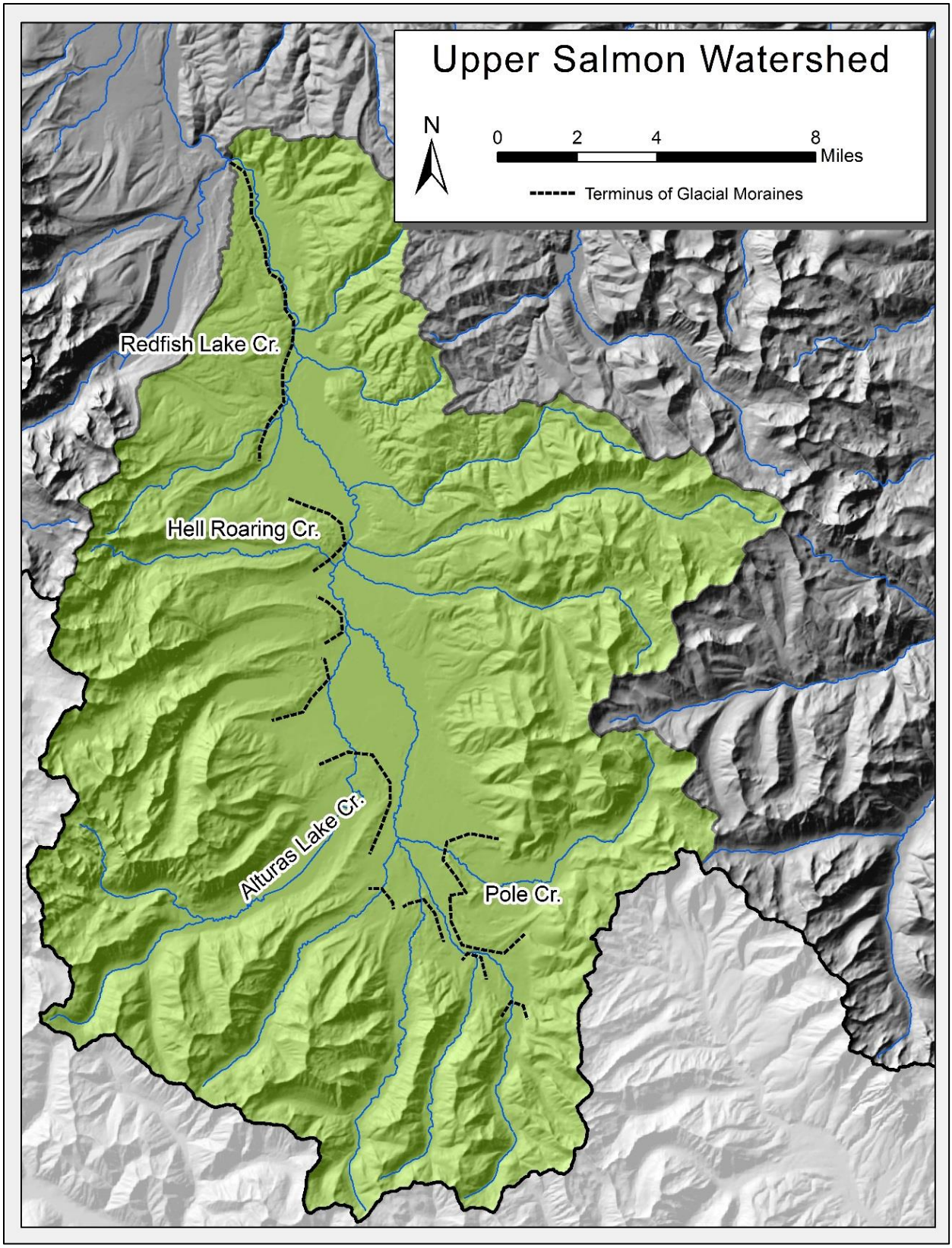


Figure 114. Ten-meter digital elevation model hill shade map illustrating the approximate terminal extent of Pleistocene glacial moraines.

The porous, ice-age alluvial deposits (moraines, fans, and outwash gravels) filling the Sawtooth Valley also enable a local aquifer. Areas where the aquifer intercepts the surface produce reaches that gain flow from groundwater, while areas where the aquifer is below the surface generally lose flow to the aquifer. Although detailed groundwater analyses are not available, aerial photograph observation reveals several locations where the local groundwater table appears to intercept the surface, resulting in visible springs. The historic conditions of the Sawtooth Valley were likely significantly influenced by the spatial variability of surface-to-groundwater interactions in the valley.

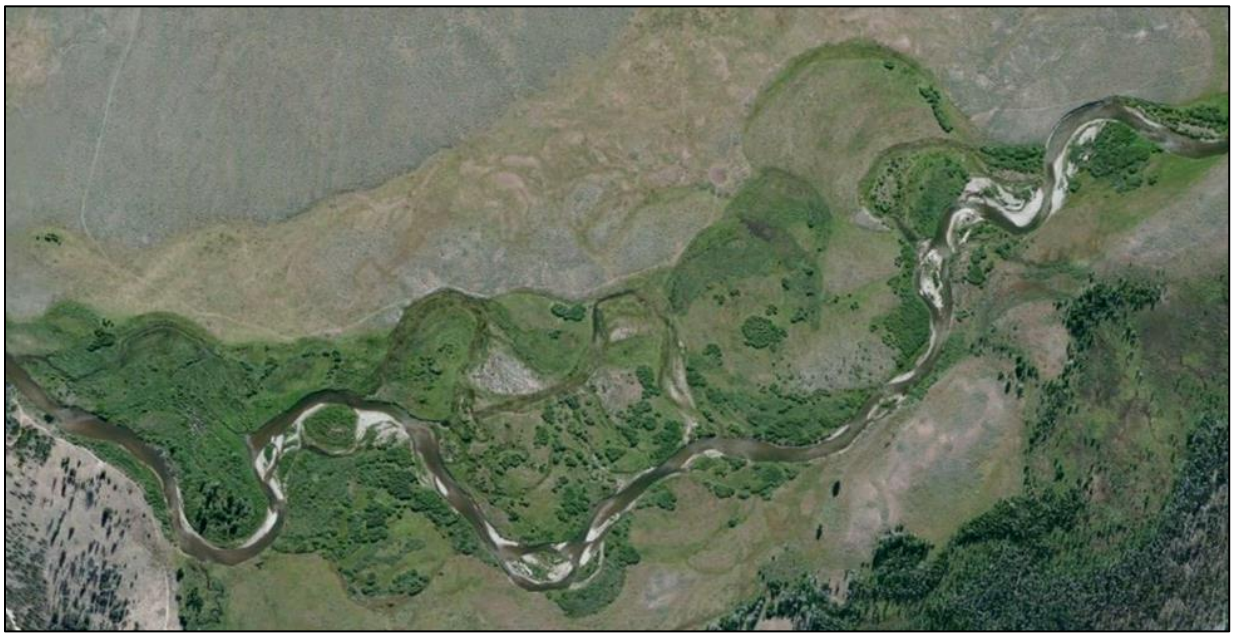
The character of the majority of the valley is driven predominantly by snowmelt-dominated (i.e., peak-flow) hydrology. These areas were historically transport-dominated, with sufficient gradient and discharge to mobilize sediment and slowly incise the bed over thousands of years, creating a narrow, inset floodplain bound by relic terraces. The primarily single-threaded channel within the terraces was characterized by a low sinuosity and a predominantly plane-bed morphology, although a forced pool-riffle morphology may have formed over small areas, given sufficient structure and/or woody debris loading (based on Montgomery and Buffington 1998).

Flashy, snowmelt-dominated hydrology provided a disturbance regime suitable for the establishment and propagation of cottonwood trees, but cottonwoods likely did not occupy the riparian areas due to incompatible climate and elevation. Cottonwoods are not currently observed in abundance above roughly 6,500 feet elevation on either the Salmon or neighboring Big Wood Rivers. Willows likely dominated the riparian areas above 7,000 feet, as they do today, providing bank stability and structure. Conifer trees, including lodgepole and whitebark pine, occupied upland areas, especially glacial moraines, which have a greater fine sediment composition and annual precipitation compared with alluvial fans and terraces. Bank erosion into areas vegetated with conifers, primarily along glacial moraines, tributaries, and upstream of Smiley Creek, provided a local source of large wood recruitment that enhanced and/or forced pool-riffle morphology and may have created localized areas of island braiding. Large floods and debris torrents may have transported large wood from the tributaries and upstream areas, but research suggests that large wood is unlikely to transport significant distances through such small streams with low channel width and depth (Braudrick and Grant 2001).

In several locations, valley-spanning grade controls forced the local groundwater table to intercept the surface, resulting in springs; the grade controls also yielded low gradients. These low-gradient, groundwater-influenced areas likely exhibited historical conditions similar to modern references of low-gradient, groundwater-influenced channels characterized by a sinuous channel pattern, frequent split flows, and spring-fed side-channels. Relic topographic variation from channel migration, occasional avulsions, beaver dams, and disturbance from grazing animals (bison, elk, and deer) likely created a mosaic of open water, emergent wetland, floodplain, and upland. The riparian community would have mirrored this diversity with areas of wetland meadow (rushes and sedges), floodplain shrubs (willow) and upland vegetation (sagebrush and grass). The sinuous and multi-threaded channel in these areas likely exhibited a pool-riffle morphology (based on Montgomery and Buffington 1998) driven by sediment deposition, bank structure from willow vegetation, and instream woody structure (including beaver dams), where present. Other natural geomorphic forcing agents likely included winter anchor ice and ice jams that obstructed flow and forced water out of the channel onto the floodplain.

Aerial photograph observation reveals many relic channel scars, oxbows, and meander scrolls visible in the modern floodplain (Photograph 27). Based on interpretation of these relic channels, it is believed that the peak-flow-dominated hydrology and readily available coarse sediment load resulted in frequent, pronounced channel migration and avulsion on all reaches of the Upper Salmon River headwaters. Low-

gradient, beaver- and groundwater-influenced areas likely exhibited greater rates of channel response and variability due to their enhanced depositional character relative to the more-confined, higher-gradient, transport-dominated areas.



Photograph 27. Aerial photograph example of relic channel scars, oxbows, and meander scrolls in a response reach of the Upper Salmon River headwaters.

Prior to Euro-American settlement, the Salmon River Mountain region was most likely inhabited by a group of Northern Shoshone known as the *Tu'kudeka,* or Sheepeaters, who wintered in the mountains, where they hunted mountain sheep (Rossillon 1980). Given the Shoshone's subsistence cycles and seasonal movements across central and southern Idaho, their impacts on the land were likely confined to their encampments, where tribes from the region would congregate and trade their goods. Reports from Lewis and Clark and others on the abundance of fur-bearing animals west of the divide spurred the business of fur trade. Independent fur trappers, as well as several companies (including the Hudson Bay Company and the American Fur Company) made their way into the northwest to explore and exploit the region. By the early 1840s, local beaver populations were brought to the brink of extinction and bison had disappeared from the Salmon River region (Albers et al. 1998).

The discovery of gold in California in 1848 began a western mining craze, leading to an influx of prospectors into Idaho and the discovery of gold there. Mining in the area consisted of placer mining along some tributaries and some hard-rock mining in the headwaters. Miners and other settlers were interested in acquiring the Shoshone Tribe's lands and waterways to support their growing agrarian and mining enterprises, and homesteads sprang up across the lower-elevation lands (Albers et al. 1998). Beginning in the 1880s, irrigation development and associated water rights were established in the mainstem Salmon River and its tributaries (ISCC 1995). Irrigation ditches withdrew water from the river and drained wetlands, redistributing the captured water across the floodplain. Such a redistribution of water had significant impacts on the hydrology of the river, causing at least one portion of the channel to run dry during the later summer months of the irrigation season.

Presently, irrigated agriculture and livestock grazing are the predominant land use activities within the valley. Grazing on public lands provides a substantial feed base for cattle in the Sawtooth Valley.

Generally, cattle graze on public lands from May to October and then return to private lands along the valley bottoms for the remainder of the year (ISCC 1995). Historical agricultural and grazing practices resulted in riparian vegetation clearing and associated streambank destabilization, as well as increased surface-water runoff and erosion.

Existing Watershed Conditions

Channel form and process have not changed significantly from historical to existing conditions, but several human-related impacts currently influence the Upper Salmon River. The headwaters are pristine, protected public lands, but along the hillslopes and valley bottom, there are localized areas of disturbances, including irrigation diversions, livestock grazing, roads, and channel alterations. Irrigation diversions have reduced instream flows and altered aquifer recharge by diverting tributaries away from and out of the mainstem Upper Salmon River. Livestock grazing and agriculture along the mainstem Salmon River and its tributaries have caused loss of woody riparian vegetation, impacting bank stability, bank erosion, and sedimentation. Road embankments artificially confine the valley in several locations, and fine sediment from dirt and gravel roads, along with dispersed campsites throughout the drainage network, have a cumulative effect on siltation in the mainstem Salmon River.

Hydrology/Floods

The Main Salmon River flow regime is snowmelt-dominated, with numerous diversions in operation from July through September. Peak snowmelt flows generally occur during May and June. While agricultural diversion locations and volumes are regulated by local water authorities and the Idaho Department of Water Resources, exact withdrawal rates on a seasonal and daily basis are unknown. Mountain lakes are another important component of the Main Salmon River hydrology, as lakes modify water, sediment, and nutrient fluxes. Flood frequency peaks were estimated at four operational USGS gages using the PeakFQ program, and at 12 ungaged locations, applying methods published in Bulletin 17C and Berenbrock (2002). Peak flood frequency values at each valley segment are presented in Table 55.

Table 55. Upper Salmon River hydrology.

River Mile	Drainage Area (mi^2)	Flood Frequency Values (cfs)								
		1	**1.5**	**2**	**2.33**	**5**	**10**	**25**	**50**	**100**
0	304	685	1,643	1,919	2,043	2,554	2,936	3,383	3,694	3,987
15.3	177	389	940	1,099	1,170	1,463	1,682	1,937	2,114	2,281
36	3.8		35.1	43.1	45.1	60.7	73.3	88.9	100	114

Surface and Groundwater Interactions

Based on aerial photograph and field observations, there are several areas within the Upper Salmon River basin where the local groundwater aquifer intercepts the surface, resulting in visible springs and spring-fed channels on the floodplain. As discussed by others (USFS 2014), aerial photograph imagery of wide, green floodplains provides the best indication of gaining reaches. These groundwater-influenced areas tend to occur immediately upstream of geologic grade controls that constrict and/or span the valley width, such as converging glacial deposits (i.e., moraines and glacial outwash fans), alluvial fans, and/or possibly resulting from shallow bedrock or other subsurface geologic features (Figure 115).

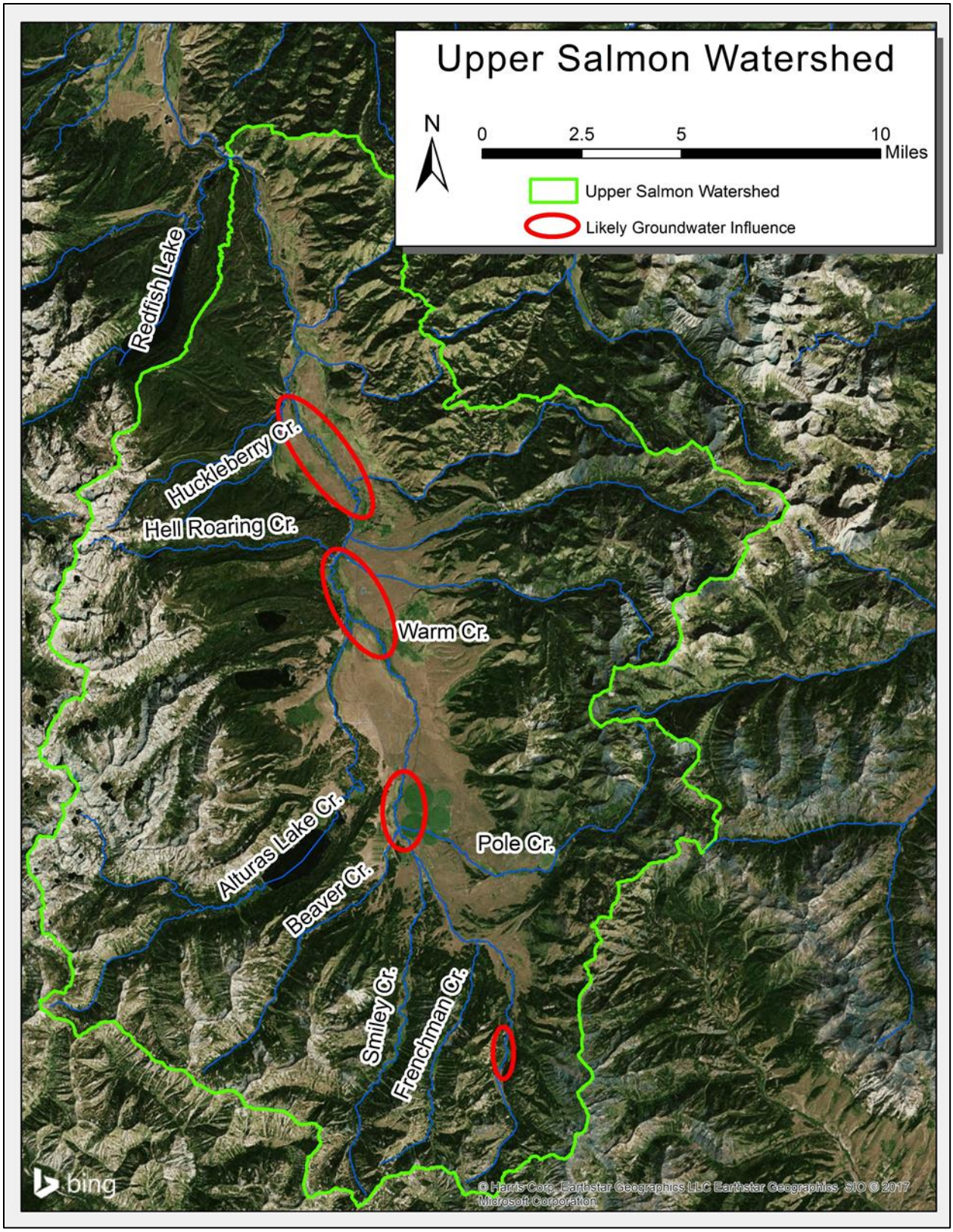


Figure 115. Aerial photo of the Sawtooth Valley identifying areas of known and expected groundwater influence, based on past seepage runs and visible green floodplains relative to surrounding areas.

There are no known groundwater analyses of the Upper Salmon River headwaters to provide comprehensive quantitative information supporting surface and groundwater interactions, but local seepage runs on and near Pole Creek were performed between 2006 and 2013 by the Idaho Department of Water Resources, USGS, and the USFS (USFS 2014). Results from these studies suggest that Pole Creek gains significantly from groundwater upstream of the Pole Creek Diversion and loses between 4 and 27 percent between the diversion and its confluence with the Salmon River. In the vicinity of the Pole Creek confluence, the mainstem Salmon River has both gains and losses from the local aquifer. Seepage runs suggest the mainstem Salmon River gains flow immediately downstream from the Pole Creek confluence (influenced by the Alturas glacial moraine near RM 24.5), then transitions into a losing condition (up to 33 percent loss) by the time it passes the former S45 diversion (i.e., Busterback diversion near RM 22.8). This losing condition persists downstream to near the Warm Creek confluence (RM 16.5), where the channel transitions again to a gaining condition between Warm Creek and roughly Huckleberry Creek (RM 6.6), where the seepage study ended (USFS 2014). These limited seepage runs support the assertion that gaining reaches tend to occur in the areas upstream of geologic grade controls (i.e., glacial moraines and/or glacial outwash fans).

Hydraulics

Coarse, at-a-station hydraulic analyses were completed from three representative locations within the watershed to provide context for the geomorphic conditions discussed below. More-detailed two-dimensional hydraulic modeling will be completed as part of the future MRA process for select reaches. Three typical cross-sections located throughout the Upper Salmon River watershed were measured and evaluated to assess existing hydraulic characteristics and to determine if any generalizations could be inferred from the calculations. Cross-sections were measured at RM 33.2 (Valley Segment 1, Geomorphic Reach 2, Figure 116), RM 13 (Valley Segment 2, Geomorphic Reach 7, Figure 117), and RM 8.2 (Valley Segment 2, Geomorphic Reach 8, Figure 118).

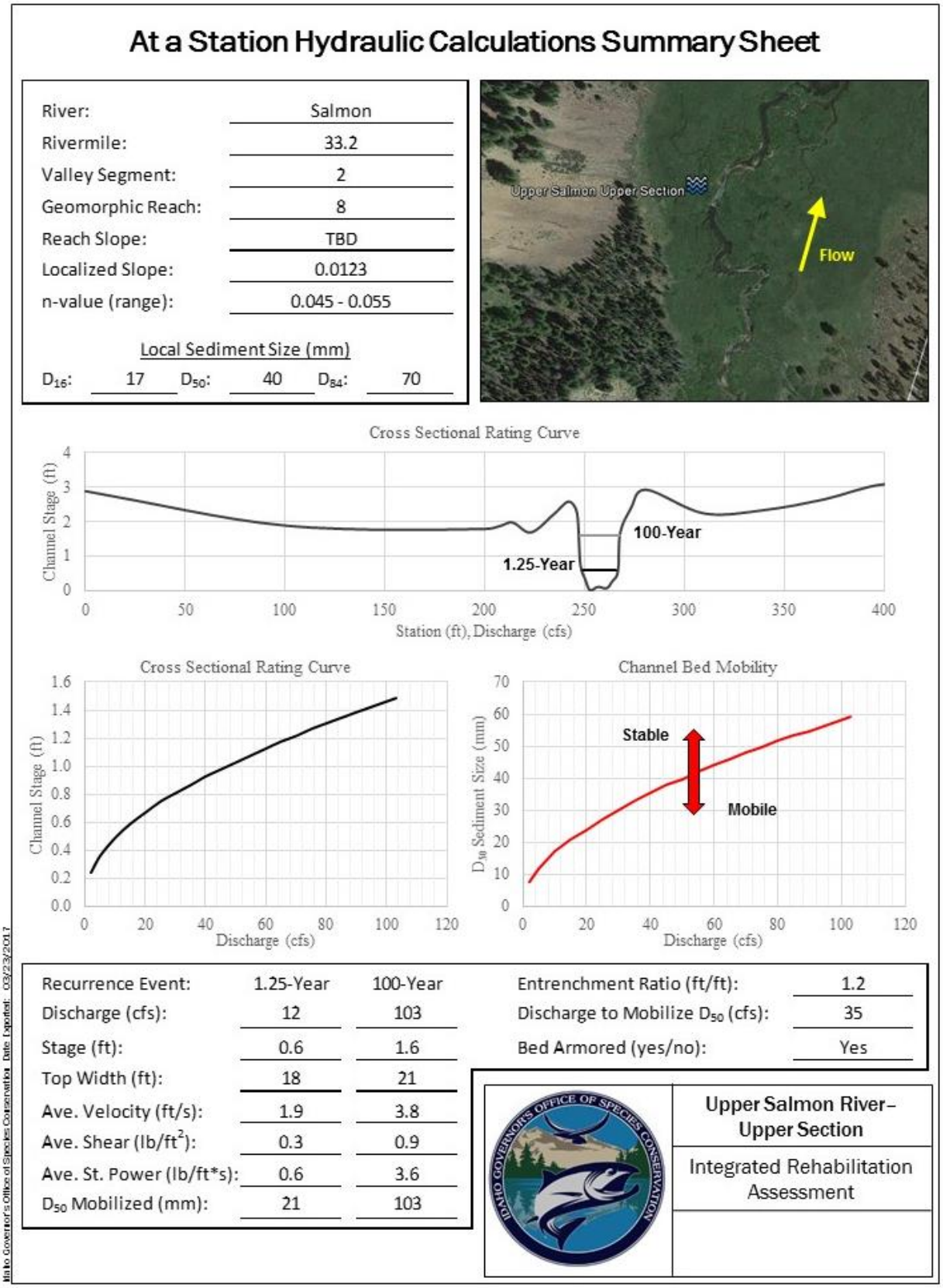


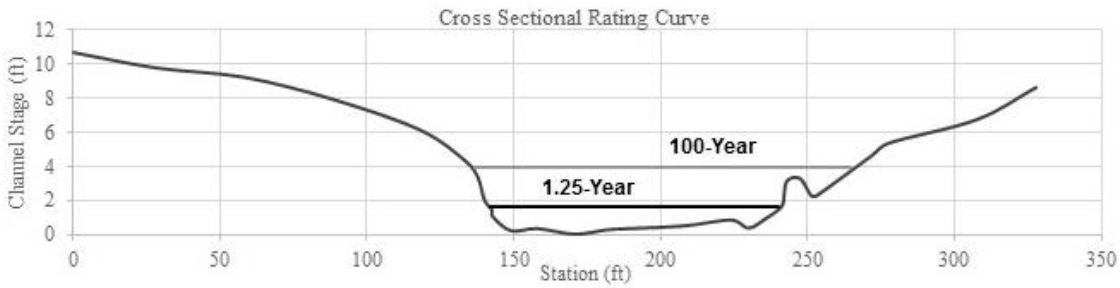
Figure 116. Summary of representative hydraulic conditions at Site 1.

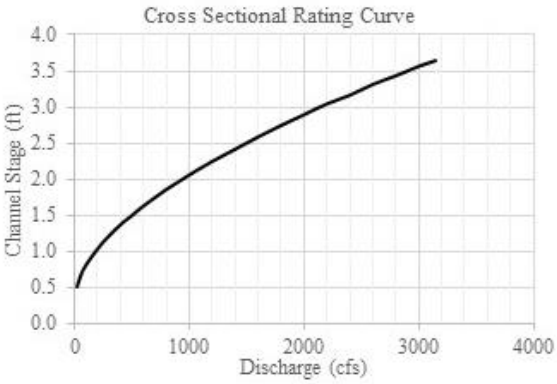
At a Station Hydraulic Calculations Summary Sheet

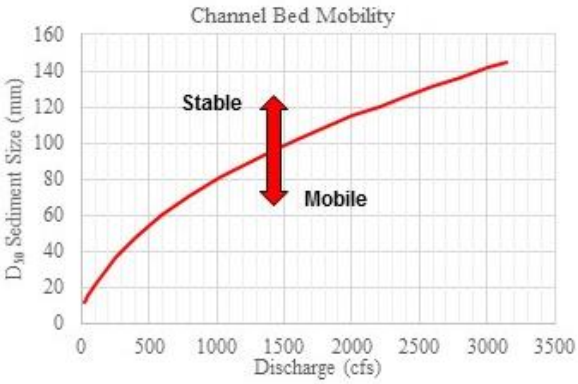
River:	Salmon
Rivermile:	13
Valley Segment:	1
Geomorphic Reach:	3
Reach Slope:	TBD
Localized Slope:	0.0089
n-value (range):	0.035 - 0.045

Local Sediment Size (mm)

D_{16}:	51	D_{50}:	143	D_{84}:	219







Recurrence Event:	1.25-Year	100-Year
Discharge (cfs):	487	3152
Stage (ft):	1.6	3.9
Top Width (ft):	100	135
Ave. Velocity (ft/s):	4.5	8.7
Ave. Shear (lb/ft^2):	0.9	2.3
Ave. St. Power (lb/ft*s):	3.8	20
D_{50} Mobilized (mm):	54	145

Entrenchment Ratio (ft/ft):	1.4
Discharge to Mobilize D_{50} (cfs):	3050
Bed Armored (yes/no):	Yes

Upper Salmon River–Middle Section

Integrated Rehabilitation Assessment

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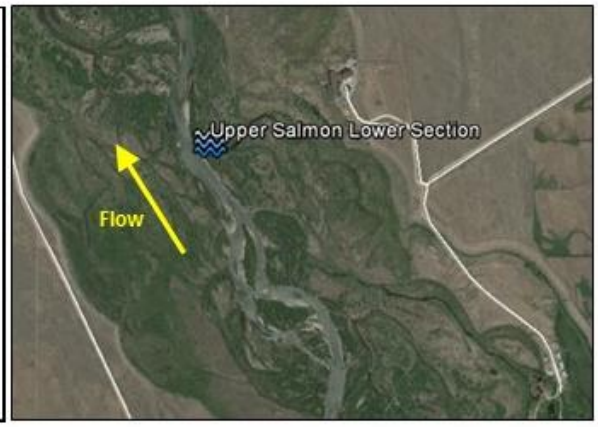
Figure 117. Summary of representative hydraulic conditions at Site 1.

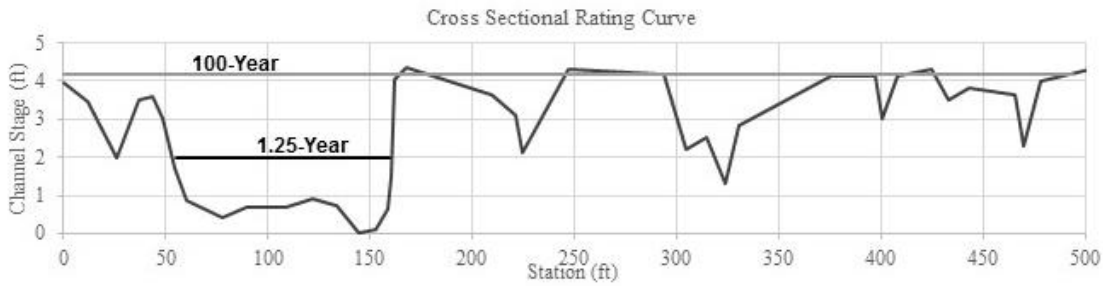
At a Station Hydraulic Calculations Summary Sheet

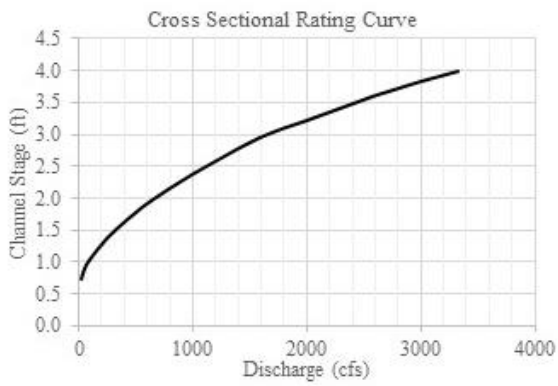
River:	Salmon
Rivermile:	8.2
Valley Segment:	1
Geomorphic Reach:	2
Reach Slope:	TBD
Localized Slope:	0.0064
n-value (range):	0.035 - 0.045

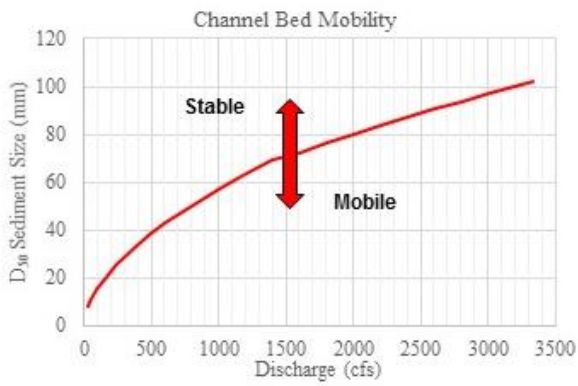
Local Sediment Size (mm)

D_{16}: 34 D_{50}: 73 D_{84}: 138









Recurrence Event:	1.25-Year	100-Year
Discharge (cfs):	597	3331
Stage (ft):	2.0	4.2
Top Width (ft):	108	533
Ave. Velocity (ft/s):	4.1	7.3
Ave. Shear (lb/ft^2):	0.7	1.6
Ave. St. Power (lb/ft*s):	2.8	11.9
D_{50} Mobilized (mm):	43	102

Entrenchment Ratio (ft/ft):	4.9[1]
Discharge to Mobilize D_{50} (cfs):	1600
Bed Armored (yes/no):	Yes

Notes: 1. Entrenchment Ratio based off main channel width not including side channel.

Upper Salmon River–Lower Section

Integrated Rehabilitation Assessment

Idaho Governor's Office of Species Conservation Date Exported: 03/23/2017

Figure 118. Summary of representative hydraulic conditions at Site 1.

The upstream-most section is located in a wide meadow with multiple beaver dam complexes. The section was taken a short distance downstream of a beaver dam. The section modeled shows the 1.25-year discharge contained within the main channel banks, with overtopping occurring above the 100-year discharge. The entrenchment ratio is 1.2, which is a completely disconnected floodplain. The sediment size showed bed mobilization beginning at less than the 1.25-year event, which allows the channel to scour and maintain pools. Average channel velocities varied from 1.9 feet per second at the 1.25-year event to 3.8 feet per second at the 100-year event. Shear stresses varied from 0.3 to 0.9 lb/ft^2 between these two events. This cross-section is likely influenced by beaver complexes, which can cause localized backwater effects, reduce sediment transport, and increase stage discharge relationships and associated floodplain activation. As a result, this section may not be representative of the reach as a whole.

The middle section is located a short distance downstream of the Salmon River's confluence with Pettit Creek. The channel is single-threaded in this area, and the section is located upstream of a bridge crossing that could be causing channel confinement. The channel geometry is such that the 1.25-year and 100-year discharge events are predominately confined within the channel, with a low entrenchment ratio of 1.4. Local sediment sizes show that the bed begins to mobilize at flows greater than 3,050 cfs, which is slightly less than the 100-year event. Channel velocities range from 4.5 ft/sec to upwards of 8.5 ft/sec. Local channel confinement and the single-threaded nature of this location have led to channel bed armoring and localized incision. The channel confining structure (bridge) located downstream is likely influencing the channel characteristics at this location.

The lower section is located in what appears to be an unconfined section of the Salmon River. At this section, there is a dominant channel, multiple relic channels, and side-channel features present throughout the section. The 100-year floodplain stage estimates show good floodplain connection through side channels and peripheral flow paths but potentially lack full floodplain width connection. The entrenchment ratio has been estimated at 4.9. Channel velocities range between 4 and 7.3 ft/sec for the 1.25- and 100-year discharge events, respectively. Shear stresses vary from 0.7 to 1.6 lb/ft^2 for the same two flow events. The channel appears to be unarmored through this section of river and begins to mobilize the D_{50} on the channel bed between the 2-year and 5-year event.

General trends observed among these three cross-sections suggest the channel bed is predominately unarmored and becomes more armored near areas confined by hydraulic control structures like bridges. Localized hydraulic controls can create either backwater conditions (i.e., beaver complexes) or localized incision and disconnection of historic floodplain. Overall channel bed material shows potential for formation and maintenance of scour pools and localized zones of deposition and scour.

A stream power assessment was also completed to examine the relative sediment transport capacity of each geomorphic reach and changes in slope. Results showed that the upper mile and lower half of the basin (RM 15.4 to RM 0) have higher stream power compared to the remainder of the basin due to a large increase in discharge from Alturas Lake Creek and slight variation in channel slope.

A two-dimensional hydraulic model is recommended for future hydraulic modeling to quantify hydraulic variables, including inundation extent, flow depth, velocity, and shear stress. A two-dimensional model (rather than a one-dimensional model) will better represent multiple channel networks, geomorphic features, and lateral flow over the floodplain. Additional data necessary for future hydraulic modeling include detailed topography, bathymetry, flow calibration data, and an improved understanding of diversion outflows, tributary inflows, and groundwater contributions.

Water Quality

The USFS reported localized areas of accelerated sediment delivery to streams in the watershed, primarily from livestock grazing, dispersed recreation, and irrigation use (SNF 2003, in NOAA 2017). In 2016, the IDEQ published a list of revisions made on tributaries and the mainstem Upper Salmon River (Table 56). The mainstem Upper Salmon River and its side channels between Decker Creek and Fisher Creek were revised to recommend delisting for sediment/siltation, based on a full-support determination for cold-water aquatic life uses and contact recreation uses. This was also the case for Alturas Lake Creek and Champion Creek. Williams Creek was not supporting cold-water aquatic life use and requires a TMDL. Further analysis will determine the pollutant(s) for the TMDL(s) on Williams Creek.

Table 56. Streams and pollutants listed in the 2016 Addendum (IDEQ 2016).

Water Body	2016 Addendum
Salmon River – Fisher Creek to Decker Creek	Sedimentation/Siltation: Recommended delisting for sediment/siltation due to insufficient information. No TMDL completed.
Alturas Lake Creek	Combined biota/habitat bioassessments: Recommended delisting for sediment/siltation due to insufficient information. No TMDL completed.
Champion Creek	Combined biota/habitat bioassessments: Recommended delisting for sediment/siltation due to insufficient information. No TMDL completed.
William Creek	Combined biota/habitat bioassessments: Recommended retaining for combined biota/habitat bioassessments. Identified as waters that need a TMDL.

Basin Geometry

Domains within a watershed can be characterized as zones that are governed by sediment supply, alluvial fan formation, sediment transfer, or deposition (Figure 119). The headwaters of the Upper Salmon River are generally classified as sediment supply zones dominated by weathering and erosion of steep slopes, where tributaries collect and transport sediment downslope to the alluvial fan zone. The alluvial fan zone is where coarse sediment has accumulated across broad alluvial fans and piedmont belts at the valley head and margins. Below the alluvial fan zone, the valley gradient flattens as the Upper Salmon River flows across the transfer zone, where the river deposits and erodes sediment, driving channel migration and occasional avulsion. Prominent grade controls influence the gradient and groundwater hydrology through the transfer zone, including terminal glacial moraines at the outlet of nearly every tributary flowing from the east face of the Sawtooth Mountains, and from Pole Creek flowing west from the White Cloud Mountains. The largest terminal moraines have impounded water, raising the local groundwater table sufficiently to form lakes on several tributaries. Prominent grade controls affecting basin and channel geometry include the Alturas Lake Creek moraine, the Hell Roaring Creek moraine, and the Redfish Lake Creek moraine (Figure 120 and Figure 121). The channel generally exhibits a typical concave curve, with decreasing slopes in the downstream direction, although several distinct breaks in slope occur as a result of grade controls formed by terminal glacial moraines, including Upper Salmon moraine (RM 33), Hell Roaring moraine (RM 13), and Redfish Lake moraine (RM 0.4). Although not a major break in slope, a moderate slope is maintained for a significant distance as a result of grade control provided by the Alturas Lake moraine (RM 23).

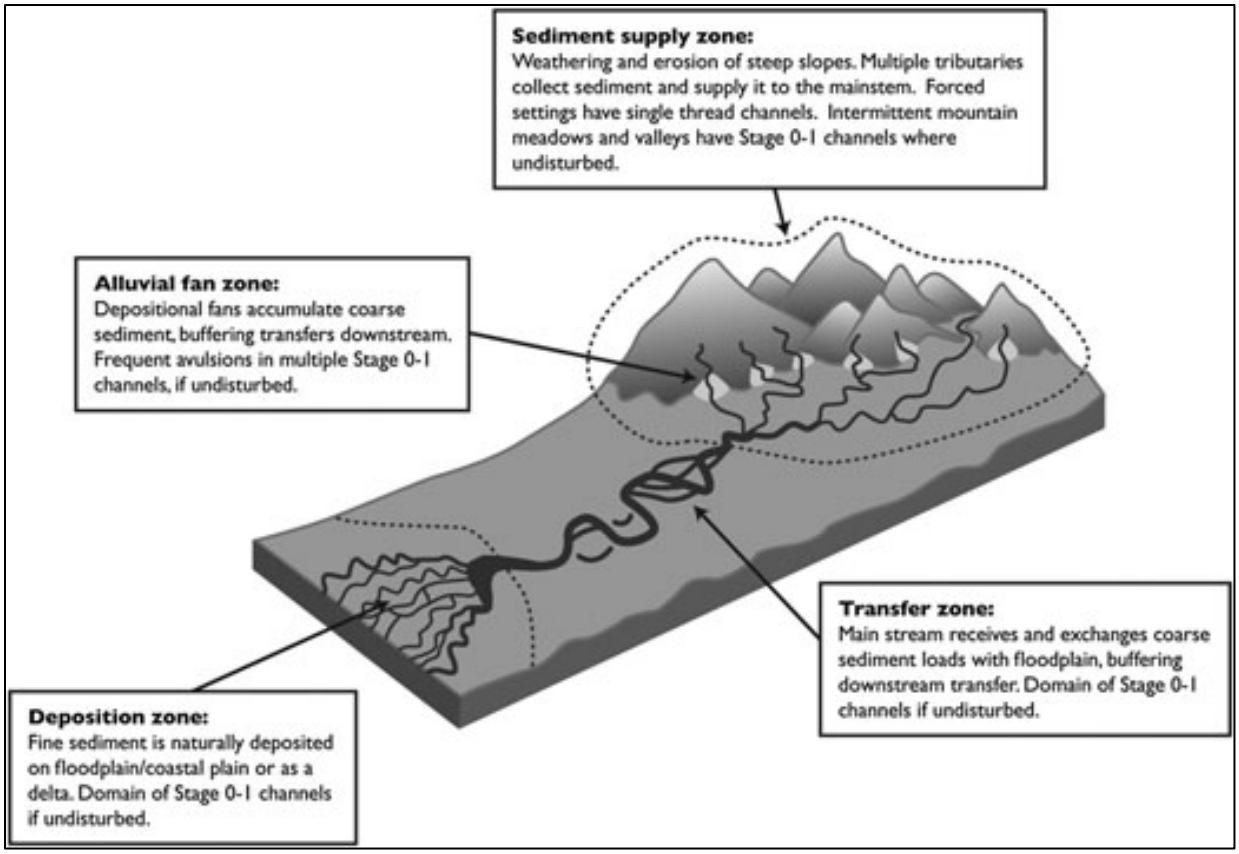


Figure 119. Locations of sediment domains within a typical watershed (Cluer and Thorne 2013).

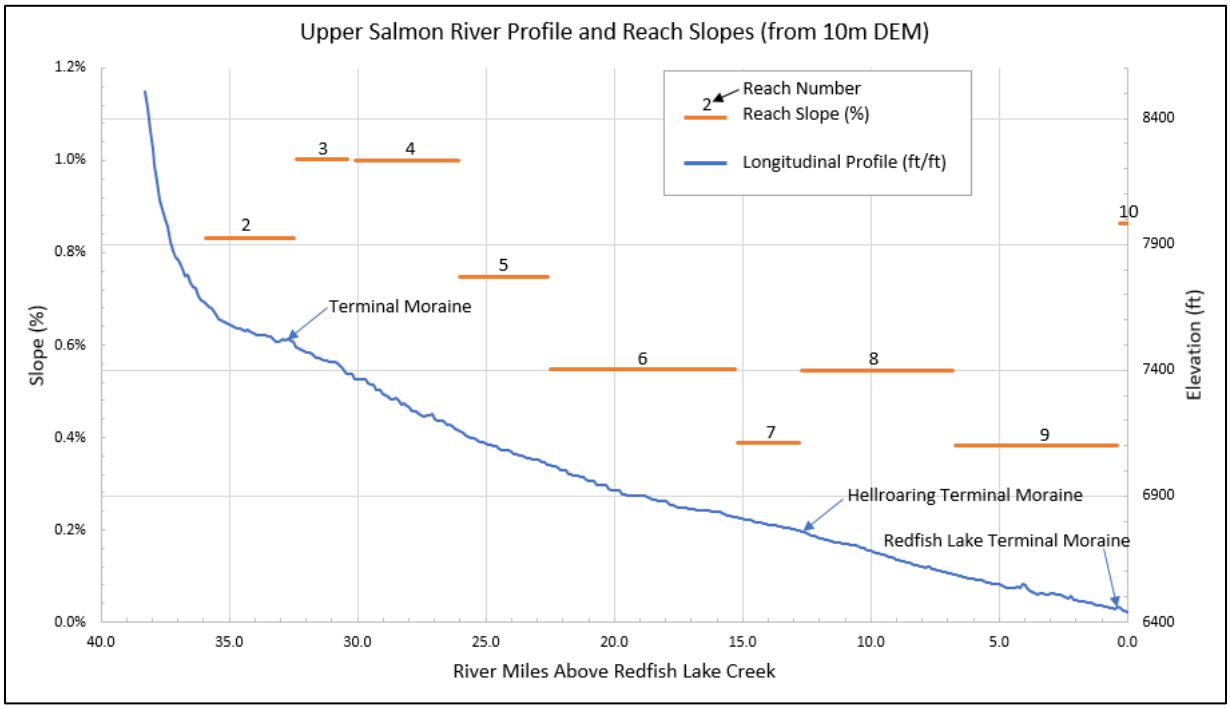


Figure 120. Upper Salmon River longitudinal profile and slope by geomorphic reach (Reach 1 slope is 6.94 percent and has been omitted from the figure to maintain a more legible scale).

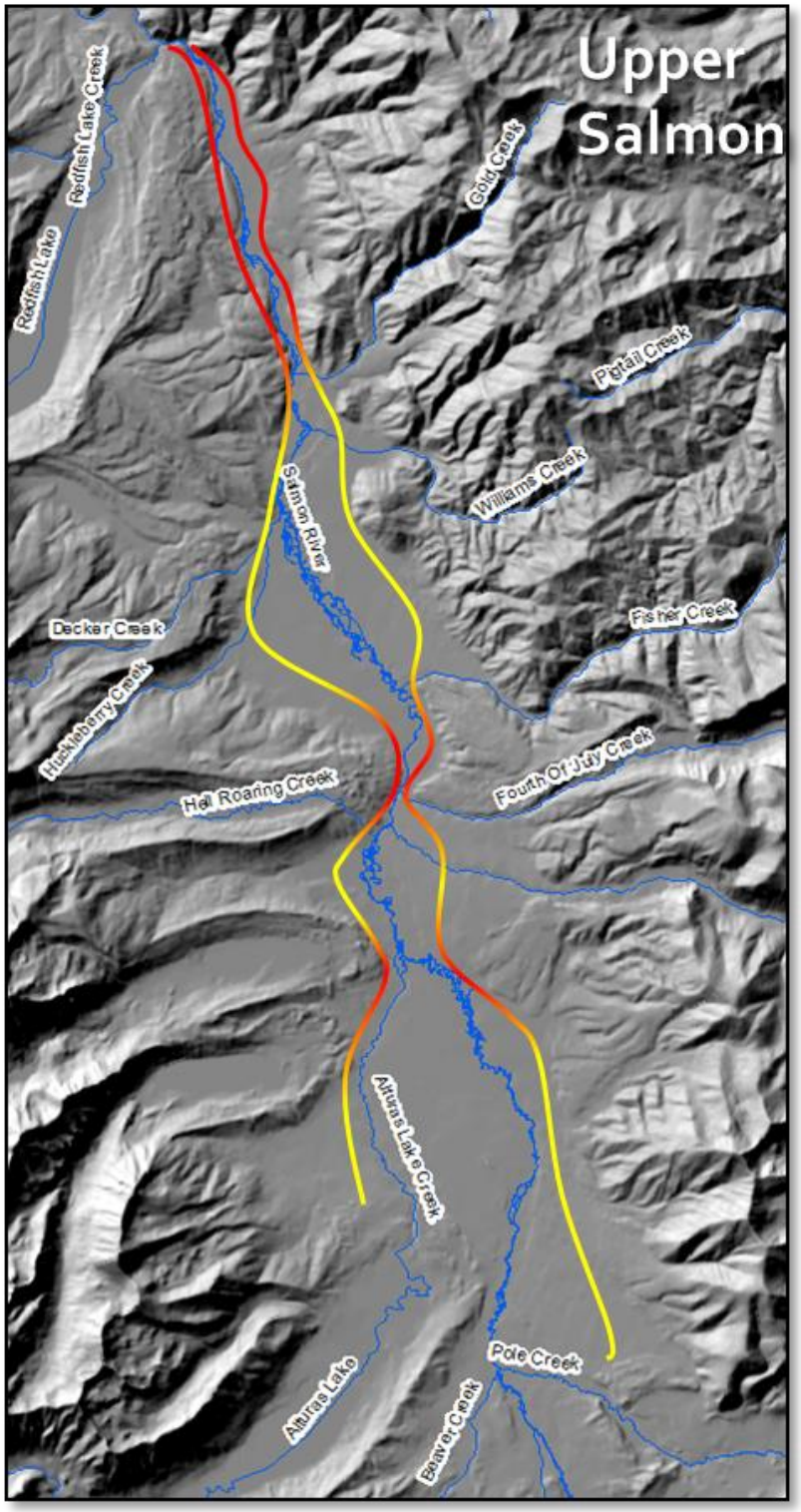


Figure 121. Illustration of valley constrictions and grade controls associated with glacial moraines and glacial outwash in the Upper Salmon River headwaters. The red lines illustrate the approximate edge of valley constrictions formed by glacial deposition on one or both sides of the valley, while the yellow lines illustrate the approximate edge of relatively unconfined valley areas.

The width of the Upper Salmon River floodplain is defined by the location of confining glacial moraines, terraces, outwash fans, and/or the valley margin. Dividing the width of the floodplain by the width of the bankfull channel produces a result called the entrenchment ratio. A small entrenchment ratio means the channel has less-accessible floodplain area and, therefore, less ability to dissipate flood energy on the floodplain, resulting in deeper, higher-velocity, more-forceful flood flows that increase the potential for erosion and/or incision (i.e., transport reach). Large entrenchment ratios are representative of channels with broadly accessible floodplains that can dissipate flood energy outside the banks of the channel, resulting in less-forceful flood flows and a tendency for deposition (i.e., response reach).

The majority of the Upper Salmon River watershed within the study area exhibits a high entrenchment ratio, with several distinct areas of confinement. The upstream-most portion of the watershed is naturally confined by a narrow valley and exhibits a low entrenchment ratio. Additionally, each of the grade controls listed above, along with other converging glacial deposits, also naturally confines the valley. Human features such as levees, road embankments, and other obstructions appear to have had minimal large-scale impact on entrenchment in the Upper Salmon River, although the impacts become more pronounced near the downstream end of the study area, where Highway 75 disconnects a large portion of the floodplain. More-detailed hydraulic modeling is required to confirm floodplain inundation timing and extent of associated entrenchment.

Soils

Geomorphic features in the Upper Salmon River valley bottom include the active channel, floodplains, alluvial fans, stream terraces, and glacial features, including moraines, outwash fans and fan terraces. Soils that have formed on these features are described in Table 57. Soil descriptions are based on the NRCS detailed soil maps and the Detailed Soil Map Units section in the report (NRCS 2003).

Table 57. Geomorphic features along the valley bottoms and margins, and associated soils.

Geomorphic Feature	Soil Description and Other Information
Active Channel	Water. Soils that have formed adjacent to or in the channel (gravel bars and islands) are described in the Floodplains soil description.
Floodplains	Soil description: a very deep, poorly drained to somewhat excessively drained soil that is dark-colored, silty loam to very cobbly sandy loam, and on floodplains and old stream channels. Slope range: 0 to 4 percent; Elevation range: 4500 to 7400 feet; Average annual precipitation: 10 to 18 inches; Average annual air temperature: 34 to 40° F; Frost-free season: 5 to 60 days; Depth class: very deep; Drainage class: very poorly drained to somewhat poorly drained; Permeability: rapid to moderate in upper part and very rapid on lower part; Available water capacity: 2.0 to 5.0 inches; Effective rooting depth: 10 to 30 inches to more than 60 inches; Runoff: slow; Hazard of water erosion: slight; Range site: mountain big sagebrush, willows, and sedges

Geomorphic Feature	Soil Description and Other Information
Alluvial Fans and Stream Terraces	Soil description: a very deep, generally well drained to somewhat excessively drained soil, is light-colored gravely loam formed on alluvial fans and stream terraces. Slope range: 1 to 8 percent; Elevation range: 6200 to 7800 feet; Average annual precipitation: 13 to 19 inches; Average annual air temperature: 33 to 40° F; Frost-free season: 5 to 60 days; Depth class: very deep; Drainage class: well-drained to somewhat excessively drained; Permeability: moderately rapid in the upper part to very rapid in the lower part; Available water capacity: 2 to 3 inches; Effective rooting depth: 10 inches to 18 inches; Runoff: slow; Hazard of water erosion: slight; Range site: mountain big sagebrush, and Idaho fescue
Outwash Fans, Fan Terraces and Moraines	Soil description: a very deep, somewhat poorly drained soil that is a darker-colored, gravely loam on outwash fans and fan terraces; sandy loam on moraines. Slope range: 2 to 10 percent (up to 15 percent on moraines); Elevation range: 6300 to 8000; Average annual precipitation: 12 to 19 inches (up to 25 inches on moraines); Average annual air temperature: 33 to 38° F; Frost-free season: 5 to 30 days; Depth class: very deep; Drainage class: well drained to excessively drained; Permeability: moderately rapid in upper part and very rapid in lower part; Available water capacity: 1 to 3 inches; Effective rooting depth: more than 60 inches; Runoff: slow; Hazard of water erosion: slight; Range site: low sagebrush, Idaho fescue, and mountain big sagebrush

Land Use

The Upper Salmon River watershed covers about 305 square miles, and about 93 percent of land is under Federal ownership. The Sawtooth National Recreation Area (SNRA) encompasses the entire watershed, with most of the upper reaches occurring in inventoried roadless areas of public land, including the Sawtooth Wilderness and the Boulder-White Clouds Wilderness. Private lands are primarily located along the more fertile valley bottoms (NOAA 2017).

The primary land uses are recreation, livestock grazing, and timber harvest. Recreation in both developed and dispersed areas is one of the most common activities. Livestock grazing and hay production are the exclusive agricultural land uses on private lands and occur across much of the middle and lower elevations in the watershed. Some timber harvesting occurs, with small operations for post and pole, personal fuelwood, or commercial saw timber and fuelwood (SNF 2006, in NOAA 2017).

Miners settled the upper Sawtooth Valley in the 1860s in the Smokey Mountains area, around the towns of Vienna and Sawtooth City, and other areas dispersed throughout the headwaters region. On August 22, 1972, Public Law 92-400 was passed, establishing the SNRA, and all lands were withdrawn from additional mineral entry, except those with existing valid claims. Currently, no active mining occurs in the SNRA (SNF 2006, in NOAA 2017).

Land Cover and Riparian Conditions

The Upper Salmon River watershed is covered by rock, water, grassland, shrubland, or meadows, including the Mountain Big Sagebrush, Montane Shrub, Basin Big Sage, Low Sage, and Dry Meadows vegetation groups. The primary forested vegetation groups include Persistent Lodgepole Pine, Warm Dry Subalpine Fir, and High Elevation Subalpine Fir. Aspen is an important component of the Persistent

Lodgepole Pine and Warm Dry Subalpine Fir groups, and whitebark pine is an important component of the High Elevation Subalpine Fir group (SNF 2003).

The riparian vegetation condition varies throughout the watershed, and localized areas have been degraded due to loss of vegetation, stream and floodplain alterations from roads, developed and dispersed recreation, water withdrawals, and livestock grazing. The native sedge and willow species are being replaced by grass species due to livestock grazing in riparian areas. In addition, irrigation diversions have had the cumulative effect of reducing wet meadows, willows, and the overall amount of riparian areas (SNF 2003).

Fire exclusion has altered vegetation succession, leading to older ages dominating structural stages, and has allowed the subalpine fir component to locally out-compete the whitebark pine component. An outbreak of mountain pine beetles and mistletoe led to large-scale mortality of mature lodgepole and whitebark stands in the late 1990s and early 2000s, which increased the fire hazard within the watershed (SNF 2003). On July 27, 2012, the Halstead Fire ignited northwest of Stanley, Idaho, and burned about 182,000 acres in timber that was described as mixed conifers, with the majority of those being dead, standing, bug-killed trees (InciWeb – Incident Information System report dated July 14, 2013).

Some noxious weeds and exotic plants are in the watershed, especially along main road and trail corridors. Plant species of particular concern are spotted knapweed and yellow toadflax that are currently found in small, scattered populations (SNF 2003).

Channel Migration

Channel migration is defined as erosion of the outside bank of a bend, coupled with concurrent deposition of sediment along the inside bank of the same bend. This process results in the lateral movement of the channel, while maintaining consistent channel shape and width (Figure 122). The peak-flow-dominated hydrology and readily available coarse sediment load in the Upper Salmon River enables frequent disturbance via pronounced channel migration throughout the Sawtooth Valley. Aerial photograph observation of active gravel bars, historical channel scars, and relic meander scrolls suggest channel migration is the dominant geomorphic process shaping the planform of the river within all but the most confined, high-gradient reaches of the study area. Low-gradient, beaver- and groundwater-influenced areas appear to exhibit greater rates of channel response and variability due to their enhanced depositional character relative to the more confined, higher-gradient, transport-dominated areas.

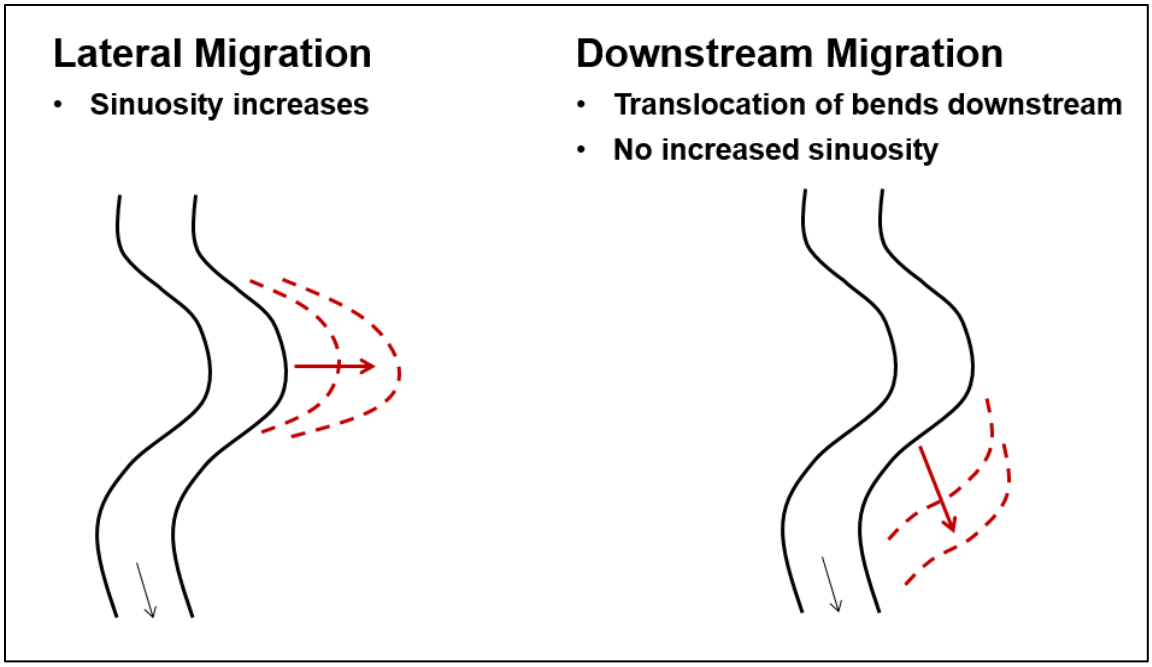


Figure 122. Simplified graphic illustrating the difference between lateral and downstream channel migration.

In areas where bank-stabilizing riparian vegetation has been cleared, bank erosion has occurred more frequently at rates greater than those of more densely vegetated banks. Sufficient coarse sediment is available to deposit gravel point bars opposite the eroding banks, generally maintaining channel geometry and preventing large-scale channel widening. Measured channel widths remain relatively consistent throughout each reach, with expected downstream gains associated with greater discharge. Conversely, where dense, woody riparian vegetation occurs, banks are stable with near-vertical to undercut geometry. The deep root systems and exposed root clumps along the banks force scour and deposition, creating and maintaining pools and riffles.

In addition to channel migration, low-gradient, beaver- and groundwater-influenced reaches also exhibit lateral channel movement via abrupt channel relocation called avulsion. Avulsions generally occur via meander cutoff or channel obstruction. Meander cutoff avulsion typically occurs when high flows bypass a large, looping meander by cutting through the narrow neck on either end of the meander. The shorter flow path rapidly expands to capture most or all of the flow, abandoning the old meander as an oxbow pond or alcove. An avulsion created by an obstruction occurs when the main flow path is blocked sufficiently to force enough flow across the floodplain to scour a new channel. Typical obstructions resulting in avulsion include excessive sediment deposition, debris jams, beaver dams, and/or ice jams.

Large Wood Recruitment and Retention

Cottonwoods are not currently observed in abundance above roughly 6,500 feet elevation on either the Salmon River or neighboring Big Wood River. Willows dominate the riparian areas above 7000 feet, providing bank stability and structure. Conifer trees, including lodgepole and whitebark pine, occupy upland areas, especially glacial moraines, which have a greater fine sediment composition and annual precipitation compared with alluvial fans and terraces. Bank erosion into areas vegetated with conifers, primarily along glacial moraines, tributaries, and upstream of Smiley Creek, provide a local source of large wood recruitment, enhancing and/or forcing channel migration and pool-riffle morphology.

Frequent, scattered pieces of large wood and several log jams are visible in recent aerial imagery of tributaries flowing through glacial moraines, but little to no large wood is visible within the mainstem Salmon River, apart from areas directly adjacent glacial moraines with conifer land cover. Large floods and debris torrents may occasionally transport large wood from the tributaries and upstream areas, but research suggests that large wood is unlikely to transport significant distances through such small streams with low channel width and depth (Braudrick and Grant 2001).

Channel Planform and Morphology

Channel planform on the Upper Salmon River is predominantly single-threaded, with a low to moderate reach-scale sinuosity ranging between 1.03 and 1.54. Sinuosity on the Upper Salmon River is the byproduct of lateral channel migration and avulsion, both of which are driven by coarse sediment deposition, with increasing response in areas of low gradient and high entrenchment ratio. Low gradients reduce overall stream power and sediment-transport capacity, and areas with high entrenchment ratios have active floodplains capable of dissipating flood energy, lowering overall channel depth and velocity. These combined characteristics tend to promote sediment deposition over transport, thereby driving channel response (including migration and avulsion), creating localized areas of high sinuosity and/or multi-threaded channels. Several reaches of the Upper Salmon River exhibit this type of response character, which is commonly enhanced by instream structure, including beaver activity and large wood. Over the past 100+ years, the removal of riparian vegetation and loss of beaver, along with irrigation diversions and channel manipulation, have likely reduced sinuosity and simplified the overall planform of the channel.

Channel morphology, as defined by Montgomery and Buffington (1998), is determined by bedform features associated with slope, discharge, sediment supply, bedrock lithology, and disturbance history. The existing channel morphology on the Upper Salmon River is predominantly characterized by a plane-bed morphology where straight and confined (Photograph 28), and is predominantly characterized by a pool-riffle morphology where sinuous and unconfined (high entrenchment ratio) (Photograph 29). Channel obstructions and bank structure-associated riparian vegetation and woody debris can increase areas of flow contraction within the channel, locally driving otherwise plane-bed morphology toward a forced pool-riffle morphology. Alternatively, where a lack of riparian vegetation has resulted in bank recession and channel widening, flow divergence reduces local transport competence and the development of scour pools driving a pool-riffle morphology toward a plane-bed morphology. Similarly, channel manipulations that have straightened and/or incised the channel tend to reduce the amount of in-stream structure and channel roughness, often creating a relatively homogenous, armored, plane-bed morphology. The significant lack of riparian vegetation and channel manipulations in some areas has likely resulted in many more linear feet of plane-bed, rather than pool-riffle, morphology relative to historic conditions. Detailed reach-scale mapping will be required to quantify this claim.

Photograph 28. Plane-bed stretch of the Upper Salmon River in Geomorphic Reach 8.

Photograph 29. Photograph example from Reach 9 illustrating a sinuous channel segment with deep scour pools along the outside of each bend, with riffles in between and woody debris associated with both.

Beaver

The existing influence from beaver has been severely limited as a result of legacy fur trapping. Evidence of existing beaver activity in several tributaries, headwaters, and small spring-fed side-channels was

observed in the field (2016; Photograph 30) and via recent aerial photographs. Limited evidence of beaver activity on the mainstem Salmon River downstream of RM 33 was observed, suggesting population numbers remain fairly low. Beaver activity likely played a significant role in modifying and developing not only the headwaters and smaller tributaries, but also the lower-gradient, multi-threaded reaches of the historic mainstem Upper Salmon River. Beavers generally require 40 to 60 percent tree/shrub canopy closure and shrub height greater than 6.6 feet within a broad/intact riparian corridor (Slough and Sadleir 1997). Beavers also require trees less than 6 inches in diameter for food source, preferring aspen, willow, cottonwood, and alder (in that order) (Denney 1952). These conditions are present in discontinuous patches throughout the valley and suggest increased beaver reestablishment is possible.

Photograph 30. Beaver dam located in a perennial side channel within a multi-threaded, groundwater-influenced portion of Reach 8.

Watershed Impacts

The Upper Salmon River watershed is within the Sawtooth National Recreation Area, and most of its upper tributary reaches occur in inventoried roadless areas of public land that include the Sawtooth Wilderness Area and the Boulder-White Clouds Wilderness. Much of the watershed is pristine and protected from anthropogenic disturbances, and only natural disturbances are allowed to occur (i.e., forest fires). Overall, the physical and ecological processes in the upper tributary reaches are intact and functioning properly. However, there are localized impacts at mid- and lower-elevations that have negatively affected riverine processes. These impacts include, but are not limited to, flow alteration from irrigation diversions, loss of riparian vegetation, excessive fine sediment, and areas of channel and floodplain alteration from roads and infrastructure.

Irrigation diversions historically dewatered (or otherwise made impassible to anadromous fish) many tributaries to the Salmon River during critical anadromous fish life cycles, including Smiley Creek, Beaver Creek, Pole Creek, Champion Creek, and Fourth of July Creek (USFS 1975). The most significant impacts were associated with irrigation diversions on the Busterback Ranch, which historically dewatered both the Salmon River and Alturas Lake Creek during the summer low flows of most years between 1941

and 1992 (USFS 1975) (Photograph 31). This action was estimated to have significantly disrupted more than 32.5 miles of spawning and rearing habitat upstream of the diversions (Moulton 2014). Water rights associated with the ranch included 65.6 cfs from the Salmon River and 37.3 cfs from Alturas Lake Creek. In 1992, the majority of the Busterback Ranch and 96.53 cfs of associated water rights were purchased through a joint effort by the USFS, Bonneville Power Administration, and the Nature Conservancy, restoring consistent, perennial flows to both the Salmon River and Alturas Lake Creek (Wells 1992). An additional roughly 100 cfs of water rights held within the Sawtooth National Recreation Area have been subsequently eliminated or discontinued for instream use since 1992. Nevertheless, substantial irrigation losses continue to adversely impact instream discharge and fish passage. Another effect of irrigation diversions is an alteration of the timing and spatial distribution of groundwater recharge. Diversions redistribute river water onto the floodplain during the summer months, often artificially increasing groundwater levels in those locations.

Photograph 31. Historic oblique aerial photograph of the dewatered section of channel immediately downstream of the Busterback diversion prior to its removal.

Livestock grazing and agricultural land use practices have changed the riparian vegetation in many areas by replacing native woody riparian species (primarily willow) with grasses and other herbaceous species incapable of providing the same level of bank stability and cover. Observations of significant bank erosion generally correspond with areas where willow riparian vegetation has been reduced or lost as a result of relic or modern livestock grazing or agriculture.

Grazing and agricultural practices, as well as dirt roads and trails, have a cumulative effect on fine sediment accumulation in the Upper Salmon River. Sheetwash erosion and excessive bank erosion associated with lost riparian vegetation contribute elevated levels of fine sediment to the system from spring snowmelt and summer rainstorm runoff. Similarly, sheetwash and wind-blown fine sediment from roads and trails adds to the level of fine sediment contribution from the watershed. Fine sediment fills

interstitial spaces between gravels and cobbles, eliminating concealment cover for over-wintering juvenile fish and reducing bed and pool scour potential through substrate embeddedness.

Channel and floodplain alterations from roads and infrastructure are prevalent primarily in the lower reaches and near the Sawtooth Fish Hatchery, where the channel has been straightened and confined, and a large portion of the floodplain has been disconnected from channel interactions by roads that function as levees (including Highway 75). Additionally, two channel-spanning weirs associated with the Sawtooth Fish Hatchery obstruct the natural passage of fish and sediment within the reach, contributing to the localized channel alterations of the reach.

Data Gaps

Future analysis could be aided by the collection of additional data currently unavailable, including:

- Hydraulic modeling to confirm floodplain inundation timing and extent, sediment transport character, and appropriate channel geometry (i.e., width-to-depth ratio).
    - Data gaps necessary for hydraulic modeling include detailed topography and bathymetry data, frequent pebble counts, and an improved understanding of diversion withdrawals/returns, tributary inflows, and groundwater contributions.
- Riparian vegetation inventory, including health and successional stages within the low surface that directly influence lateral channel migration, force pool-riffle bedforms, sort and retain gravel, and provide bank stability.

The acquisition of LiDAR will aid hydraulic modeling and riparian vegetation inventories in addition to future assessment and design efforts in the Sawtooth Valley.

Upper Salmon Valley Segments and Geomorphic Reaches

Valley segments, geomorphic reaches, and channel units are three hierarchically nested subdivisions of the drainage network (Frissell et al. 1986). Within the hierarchy of spatial scales, valley segments, geomorphic reaches, and channel units represent the largest physical subdivisions that can be directly altered by human activities. As such, it is useful to understand how they respond to anthropogenic disturbance, but to do so requires classification systems and quantitative assessment procedures that facilitate accurate, repeatable descriptions and convey information about biophysical processes that create, maintain, and destroy channel structure (Bisson, Buffington, and Montgomery 2006).

Valley Segments

The Upper Salmon River has a predominantly alluvial valley and has varying discharge and morphology along its course due to flow and sediment inputs from sub-watersheds (Table 58). Two valley segments were identified based on the location of where the Upper Salmon River begins and where the sub-watersheds interact with or are identified along the mainstem (Figure 123).

Table 58. Upper Salmon River watershed valley segment delineations and sub-watersheds.

Valley Segments and Locations	Sub-watershed	HUC 10	River Miles	Square Miles
Pole Creek Valley Segment (Headwaters to RM 15.3)	Pole Creek – Salmon River	1706020102	Upstream of 15.3	106
	Alturas Lake Creek	1706020103		70
Redfish Lake Creek Valley Segment (RM 15.3 to 0)	Portion of Redfish Lake Creek – Salmon River	1706020104	15.3 - 0	128
Total				**195,200 acres**

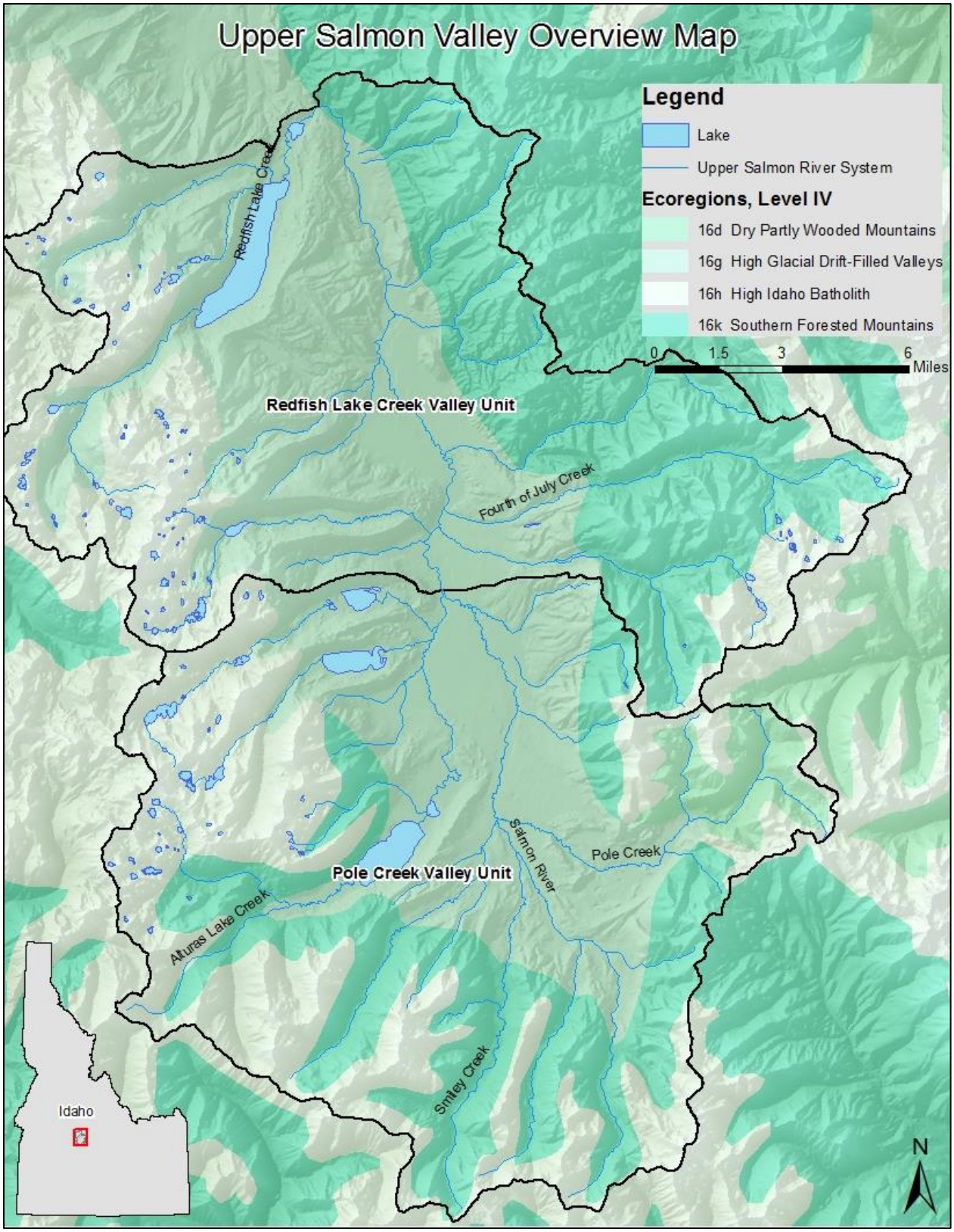


Figure 123. Upper Salmon River watershed valley segment locations.

Reach Characteristics

Reach characteristics are summarized per reach in Table 59 below.

Table 59. Summary of geomorphic reach characteristics for the Upper Salmon watershed.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-1	GR-1	38.3 - 36.0	0.0767	97	96	0.0713	11	1.1	9	9	1%	-	0%	100%	0%
VS-1	GR-2	36.0 - 32.5	0.0131	499	501	0.0092	17	1.4	29	29	8%	-	73%	11%	0%
VS-1	GR-3	32.5 - 30.4	0.0121	339	340	0.0091	18	1.3	18	18	2%	-	77%	20%	3%
VS-1	GR-4	30.4 - 26.1	0.0123	252	228	0.0099	17	1.2	15	13	3%	-	36%	62%	3%
VS-1	GR-5	26.1 - 22.6	0.0095	652	650	0.0072	33	1.3	20	20	1%	Gaining	70%	28%	2%
VS-1	GR-6	22.6 - 15.3	0.0083	944	877	0.0054	37	1.5	26	24	1%	Losing	62%	38%	0%
VS-2	GR-7	15.3 - 12.8	0.0050	1584	1,525	0.0038	68	1.3	23	22	1%	Gaining	76%	24%	0%
VS-2	GR-8	12.8 - 6.6	0.0063	1280	1280	0.0048	66	1.3	19	19	6%	Gaining	81%	14%	5%
VS-2	GR-9	6.6 - 0.4	0.0057	1123	903	0.0052	72	1.1	16	13	3%	-	73%	18%	9%
VS-2	GR-10	0.4 - 0.0	0.0020	122	-	0.0020	78	1.0	2	-	0%	-	56%	44%	0%

- No constraints exist within the approximated floodplain.

Pole Creek Valley Segment (VS-1)

The Pole Creek Valley Segment comprises the Pole Creek sub-watershed (HUC 10 – 1706020102) with 106 square miles (68,129 acres), and the Alturas Lake Creek sub-watershed (HUC 10 – 1706020103) with 70 square miles (45,008 acres), for a total of 177 square miles (113,137 acres) (Figure 124). The valley segment is along the Upper Salmon River from the headwaters to about RM 15.3 and contains Geomorphic Reaches GR-1 through GR-6. In the Pole Creek sub-watershed, elevations range from a low of about 6820 feet at the Upper Salmon River and Alturas Lake Creek confluence to a high of about 10100 feet along the ridgeline near Bromaghin Peak. Named tributaries in this valley segment include Beaver Creek, Smiley Creek, Frenchman Creek, Pole Creek, Taylor Creek, Lost Creek, Warm Creek, and Camp Creek. In the Alturas Lake Creek sub-watershed, elevations range from a low of about 6820 feet where Alturas Lake Creek enters the Upper Salmon River to a high of about 10600 feet along the ridgeline near Snowyside Peak. Named waterbodies include Alturas Lake, Perkins Lake, Twin Lakes, Alice Lakes, Toxaway Lake, Pettit Lake, and Yellow Belly Lake. Named tributaries include Alpine Creek, Cabin Creek, Vat Creek, and Alturas Lake Creek.

This valley segment includes portions of the supply, alluvial fan, and transfer zones where coarse sediment is generated in the headwaters, accumulates across broad alluvial fans, and finally enters the mainstem, where it is exchanged with bed, bar, and floodplain deposits through channel/floodplain interactions. The Upper Salmon River is believed to lose water to the groundwater system through

geomorphic reaches GR-1 and GR-2 and naturally runs dry during low-flow periods from about RM 35.55 to 34.72.

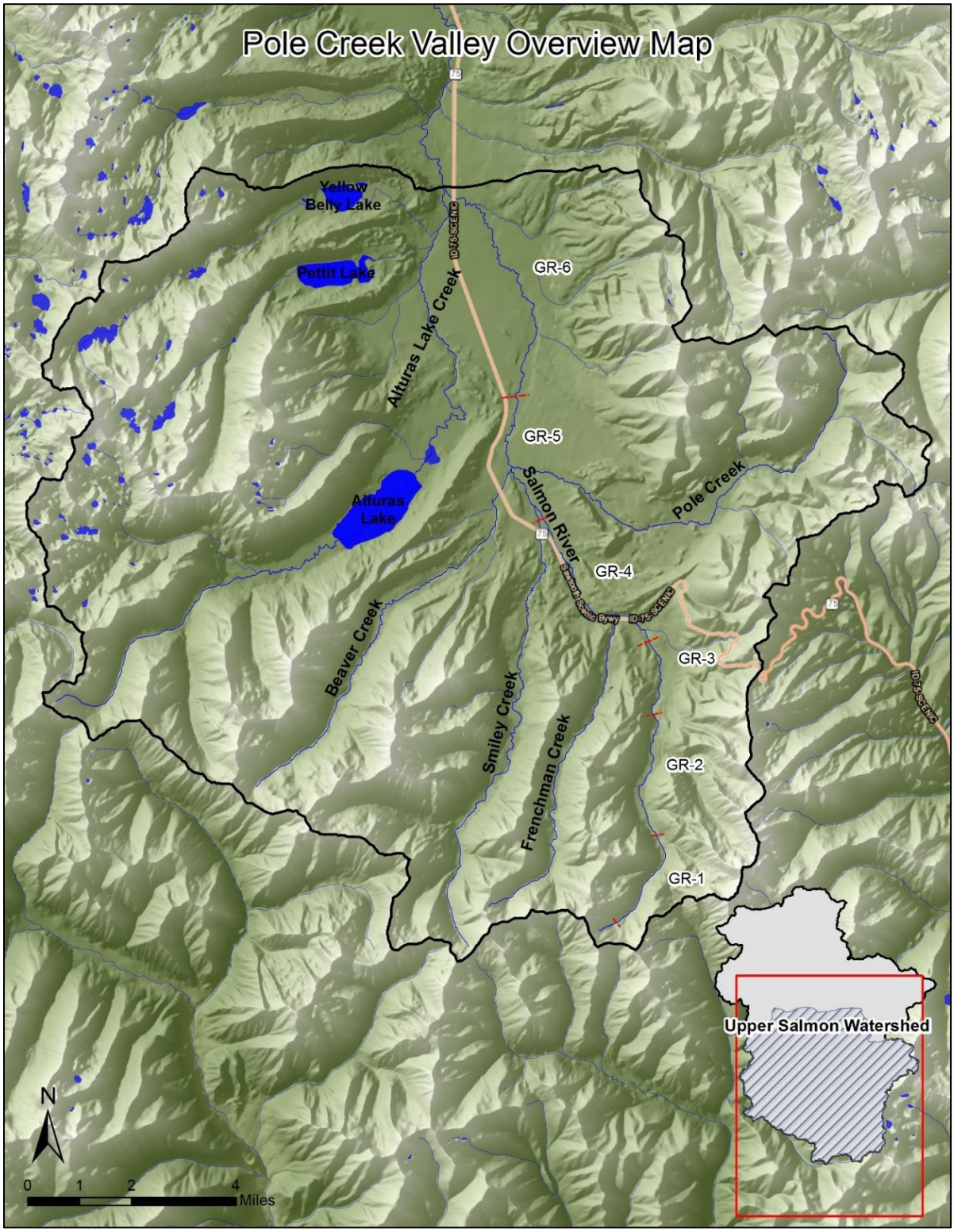


Figure 124. Location of Pole Creek Valley Segment and associated geomorphic reaches (GR-1 through GR-6).

Geomorphic Reach GR-1 (RM 38.3 – 36.0)

Geomorphic Reach GR-1 is located along the Upper Salmon River between RM 38.3 and RM 36.0. The riverine system begins where water flowing through glacial debris and colluvium daylights near RM 38.3 in a channelized colluvial valley. The reach becomes less confined farther downstream, with no valley bottom constraints (Figure 125). The downstream end of the reach is defined by a geological grade control near RM 36.0. Reach characteristics are summarized below in Table 60.

Table 60. Summary of attributes for Geomorphic Reach GR-1.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-1	GR-1	38.3 - 36.0	0.0767	97	97	0.0713	11	1.1	9	9	1%	-	0%	100%	0%

Forms

- Relatively straight, single-thread, headwater channel confined by the valley margins.
- Primarily step-pool (or forced step-pool) morphology.
- Significant volume of individual pieces of large wood (no log jams).
- Geologic grade control associated with ancient glacial activity enables the establishment of a relatively low-gradient, wet meadow at the downstream end of the otherwise high-gradient reach.

Processes

- Dominated by sediment transport.
- Presumed to be primarily losing flow to groundwater, with the exception of the wet meadow at the downstream end of the reach, where a geologic grade control enables what appears to be a small gaining area.
- Large wood recruitment via avalanches, mass wasting, and wind throw; little to no large wood transport due to the small width and shallow depth of the channel.
- Probable beaver activity in the wet meadow.

Human Impact

- Minimal human impact.
- Fine sediment from an abandoned road (recently closed and converted to a trail).

Response Potential

- Minimal.
- Sediment transport and incision.
- Bank erosion and localized large wood recruitment.

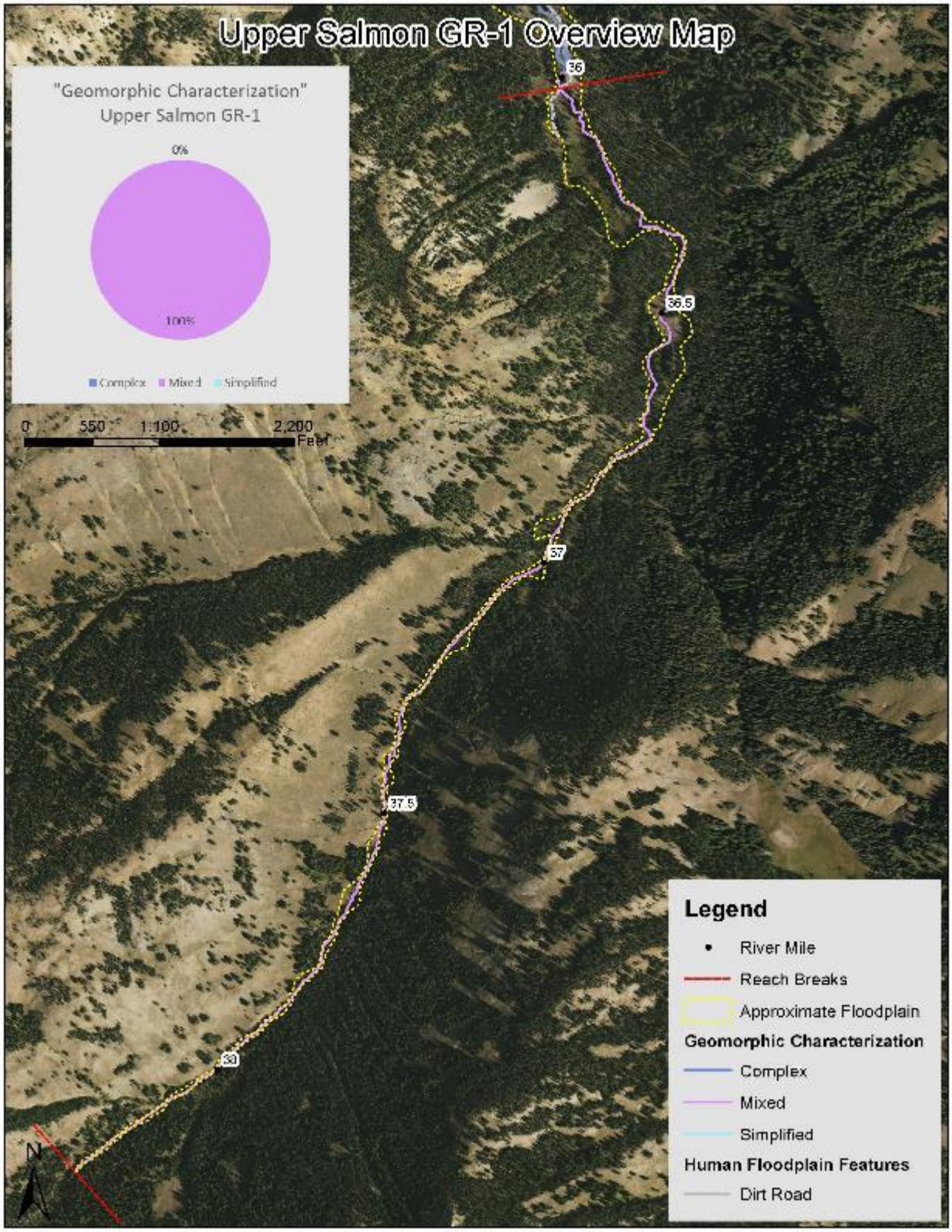


Figure 125. GR-1 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-2 (RM 36.0 – 32.5)

Geomorphic Reach GR-2 is located along the Upper Salmon River between RM 36.0 and RM 32.5 in a naturally unconfined valley, with no human features constraining valley or channel width (Figure 126). Reach characteristics are summarized below in Table 61.

Table 61. Summary of attributes for Geomorphic Reach GR-2.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-1	GR-2	36.0 - 32.5	0.0131	499	499	0.0092	17	1.4	29	29	8%	-	73%	11%	0%

Forms

- Moderate sinuosity, single-thread channel with numerous side channels and ponds.
- Upper reach is naturally dewatered during low-flow periods (RM 35.55 to RM 34.72).
- Primarily grass and shrub species in the dewatered section; dense riparian vegetation consisting primarily of willow and other shrubs downstream of dewatered section.
- Dry upper reach has unstable banks and a braided morphology.
- Groundwater-influenced lower reach has well-vegetated, stable banks with a pool-riffle morphology.

Processes

- Mixed sediment-transport regime, including deposition, temporary storage, and transport.
- Beaver activity in the wet meadows visible in aerial photography.

Human Impact

- Minimal human impact; an access road to the upper section has been decommissioned and is now a trail. There is a developed campsite and dispersed campsites in the lower section.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations. The historical cattle grazing allotment in this area may have been closed in conjunction with the decommissioning of the access road.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams).
- Channel avulsion associated with instream obstruction (coarse sediment deposition, beaver dams, debris flows).
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

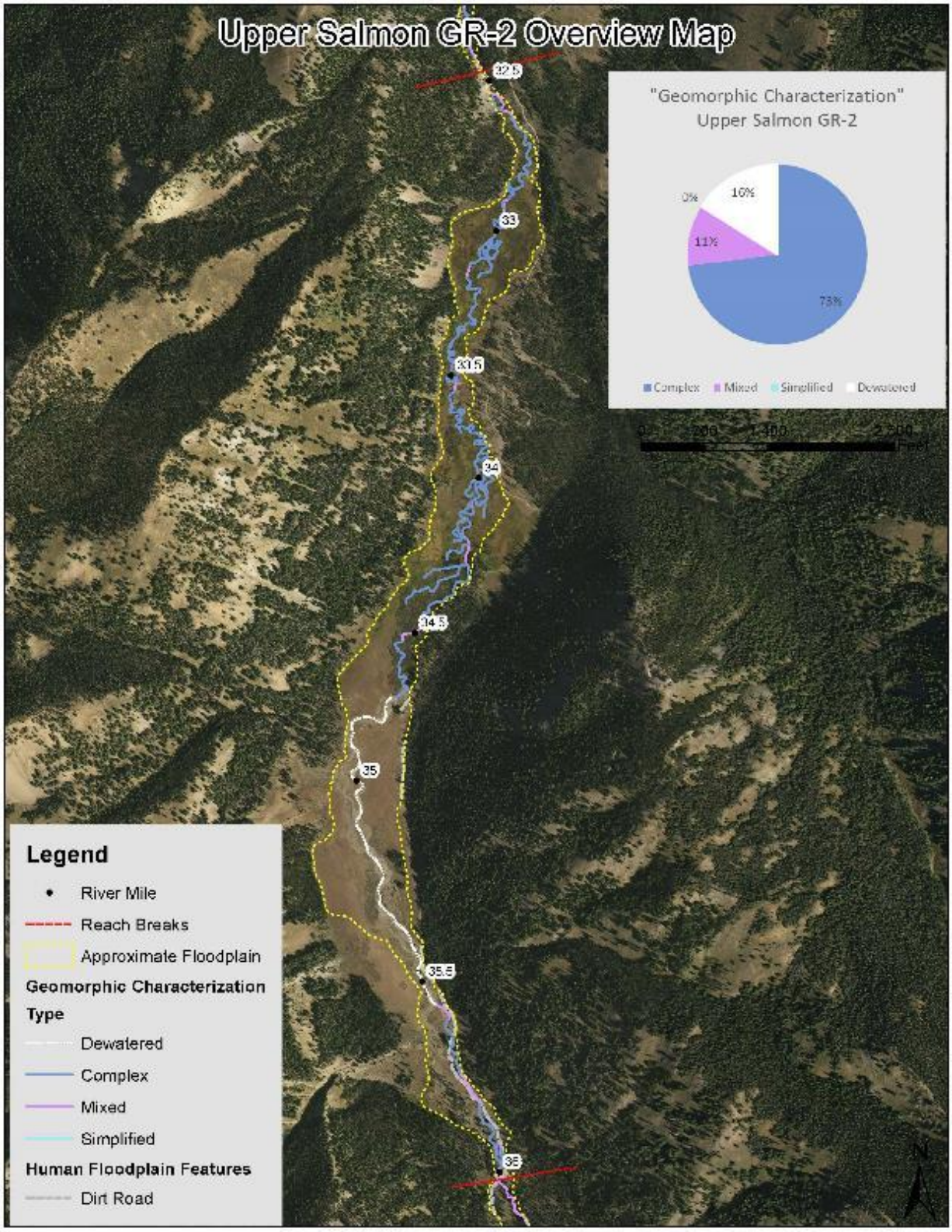


Figure 126. GR-2 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-3 (RM 32.5 – 30.4)

Geomorphic Reach GR-3 is located along the Upper Salmon River between RM 32.5 and RM30.4 in an unconfined valley, with no human features constraining the valley bottom (Figure 127). The upper end of the reach is defined by a glacial moraine that constricts the valley width. Much of the reach flows through variable glacial terrain, providing apparent areas of groundwater gains and losses. Reach characteristics are summarized below in Table 62.

Table 62. Summary of attributes for Geomorphic Reach GR-3.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-1	GR-3	32.5 - 30.4	0.0121	339	339	0.0091	18	1.3	18	18	2%	-	77%	20%	3%

Forms

- Moderate sinuosity, single-thread channel with occasional side channels and ponds.
- Primarily pool-riffle morphology.
- Significant volume of individual pieces of large wood with a few log jams.
- Continuous dense riparian vegetation consisting primarily of willow and pine trees with sections of grass and shrubs.

Processes

- Relatively stable banks; minimal channel migration; some widening observed upstream of beaver dams.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.
- Observable beaver activity in the wet meadows.

Human Impact

- Minimal human impacts.
- Several dispersed campsites along the river.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction.
- Channel avulsion associated with instream obstruction (debris jams and beaver dams).

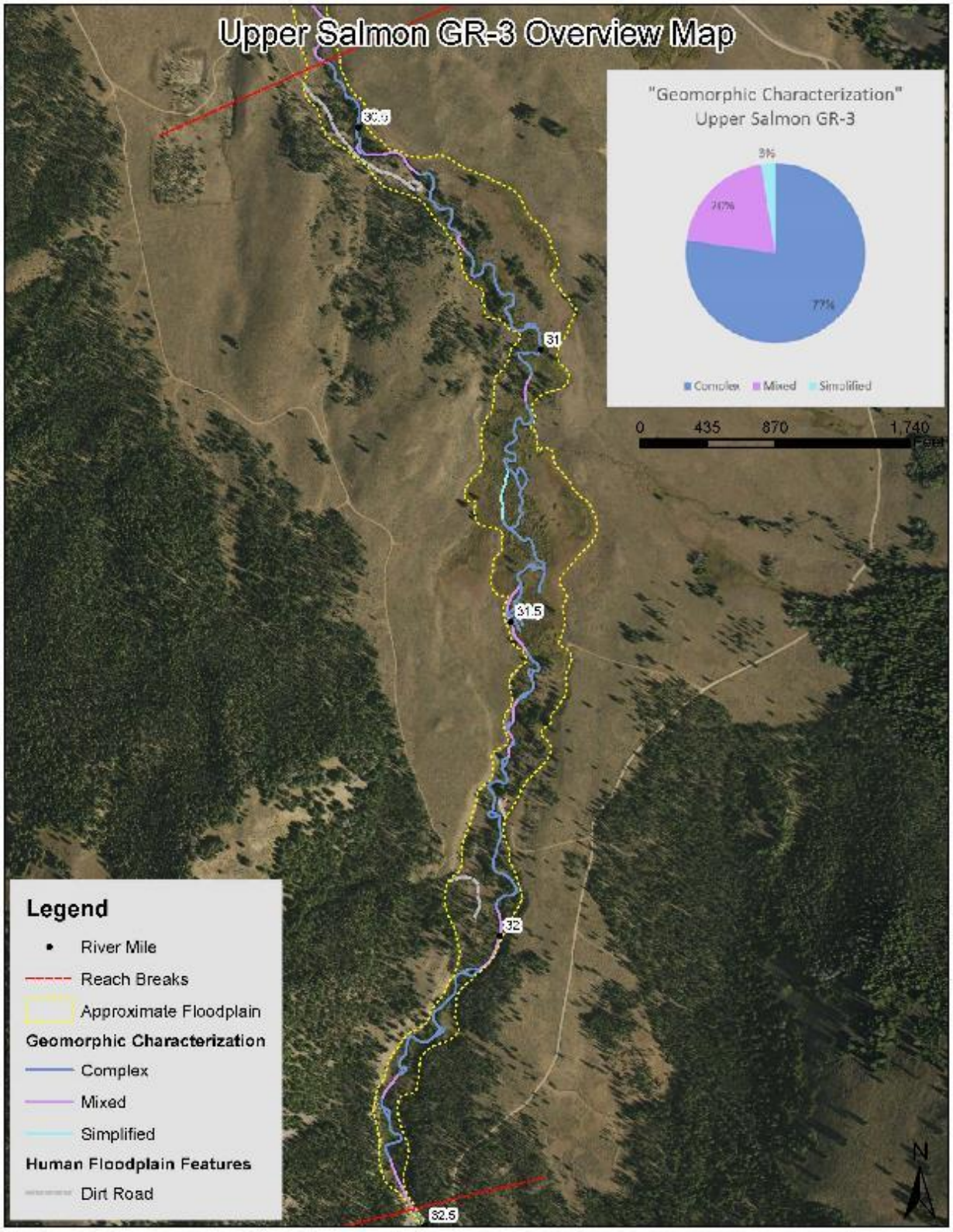


Figure 127. GR-3 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-4 (RM 30.4 – 26.1)

Geomorphic Reach GR-4 is located along the Upper Salmon River between RM 30.4 and RM 26.1 and is naturally confined by glacial terraces, with minor valley-bottom constraints associated with Highway 75 (Figure 128). Reach characteristics are summarized below in Table 63.

Table 63. Summary of attributes for Geomorphic Reach GR-4.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-1	GR-4	30.4 - 26.1	0.0123	252	218	0.0099	17	1.2	15	13	3%	-	36%	62%	3%

Forms

- Low to moderate sinuosity, single-thread channel with occasional side channels.
- Primarily pool-riffle morphology.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs.

Processes

- Relatively stable banks; minimal channel migration; some widening observed where riparian vegetation is lacking.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.

Human Impact

- Minor human impacts.
- Cattle grazing impacts including bank erosion and lost riparian vegetation in several locations.
- Minimal valley confinement associated with Highway 75.
- Cattle grazing, dirt roads, bridges and irrigation diversion.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams).
- Channel avulsion associated with instream obstruction (coarse sediment deposition, debris, and ice jams).
- Channel widening and simplification associated with lost bank vegetation.

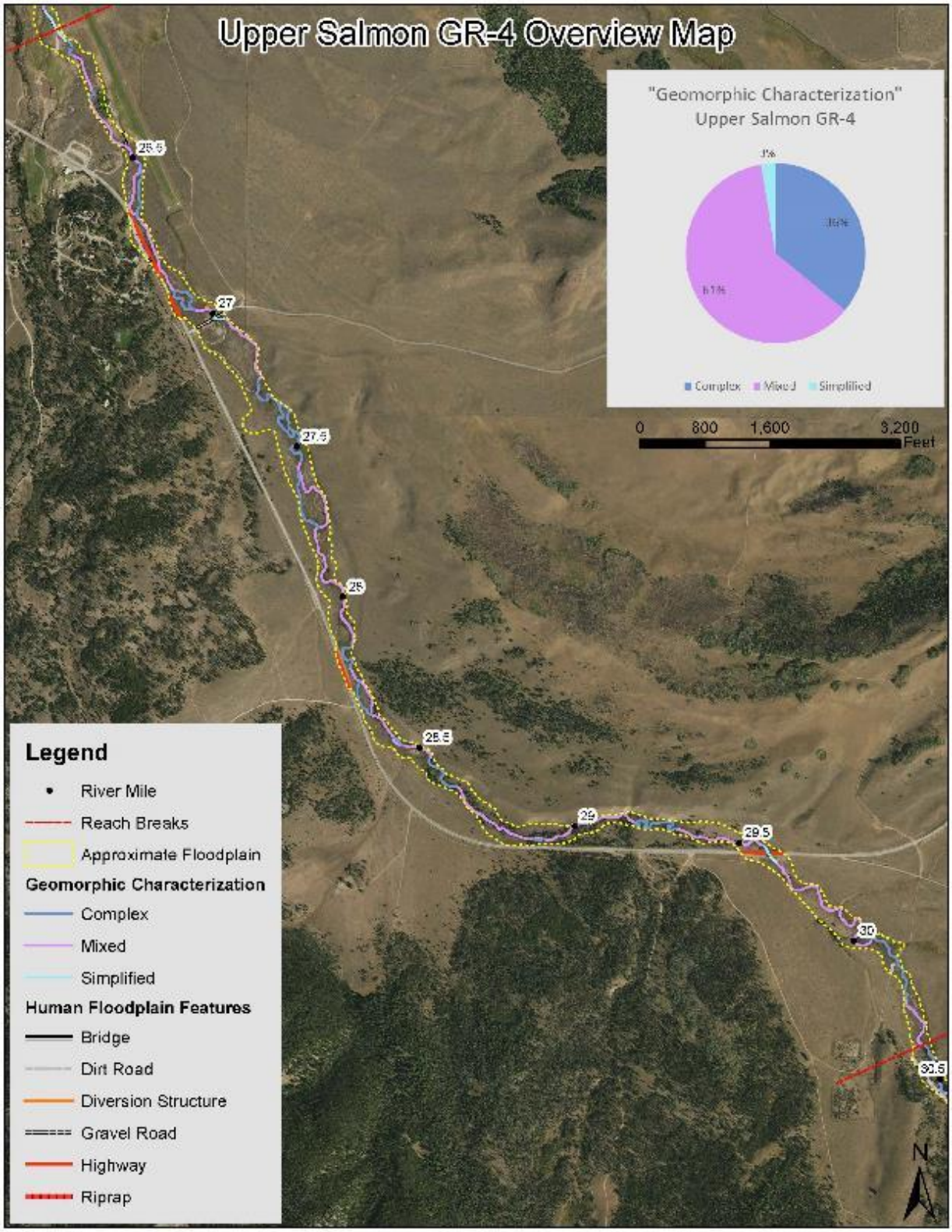


Figure 128. GR-4 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-5 (RM 26.1 – 22.6)

Geomorphic Reach GR-5 is located along the Upper Salmon River between RM 26.1 and RM 22.6 in an unconfined valley, with no significant valley-bottom constraints (Figure 129). Reach characteristics are summarized below in Table 64.

Table 64. Summary of attributes for Geomorphic Reach GR-5.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-1	GR-5	26.1 - 22.6	0.0095	652	652	0.0072	33	1.3	20	20	1%	Gaining	70%	28%	2%

Forms

- Moderate sinuosity, single-thread channel with numerous side channels and ponds.
- Primarily pool-riffle morphology.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs. Greater riparian density in multi-threaded areas.
- Gaining reach associated with geologic control formed by the Alturas glacial moraine.

Processes

- Relatively stable banks; minimal channel migration; some widening observed where riparian vegetation is lacking.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport.
- Beaver activity in the wet meadows visible in aerial photography.

Human Impact

- Minor human impacts.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations.
- Cattle grazing, dirt roads, and bridges.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams).
- Channel avulsion associated with instream obstruction (coarse sediment deposition, beaver dams, debris, and ice jams).
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

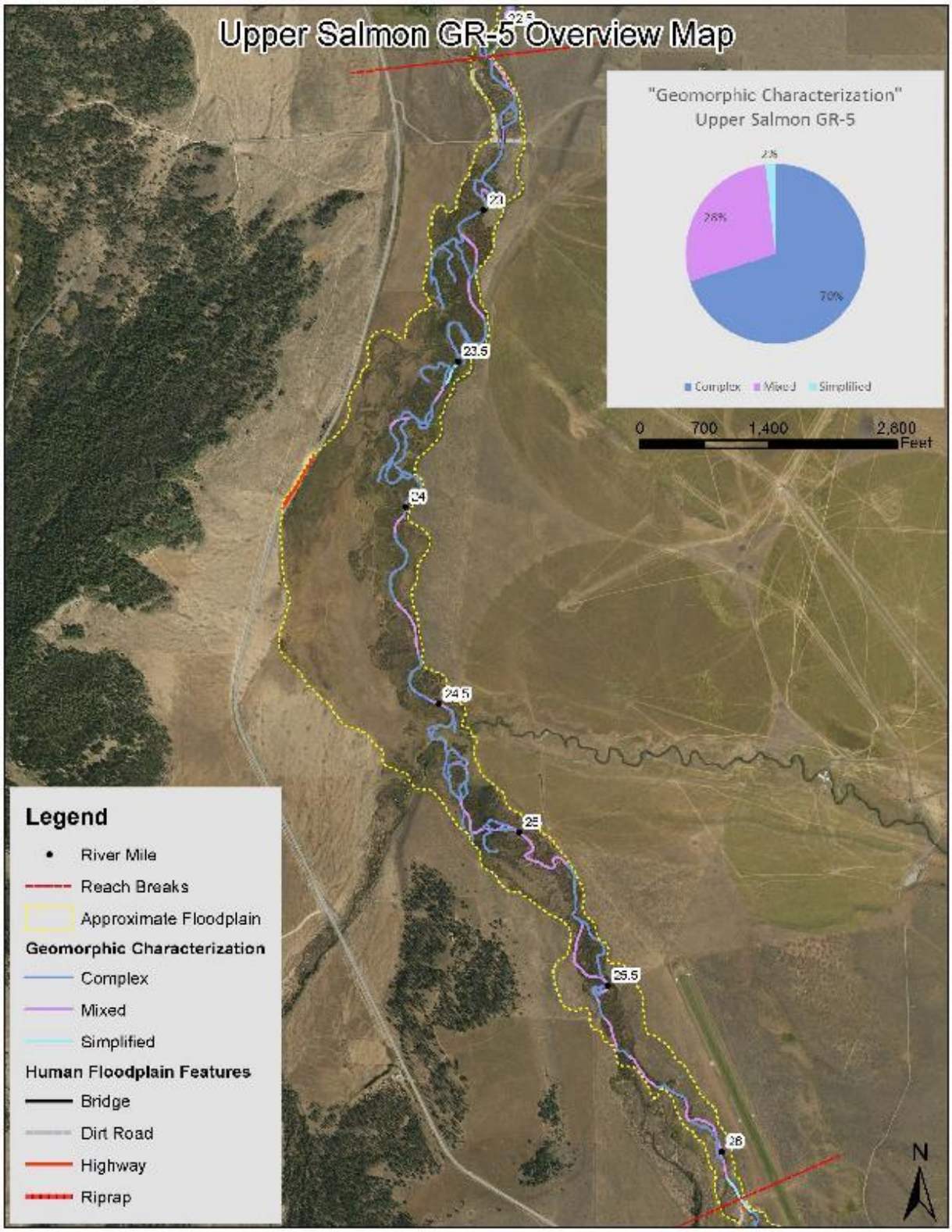


Figure 129. GR-5 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-6 (RM 22.6 – 15.3)

Geomorphic Reach GR-6 is located along the Upper Salmon River between RM 22.6 and RM 15.3 in a naturally unconfined valley, with minimal valley-bottom constraints associated with human infrastructure (Figure 130). Reach characteristics are summarized below in Table 65.

Table 65. Summary of attributes for Geomorphic Reach GR-6.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-1	GR-6	22.6 - 15.3	0.0083	944	877	0.0054	37	1.5	26	24	1%	Losing	62%	38%	0%

Forms

- Sinuous, single-thread channel with numerous side channels and ponds.
- Primarily plane-bed morphology in areas of low sinuosity and pool-riffle morphology in more sinuous sub-reaches.
- Thin ribbon of riparian vegetation consisting primarily of willow and other shrubs throughout the majority of the reach; more continuous and densely vegetated riparian area within the downstream, groundwater-influenced portion of reach.
- Active point bars throughout the middle portion of the reach.

Processes

- Losing to groundwater throughout the majority of the reach; gaining from groundwater below RM 17.
- Increasing evidence of channel migration, especially where riparian vegetation is lacking.
- Complex sediment-transport regime, including deposition, temporary storage, and transport.
- Island braiding around densely vegetated patches primarily in groundwater-influenced area.
- Beaver activity in the wet meadows visible in aerial photography.

Human Impact

- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations.
- Irrigation diversions, bridge and dirt roads.

Response Potential

- Increased sinuosity, island braiding, and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams).
- Channel avulsion associated with instream obstruction (coarse sediment deposition, beaver dams, debris jams).
- Channel widening and simplification associated with lost bank vegetation and eroding banks.

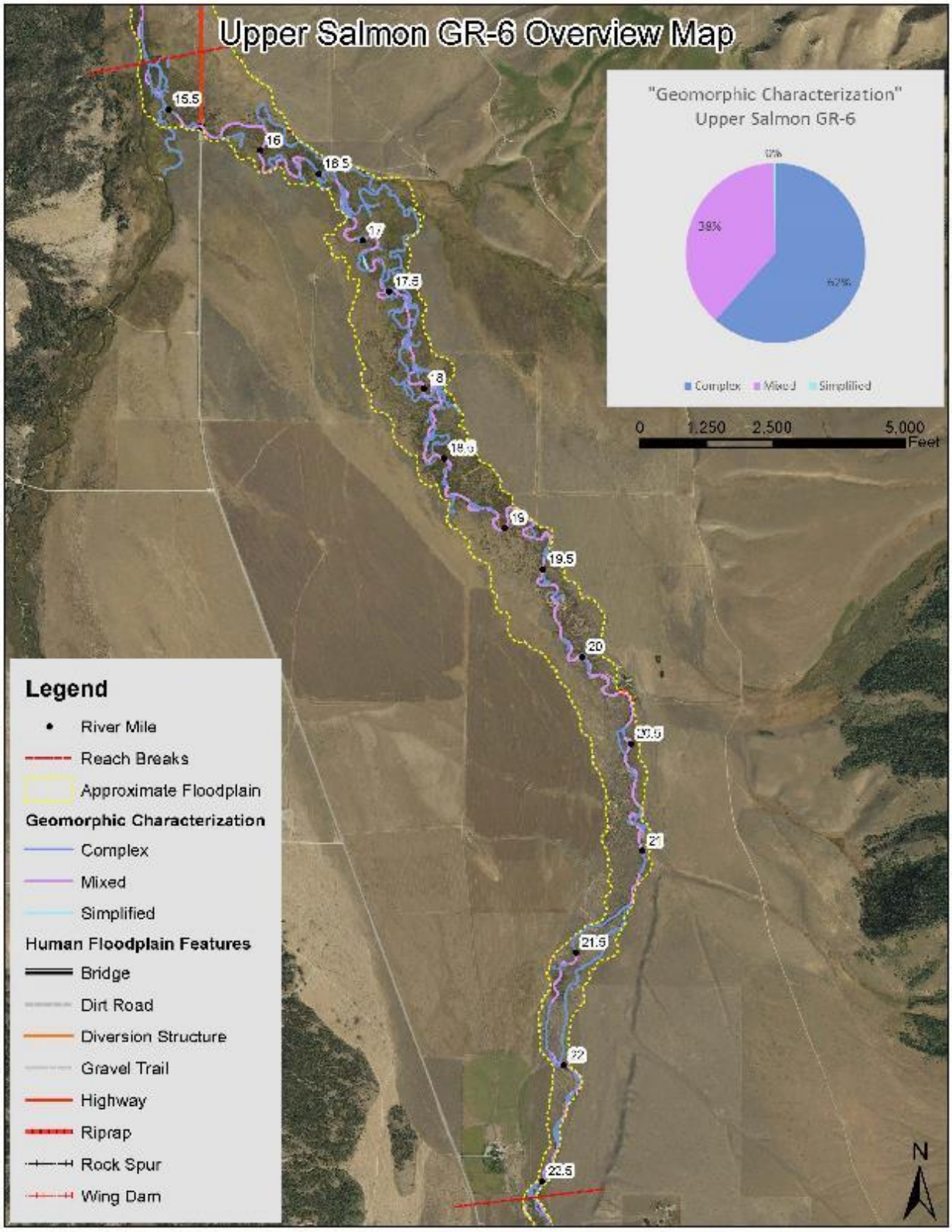


Figure 130. GR-6 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Redfish Lake Creek Valley Segment (VS-2)

The Redfish Lake Creek Valley Segment comprises the Upper Salmon River upstream of Redfish Lake Creek from about RM 15.3 to RM 0.0 and contains Geomorphic Reaches GR-7 through GR-10 (Figure 131). Elevations range from a low of about 6440 feet at the Upper Salmon River and Redfish Lake Creek confluence to a high of about 10700 feet in the Sawtooth Mountains. This valley segment is in the transfer zone where coarse sediment is exchanged with the bed, bars, and floodplain through channel/floodplain interactions. Named waterbodies in this valley segment include Imogene Lake, Hell Roaring Lake, Upper Cramer Lake, Redfish Lake, Little Redfish Lake, Heart Lake, and Fourth of July Lake. Named tributaries in this valley segment include Fishhook Creek, Decker Creek, Huckleberry Creek, Hell Roaring Creek, Mays Creek, Champion Creek, Fourth of July Creek, Fisher Creek, Williams Creek, and Gold Creek.

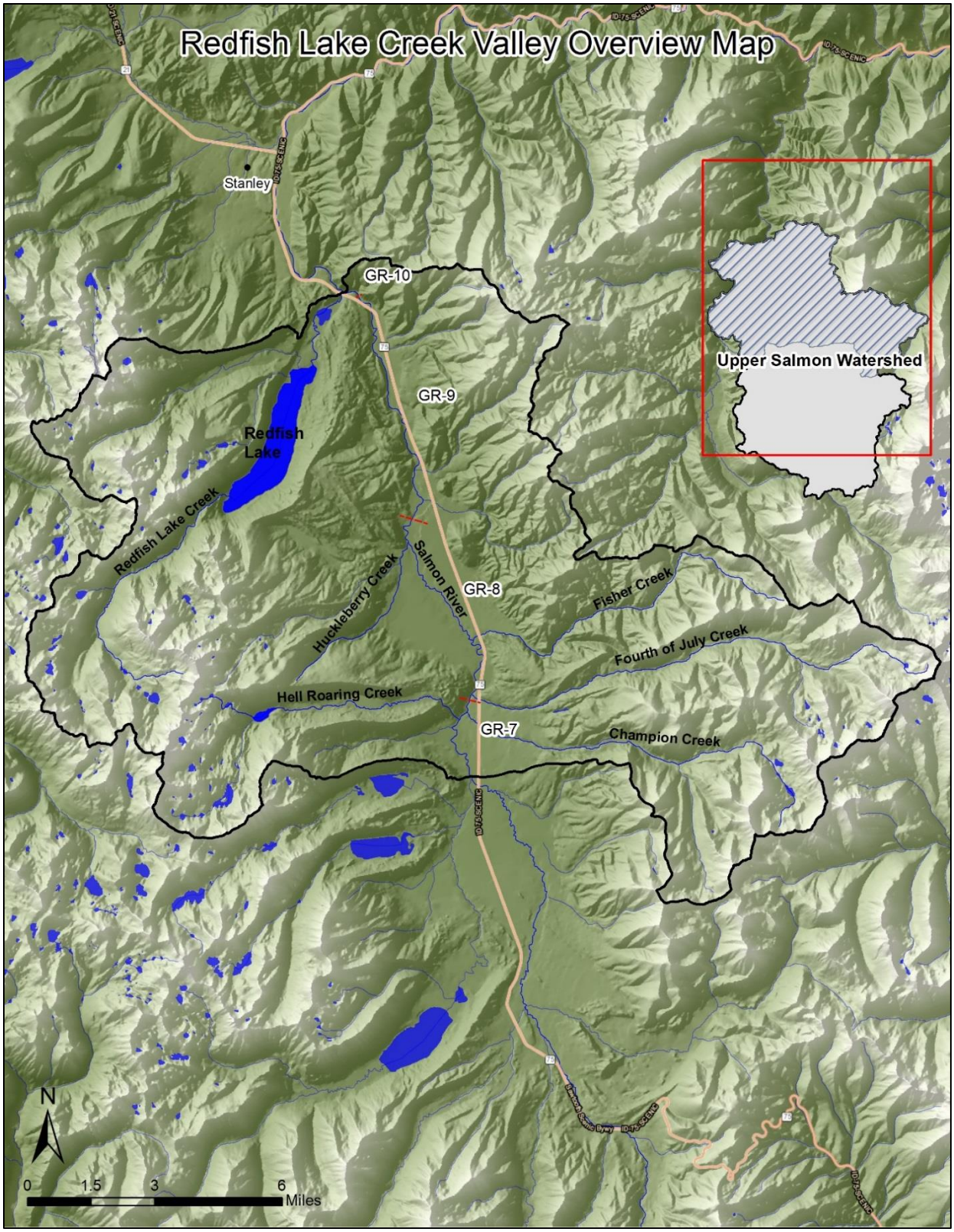


Figure 131. Location of Redfish Lake Creek Valley Segment and associated geomorphic reaches (GR-7 through GR-10).

Geomorphic Reach GR-7 (RM 15.3 – 12.8)

Geomorphic Reach GR-7 is located along the Upper Salmon River between RM 15.3 and RM 12.8 in a naturally unconfined valley, with no major valley-bottom constraints associated with human features (Figure 132). Reach characteristics are summarized below in Table 66.

Table 66. Summary of attributes for Geomorphic Reach GR-7.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-7	15.3 - 12.8	0.0050	1584	1,584	0.0038	68	1.3	23	23	1%	Gaining	76%	24%	0%

Forms

- Moderate sinuosity, single-thread channel with numerous side channel and ponds.
- Primarily pool-riffle morphology.
- Little to no observed instream structure.
- Discontinuous riparian vegetation consisting primarily of grass, willow, and other shrubs.
- Active gravel bars and observable meander scrolls in the floodplain.
- Gaining reach associated with geologic control from Hell Roaring glacial moraine.

Processes

- Lateral channel migration.
- Relatively stable banks where well-vegetated.
- Complex sediment-transport regime, including deposition, temporary storage, and transport.
- Beaver activity in the wet meadows and spring-fed tributaries visible in aerial photography.

Human Impact

- Minor human impacts.
- Cattle grazing, dirt roads, dispersed campsites, and bridge.

Response Potential

- Increased sinuosity, island braiding, and pool-riffle formation associated with riparian vegetation and instream obstruction (including beaver dams in side channels and spring-fed tributaries).
- Channel avulsion associated with instream obstruction (coarse sediment deposition, debris, and ice jams).
- Channel simplification associated with lost bank vegetation.

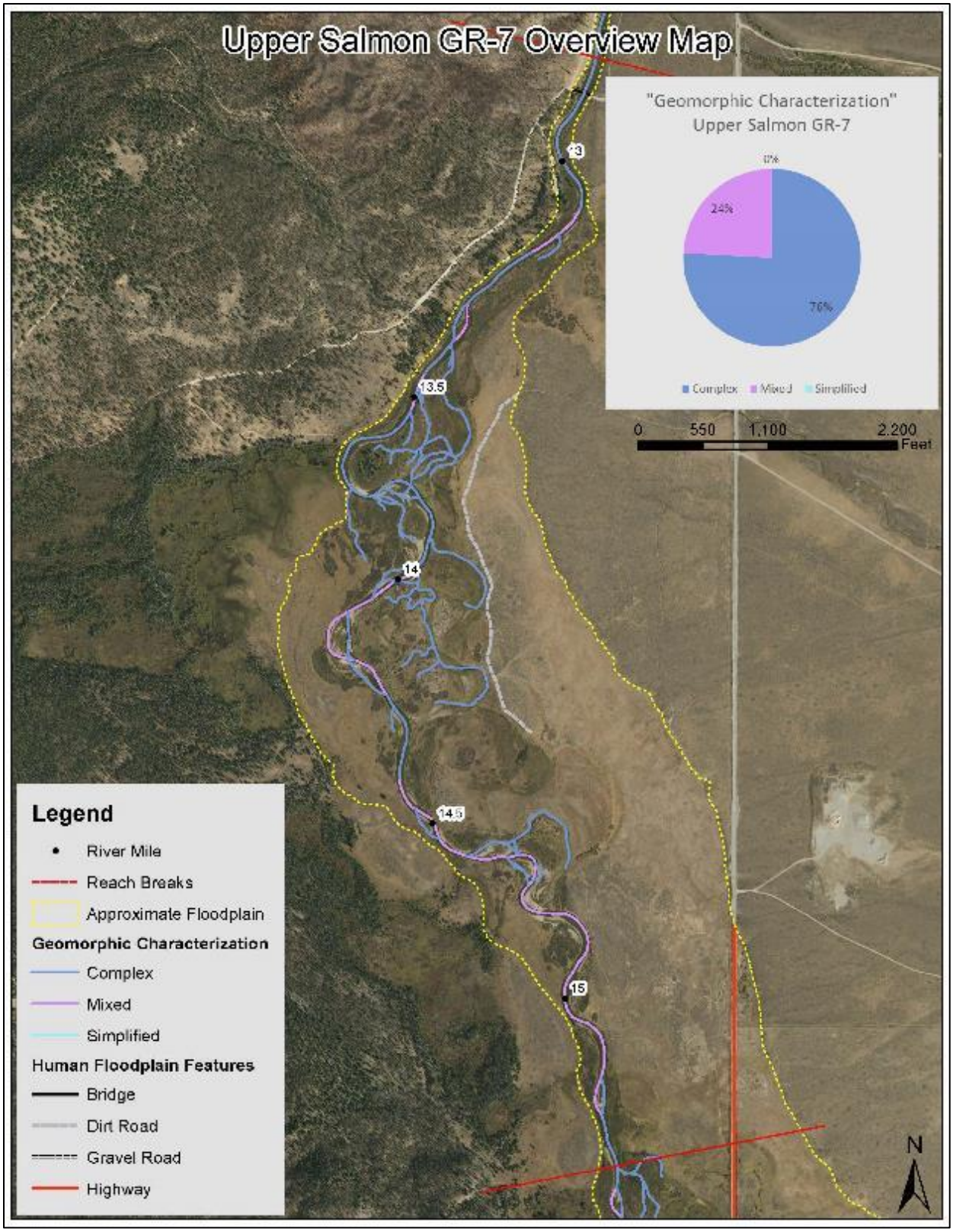


Figure 132. GR-7 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-8 (RM 12.8 – 6.6)

Geomorphic Reach GR-8 is located along the Upper Salmon River between RM 12.8 and RM 6.6 in a naturally unconfined valley, with no significant valley-bottom constraints associated with human features (Figure 133). The downstream reach break is defined by constriction from the Redfish Lake glacial moraine. Reach characteristics are summarized below in Table 67.

Table 67. Summary of attributes for Geomorphic Reach GR-8.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-8	12.8 - 6.6	0.0063	1280	1280	0.0048	66	1.3	19	19	6%	Gaining	81%	14%	5%

Forms

- Moderate sinuosity, single-thread channel with numerous side channels and ponds.
- Primarily pool-riffle morphology associated with meander bends.
- Active point bars and visible meander scrolls in the floodplain.
- Relatively continuous riparian vegetation consisting primarily of willow and other shrubs; poor riparian vegetation on elevated terraces.

Processes

- Channel migration and avulsion, including side-channel formation.
- Complex sediment-transport regime, including deposition, temporary storage, and transport.
- Beaver activity in side channels and spring-fed tributaries visible in aerial photography.

Human Impact

- Series of weirs for irrigation diversions in the upper reach.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation.
- Irrigation diversions, dirt roads, and dispersed campsites.

Response Potential

- Increased sinuosity, island braiding, and pool-riffle formation associated with riparian vegetation and instream obstruction.
- Channel avulsion associated with instream obstruction (coarse sediment deposition, debris, and ice jams).
- Channel simplification associated with lost bank vegetation.

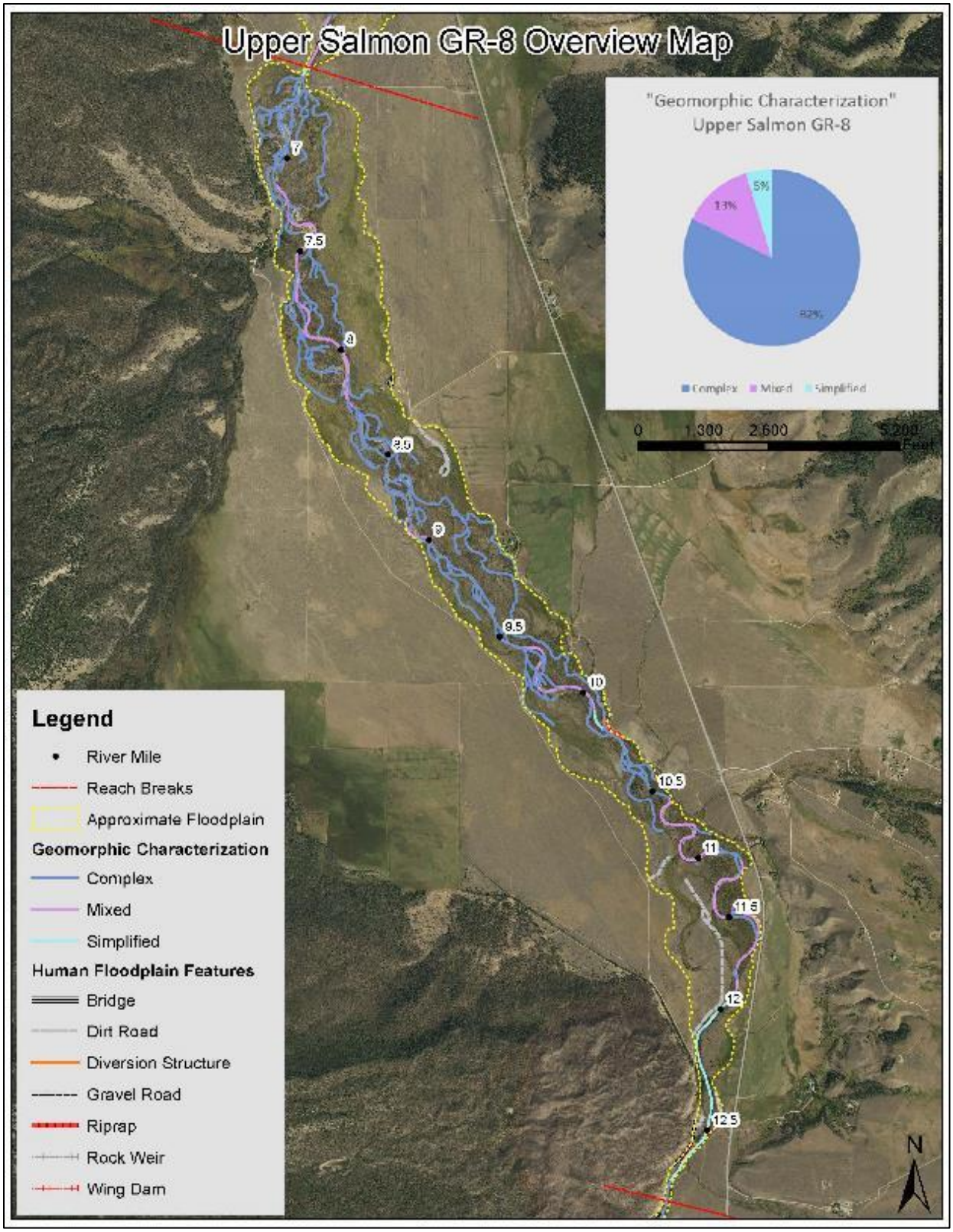


Figure 133. GR-8 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-9 (RM 6.6 – 0.4)

Geomorphic Reach GR-9 is located along the Upper Salmon River between RM 6.6 and RM 0.4 in a naturally unconfined valley with several valley-bottom constraints associated with human features (Figure 134). The western valley margin is defined by the Redfish Lake glacial moraine. Reach characteristics are summarized below in Table 68.

Table 68. Summary of attributes for Geomorphic Reach GR-9.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-9	6.6 - 0.4	0.0057	1123	868	0.0052	72	1.1	16	12	3%	-	73%	18%	9%

Forms

- Relatively low sinuosity, single-thread channel with numerous side channels.
- Mixed morphology. Plane-bed where relatively straight; pool-riffle where relatively sinuous.
- Many active point bars; visible meander scrolls and abandoned channel scars in the floodplain extending well beyond the existing meander belt width.
- Discontinuous riparian vegetation consisting primarily of willow and other shrubs.

Processes

- Active channel migration and avulsion; side channel and alcove creation.
- Mixed sediment-transport regime, including deposition, temporary storage, and transport; appears to become more transport-dominant in the lower reach.
- Beaver activity visible in downstream wetland area in aerial photography.

Human Impact

- Channel and floodplain confined by road embankments along the hatchery and Highway 75.
- Channel confinement and straightening may increase local transport capacity, armoring the bed.
- Cattle grazing impacts, including bank erosion and lost riparian vegetation in several locations.
- Road embankments, the fish hatchery's permanent intake and weir structures, dispersed campsites, dirt roads, cattle grazing, discontinuous levees, rock weirs, riprap, and bridge.

Response Potential

- Increased sinuosity and pool-riffle formation associated with riparian vegetation and instream structure.
- Channel avulsion associated with instream obstruction (coarse sediment deposition; debris and ice jams).
- Channel simplification associated with lost bank vegetation and confinement.

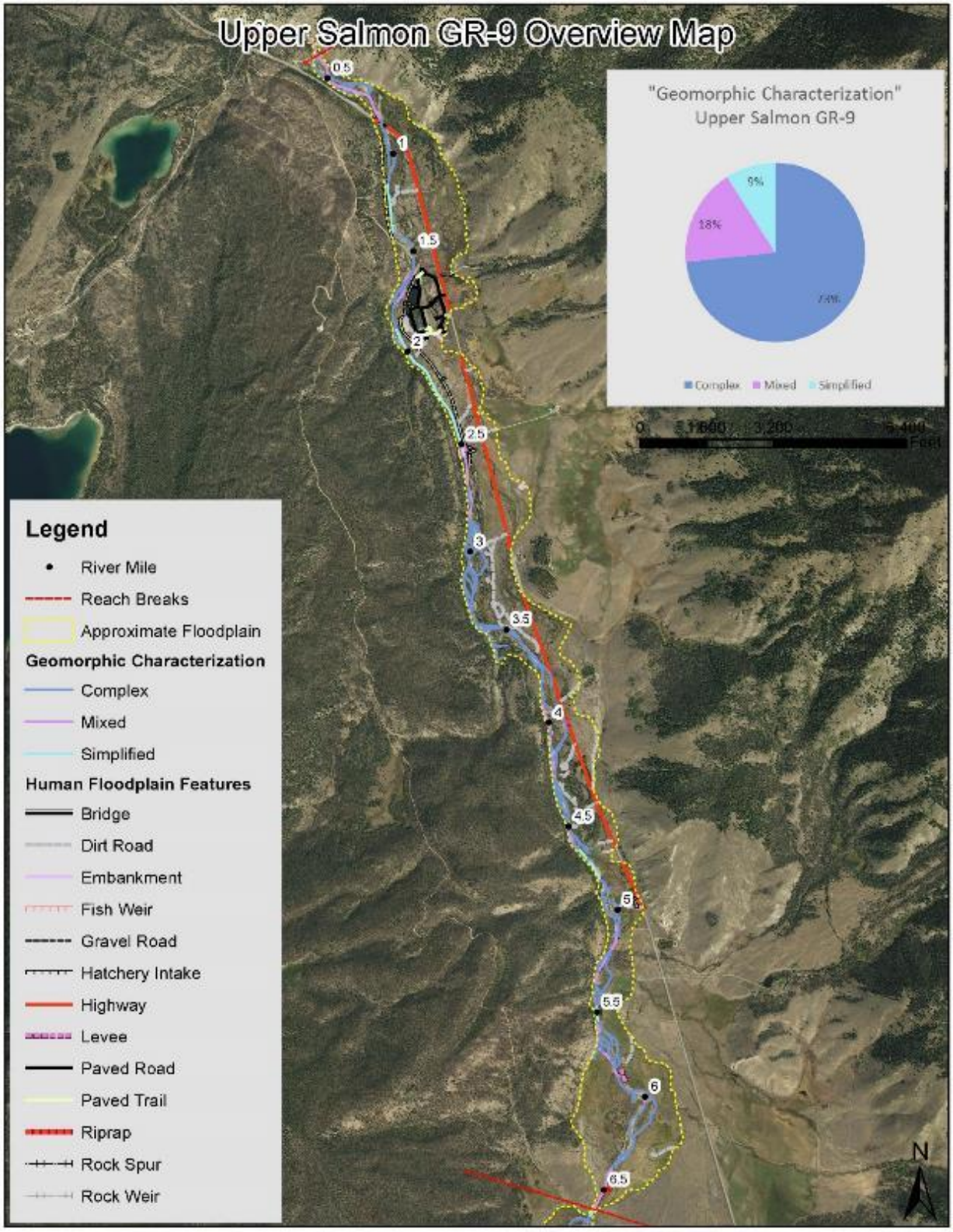


Figure 134. GR-9 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Geomorphic Reach GR-10 (RM 0.4 – 0.0)

Geomorphic Reach GR-10 is located along the Upper Salmon River between RM 0.4 and RM 0 in a confined valley, with no additional valley-bottom constraints associated with human features (Figure 135). Reach characteristics are summarized below in Table 69.

Table 69. Summary of attributes for Geomorphic Reach GR-10.

Valley Segment	Reach	River Miles	Valley Slope (ft/ft)	Average Valley Width (ft)	Average Constrained Valley Width (ft)	Channel Slope (ft/ft)	Average Channel Width (ft)	Sinuosity	Entrenchment Ratio (ft/ft)	Constrained Entrenchment Ratio (ft/ft)	Human Disturbance Ratio (%)	Groundwater Characteristics	Geomorphic Characterization "Complex"	Geomorphic Characterization "Mixed"	Geomorphic Characterization "Simplified"
VS-2	GR-10	0.4 - 0.0	0.0020	122	122	0.0020	78	1.0	2	2	0%	-	56%	44%	0%

Forms

- Relatively straight, single-thread channel.
- Primarily plane-bed morphology.
- Primarily grass, shrub, and coniferous tree species along stream corridor.

Processes

- Confined channel; stable banks; continual sediment inputs from a slide area along river right
- Transport-dominated sediment regime.

Human Impact

- Minimal human impacts.
- Dispersed campsites.

Response Potential

- Sediment transport, incision, bed armoring.
- Bank erosion and localized large wood recruitment.

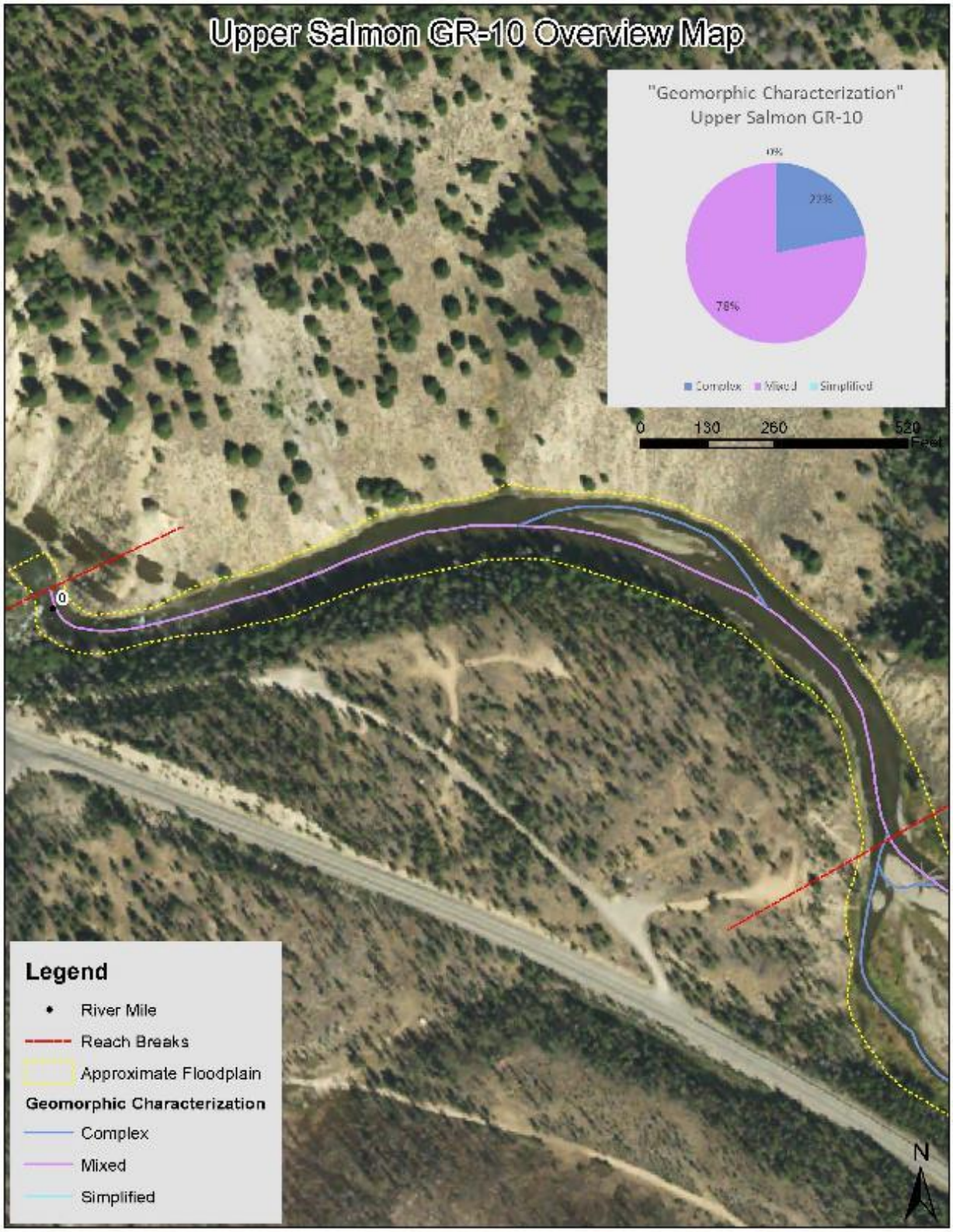


Figure 135. GR-10 overview map illustrating the approximate floodplain, geomorphic characterization, and human alterations to the floodplain.

Temperature and Climate Change Assessment

Chinook salmon

Under current conditions, spring water temperatures are generally below minimum or optimum values for Chinook salmon smolts. Alternatively, summer water temperatures can be above maximum or optimum values for a portion of the adult spawning and summer parr rearing life stages. Under current conditions, however, water temperatures in the Upper Salmon River are often within optimum temperatures for each of the five life stages evaluated (Figure 136). Under an assumed 3° C water temperature increase scenario (Figure 137), conditions improve during the spring (emergence, spring smolt emigration) but notably worsen for summer life stages (adult holding and spawning, parr rearing). Summer water temperatures potentially increase to above maximum (adult spawning, parr rearing) or above acute (summer spawning) during portions of the summer life stages.

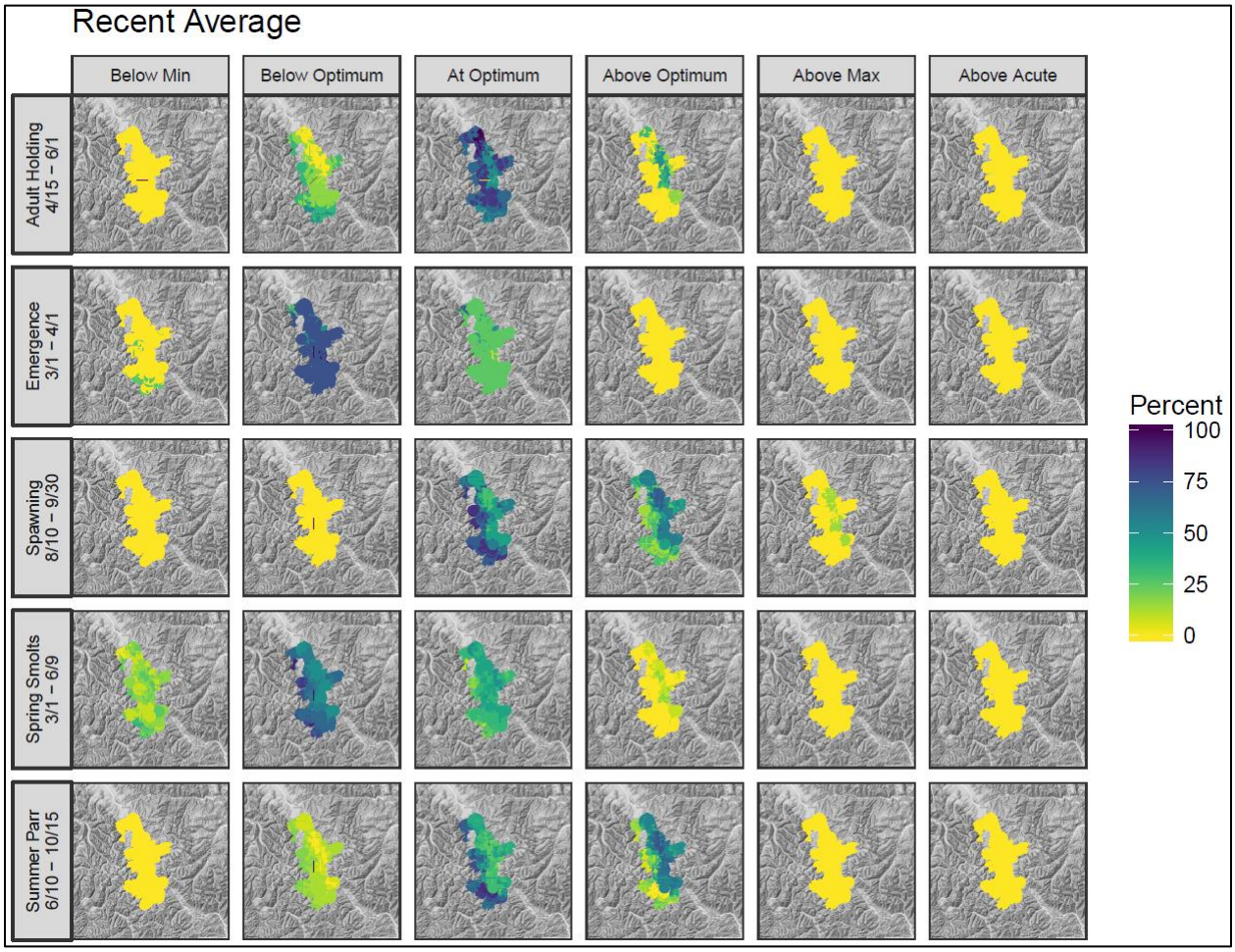


Figure 136. The percentage of time that Upper Salmon River watershed water temperatures were below, within, or above a given temperature threshold (Carter 2005) for five Chinook salmon life stages. Water temperatures were averaged across years for which complete modeled temperature data were available (2011 and 2013).

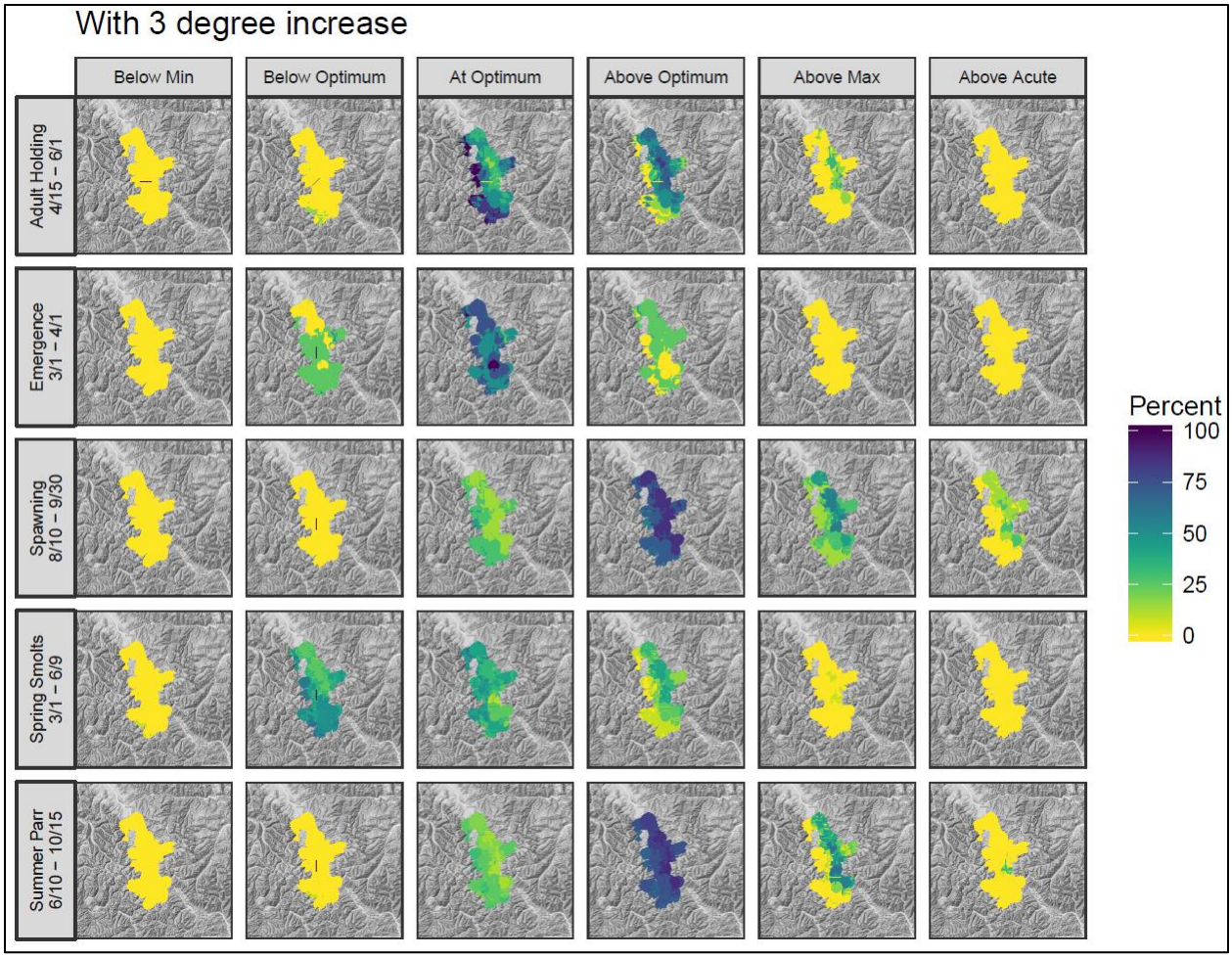


Figure 137. The percentage of time that Upper Salmon River watershed water temperatures may potentially be below, within, or above a given temperature threshold (Carter 2005) for five Chinook salmon life stages, assuming a potential climate change scenario.

Steelhead

Under current conditions, spring water temperatures are below optimum values for steelhead for portions of the spring smolt emigration. Alternatively, summer water temperatures can be above optimum or maximum values for a portion of the egg incubation and fry emergence life stages. Under current conditions, however, water temperatures in the Upper Salmon River are often within optimum temperatures for three (spawning, incubation, summer parr rearing) of the life stages evaluated (Figure 138). Under an assumed 3° C water temperature increase scenario (Figure 139), water temperature conditions improve during the spring smolt emigration but notably worsen for late-spring and summer life stages (incubation/emergence, spawning, parr rearing). Summer water temperatures potentially increase to above maximum during portions of the spawning or summer parr rearing stages. It is unclear to what degree late incubation and emergence timings might overlap with summer high temperatures in the Upper Salmon River.

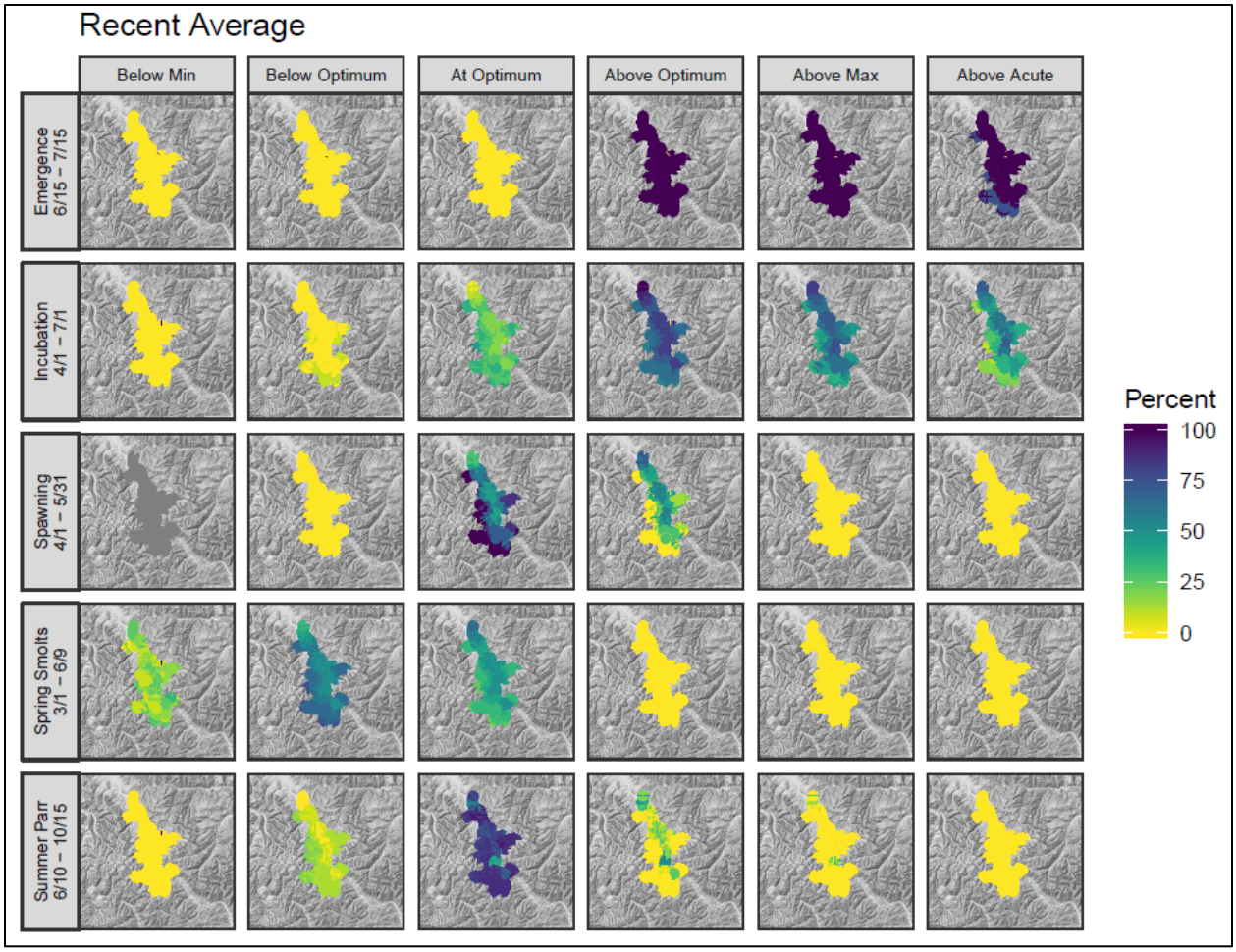


Figure 138. The percentage of time that Upper Salmon River watershed water temperatures were below, within, or above a given temperature threshold (Carter 2005) for five steelhead life stages. Water temperatures were averaged across years for which complete modeled temperature data were available (2011 and 2013).

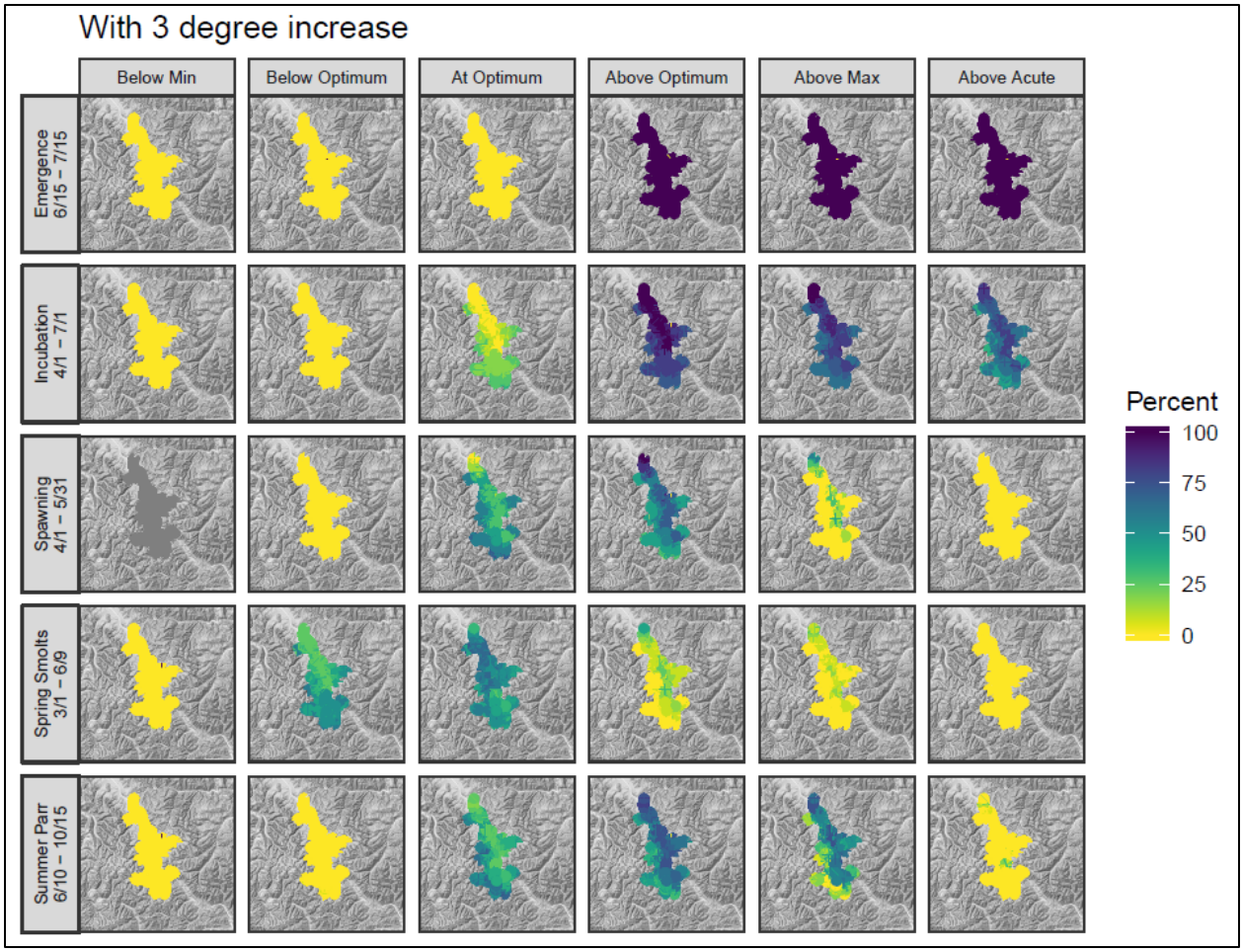


Figure 139. The percentage of time that Upper Salmon River watershed water temperatures may potentially be below, within, or above a given temperature threshold (Carter 2005) for five steelhead life stages, assuming a potential climate change scenario.

Results and Discussion

In the Upper Salmon River Biological Assessment, the lack of quantity and quality juvenile rearing habitat during summer and winter months was identified as the highest-priority limiting PBF for Chinook salmon. Assuming recent mean adult Chinook salmon escapement, habitat capacity does not appear to limit production of summer parr or winter presmolts (Table 51). However, currently available rearing habitat (summer and winter) is likely not sufficient to support recent high escapements or support escapements necessary for ESA delisting. Juvenile rearing habitat during summer and winter does not appear to be a limiting PBF for steelhead in the Upper Salmon River. Finally, redd capacity (i.e., available spawning habitat) does not appear to be limiting Chinook salmon or steelhead in the Upper Salmon River.

Limiting Physical and Biological Features

The lack of quantity and quality summer (parr) and overwinter (presmolt) rearing habitat downstream of current spawning habitat were identified as high-priority PBFs for Chinook salmon in the Upper Salmon River. During typical recent adult escapements for Chinook salmon in the Upper Salmon River, available summer and winter rearing capacity appears sufficient to support juvenile productions. However, the

available capacity is below values required to support parr and/or premolts during high escapement years (Table 51) or to sustain adult Chinook salmon escapement required to achieve ESA delisting goals (Table 52). This finding is supported by the fact that roughly 90 percent of total Chinook salmon production from this reach emigrate past the Sawtooth Hatchery rotary screw trap as fry, parr, or presmolts prior to the winter rearing season, suggesting that summer and winter rearing capacity is limited. Redd capacity does not appear to be a PBF limiting Chinook salmon in the Upper Salmon River.

Available juvenile rearing and spawning habitat in the upper Salmon River do not appear to be limiting PBFs for steelhead in the Upper Salmon River.

- Winter (presmolt) juvenile rearing habitat was identified as a high-priority PBF limiting Chinook salmon production in the Upper Salmon River (headwaters).
- Summer (parr) juvenile rearing habitat was identified as a medium-priority PBF limiting Chinook salmon production in the Upper Salmon River (headwaters).

Priority Areas

To address both PBFs limiting Chinook salmon production in the Upper Salmon River (overwinter and summer rearing habitat), rehabilitation to reaches within the Upper Salmon should be considered in the following order:

- **First priority: mainstem Upper Salmon from Alturas Creek to Redfish Lake Creek.** This section is where the majority of the Chinook salmon production currently occurs.
- **Second priority: Alturas Lake Creek and the mainstem Upper Salmon above Alturas Lake Creek including Pole Creek.**
- Summer flow limitations at the Busterback Ranch Diversion area.

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Appendices