Silver Creek Assessment Report

for The Nature Conservancy and Silver Creek Alliance
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Prepared by Rio ASE and Ecosystem Sciences
Ecosystemsciences.com | Boise, ID | drisso@ecosystemsciences.com
RioASE.com | Boise, ID | Rob@RioASE.com

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1 Introduction

1.1 Assessment Rationale and Purpose

The philosophy behind the rationale for an effort such as this geomorphic assessment can be broken down into two essential elements: the need and the overall purpose of a geomorphic-based assessment.

The Need for A Geomorphic-Based Assessment

- Silver Creek is biologically, culturally, historically, and economically relevant to Idaho and the West: Silver Creek is prized for its stunning clear waters, catch and release trout fishery, abundant wildlife, and vibrant history. It is historically and culturally relevant due in part to its connection to Ernest Hemingway and The Nature Conservancy Preserve. Silver Creek is an important part of the fabric of Idaho and has drawn people from all over the nation and the world to fish its waters, see its trout, and experience the unique spring-fed waters and stunning central Idaho setting (Figure 1-1), providing many jobs and economic benefits to the region. Its spring-fed waters provide a cold-water refuge from climate change and provide habitat for key game fish species such as brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) among many other fish and aquatic organisms. Yet this system is still at risk.
- Although many isolated investigations concentrating on one part of Silver Creek or on general conditions within the watershed have been performed, a geomorphic-based assessment at multiple scales of this type has not been performed. Though monitoring of key watershed parameters such as temperature, dissolved oxygen, and sediment levels has recently been conducted they do not assess the geomorphic causes and solutions at multiple scales.

Figure 1-1. Silver Creek Setting

The clear waters of Silver Creek, combined with its world-class trout fishery and vibrant history make it culturally, economically, and ecologically significant stream.

The Overall Purpose of the Assessment

- The overall purpose of the assessment is to develop a report suitable for guiding approaches and implementation strategies for future restoration and enhancement projects. Many restoration and enhancement projects have been performed within the watershed (see Section 2.4), with a wide range of goals and objectives and have often been opportunistic in nature or have lacked a scientific basis. The success of these projects varies considerably. This report seeks to provide a reference for landowners and stakeholders to guide future restoration and enhancement efforts, with the assistance of technical professionals. It is not meant to be a cookbook for all locations; each reach or site must be assessed in detail by technically skilled professionals who are capable of designing suitable and effective projects.

1.2 Level of Work

This assessment is based on a combination of office and field work. The effort utilized existing data and reports, remote sensing, and targeted field-collected data. Background information was gleaned from existing reports, published and unpublished data, and professional experience. A Geographic Information System (GIS) analysis was utilized on the watershed scale to identify reaches and feed into the prioritization process. The result of the prioritization process was prioritized target reaches for reach-scale assessment.

1.3 Audience

The audience for this assessment is stakeholders, landholders, and other groups seeking to enhance the long-term viability of the Silver Creek trout fishery.

1.4 Goals

- Goal for Silver Creek
  - Create habitat conditions suitable for a sustainable, resilient wild trout spring creek fishery.
- Goals of the assessment
  - Document past, existing (baseline), and potential target conditions.
  - Identify potential actions to improve habitat relative to the Silver Creek goal (listed above) that can be applied throughout the watershed.
  - Provide a conceptual restoration plan for two priority reaches within the watershed.

1.5 Report Organization

- Background Information: Much work and previous analysis has been completed within the Silver Creek watershed. Aspects of available past work have been used to facilitate and economize the efforts of this assessment and conceptual restoration effort. A brief summary and references to pertinent background information has been provided in this report. Key watershed issues and restoration targets are identified. A more detailed summary of the existing background information is found in Appendix A.
- Methods: A brief summary of assessment and evaluation methods is provided in this section to facilitate understanding of the results presented subsequently. For consistency and to reduce potential redundancy in the report, methods for both parts of the report are summarized in one section.
- Generally, the remainder of the assessment is divided into two parts.
  - Watershed-scale assessment including general reach characteristics and proposed restoration actions for the entire Silver Creek watershed

  - Reach-scale evaluation of two priority reaches including proposed restoration concepts for both
- Watershed-Scale Conditions
  - Silver Creek and its principal tributaries were divided into reaches of similar character, and a summary of each reach is provided.
  - Potential restoration actions: Key conclusions for the watershed have been summarized along with potential restoration actions to improve conditions for a sustainable, resilient wild trout spring creek fishery.
  - Reach prioritization: All of the reaches delineated from the watershed-scale effort were prioritized based on specific metrics. A summary of this prioritization process and results is provided.
- Reach-Scale Evaluation and Conceptual Design
  - Detailed assessment of two priority reaches: Two of the top priority reaches were evaluated in greater detail, including the development of refined target conditions in support of restoration design development.
  - Conceptual restoration design for two priority reaches: This report concludes with conceptual designs for the two priority reaches illustrating our recommended restoration approach based on the information collected and evaluated from the watershed- and reach-scale analyses.

1.6 Intended Use and Limitations of the Assessment

The intended use and limitations of this assessment are provided below. Additional limitations are provided in Appendix D.

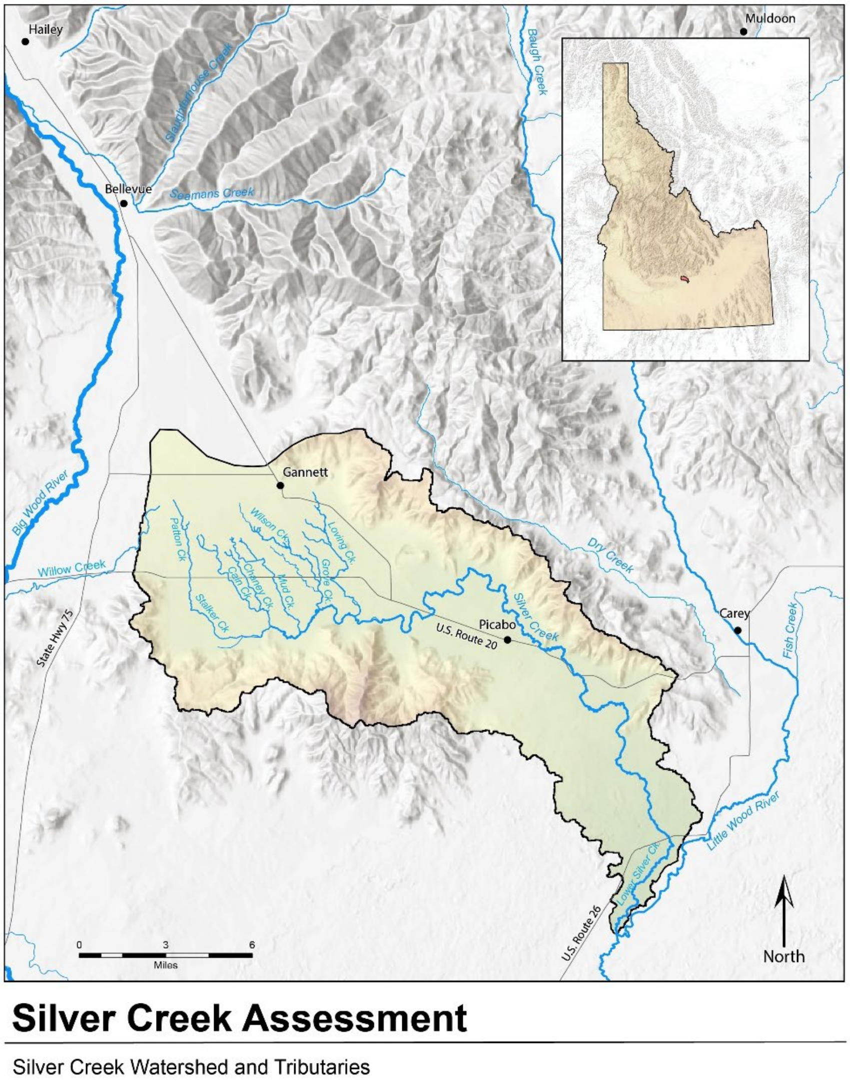
- Intended use of the assessment: The assessment is intended to be utilized by stakeholders, landowners, and other groups within the watershed to inform future restoration and enhancement efforts. It seeks to provide information on the geomorphic setting, key parameters, watershed and reach-specific conditions. The reach-scale analysis and conceptual restoration plans are meant to provide design guidance for implementation efforts.
- Limitations of the assessment: The assessment is based on available information, and restoration tools and concepts are meant to be implemented by professionals informed by site-specific conditions. This is not a cookbook to be used for implementation without further data collection and design of construction-ready plans.

2 Background Information

2.1 Project Location

The project is located in south-central Idaho in Blaine County (Figure 2-1). The roughly 68,000-acre watershed is dominated by agricultural land uses and is bounded by mountains that rise 2,000 to 3,000 feet (ft) above the valley floor, which is generally flat. Silver Creek is a spring-driven system, fed by several spring heads and gaining reaches. The water is fed by precipitation and both surface and groundwater flow from the Big Wood River Basin. Silver Creek empties into the Little Wood River at its mouth.

Figure 2-1. Silver Creek Watershed



Silver Creek Watershed is a spring-fed system tied hydrologically to both the Big Wood and Little Wood River systems.

2.2 Background Information

A review of available relevant investigations on Silver Creek was performed. The earliest reports found are from the mid-1940s when Idaho Department of Fish and Game decided to close the stream to fishing for an extended period of time due to reports of low fish population numbers. The stream had been a prized fishery for decades at that time\me. Our review of background information and data (Appendix A) focused on the condition of Silver Creek's geomorphology, habitat, sediment, vegetation, and fishery to provide historical context to the current condition and to inform target conditions.

2.3 Summary of Ecosystem Conditions and Restoration Targets

Our review of existing literature on Silver Creek (Appendix A) is summarized below and represents possible restoration targets for the assessment, separated by ecosystem component, though most of the components are interrelated.

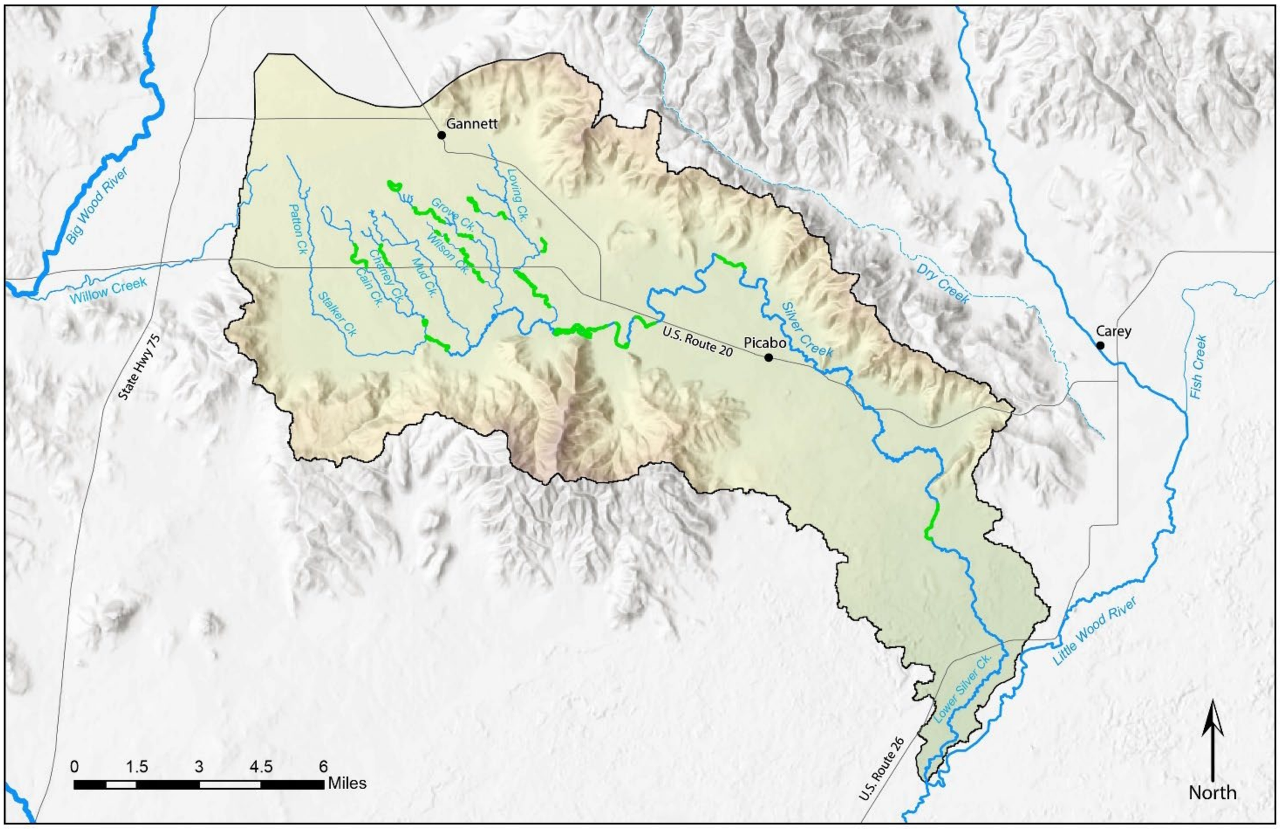
- Submerged Aquatic Vegetation
    - Submerged aquatic vegetation (or aquatic macrophytes) is important for the food base of trout (due to their association with stream macroinvertebrates), but *Chara* beds that grow on gravel substrates with higher velocities are superior to the communities that flourish in slow-moving silty areas. There were conflicting reports of *Chara* being present in silty areas as well.
    - Aquatic vegetation volume in the creek follows a yearly cycle, with lowest densities in the late winter and early spring, and highest densities in August. This affects channel conditions, as water levels and velocity profiles are modified by the vegetation volume. The vegetation also affects dissolved oxygen concentrations, which can vary greatly during summer months.
    - The aquatic vegetation provides cover for trout. When vegetation is absent, trout require cover in the form of deep pools, overhanging streambanks and large wood. Much of Silver Creek lacks deep pools, and fish congregate in those that do exist.
    - Aquatic vegetation can trap fine sediment, covering gravels and changing hydraulics.
- Silt and Fine Sediment
    - Silver Creek was likely originally a gravel bed system.
    - Silt and fine sediment have been identified as a problem in Silver Creek since at least the 1940s. The origins and historical presence are a subject of some debate, but land use practices, past and present, are most often cited as responsible for the sediment loads, which vary between tributaries and the mainstem reaches.
    - Loving, Stalker, and portions of Chaney Creeks are noted as containing high volumes of silt, while Stalker and Loving Creeks have been identified as the largest sources of sediment to Silver Creek.
    - Silt deposition areas free of aquatic vegetation are associated with a community of insects considered undesirable for producing a trout food base.
    - Removal of silt coupled with increased depths and velocities through restoration action have been shown to benefit macroinvertebrate community composition.
    - A diversity of substrates, including multiple gravel sizes as well as areas of fine sediment have been found to have the highest macroinvertebrate species richness.
    - Silt has been attributed to higher increased stream temperatures and a decrease in suitable spawning habitat.

- Habitat Use by Fish
    - Although fish are known to migrate within the stream, many reports indicate fish do not move large distances.
    - Having a diversity of habitats where fish can hold, feed, and even spawn in close proximity are desired. Having riffles and pools in close proximity will allow trout to move between holding and feeding areas.
    - Water depth and large hiding pools have been associated with high trout numbers.
    - Winter cover and food are needed in Silver Creek, as they are lacking. Fish go into a metabolic deficit in September. Winter brings reduced swimming abilities. A diversity of habitats with cover throughout the stream is therefore desirable.
    - Additional cover in the form of undercut banks, large wood, and deep pools are desirable.
- Riparian Vegetation
    - Many investigations noted the need for woody vegetation along streambank margins. They stabilize streambanks, provide food and cover for fish, and reduce airborne sediment inputs to the creek. Species such as Booth's willow (*Salix boothii*), yellow willow (*Salix lutea*), coyote willow (*Salix exigua*) Drummonds willow (*Salix drummondiana*), red-osier dogwood (*Cornous stolonifera*), and water birch (*Betula sp.*)
    - Reed canary grass has invaded the system and has moved into the channel in shallow areas with low velocities, negatively affecting stream morphology. To prevent reed canary grass invasion into the channel, restoration creating increased depths and velocities is recommended.
    - Other invasive plants such as purple loosestrife (*Lythrum salicaria*) and yellow flag iris (*Iris pseudacorus*) are known to occur within the area and are a threat to the ecosystem's native vegetation. Monitoring for invasive plants and an Early Detection and Rapid Response (EDRR) program is recommended.
- Temperature and Dissolved Oxygen
    - Temperatures in portions of Silver Creek reach temperatures over 70°F in mid-summer, which is stressful for trout. These conditions most often occur in upper Stalker Creek, lower Mud, Loving Creek (especially the North Fork of Loving) and lower reaches of Silver Creek (HWY 20 downstream).
    - Dissolved oxygen levels can fluctuate from super-saturated to very low levels in some reaches of Silver Creek in summer months. Fish kills and closures of the fishery have been attributed to dissolved oxygen levels.

2.4 Past Restoration Projects

Between 1988 and 2019, the Blaine County Land Use Department had 52 restoration and enhancement projects on record, which varied widely in size, complexity, and goals. A sampling of these projects shows a wide distribution throughout the watershed (Figure 2-2). The projects included dredging, wetland creation, channel reconfiguration, island creation, and pond creation.

Figure 2-2. Location of Selected Restoration Projects within the Silver Creek Watershed

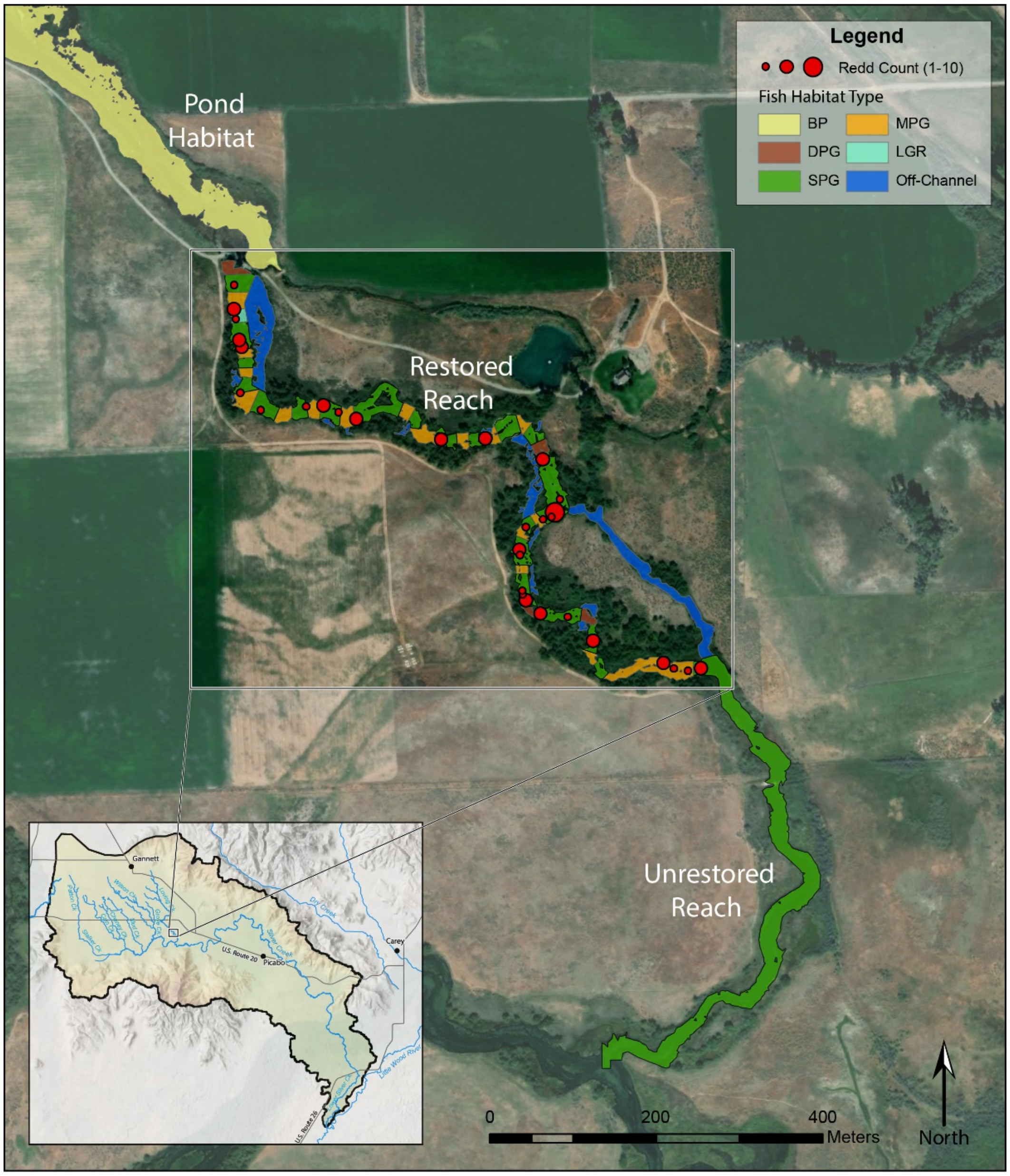


Silver Creek Assessment

The locations of past stream restoration projects within the Silver Creek watershed are shown in green.

There is evidence that resoration projects have increased habitat diversity in the watershed. For example, a project on lower Loving Creek increased the diversity of fish habitat over a non-restored reach imedaitely downstream. The restored reach had six times as many habitat types over about twice as much stream length, and habitat patches were 34 times smaller, creating a diversity of habitat types for fish to use in close proximity. That reach had 51 redds in the same spring where 0 were observed before the reach was restored (Figure 2-3).

Figure 2-3. Comparison of Habitat Units in Restored and Unrestored Reaches of Lower Loving Creek



Silver Creek Assessment

Habitat delineation in restored and unrestored reaches of Lower Loving Creek

3 Methods

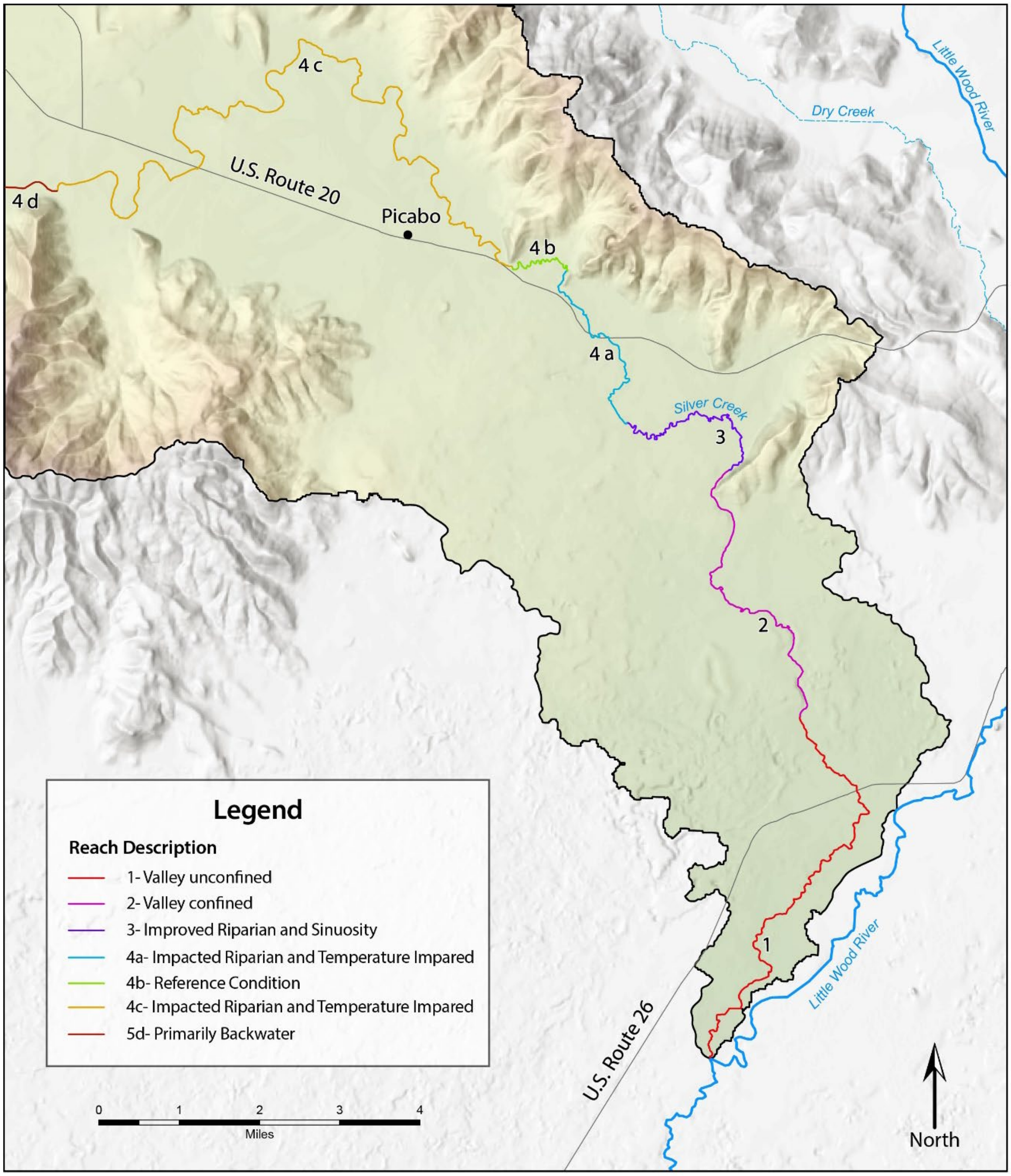
This assessment is divided into two parts: general watershed and detailed reach scale. The mainstem of Silver Creek and all major tributaries were evaluated at the watershed scale to assess general channel character, to prioritize different areas of the watershed, and to develop broad restoration strategies appropriate for different segments of the Silver Creek watershed that work together to create habitat conditions suitable for a sustainable, resilient wild trout spring creek fishery.

3.1 Watershed-Level Assessment

To assess watershed characteristics, the mainstem of Silver Creek and all major tributaries were divided into separate reaches (Figure 3-1 and Figure 3-2). Reach divisions were selected based on areas where conditions varied significantly between several key components, while subreach divisions were selected where conditions changed but not to such a magnitude or spatial extent as to warrant a new reach (e.g., ponds and restoration areas within larger reaches that otherwise exhibit similar geomorphic characteristics). Existing geomorphic conditions for each reach were measured (e.g., sinuosity, average channel width, etc.) and compared with historical conditions. Historical conditions were assessed via a combination of historical records, anecdotal information, and by comparing with current streams with similar characteristics to Silver Creek that are less impacted. General target conditions for each reach were generated using a combination of reference reaches and literature references. Comparing existing conditions to target conditions provides information regarding potential habitat issues and potential restoration actions within each reach. Some issues were present in most reaches; these issues are considered watershed-level concerns.

Many conditions can be used to differentiate/describe stream reaches. Specific reach conditions were evaluated based on their ability to help differentiate habitat restoration potential within the Silver Creek watershed and by the accessibility of data to characterize each. By measuring/assessing these data, we were able to divide the Silver Creek watershed into geomorphically similar reaches and subreaches. Listed below are the conditions used to evaluate reaches. All measurements at this scale were captured remotely using GIS unless otherwise noted. A summary of conditions pertinent to each reach has been provided in Appendix B. Along with the measured geomorphic conditions, reaches were prioritized qualitatively based on fish use potential, restoration feasibility, and habitat uplift potential to select two reaches for more detailed analysis and conceptual restoration design. The reach prioritization process is further described in Section 5.

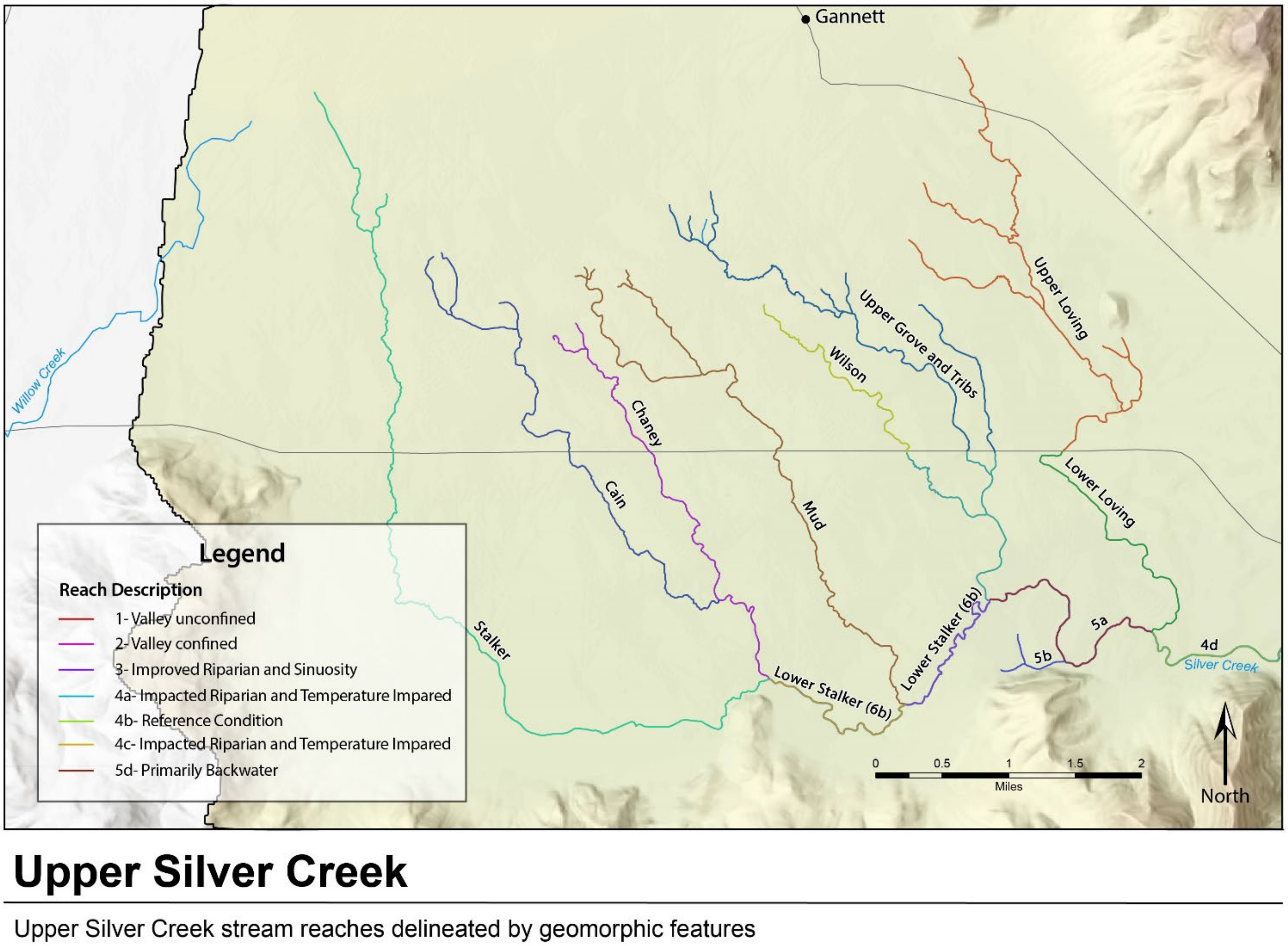
Figure 3-1. Lower Silver Creek Reaches



Lower Silver Creek

Lower Silver Creek stream reaches delineated by geomorphic features

Figure 3-2. Upper Silver Creek and Tributary Reaches



3.1.1 Reach Delineation Variables

Summarized below are the variables evaluated in the reach delineation process along with their method of evaluation.

Sinuosity: Channel length divided by valley length measured from high-resolution aerial photo.

Gradient: Change in elevation divided by channel length from the upstream end to the downstream end of the reach, multiplied by 100 to yield percent; measured from detailed Light Detection and Ranging (LiDAR) topography.

Average stream width: Average of 10–15 GIS stream width measurements within a given reach from a variety of settings (e.g., the middle of a meander bend, the start of a meander bend, in a straightened stretch, etc.); measured from high-resolution aerial photo.

Hydrology: General estimate of groundwater interactions within the reach: whether the reach is likely gaining flow, losing flow, or mixed/uncertain. Data derived from professional judgment and anecdotal information.

Floodplain connection: Qualitative estimate of the floodplain inundation recurrence frequency based on professional judgement and anecdotal information.

Riparian conditions: Qualitative assessment of the extent (canopy density and buffer width) and size (height) of riparian vegetation observed in detailed aerial photographs. Larger buffer zones between the stream and areas of human activity are assumed to represent a better riparian condition, along with larger, more mature riparian vegetation.

Sedimentation: The area of the streambed within a measured cross section covered by fine sediments. These measurements informed the degree to which fine sediment deposition is considered a problem within a stream segment; data derived from existing reports (Ecosystem Sciences 2011–2018).

Human features: Human features visible in aerial imagery that likely impact stream function and/or process (e.g., roads, bridges, agricultural fields, irrigation diversions, etc.).

Temperature: The average number of days within the stress band (70–78°F) and number of days exceeding 78°F within a given year. Data derived from temperature loggers placed throughout the watershed (Ecosystem Sciences 2011–2018).

Habitat Connectivity: Qualitative assessment of the degree one reach is physically connected to habitat in other nearby reaches. A reach surrounded by high-quality habitat immediately upstream and downstream has the best (high) connectivity, and a reach surrounded by poor/no habitat has the lowest (poor) connectivity. Fish passage barriers can also reduce habitat connectivity by blocking access to areas of high-quality habitat.

3.2 Detailed Reach-scale Analysis

In addition to the high-level reach characterization summarized in Appendix B, a more detailed reach-scale analysis was conducted for two prioritized reaches (lower Loving Creek and lower Stalker [6b]/Chaney) to inform an assessment and conceptual design for restoration actions in those two reaches. Detailed information collected/analyzed for these two reaches included the following:

- Field Observations
  - Observed geomorphic conditions of the bed, bank, and floodplain including areas of erosion (pool scour and bank erosion), deposition (fine- and coarse-grained), substrate character, channel width and depth, aquatic vegetation, bank conditions, riparian conditions, and evidence of over-bank activation (flooding)
  - Surveyed channel cross sections every 200–500 ft
  - Cross section spacing sufficient to document changes in channel width and/or thalweg elevation
  - Points surveyed included floodplain, top of bank, toe of bank, thalweg elevation, and locations of significance (i.e., islands, human features, in-channel structures, etc.)
    - Top and bottom of silt were measured at ground shots where silt deposition was present.
  - Discharge measured at the time of survey to aid in calibration of hydraulic models
- Hydrology
  - Over 30 years of continuous discharge measurements are available on the mainstem of Silver Creek, at U.S. Geological Survey gage 13150430. As a part of programs funded by the Silver Creek Alliance, Ecosystem Sciences has been measuring tributary and mainstem discharges since 2011 with the resulting data provided in multiple annual reports.
  - The U.S. Geological Survey data were used to calculate recurrence intervals for flood flows on the mainstem Silver Creek, while Ecosystem Science's annual reports were used to calculate the percent of flow contribution from each tributary. For a given mainstem recurrence interval, the associated mainstem

discharge multiplied by the percent of flow contribution for a given tributary was used to estimate recurrence intervals within most tributaries. Calculations assumed the percent of flow contribution within each tributary remains relatively constant between peak flow and baseflow, because as with many spring-fed streams, there is relatively little variation between baseflow and high-water conditions in a given year.

- Hydraulic Modeling
    - Measured channel cross sections were combined into a one-dimensional hydraulic model (U.S. Army Corps of Engineers HEC-RAS version 5.0.7) for lower Loving and for lower Stalker/Chaney Creek to evaluate changing water levels (i.e., stage), velocity, and erosion potential given different flows. The model was calibrated by varying the channel roughness (Manning's n-values) to match observed water surface elevations. Aquatic vegetation is expected to be less dense during high flows, leading to a change in roughness for these periods. The 1.5-year recurrence interval discharge was selected as an appropriate bankfull flow.
- At-a-station hydraulic modeling (i.e., from one cross section) was used to estimate what size sediment would mobilize at the bankfull flow (i.e., incipient motion) using common hydraulic calculations (Manning's formula and the depth-slope product).
- Channel Migration Analysis
    - Comparing aerial images from the 1940s to present day enabled measurements of extent, rate, and type of channel planform changes over the last approximately 70 years.
- Channel Morphology Analysis
    - Channel geometry: Width and depth were measured from multiple cross sections.
    - Meander geometry: Up to 10 representative measurements of sinuosity, meander amplitude, meander wavelength, and bed radius of curvature were evaluated from aerial photographs.
    - Planform: The historical and existing shape of the channel (single-thread, multi-thread, meander pattern, irrigation and drainage ditches, etc.) was qualitatively evaluated from aerial photographs and visible meander scars in LiDAR topography.
- Target Conditions: Reference reaches and literature-based relations were used to identify several geomorphically appropriate target conditions for all reaches and even more detailed target conditions for lower Loving and lower Stalker. Reference reaches were collected from a variety of sources (prior work conducted by Rio Applied Science and Engineering (ASE), undisturbed Columbia Habitat Monitoring Program (CHaMP) sites, and Rio ASE's professional experience). Target conditions were evaluated using data appropriate for natural spring-fed channels and germane to wild trout health and survival (e.g., temperature criteria were based on prior research on trout health and survival). Target conditions for geomorphic metrics focused on geomorphically appropriate conditions that would improve habitat in a sustainable manner. Many geomorphic target conditions were scaled based on bankfull width, as determined by the hydrologic analysis.
- Development of potential habitat improvement actions and conceptual designs: Professional judgement, past experience from similar spring-fed streams, and observations of existing restoration projects in the Silver Creek watershed informed our development of potential habitat improvement actions. Specific actions were identified to address specific target conditions either directly or indirectly. Those actions believed to have the highest benefit with the lowest cost (monetary and/or risk) were selected for use in site-specific conceptual designs (Appendix C).

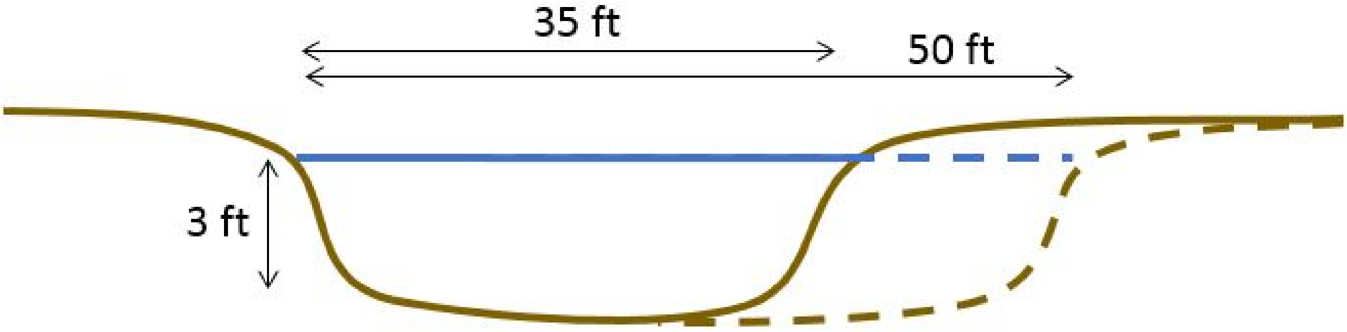
4 Watershed-Scale Assessment

The Silver Creek watershed has been impacted directly and indirectly by human influences for over 100 years. Agriculture and widespread grazing beginning in the 1880s has denuded many riparian areas and destabilized channel banks. Irrigation practices have altered the natural spring-fed hydrology, causing periods of augmented or diminished stream discharge. Channel manipulation has eliminated many side channels, reduced areas of off-channel habitat, and effectively drained floodplain wetlands. These human-caused changes have altered conditions throughout the watershed, with some common trends summarized below.

4.1 Common Conditions Throughout the Watershed

Many stream reaches in the Silver Creek watershed exhibit excessive average channel widths, well in excess of targeted conditions developed from reference reaches and regression equations based on bankfull discharge. Channel widths measured for each reach (Appendix B) tended to vary based on local conditions, with wider streams able to convey more water within their banks (i.e., less frequent floodplain activation) (Figure 4-1). Stream segments observed with broad and mature riparian corridors tended to be narrower than those without. Additionally, very few pools were observed in most reaches based on limited field observations and past reporting (Ecosystem Sciences 2011–2018), suggesting pool frequency in most reaches is less than what would otherwise be appropriate for an undisturbed system. Field observations and past reporting (Ecosystem Sciences 2011–2018) also suggest excessive amounts of fine sediment throughout many stream reaches in the watershed. Sediment deposition occurs along the bed of the channel commonly associated with aquatic vegetation and in backwater areas upstream of dams that are present in several reaches of the Silver Creek watershed (Figure 4-2). Many of these backwater areas have been dredged of fine sediment over the past several years but have experienced further deposition after dredging. Beneath the fine sediment is gravel lag deposited as part of the alluvial fan originally forming the Bellevue Triangle. These gravels are exposed periodically in pools and other areas of localized scour. It is assumed these gravel sediments underly the entire valley.

Figure 4-1. Increased Conveyance Through Over-Widened Channels



Channel widening represented by dashed lines illustrates greater cross-sectional area (105 square ft increased to 150 square ft), which enables more flow to pass between the banks (i.e., conveyance) before overtopping and activating the floodplain.

Figure 4-2. Representative Photo of Fine Sediment and Aquatic Vegetation

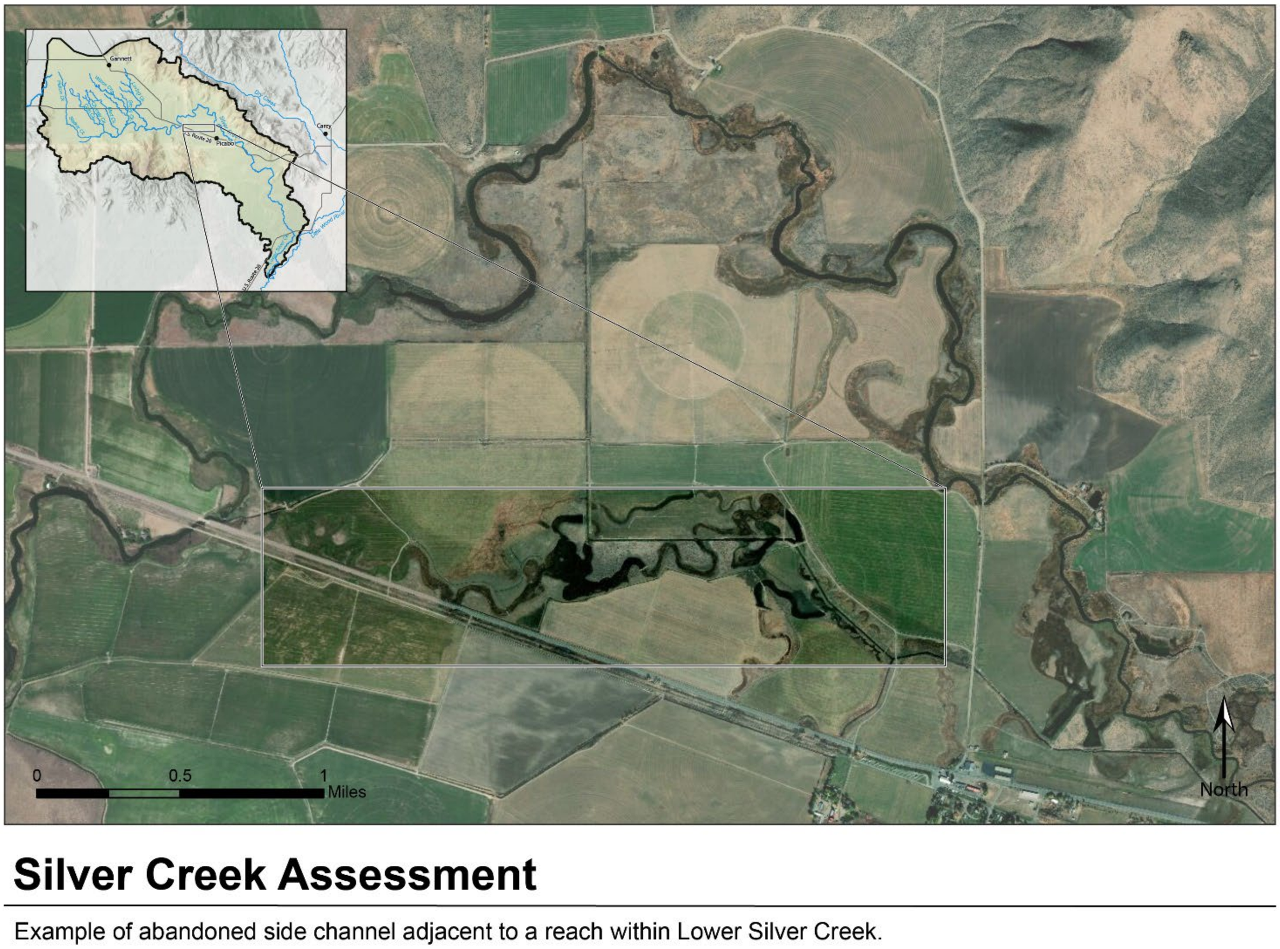
Lower Chaney Creek. The photo was taken upstream of a check dam impounding water near the confluence of Chaney and Stalker Creeks. Fine sediment and aquatic vegetation have accumulated in the backwater upstream of the check dam. Flow is from right to left.

Long segments of many reaches within the watershed lack broad and mature riparian corridors along the banks of the channel and across large areas of the floodplain. Additionally, many upland areas of the watershed have been converted to agricultural and/or grazing land use and have been observed to be bare of vegetation for periods of time in the aerial photo record. Over-widened channels, poor in-stream habitat, a lack of in-stream structure and cover, and homogeneous silt-covered bed conditions tended to coincide with those areas observed to lack mature riparian vegetation.

A near continuous record of in-stream temperature from 21 sites throughout the watershed has been collected by Ecosystem Sciences (2011–2018). The results of these data illustrate that summer temperatures in several reaches frequently fall within the 70–78°F stress band that has been shown to adversely affect the physiological health and distribution of wild trout (Richter and Kolmes 2005; EPA 2003).

Most reaches in the Silver Creek watershed are relatively stable, exhibiting little or no bank erosion or evidence of channel migration. From 1946 (the oldest available aerial imagery) to present day, channel migration has only been observed in a handful of bends with measured rates of lateral and downstream migration averaging less than 1 ft/year. These rates of natural channel evolution have been significantly outpaced by occurrences of human-caused channel simplification visible in most reaches. Relic channel scars visible on aerial photographs and detailed LiDAR topography suggest where a channel was once multi-threaded, most streams within the watershed have been manipulated to now flow as a single thread with very few side channels (Figure 4-3). Channel straightening and floodplain ditching appear to have reduced sinuosity and floodplain area further simplifying the overall channel character and habitat conditions.

Figure 4-3. Aerial Image Illustrating Abandoned Side Channels



Silver Creek has been channelized and disconnected from historical side channels, off-channel habitat, and floodplain wetlands. Shown in the red oval are apparent disconnected side channels and off-channel areas bisected by linear irrigation ditches that have altered the natural hydrology and habitat of the area.

Gage data and Ecosystem Sciences monitoring (2011–2018) have quantified years of hydrologic response in the Silver Creek watershed. This information supports anecdotal information that Silver Creek hydrology is primarily driven by groundwater resulting in streams that are mostly spring-fed and exhibit relatively consistent discharge (compared to snowmelt dominated streams). Silver Creek watershed hydrology has been historically influenced by irrigation; surface water from the Big Wood River has been diverted into the Silver Creek watershed, which along with water from Silver Creek, has been extracted for upland irrigation. Transferring Big Wood River surface water to flood irrigate fields in the Bellevue Triangle during the 1900s likely augmented Silver Creek groundwater and surface water hydrology during this time. More recent irrigation efficiencies including greater use of sprinklers, and groundwater pumping has likely diminished the Silver Creek hydrology relative to conditions from several decades ago (Figure 4-4). Ecosystem Sciences' monitoring has shown that, over the past 10 years, some springs dry up in mid-summer during low snowpack years, while few to none dry up during high snowpack years (Ecosystem Sciences 2011–2018). While the average stream flow for a given tributary does vary from year to year, the relative percent contribution to Silver Creek from each tributary remains fairly consistent.

Figure 4-4. Estimated Silver Creek Discharge Trend

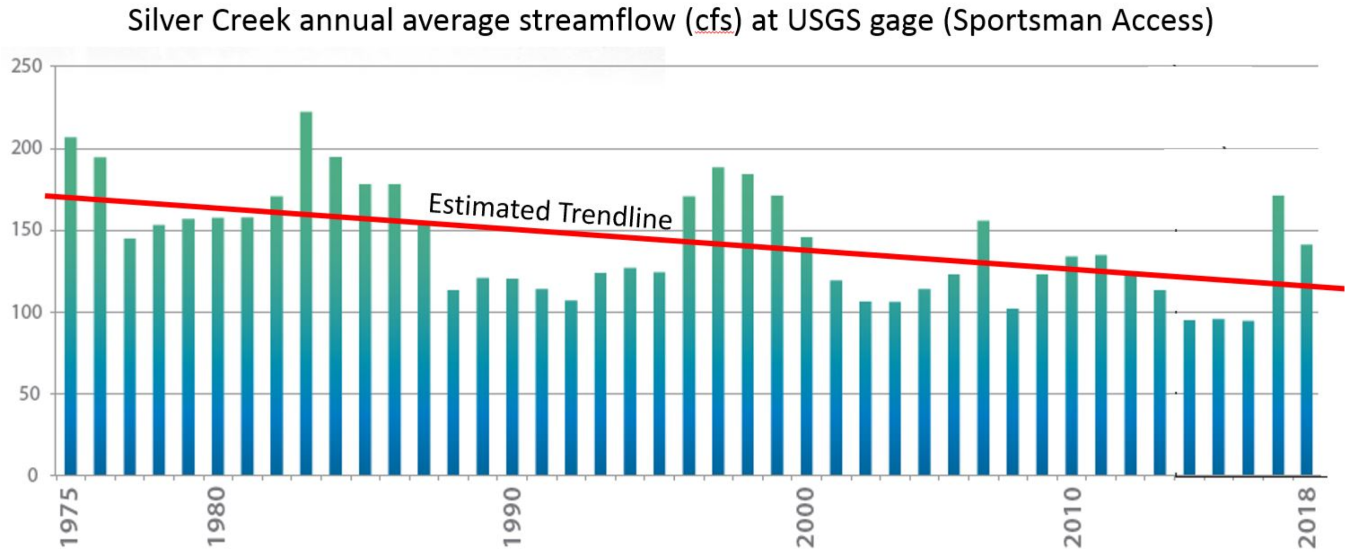
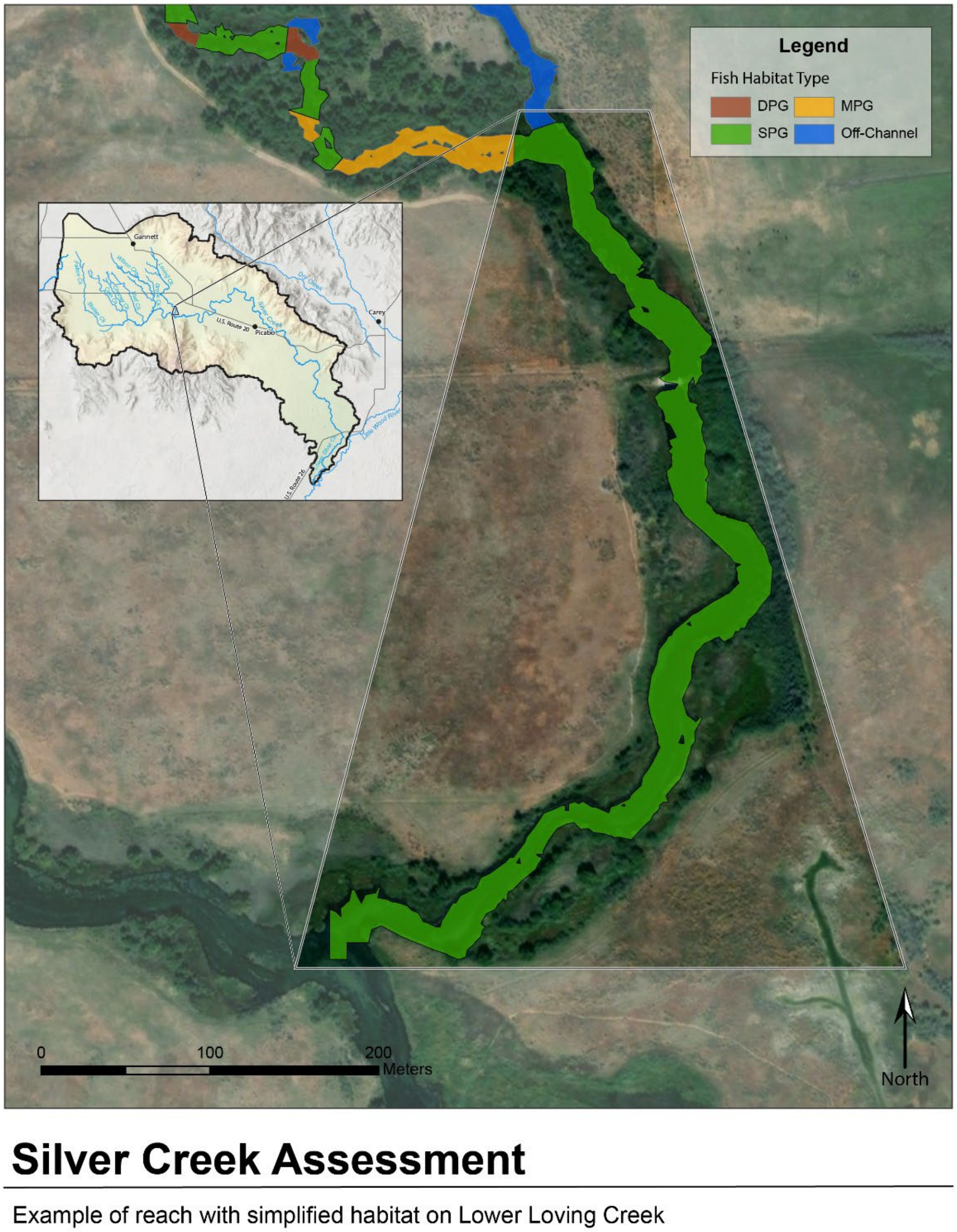


Figure taken from Ecosystem Sciences (2018) with estimated trendline added for this report. The trendline shows a decreasing average discharge over the period of record.

While hydraulic modeling was only completed for lower Loving and lower Stalker/Chaney, some of the hydraulic modeling results point to systemic generalizations observed throughout the watershed. Dense aquatic vegetation occupies much of the streambed in many of the reaches, creating hydraulic roughness, slowing water velocities, and increasing fine sediment deposition. Aquatic vegetation and sediment therefore obstruct flow and force an increase in channel width and/or depth. This phenomenon is most pronounced in the summer when aquatic vegetation growth peaks and is diminished in the winter when vegetation dies back and stored sediment is released. This annual cycle of changing channel geometry roughly corresponds with natural variations in local hydrology such that when discharge is lowest in the summer, vegetation/sediment is at its peak, propping up the water surface during these low-flow times. When discharge is at its peak in the late winter/spring, the vegetation/sediment is at its lowest, lowering the water surface during these high-flow times. The result is a highly consistent water surface with minimal floodplain interaction except during periods of extreme runoff, especially late in the spring/summer when aquatic vegetation growth has occurred.

Past habitat mapping (Ecosystem Sciences unpublished data) shows that most reaches in the Silver Creek watershed exhibit multiple habitat units (i.e., riffle, run, pool glide), but the frequency and magnitude of change between habitat units is very low, resulting in low habitat diversity (Figure 4-5). For example, a single habitat unit may extend for over 1,000 ft in a reach where transitions between habitat units should occur on the order of every 10–100 ft. Channel over-widening and a significant lack of in-stream structure (primarily woody vegetation encroachment and woody debris) preclude the formation and maintenance of such habitat diversity. Poor habitat continuity results from these large gaps between complex/diverse habitats, which can isolate and segregate fish and potentially reduce available habitat capacity, thus creating a density dependence limiting overall production.

Figure 4-5. Example of Simplified Habitat



A single habitat unit occupies lower Loving Creek for over 1000 linear ft illustrating the lack of habitat complexity in this reach. Many other reaches in the watershed exhibit similar characteristics. BP = Backwater Pool, DPG = Deep Pool-Glide, LGR = Low-Gradient Riffle, MGR = Medium-Gradient Riffle, MPG = Medium Pool-Glide, PT = Pool-Trench, RUN = Run, SPG = Shallow Pool-Glide.

4.2 Common Watershed-Scale Trends

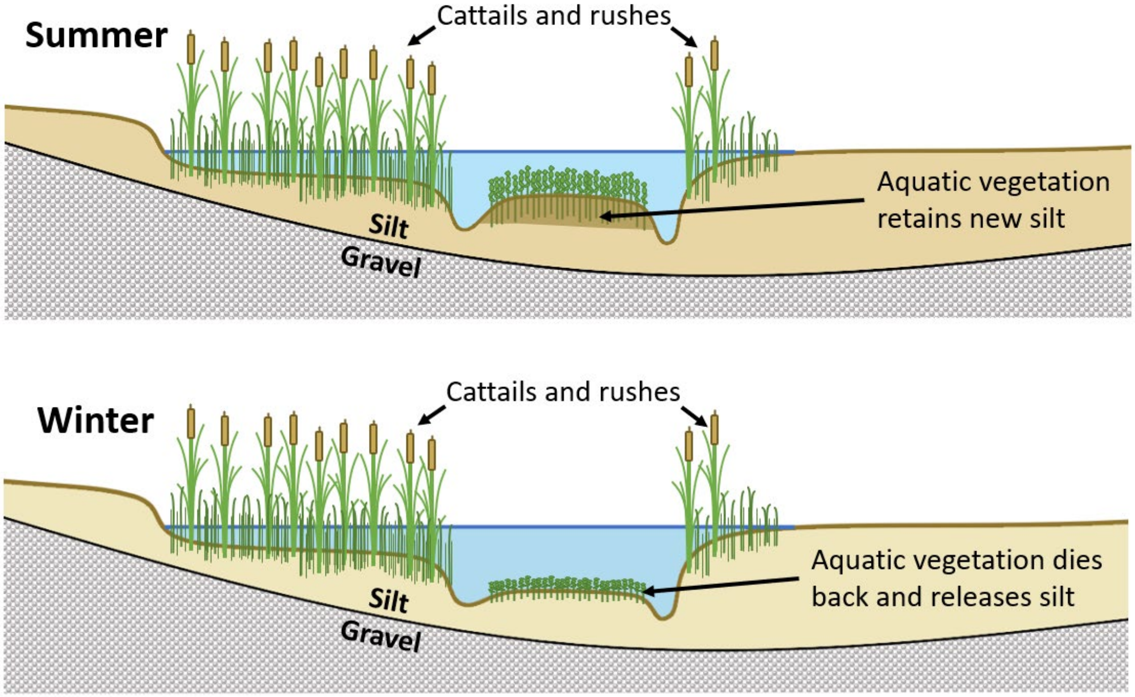
The systemic conditions described above result in persistent trends observed throughout the watershed including changes in channel shape, sediment transport, and habitat. Channel over-widening appears to have peaked in roughly the 1990s, and gradual narrowing via vegetation encroachment is beginning to occur. Historical aerial photograph measurements suggest average channel widths increased from the 1940s to present day, but most widening occurred prior to the 1990s, with little or no widening occurring in recent years. Several reaches have even contracted, either due to active restoration (rebuilding narrower banks) or from passive vegetation encroachment. Rates of natural vegetative encroachment are very slow and would require many decades to reduce overall stream widths to preferred target conditions without additional active restoration in most reaches.

Channel shape and character is also affected by riparian vegetation. Steady flows in a spring-fed stream and an associated high-water table typically supports growth of robust riparian vegetation (Whiting and Moog 2001). Based on this information and professional judgement, Silver Creek likely exhibited a much more dense, robust, and continuous riparian corridor prior to wide-spread human disturbance associated with agriculture and grazing land use. Historical aerial photographs suggest riparian clearing was widespread by the 1940s, and restoration efforts and expanded riparian corridors in recent years have only minimally improved riparian vegetation. A general lack of riparian vegetation has likely exacerbated channel over-widening, reduced in-stream structure and cover resulting in less habitat, and reduced shade causing higher stream temperatures in the summer. It is not anticipated that riparian conditions or the habitat they promote will be restored naturally without a change in land use adjacent streams.

The shape of the streambed has also changed over time. Channels with small drainage areas and consistent spring-fed hydrology are not subject to significant runoff and associated high peak floods that would mobilize and transport large volumes of bedload creating point bars, bank erosion, and channel migration. The banks of the streams in the Silver Creek watershed would have been historically highly stable, enabling vegetative encroachment that provides hydraulic roughness and in-stream structure. This roughness and structure would have enabled the formation of localized pools throughout the system, and with minimal bedload inputs from upstream to fill or alter the bedform, pools would have likely persisted over the long term. Beaver activity was common throughout Idaho prior to wide-spread trapping (Baker and Hill 2003). Beaver dams also provide significant in-stream structure and create backwater pools that force overland flow through riparian areas occasionally causing channel avulsions. These avulsions around beaver dams and through dense riparian vegetation created the sinuous channel planform visible in the Silver Creek watershed and provided copious amounts of localized woody/vegetative structure and irregular topography enabling pools and other diverse bedforms (Whiting and Moog 2001).

Fine sediment also influences bedform, channel shape, and overall habitat. The degree to which fine sediment deposition has changed over time is not clear. However, spring-fed channels often are relatively free of fine sediments because sediment transport occurs often enough to flush fine sediments (Whiting and Moog 2001). Prior to wide-spread human disturbance, Silver Creek likely exhibited far less fine sediment deposition, and more of the channel surface was covered by gravels similar to other less-disturbed spring-fed channels. Human disturbance in the watershed has increased the amount of upland sediment entering the stream every year. This sediment is captured along the bed in aquatic vegetation in the summer. When aquatic vegetation dies back each year in the winter, previously captured sediment becomes exposed and is transported downstream (Figure 4-6). This process repeats annually as sediment slowly moves downstream, replaced by new sediment from upstream sources. The lack of recently observed bank and/or bed erosion suggests in-stream fine sediment sources may be diminishing, but anecdotal accounts of highly turbid water during spring runoff, frequent pond dredging, and recent measurements of channel substrate suggest the ongoing trend of fine sediment deposition is relatively unchanged and likely to persist for years into the future.

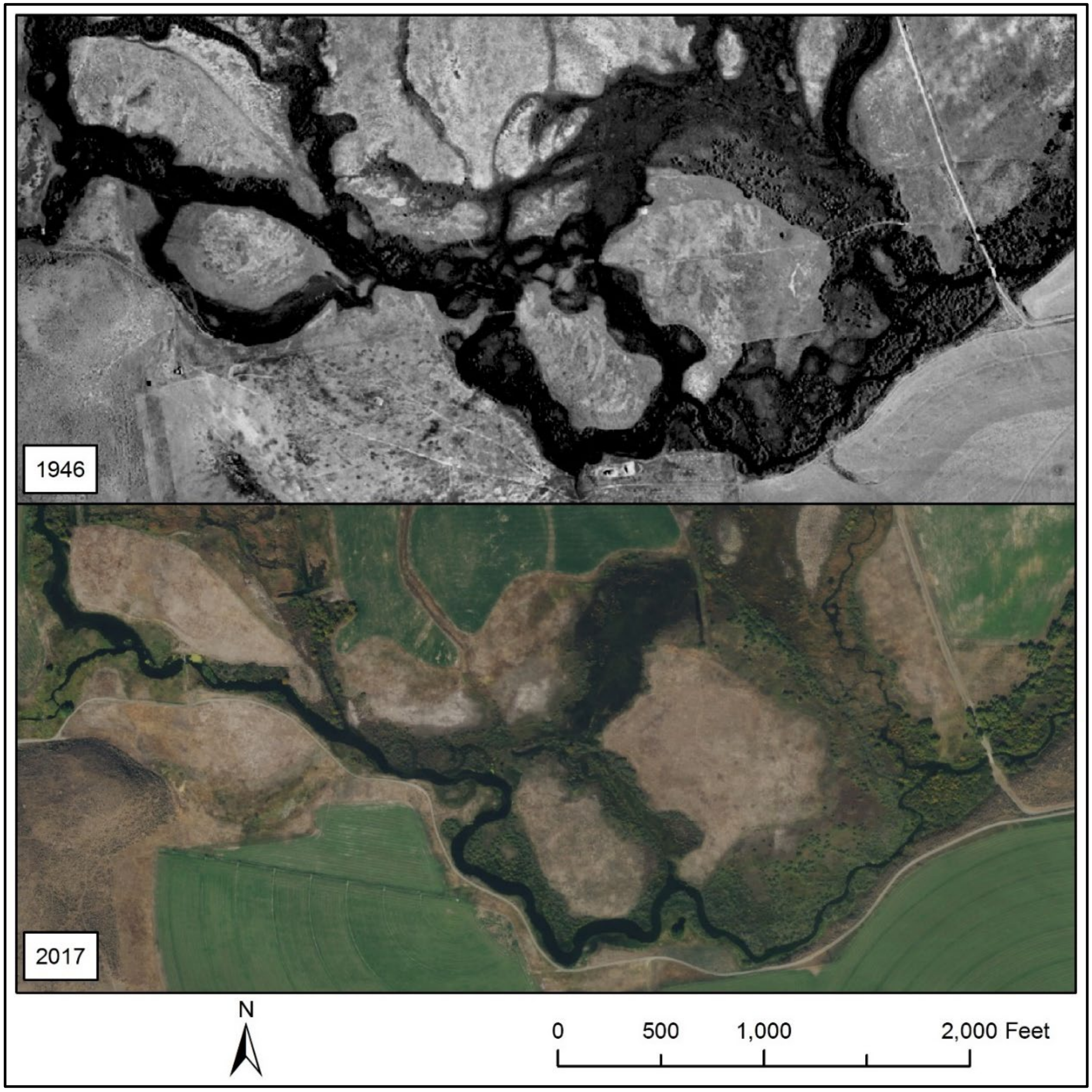
Figure 4-6.Illustration of Aquatic Vegetation and Sediment Accumulations in Summer vs. Winter



This figure shows a simplified illustration of the relationship between aquatic vegetation and fine sediment accumulations in the summer and the partial release and mobilization of those sediments in the winter when aquatic vegetation dies down. Silt and aquatic vegetation tend to accumulate less near the margins of the channel as shown.

The most pronounced changes to channel shape and habitat have been a result of physical channel alterations. Historical aerial photographs and relic topography visible in LiDAR reveal many abandoned and disconnected channels across much of the Silver Creek valley bottom along with dozens of linear ditches that redirect surface flows and/or drain wetlands. While it is believed that many channel alterations likely occurred prior to the 1940s, especially resulting from beaver eradication, comparing 1940s aerial photographs to recent photographs reveals many more areas of relatively recent channel simplification where a multi-threaded channel was consolidated to a single thread (Figure 4-7). Photographs from the 1940s also illustrate locations where the stream previously flowed around vegetated islands within the floodplain and several side channels that exhibited a longer flow path than the main stem. Many historically sinuous side channels are now blocked or converted into linear irrigation ditches. Similar to other characteristics in the Silver Creek watershed, this trend of channel simplification appears to have peaked by the late 1900s and has begun to slowly reverse as a result of several recent restoration efforts.

Figure 4-7. Channel Simplification at Lower Stalker and Downstream Portions of Mud and Chaney Creeks



4.3 Common Watershed-Scale Conclusions

A comparison of current and historical conditions throughout the Silver Creek watershed indicate several common issues as indicated below.

- Over-widened channel geometry
- Lack of pools
- Excessive fine sediment deposition
- Degraded and/or denuded riparian vegetation
- Channel simplification
- High summer stream temperatures

After delineating and evaluating each reach in the watershed (as described in Appendix B), it is clear the width of the channel in most reaches exceeds (in some cases significantly exceeds) the geomorphically appropriate target width for a stream of that size, gradient, and hydraulic character. It is believed there are two likely causes of this channel over-widening.

1. Land use practices have degraded or denuded riparian vegetation resulting in increased bank erosion.
2. A lack of riparian shade has enabled an increase in aquatic vegetation density which has reduced in-stream conveyance, increased water surface elevations, and expanded channel width.

Recent changes in land use within some reaches have not produced a measurable decrease in channel widths over the last several decades even where riparian vegetation has been reestablished. Active channel restoration is likely the only means to narrow over-widened channels within reasonable timescales.

Pools are a good indicator of overall habitat complexity (Bjornn and Reiser 1991), and they are lacking in many reaches within the Silver Creek watershed. Wide channels with aquatic vegetation distribute stream energy over a broad surface area, reducing in-stream velocity and the potential for concentrated flow and energy to scour pools. A stream's velocity and associated capacity to scour pools increases when the channel width is contracted (like reducing the size of a fire hose nozzle), because the same volume of water must now pass through a smaller opening. Without frequent structures creating channel constrictions that can scour pools, the bed of the channel becomes relatively homogenous and lacking for fish habitat. As with channel narrowing, riparian vegetative encroachment required to create in-stream structure is a very slow natural process. Without active restoration, the amount of pools is unlikely to significantly increase within the foreseeable future.

These conditions (over-widened channel and lack of pools) are exacerbated by high volumes of fine sediment derived from ongoing periodic upland runoff and remobilized legacy sediments already in the stream channel. It is not well understood whether fine sediment deposition rates have increased, decreased, or remained constant over time, but based on the lack of observed bank and bed erosion, it is believed legacy sediments are becoming more and more stable over time with a greater and greater proportion of sediment derived from upland runoff. While fine sediment inputs are believed to have decreased with recent improvements to land use practices, excessive fine sediment deposition continues to be an issue. The continued fine sediment deposition indicates that existing/ongoing natural processes are unlikely to reverse this trend in the foreseeable future. Fully addressing the fine sediment supply to the stream would require significant changes in land use practices, development of broad, continuous riparian buffers, and removal of the existing sediment. Addressing the source of the fine sediment issue may take many decades to address, suggesting in-stream restoration actions may be required over the short- and medium-term to increase transport capacity to scour/remove existing fine sediments and decrease sediment supply where feasible.

Stream temperatures fall within the stress band for trout in many reaches during the summer months (Ecosystem Sciences 2011–2018). Elevated summer temperatures are believed to be a result of insufficient shade from poor riparian conditions and from over-widened channels that result in larger surface areas of water exposed to solar heating, reduced velocity, and therefore increased duration of heating, as well as reduced pool formation that would otherwise enhance contact with cool groundwater. Potential restoration actions will need to focus on creating and maintaining a healthy riparian buffer to reduce summer stream temperatures.

Extensive channel simplification has occurred in some reaches resulting from a lack of beaver influence and from human channel manipulation. The reaches where simplification has occurred are characterized by predominantly single-threaded channel morphology with reduced sinuosity and poor floodplain/off-channel connectivity. Given a lack of formative processes such as beaver activity and riparian vegetation encroachment, side channels and improved channel form are unlikely to form naturally within a reasonable timeframe, suggesting active channel restoration is required.

The streams in the Silver Creek watershed are spring-fed, exhibit a relatively consistent hydrology, and other than human influence, function like most other spring-fed streams that are highly stable and exhibit very slow rates of natural recovery. It is apparent that improving habitat conditions for wild trout within the foreseeable future will require active restoration actions including narrowing over-widened channel segments, adding woody debris and other forms of in-stream structure, excavating new and more sinuous channels, and reducing fine sediment deposition. Implementation of any restoration action requires an understanding of the desired target conditions from which a restoration plan/design can be established. The following section summarizes common target conditions for restoration within the Silver Creek watershed.

4.4 Common Target Conditions for Reaches throughout the Watershed

Target conditions describe geomorphically appropriate and habitat-optimized metrics for a given area based on reference reach comparisons and published literature recommendations. These recommendations build off of the targets established from the existing background information by integrating the results of this assessment and reference reach and other published recommendations. Some target conditions for the Silver Creek watershed are the same for all reaches. To avoid redundancy in the target descriptions for each reach summarized in Appendix B, those that could be generalized for all reaches have been described below. Examples of potential treatments to achieve these target conditions have also been described later in this report (Section 4.5 and Appendix B).

- Channel Width: For many reaches, the target bankfull channel width was determined to be substantially less than the existing condition. Target width conditions were determined via several sources. Within the mainstem, the most common approach was using reference sites also within the mainstem (Figure 4-8). For tributaries where channel hydrology was available, target channel width was determined from regression equations based on the bankfull discharge, which in this system was determined to be the 1.5-year recurrence interval flood (Castro and Jackson 2001). Specific target bankfull widths are summarized per reach in Appendix B.

Figure 4-8. Photograph of Reference Channel Width for Lower Stalker Creek

Photograph of lower Stalker Creek downstream of confluence with Mud Creek. Photo is looking downstream.

- ▲ Pools: Although not every reach was observed in the field as part of this assessment effort, it is understood from anecdotal information and from those areas observed that many stream reaches in the Silver Creek watershed are fairly homogenous, plain-bed and/or otherwise lacking pools. Target conditions per reach generally support more frequent pools as summarized per reach in Appendix B.
- ▲ Sediment: Excessive fine sediment is the result of overly abundant source material and/or poor sediment transport characteristics enabling deposition. Target conditions addressing sediment include the following:
  - o Reduce fine sediment supply from surrounding floodplain and uplands. This likely would require modifying land use practices to reduce the area of exposed soil subject to water and wind erosion.
  - o Reduce fine sediment runoff before it reaches the stream with riparian buffers, wetlands, and/or other stormwater management best use practices (BMPs).
  - o Retain in-stream fine sediment in specified sediment traps (ponds and other low-velocity areas within the stream and floodplain) where it results in less impact to wild trout and/or can be actively managed (i.e., periodically dredged).
  - o Reduce in-stream width-to-depth ratio to increase sediment transport capability to pass fine sediment through specified reaches without depositing in undesirable locations.
- ▲ Riparian Conditions: Many banks lack a robust riparian corridor providing structure to banks and a buffer from agricultural land use practices. Target conditions generally include a mature and broad riparian buffer consisting of native/appropriate vegetation along both banks (Figure 4-9). Stream width should be used to determine riparian buffer width as shown in Table 1.

Figure 4-9. Photograph of Reference Riparian Vegetation

Photograph looking downstream on the East Fork Potlatch River, Northern Idaho. Dense shrubs (willow and alder) are encroaching the bankfull channel width, interacting with flows at all discharges, and providing bank structure, in-stream hydraulic roughness and cover.

Table 1. Recommended Riparian Buffer Widths for Silver Creek

Stream Width (ft)	Riparian Buffer Width* (ft)
0-16.5	33
16.5-50	2x stream width
50+	100

*Buffer widths determined by combining Wenger 1999, USACE 1991, and Palone and Todd 1998.

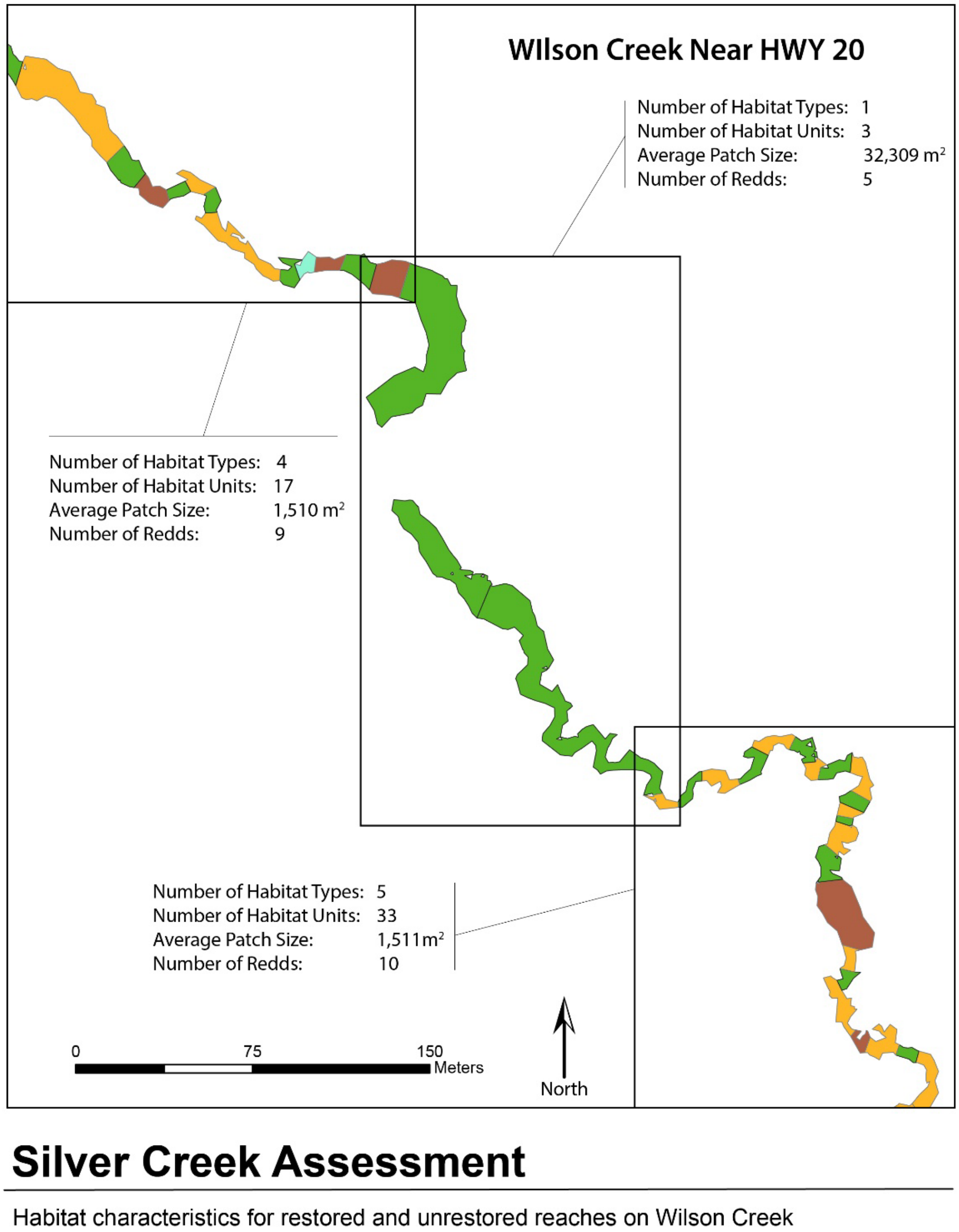
- ▲ Habitat Diversity/Complexity: There are large areas of poor/homogenous habitat within the watershed where the stream channel often exhibits a plain bed character. Target conditions include a greater frequency of changing habitat units (pools, riffles, glides, and runs) derived from greater sinuosity and a greater frequency and magnitude of in-stream structure forcing channel constrictions, sorting sediment, and otherwise creating in-stream complexity with cover (Figure 4-10).

Figure 4-10. Pool and Riffle Habitat

A mix of clean gravels in a riffle, a deep pool with overhanging riparian vegetation, and sections with submerged aquatic vegetation provide multiple habitats suitable for trout.

- Habitat Connectivity: Although there are many areas of high-quality habitat in the Silver Creek watershed, continuity between these high-quality areas is often lacking. If a large area of poor habitat separates two areas of high-quality habitat, the habitat connectivity in that area is poor, because the poor habitat discourages trout movement that would otherwise connect upstream and downstream reaches (Figure 4-11). Target conditions include connecting areas of high-quality habitat together to provide greater habitat continuity. Habitat restoration priority should be given to reaches with a high potential for improving habitat connectivity (i.e., improve one poor section that is isolating two good sections).

Figure 4-11. Example of Poor Habitat Connectivity



Long stream segments with poor/simplified habitat (i.e., single habitat unit for hundreds of feet as shown in the example from Wilson Creek above) potentially discourage fish migration through these areas isolating upstream from downstream habitat. BP = Backwater Pool, DPG = Deep Pool-Glide, LGR = Low-Gradient Riffle, MGR = Medium-Gradient Riffle, MPG = Medium Pool-Glide, PT = Pool-Trench, RUN = Run, SPG = Shallow Pool-Glide.

4.5 Potential Restoration Actions

Conditions in the Silver Creek watershed have evolved over decades resulting in many of the observed impacts adversely affecting fish habitat. The magnitude of impacts relative to the rates of "natural" recovery suggest habitat is unlikely to be repaired by natural stream evolution within the foreseeable future (i.e., many decades). Channel restoration is therefore recommended to improve conditions by building new habitat (active restoration) and/or accelerating the stream's ability to naturally repair itself and create new habitat (passive restoration).

Restoration objectives should focus on addressing the project goal of creating a sustainable, wild trout fishery by reducing over-widened and simplified channel forms, increasing in-stream hydraulic structural complexity, and improving riparian vegetation. Any restoration effort will also need to address several geomorphic constraints to be sustainable over the long term including the following:

- Reduce fine sediment supply and/or increase sediment transport capacity to prevent infilling of restored habitat.
- Create robust riparian corridors to provide long-term bank and channel structure along with shade and floodplain roughness.
- Design and build channel forms suitable and geomorphically appropriate for the reach in which they are installed (i.e., use appropriate target conditions).

Summarized below are active and passive restoration actions generally suitable for the Silver Creek watershed to directly address target conditions to improve habitat suitable for a sustainable, resilient wild trout spring creek fishery. Specific details of each proposed restoration action are provided in Appendix C (Drawings D1–D6).

Reduce Channel Width: Many reaches and/or subreaches in the watershed have become significantly over-widened. Natural vegetation encroachment will take many decades to reduce the channel width to meet target conditions. Active channel restoration can be used to build new banks, creating a more appropriate width immediately. Likewise, given the perceived high volume of fine sediment available in the system, building features along the banks to capture fine sediment and reduce the effective width of the channel can be used to accelerate rates of natural narrowing. Reducing the effective channel width can also increase in-stream velocity and sediment transport capacity, which can reduce potential future fine sediment deposition between the new banks and/or locally scour existing fine sediment from the bed forming pools.

- Active Bank Fill: Build new banks using suitable materials (Figure 4-12; see also Appendix C)
  - Gravel Bank Fill: Build new banks using gravel or a gravel/cobble mix capable of withstanding anticipated bank erosion forces. It may be necessary to create a borrow source to acquire a sufficient volume of suitable gravel material for bank fills depending on the cut/fill ratios for a given project area. Excavating off-channel oxbow wetlands and/or ponds (with or without main-steam surface water connections as desired) is an appropriate means by which suitable bank fill material can be generated locally thereby minimizing haul distances. Appropriate riparian planting is recommended for long-term bank structure, stability, and shade in all bank fill applications.
  - Fabric-Encapsulated Soil Lift (FESL): If available fill material is not suitable for standalone bank construction (i.e., dredge spoils, silt, etc.) or cannot withstand anticipated stream forces, these materials can be wrapped in biodegradable fabric and placed in lifts to facilitate construction. Additionally, the FESL enables the construction of near-vertical banks if desired, where most other bank treatments require

sloped banks. The biodegradable fabric provides short-term stability enabling vegetation to establish and grow providing long-term stability.

Figure 4-12. Bank Fill Treatment Example

Photograph of bank fill treatments (brush bank and FESL) being installed on Big Springs Creek in central Idaho. The treatments were used to reduce the over-widened channel and provide floodplain area to establish riparian vegetation. The treatment area shown in the photo was isolated from surface water stream flow during construction.

  - Brushlayer: If available fill material is suitable for bank construction (i.e., gravel), banks can be built directly with the suitable material then protected from short-term erosion using an integrated brush layer along their margins.
  - Wetland sod: Similar to the brushlayer, harvested or nursery-grown wetland sod can be used to provide immediate bank stabilization to newly constructed banks, providing the added benefit of also providing long-term stability once fully rooted/established, although willow plantings should be included to meet riparian vegetation targets.
  - Retention fence: Similar to FESL, to be used if available fill material is not suitable for stand-alone bank construction and/or to create a near-vertical bank. A retention fence composed of wood can be used in conjunction with a biodegradable filter fabric along its face to retain bank fill material and provide short-term stability until riparian vegetation can become established.
  - Willow clumps: Similar to a brushlayer, live or dead willow clumps (rootwad and plant) can be integrated in series along newly constructed bank margins to provide a buffer against erosion until riparian vegetation can be established.
- Passive Bank Fill: Install in-stream structure(s) to capture and retain sediment along the banks resulting in a narrower effective channel width (Figure 4-13).

Figure 4-13. Passive Bank Fill Example Using Post Line Willow-Weave

Image of post line willow-weave passive bank treatment installed on Big Springs Creek 2 months after construction in central Idaho. Flow is from the bottom of the image to the top. Fine sediment is already being captured between the willow-weaves which also provide low-velocity habitat and cover for juvenile fish until completely filled with sediment. The filled area will become the future right bank of the channel.

- Willow Clumps: Placing willow-clumps (rootwad and plant) in series along an existing bank can increase bank roughness and buffer the bank from erosion. Individual clumps are typically held in place with small-diameter wooden piles driven into the channel bed. Like bank barbs, a series of closely spaced willow clumps can accumulate fine sediment directly adjacent the bank reducing channel width over the long term while providing enhanced in-stream structure and cover over the short term.
- Post-Line Willow Weave: Oriented perpendicular to the bank, a post-line willow weave consists of vertical wooden posts driven into the streambed and willow branches woven between them to create a fence-like structure obstructing flow extending outward from the bank. If constructed in a series, post-line willow weaves can create a depositional area adjacent the bank that can accumulate fine sediment and reduce channel width over the long term. Due to their variable length, post-line willow weaves can be used to accommodate very large bank fills.

Reduce Sediment Sources: Fine sediment consisting primarily of silt is pervasive throughout the Silver Creek watershed. Fine sediment sources include both upland and in-stream sediments. Reducing the sources of fine sediment can improve habitat diversity by reducing the potential for filling pools and covering spawning gravels.

- Upland Sediment Sources: Most upland sediment sources are derived from land use practices that result in exposed bare soil such as agricultural plowing and/or cattle grazing. Upland sediment can be controlled at its origin or by limiting its ability to runoff into adjacent streams via riparian buffers.
- Riparian Planting: Establishing or maintaining a dense, mature riparian buffer both separates potential upland sediment sources from the stream, but also provides a filter to capture sediment from runoff before entering the stream (Figure 4-14).

Figure 4-14. Riparian Planting Example

Photograph during construction of a bank fill and associated riparian planting effort used to narrow an over-widened segment of the Lemhi River in central Idaho. Riparian planting included native sod mats harvested from the project area along the bank and potted willows and shrubs located behind the sod mats.

- Stormwater Runoff BMPs: Although beyond the scope of this assessment, and therefore not discussed in further detail elsewhere in this report, there are many potential means by which upland sediment sources can be reduced directly via stormwater runoff BMPs including planting cover crops, planting windrows, fencing, creating filter strips, contour farming, excavating sediment basins, etc.
- In-Stream Sediment Sources: Years of historical upland runoff coupled with aquatic vegetation along the streambed and over-widened channels incapable of transporting their fine sediment load have resulted in substantial accumulations of silt on the streambed throughout much of the watershed.
- Reduce in-stream aquatic vegetation and channel width-to-depth ratio via bank fills (described above) and/or in-stream structure (described below) creating localized areas of channel contraction scour. Because the majority of the frequently mobilized in-stream fine sediment is believed to be captured and remobilized from aquatic vegetation each year, reducing the amount of aquatic vegetation can reduce the rate of sediment retention effectively increasing the transport efficiency of the stream. If the stream retains less fine sediment, there will be less available for future mobilization.

- Stabilize eroding banks using bioengineering methods as described for "Bank Fill" treatments above. Such treatments can provide short-term bank stabilization, while riparian vegetation is ultimately required for successful long-term stabilization. Very few areas of bank erosion have been documented, and this is not believed to be a substantial source of fine sediment in the system.

Capture and Retain Fine Sediment: Use strategic low-velocity areas to capture and retain (and potentially remove) fine sediment where appropriate. Floodplains are natural areas of sediment deposition and accumulation. Increasing the frequency and area of floodplain inundation by narrowing the channel (described above) or by creating backwater areas from channel constriction (described below) will enable greater sediment accumulation on the floodplain and a proportional reduction of in-stream sediment. Increased floodplain inundation is appropriate anywhere in the watershed where greater flooding is permissible. Additionally, fine sediment can be captured in slack-water ponds that are natural sediment traps. Several existing in-line ponds currently capture sediment which is periodically dredged and removed from the system. Although not a long-term solution, dredging existing ponds can be an effective management strategy to remove sediment from the stream until more long-term solutions can be established (Figure 4-15). Sediment retention ponds should also be considered to capture agricultural runoff from irrigation returns and/or other known point sources of sediment before it enters streams. In-line pond creation should be considered carefully so as not to diminish the natural character of the free-flowing stream with an overabundance of slack-water ponds. New ponds should be strategically located in low-gradient areas immediately downstream of sediment sources and/or in areas with the greatest volume of in-stream fine sediment. Sediment sampling (i.e., turbidity tests) taken during high flows can be used to quantify in-stream fine sediment.

Figure 4-15. Dredging of Kilpatrick Pond

Photograph of dredge removing fine sediment from Kilpatrick Pond (Reach 4D) in 2013 (photo from The Nature Conservancy: http://idahonaturenotes.blogspot.com/2013/10/update-on-kilpatrick-pond-restoration.html)

Add In-Stream Structure: Woody debris, dense root mats, boulders, and other hard points along the banks and in the channel that are erosion-resistant and/or obstruct flow provide structure and roughness to a stream (Figure 4-16). In-stream structure can force localized areas of contraction and expansion creating areas of potential scour and deposition, respectively. Vegetation encroachment and beaver dams commonly provide in-stream structure in un-impacted, small, spring-fed channels. Restoration actions that mimic vegetative encroachment and beaver dams include small and large woody debris habitat structures, bank structure (bioengineering and woody vegetation), boulders where appropriate (near bedrock and/or valley margin) and post-line willow weave beaver dam analogues.

Figure 4-16. Willow Clump Example

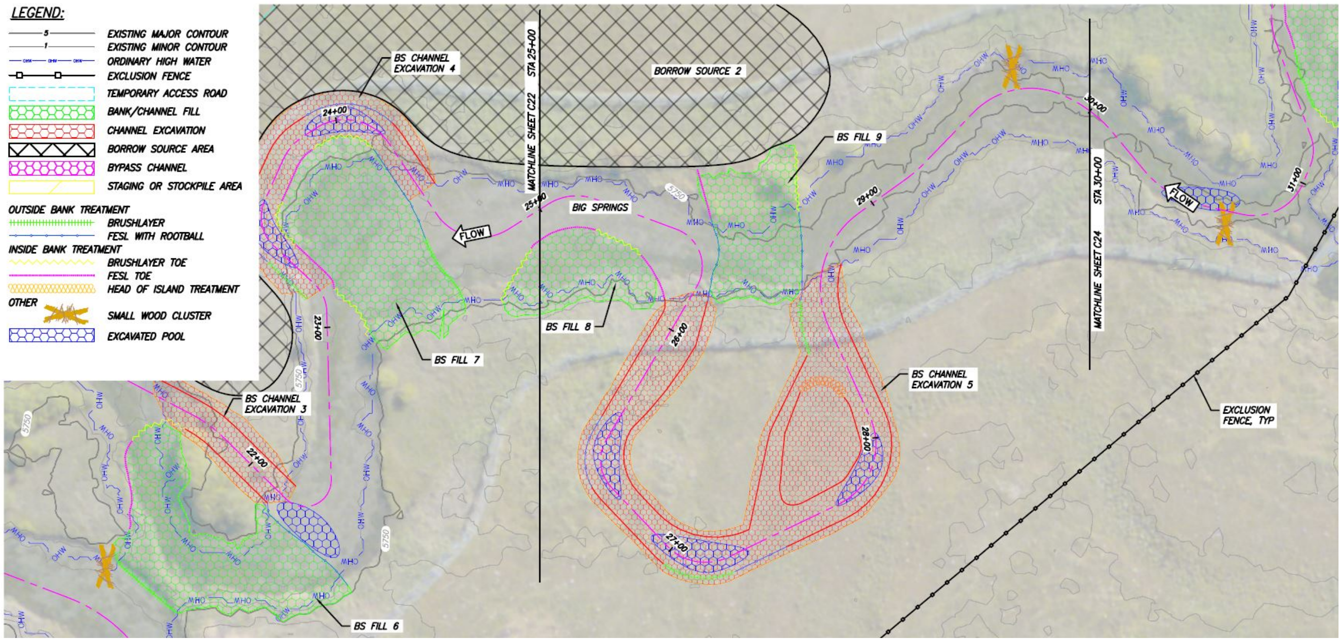
Photograph of three willow clumps installed along the newly constructed bank fill on Big Springs Creek in central Idaho. The willow clumps provide structure and cover along the left bank, constrict flow, and maintain the pool excavated at this location providing improved habitat to native salmonids. The photo looks downstream in the first growing season after construction.

- Woody Debris Constriction: Small and large woody debris, slash, and/or willow clumps can be placed strategically along both banks opposite each other forcing a channel constriction. The woody debris structure must be constructed to be robust, able to withstand anticipated increased stream forces, and promote vegetative growth providing long-term stability and function. A constriction of this sort (structures on both banks) are commonly used on otherwise straight, over-widened reaches where structure is lacking. Hydraulically ineffective areas along the banks immediately upstream and downstream of the construction often fill with sediment and promote further channel narrowing.
- Small Woody Debris or Willow Clump Habitat Structure: Bundles of small woody debris and/or willow clumps can be installed together and secured to the streambed along one or both banks of the channel providing in-stream structure forcing hydraulic variability. When placed on only one bank, the opposite bank must be adequately stable so as to encourage vertical scour as opposed to lateral bank erosion given the concentrated stream forces created by the structure.
- Large Woody Debris Habitat Structure: Larger trees can be embedded into the bed and bank to emulate windfall that can obstruct flow creating in-stream roughness and hydraulic variability. Large woody debris can be oriented with the rootwad in the channel for more robust structure where stream forces are great or the top of the tree with branches in the water providing hydraulic roughness, and cover where stream forces are less severe.

- Post-Line Willow Weave: Similar to a beaver dam (or partial beaver dam), willow weave structures can be built across all or part of the channel to obstruct flow. The construction of these structures is low impact, can commonly be completed by hand or with minimal machine assistance, and does not require large amounts of imported material. Willow weaves do not include imported fill and therefore require adequate incoming sediment load to fill adjacent ineffective flow areas along the banks immediately upstream and downstream of the structures promoting vegetation encroachment for long-term success.

Increase Channel Sinuosity Where Straightened: Increased sinuosity should be used to add stream length and bank structure (i.e., relocate the channel adjacent existing mature riparian vegetation) where appropriate (Figure 4-17). One of the principal restoration actions recommended above is reducing the channel width, which can increase in-stream velocity. If the predicted velocity resulting from reducing the stream width is greater than desired, additional stream length (greater sinuosity) can be used (potentially in conjunction with greater bank roughness and over-bank flood activation) to reduce in-stream velocities to more acceptable levels. Additional sinuosity should always be designed using appropriate meander beltwidth, amplitude, wavelength and bend radius of curvature (requires additional analysis). Inappropriate sinuosity can cause unintended consequences such as increased flooding and channel avulsion.

Figure 4-17. Increased Sinuosity Example



The image above illustrates a plan view of the final design for a stream restoration project on Big Springs Creek in central Idaho. Shown in red are proposed excavations (cuts) and in green proposed fills with the intended goal of increasing channel sinuosity and reducing overall channel width. This project designed by Rio ASE and was later constructed by the Lemhi Regional Land Trust in 2019.

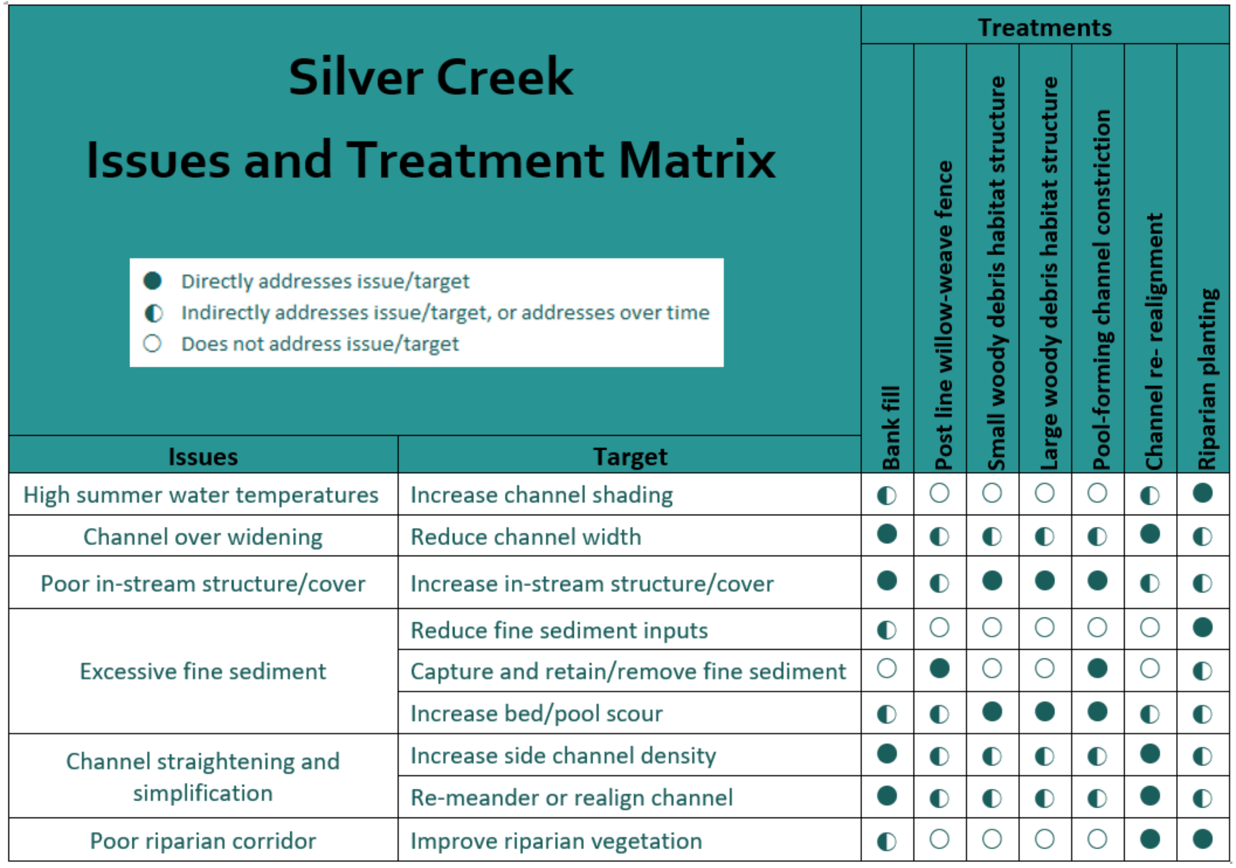
- Channel Realignment: Filling over-widened portions of the channel and/or excavating new channels to create a more appropriate channel alignment (and to create side-channels) is an effective restoration action creating immediate channel response and associated habitat. All channel realignments should seek to interact with existing mature riparian vegetation for immediate bank structure, cover, and shade and/or add appropriate bank structure and vegetation where otherwise lacking – particularly where stream forces are greatest such as along the outside of bends and downstream of channel constrictions.

Improve Riparian Buffer: The root cause of most impacts associated with the Silver Creek watershed stems from poor riparian vegetation including a lack of vegetative encroachment and associated in-stream structure, poor bank structure enabling erosion and channel widening, diminished buffering of upland runoff, and inadequate shade causing elevated summer stream temperatures. Planting riparian vegetation and encouraging the propagation of existing riparian vegetation will provide long-term bank structure/stability, shade, and capture sediment. Planting appropriate riparian vegetation should be utilized with any/all other habitat restoration actions.

Summary

When considering a restoration project, there are several steps that should be taken to increase the chance of success. First, the problems (i.e., issues) must be identified and prioritized. It is generally better to address the problems directly rather than simply treating the symptom(s). Second, developing a restoration plan requires a goal or desired outcome. It is assumed for the sake of this report that the common goal of restoration for projects in the Silver Creek watershed is to improve habitat for native trout. With that goal in mind, the next step is to determine which restoration actions (i.e., treatments) can be used to directly or indirectly address those issues to achieve a desired outcome (i.e., target). Achieving the restoration targets for a given area is a prerequisite for achieving the restoration goal. The treatments discussed previously in this section each directly or indirectly address common issues and targets in the watershed as summarized in Table 2. By combining appropriate treatments specifically selected to address the known issues/targets within a given reach, a conceptual restoration plan can be developed and refined through additional engineering design.

Table 2. Summary of Issues, Targets, and Restoration Treatments for Silver Creek



Silver Creek
Issues and Treatment Matrix

● Directly addresses issue/target
◐ Indirectly addresses issue/target, or addresses over time
○ Does not address issue/target

		Treatments						
Issues	**Target**	**Bank fill**	**Post line willow-weave fence**	**Small woody debris habitat structure**	**Large woody debris habitat structure**	**Pool-forming channel constriction**	**Channel re- realignment**	**Riparian planting**
High summer water temperatures	Increase channel shading	◐	○	○	○	○	◐	●
Channel over widening	Reduce channel width	●	◐	◐	◐	◐	●	◐
Poor in-stream structure/cover	Increase in-stream structure/cover	●	◐	●	●	●	◐	◐
Excessive fine sediment	Reduce fine sediment inputs	◐	○	○	○	○	○	●
	Capture and retain/remove fine sediment	○	●	○	○	●	○	◐
	Increase bed/pool scour	◐	◐	●	●	●	◐	◐
Channel straightening and simplification	Increase side channel density	●	◐	◐	◐	◐	●	◐
	Re-meander or realign channel	●	◐	◐	◐	◐	●	◐
Poor riparian corridor	Improve riparian vegetation	◐	○	○	○	○	●	●

5 Reach Prioritization

A reach prioritization was completed to identify two reaches for additional analysis in support of the assessment and conceptual restoration of those reaches. The reach prioritization focused on three metrics described below: Fish Use Potential, Restoration Feasibility, and Habitat Uplift Potential. Each reach was qualitatively evaluated for these three primary metrics based on a weighted average of three sub-metrics each, then summed for a final score and ranking (Figure 5-1 and Table 3). Additionally, restoration goals are centered around wild trout, which have been defined broadly as salmonids for the sake of evaluation. Conditions suitable/preferable for steelhead trout were assumed to be equivalent for rainbow trout for this interpretation.

Figure 5-1. Reach Prioritization Decision Tree

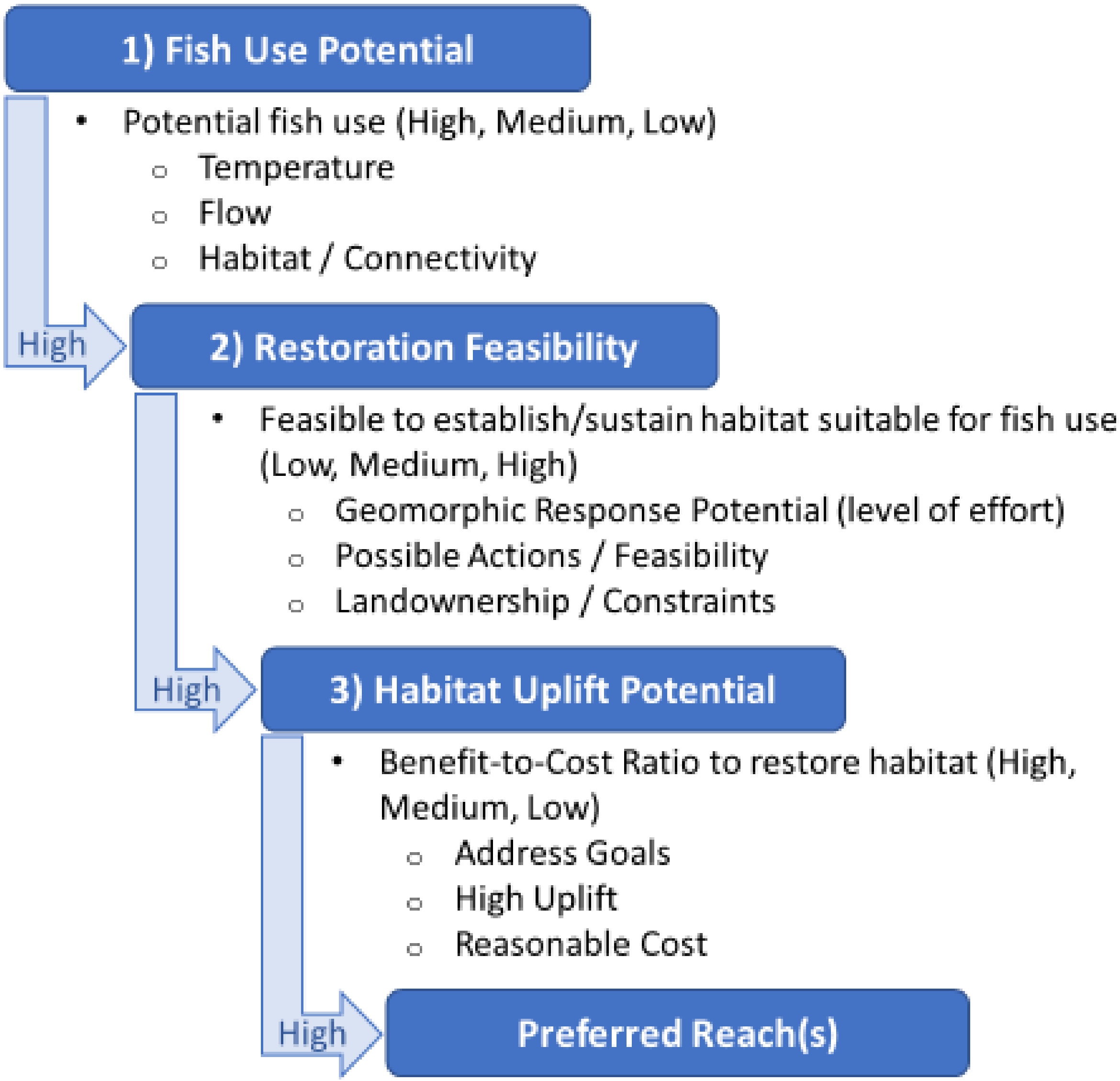


Table 3. Reach Prioritization Summary Table*

Reach ID	Fish Use Potential					Restoration Feasibility					Habitat Uplift Potential					Overall Score	Ranking
	Temp	Connectivity	Flow	Score (0-3)	Weight (0-3)	Geomorphic Response	Actions / Feasibility	Landowner / Constraints	Score (0-3)	Weight (0-3)	Address Goals	Uplift Potential	Cost	Score (0-3)	Weight (0-3)		
1 - Lower Silver	0	0	1	1	1	1	1	0	2	1	0	0	0	0	1	3	16
2 - Lower Silver	0	0	1	1		0	0	1	1		0	0	0	0		2	20
3 - Lower Silver	0	0	1	1		1	0	0	1		1	1	1	3		5	11
4a - Lower Silver	0	0	1	1		1	1	0	2		1	1	0	2		5	11
4b - Lower Silver (Susie Q)	0	0	1	1		1	0	1	2		1	0	1	2		5	11
4c - Middle Silver	0	0	1	1		1	1	0	2		1	1	0	2		5	11
4d - Upper Silver (Ponds)	0	0	1	1		1	1	1	3		1	0	1	2		6	9
5 - Upper Silver (Preserve)	0	1	1	2		1	0	1	2		1	0	1	2		6	9
6a - Lower Stalker	0	1	1	2		1	0	1	2		1	1	1	3		7	5
6b - Lower Stalker	0	1	1	2		1	1	1	3		1	1	1	3		8	1
Lower Loving	0	1	1	2		1	1	1	3		1	1	1	3		8	1
Upper Loving	0	0	1	1		1	1	1	3		1	1	1	3		7	5
Lower Grove and Wilson	1	1	1	3		1	0	0	1		1	1	1	3		7	5
Upper Grove and Tribs	1	1	1	3		1	1	0	2		1	1	1	3		8	1
Wilson	1	1	1	3		1	1	0	2		1	0	1	2		7	5
Mud	0	0	0	0		1	0	1	2		0	0	1	1		3	16
Chaney	1	0	1	2		1	1	1	3		1	1	1	3		8	1
Cain	0	0	0	0		1	0	1	2		0	0	1	1		3	16
Upper Stalker	0	0	0	0		1	0	1	2		0	0	1	1		3	16
Sullivan Pond	0	0	0	0		1	1	1	3		0	0	1	1		4	15

*See explanation on next page.

Table 3 Explanation:

1) Fish Use Potential
    a. Temp (1 point for good, 0 for poor): Poor temp if an average of more than 10 days in 70–78°F stress band from 2011–2018; good if below stress band
    b. Connectivity (1 point for good, 0 for poor): Poor connectivity if separated by more than one reach from good habitat or if passage barrier present in/near reach
    c. Flow (1 point for good, 0 for poor): Poor flow if stream size considered too small for most fish use
2) Restoration Feasibility
    a. Geomorphic response potential (1 point for good, 0 for poor): Poor if severely confined
    b. Possible actions/feasibility (1 point for good, 0 for poor): Poor if main impacts are associated with conditions outside of the reach
    c. Landownership/constraints (1 point for good, 0 for poor): Poor if likely no landowner cooperation from 1 or more landowners in reach or many landowners to coordinate
3) Habitat Uplift Potential
    a. Address goals (1 for good, 0 for poor): Poor if restoration goals are unlikely to be met by feasible restoration actions
    b. High Uplift (1 for good, 0 for poor): Poor if habitat uplift potential is low (already good, low potential, or too difficult to restore) or if long-term sustainability is low
    c. Reasonable cost (1 for good, 0 for poor): Poor if cost of required restoration is exorbitant
4) Weights applied evenly (1 each)
5) Spreadsheet multiplies each score by the weight and sums the results per reach yielding the Overall Score and Rank

- **Fish Use Potential**: The ability for trout to access, live, and thrive in a given reach. Reach conditions that preclude/limit fish use or risk fish mortality result in "Low" fish use potential and therefore reduce the priority for restoration within a reach. Factors evaluated include the following:
  - **Water Temperature**: Temperatures >18–20°C (>64.4–68°F) have been shown to adversely affect the physiological health and distribution of salmonids (Richter and Kolmes 2005; EPA 2003). Temperatures exceeding 70°F (about 21°C) for an average of 10 or more days annually between 2011–2018 results in low fish use potential.
  - **Flow**: Low flow, insufficient water volume (wetted area), and/or excessively shallow depth can reduce fish occupancy potential and access (Roni et al. 2012). Stream reaches considered too small to sustain healthy fish populations have low fish use potential.
  - **Habitat Connection/Access**: Areas of insufficient habitat connectivity and/or access (i.e., passage barriers) also limit fish use potential such that low connectivity would result in a low fish use potential.
- **Restoration Feasibility**: The geomorphic, monetary, political, and/or landownership potential to implement a project that will address restoration goals. Conditions that limit the ability to implement necessary restoration projects result in a "Low" restoration feasibility for the reach. Factors evaluated include the following:
  - **Geomorphic Response Potential**: The intrinsic ability for a stream/reach to recover or repair habitat conditions naturally with little or no human influence. Additionally, response potential refers to the physical conditions naturally or intrinsically suitable for a given reach suggesting that restoring those types of features requires inherently less effort; and conversely, attempting to restore features that are not geomorphically suitable for a given reach requires more effort and may not be feasible or sustainable over the long term. Reaches that are severely confined (naturally or artificially) have limited response potential resulting in low restoration feasibility.
  - **Possible Action/Feasibility**: The identified issues/problems within a reach must be treatable with actions that are feasible and appropriate within the reach. If the issues/problems are not treatable within the reach, the feasibility of addressing the root cause of the issue is poor and the restoration feasibility is low.
  - **Landownership**: Landowner cooperation and/or other constraints such as funding, social or political will, conflicting management objectives, recreational opportunities, safety/risk and other non-technical factors can also affect restoration feasibility. Many landowners within a reach and/or uncooperative landowners reduce the feasibility of restoration.
- **Habitat Uplift Potential**: The overall amount of potential habitat benefit related to the stated goal and associated cost yields the relative habitat uplift potential. The greater the potential habitat (by volume, length, or other measure) relative to the cost (i.e., level of effort) the greater the priority for a given reach.
  - **Address Goals**: Benefit is determined by whether or not the overall goal can be reasonably addressed within a given reach. A reach with potential to address stated goals has high uplift potential.
  - **Uplift**: Uplift is the relative amount (quantity or magnitude) of habitat improvement that can be reasonably expected to result from restoration efforts. If the habitat is already in good condition, cannot be reasonably restored, or if the restoration does not address the root issue or is not likely to persist over the long term, then the uplift potential is low.
  - **Reasonable Cost**: Different types of restoration efforts require more effort (cost) than others. Depending on the principal type(s) of restoration, the relative cost for reach restoration can be estimated. Expensive restoration efforts have proportionally high opportunity cost (i.e., the loss of potential uplift from other

alternatives when one is chosen) and therefore have relatively low uplift potential assuming less expensive alternatives are available.

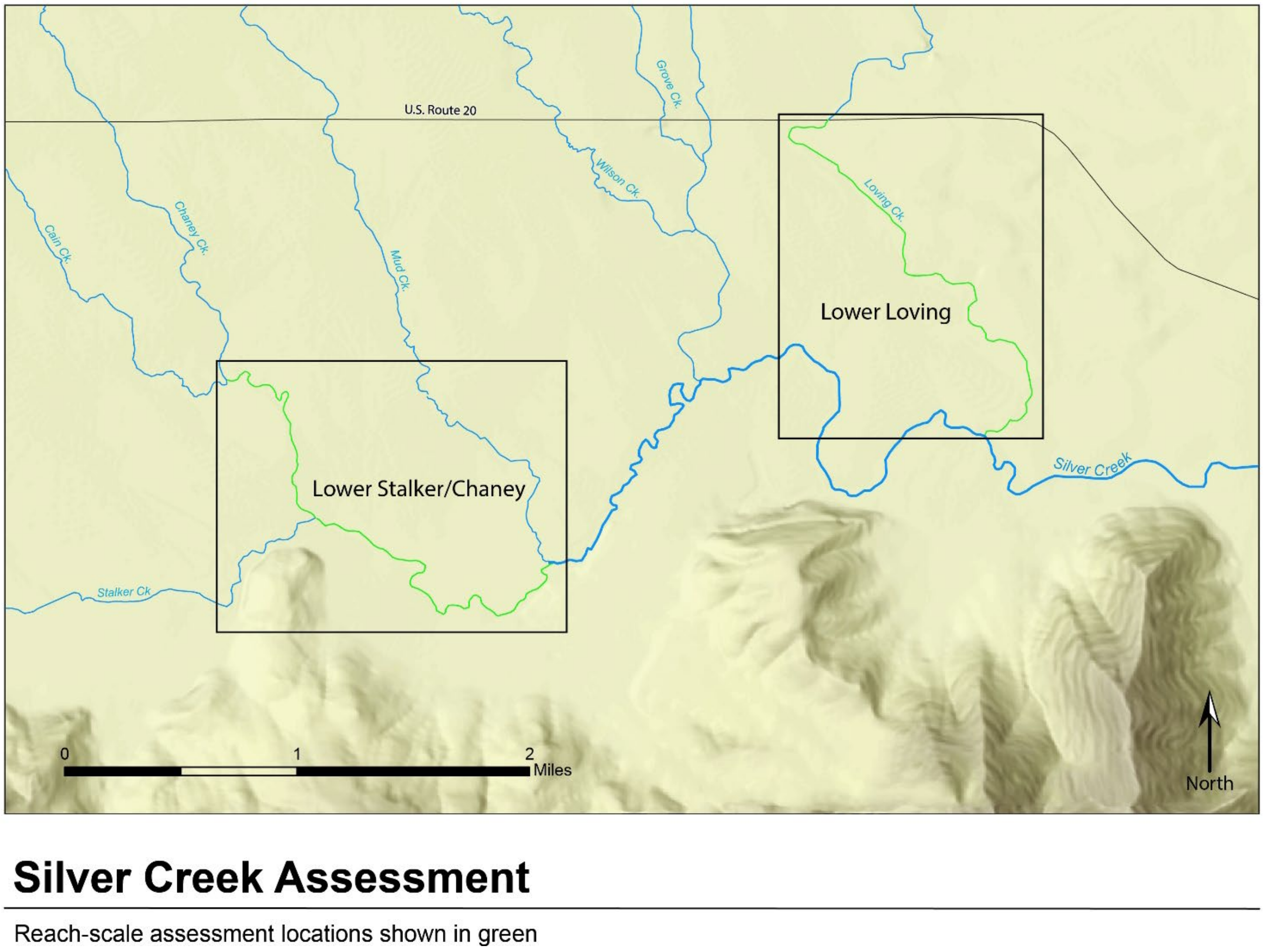
The reach prioritization effort resulted in four reaches identified as 1st tier priority. Time and budget constraints dictated that only two reaches would be further evaluated with a refined reach-scale assessment and concept development. Of the four reaches identified, two are adjacent and were therefore combined into a single effort (6b-lower Stalker and the lower portion of Chaney), and one was eliminated (upper Grove and Tribs) due to the large number of landowners and potential constraints associated with coordinating restoration actions amongst such a relatively large group of stakeholders. Therefore, the two reaches further evaluated in the subsequent sections consist of the following:

- Lower Loving
- 6b-lower Stalker and the lower portion of Chaney

6 Reach-Scale Detailed Assessment

Detailed assessments including bathymetric cross sections, on-site observations, and rough, reach-scale one-dimensional hydraulic modeling were conducted at lower Loving and lower Stalker/Chaney reaches (Figure 6-1). The results of these reach-scale assessments informed conclusions, target conditions, and potential actions as described in this section. Lower Loving and lower Stalker/Chaney exhibited many similar characteristics. Characteristics that are similar between the two reaches were summarized together to reduce redundancy while unique/individual characteristics were summarized independently for baseline, historical, and future target conditions.

Figure 6-1. Example of Previously Restored Upper Subreach of Lower Loving Creek



6.1 Baseline Conditions

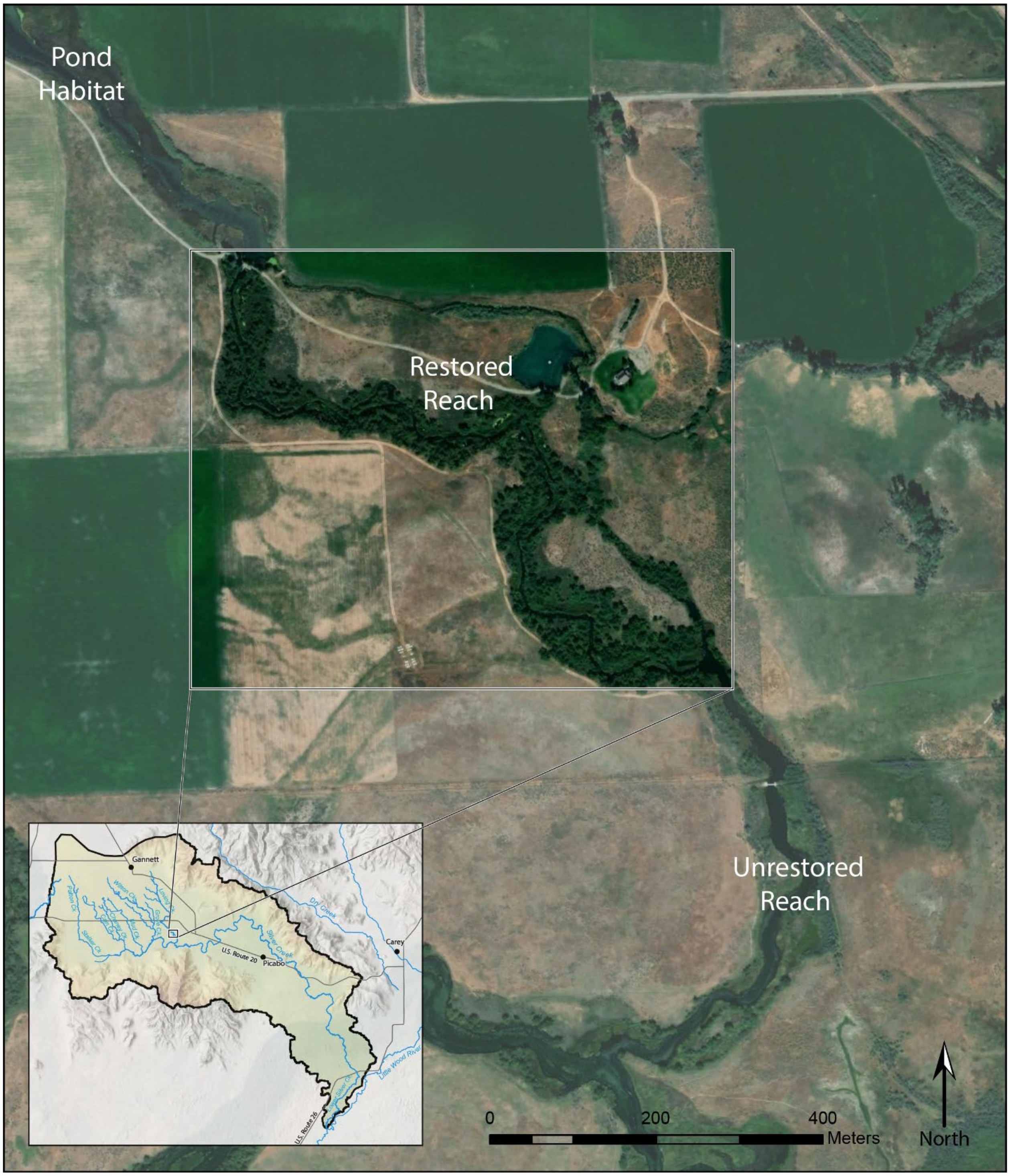
Similar to watershed-scale conditions described previously in this report, on-site observations showed both lower Loving and lower Stalker/Chaney reaches contained extensive silt deposits. The thalweg was poorly defined with few locations where the underlying gravel was not covered by silt generally 1–3 ft deep. There was very little complexity of in-stream habitat, and the reaches exhibited a predominantly plane-bed morphology with few pools. While measured width-to-depth ratios averaged near 15, both reaches had significant over-widened areas where width-to-depth ratios exceeded 30. Channel banks were generally characterized by sedges, rushes, and cattails growing in cohesive fine sediments. The active floodplain extent was identified by the locations where vegetation shifted from riparian (i.e., willows, cattails, and rushes) to upland (i.e., sagebrush and grasses). Floodplain width generally matched the maximum extent of river meanders (i.e., meander amplitude). In both reaches, the channel planform was single-threaded and sinuous. Soils in the floodplain consisted of silt and sand with organic materials overlying gravel.

Lower Loving and lower Stalker/Chaney are both spring-fed streams with relatively consistent discharge (compared to snowmelt dominated streams) but do exhibit somewhat higher flows in the spring associated with snowmelt runoff and higher groundwater inputs at that time. Aquatic vegetation is prevalent throughout both reaches and tends to increase in the summer months and decrease in the winter months. Aquatic vegetation can occupy a significant portion of the channel cross sectional area and increase in-stream roughness such that the water velocity is reduced and the water surface elevation (i.e., stage) is increased. Anecdotally, the river stage does not change dramatically over the course of a typical year. The increased density of aquatic vegetation in the late summer may offset reduced flows at that time resulting in a relatively consistent stage during average runoff years (i.e., the water level does not drop significantly during the later summer, low-flow periods). Similarly, during the early summer months, aquatic vegetation density may increase while flows are still elevated above baseflows, causing flooding. This may have occurred at the time of survey (August 21, 2019) when water was observed overtopping one or both banks in both reaches. In places, standing water was present on the floodplain approximately 50 ft from the channel.

6.1.1 Lower Loving

Lower Loving Creek is characterized by an upper subreach that was restored (in 2011) by increasing the sinuosity, narrowing the channel width, excavating pools and planting riparian vegetation (Figure 6-2 and Figure 6-3), and a lower subreach that is over-widened (approximately 100 ft wide) and relatively deep (approximately 3.4 ft) (Figure 6-2 and Figure 6-4). Near the upstream end of the restored subreach is a constructed (and periodically dredged) slack-water pond. (See reach description for lower Loving in Appendix B.) The lower, unrestored portion of the reach is generally characterized similar to the watershed-scale conditions described previously in this report. The channel is over-widened and has excessive silt deposition along the bed, with the least silt deposition immediately alongside patches of riparian vegetation where depth was greatest. The over-widened channel conveys most high flows within the banks precluding frequent floodplain connection. Poor floodplain connectivity was additionally supported by the lack of observed riparian vegetation on the floodplain and by hydraulic modeling results. Some small trees and shrubs were observed alongside the bank, but for the most part the vegetation does not shade the stream enough to prevent high water temperatures in the summer. Summarized in Table 4 are existing and target conditions for the portion of lower Loving Creek downstream of the restored reach.

Figure 6-2. Example of Previously Restored Upper Subreach of Lower Loving Creek and Unrestored Lower Subreach of Lower Loving Creek



Silver Creek Assessment

Restored and unrestored reaches on Lower Loving Creek

Figure 6-3. Example of Previously Restored Upper Subreach of Lower Loving Creek

Photo of restored reach in lower Loving Creek. Bank fills were placed to reduce channel width and increase overall sinuosity within the existing channel corridor. Pools were excavated, exposing gravel along meander bends. The photo looks upstream.

Figure 6-4. Example of Lower Subreach of Lower Loving Creek

This photo of lower Loving Creek exemplifies the over-widened, low-energy environment present in the lower subreach that facilitates aquatic vegetation and fine sediment seen across the channel bottom. Flow is from left to right in this image.

Table 4. Lower Loving Creek Existing and Target Conditions Downstream of Existing Restoration

Condition	Existing (min, avg, max)	Target (min, avg, max)
Bankfull Discharge (cfs)	65.0 (avg)	65.0 (avg)
Width (ft)	32, 58, 71	15, 25, 35
Width/depth ratio	17 (avg)	12.5 (avg)
Sinuosity	1.2	1.5
Planform	Single thread	Single thread
Meander Amplitude (ft)	138, 166, 213	125 (avg)
Meander Wavelength (ft)	296, 358, 423	275 (avg)
Bend Radius of Curvature (ft)	57, 105, 158	70 (avg)
Pool Spacing	N/A – No discernable pools observed	Every meander

6.1.2 Lower Stalker/Chaney

Site-specific characteristics for lower Stalker and Chaney were evaluated for the lower-most segment of Chaney Creek downstream of a constructed pond to its confluence with lower Stalker Creek and downstream again to the confluence of Mud Creek. Channel straightening and other human manipulation has simplified overall channel character and cut off several side channels in the reach, while ditches and check dams have also altered wetland conditions in the floodplain area. The upper reach is characterized by a pronounced backwater formed by a large rock check dam (Figure 6-5). Downstream of the check dam the stream transitions from an over-widened channel with limited in-stream structure and poor riparian vegetation to a relatively narrow, more sinuous channel with greater in-stream structure, lower width-to-depth ratio, and improved riparian vegetation. The reach downstream of the confluence with Mud Creek (Reach 6a) improves even more, as discussed in Appendix B, and provides good reference conditions for the more greatly impacted portion of lower Stalker (Reach 6b).

Figure 6-5. Rock Check Dam in Lower Stalker Creek

Photo of rock check dam in lower Stalker Creek shown creating pond-like backwater conditions upstream (right side of image) and concentrated flow scouring a large pool immediately below the structure (left side of image). A wooden walking bridge has been installed over the check dam.

Like other reaches in the watershed, lower Stalker/Chaney was observed to be generally over-widened and exhibited significant silt deposition, especially in the upper half of the reach. Unique to lower Stalker/Chaney though were more areas where in-stream gravel was exposed on the bed characterized by scour associated with localized high velocities and/or sharp changes in flow direction/magnitude, especially in the lower half of the reach. Outside of those areas, dense aquatic vegetation captured silt, reduced water velocity, and increased water height. The check dam structure downstream of the confluence between Stalker and Chaney has also backwatered a portion of both streams creating pond-like conditions with wider banks and more silt deposition. Conversely, where concentrated flows spill over the check dam, a large/deep gravel scour pool has formed. Riparian vegetation generally consisted of cattails, rushes, and sedges with few shrubs and even fewer trees providing shade. Regardless of the lack of shade, summer stream temperatures are relatively low in Chaney, possibly due to groundwater inputs, while summer temperatures are relatively high in upper Stalker. There are no temperature sensors in lower Stalker below the Chaney Creek confluence; temperatures are suspected to be closer to Chaney than Stalker, because Chaney provides the larger volume of flow.

Observed conditions in lower Stalker/Chaney Creek included average bankfull channel width and depth of 42 and 2.8 ft, respectively. In the lower-most portion of the reach, for several hundred feet upstream of the confluence with Mud Creek, channel widths decreased by approximately 8–12%. Also, in this area, the river right bank elevation increased relative to the left bank and exhibited less frequent inundation. The lower-most portion of the reach also contained more in-stream habitat than the upper reach, depths increased, and channel banks contained relatively more trees and woody debris than upstream. The active floodplain varied spatially overall throughout the entire reach, ranging from 80–450 ft. Side channels were present in portions of the reach, but most of the channel is single threaded with a sinuosity of 1.52. Small, backwater alcoves that may have been flow-through side channels in the past were present throughout much of the reach. Specific reach conditions measured in lower Stalker/Chaney Creek are quantified in Table 5.

Table 5. Lower Stalker/Chaney Creek Existing and Target Conditions

Condition	Existing (min, avg, max)	Target (min, avg, max)
Bankfull Discharge (cfs)	55.8 (avg)	55.8 (avg)
Width (ft)	16, 42, 69	16, 25, 39
Width/depth ratio	15 (avg)	10 (avg)
Sinuosity	1.52	1.8
Planform	Single thread	Single thread
Meander Amplitude (ft)	63, 241, 366	125 (avg)
Meander Wavelength (ft)	195, 304, 430	272 (avg)
Bend Radius of Curvature (ft)	44, 90, 171	54 (avg)
Pool Spacing	N/A too few pools to discern avg. spacing	Every meander

6.2 Trends

It is assumed prior to current agricultural and cattle land use practices both lower Loving and lower Stalker/Chaney reaches historically contained relatively fewer fine sediments and relatively more in-stream structure than are currently present. Without the fine sediment deposition and with greater in-stream structure historically, both reaches most likely had a greater degree of in-stream complexity (Figure 6-6). It is believed aquatic vegetation was historically present in both reaches but potentially was not as dense as today. Aquatic vegetation requires sunlight to grow and can only persist if not scoured from the bed during high flows. Historical conditions likely exhibited more riparian vegetation shading the stream and constricting flow increasing scour. These conditions likely limited aquatic vegetation growth and expansion. Prior to large-scale agricultural and cattle use practices, the Silver Creek watershed also would have been expected to supply less fine sediment to the channel than after the implementation of such land use practices; although recent changes, such as cattle exclosures and the establishment of riparian buffers, may reduce the rate of fine sediment supplied to the stream. Much of this increased fine sediment is captured in aquatic vegetation.

Figure 6-6. Reference Stream Example Illustrating In-Stream Complexity

Photograph looking downstream in a spring-fed reference reach of the Pahsimeroi River in central Idaho. This channel segment exhibits dense woody riparian vegetation that encroaches into the active channel providing bank structure, cover, and hydraulic roughness supporting complex and diverse habitat conditions.

Whiting and Moog (2001) conducted a survey of 26 spring-fed channels in the United States Pacific Northwest assumed to represent typical conditions common to relatively undisturbed spring-fed channels. According to this study, typical spring-fed channels lack significant fine sediments, have high in-stream heterogeneity, and are often armored when the channel is comprised of gravel. Most spring-fed channel beds surveyed also contained aquatic vegetation and high associated in-stream roughness. Whiting and Moog (2001) also showed that spring-fed channels typically maintain a dense riparian corridor with "luxuriant growth." A robust riparian corridor increases in-stream shading and decreases summer temperatures (Wondzell et al. 2019). A dense riparian corridor with tall trees shading the stream, coupled with the observed relatively constant-temperature water contributions from spring heads (Ecosystem Sciences 2011–2018) leads to the conclusion that both lower Loving and lower Stalker/Chaney historically had summer stream temperatures lower than existing summer temperatures and likely below the documented stress band for trout.

Based on observations of reference reaches and literature (Whiting and Moog 2001), it is believed that both lower Loving and lower Stalker/Chaney exhibited the following historical (pre-disturbance) conditions:

- More sinuous, narrower channel with side channels, off-channel habitat and connected floodplain
- Less silt, more gravel substrate
- More in-stream structure and associated constrictions forming frequent scour pools
- More woody riparian vegetation providing bank structure, cover, and shade

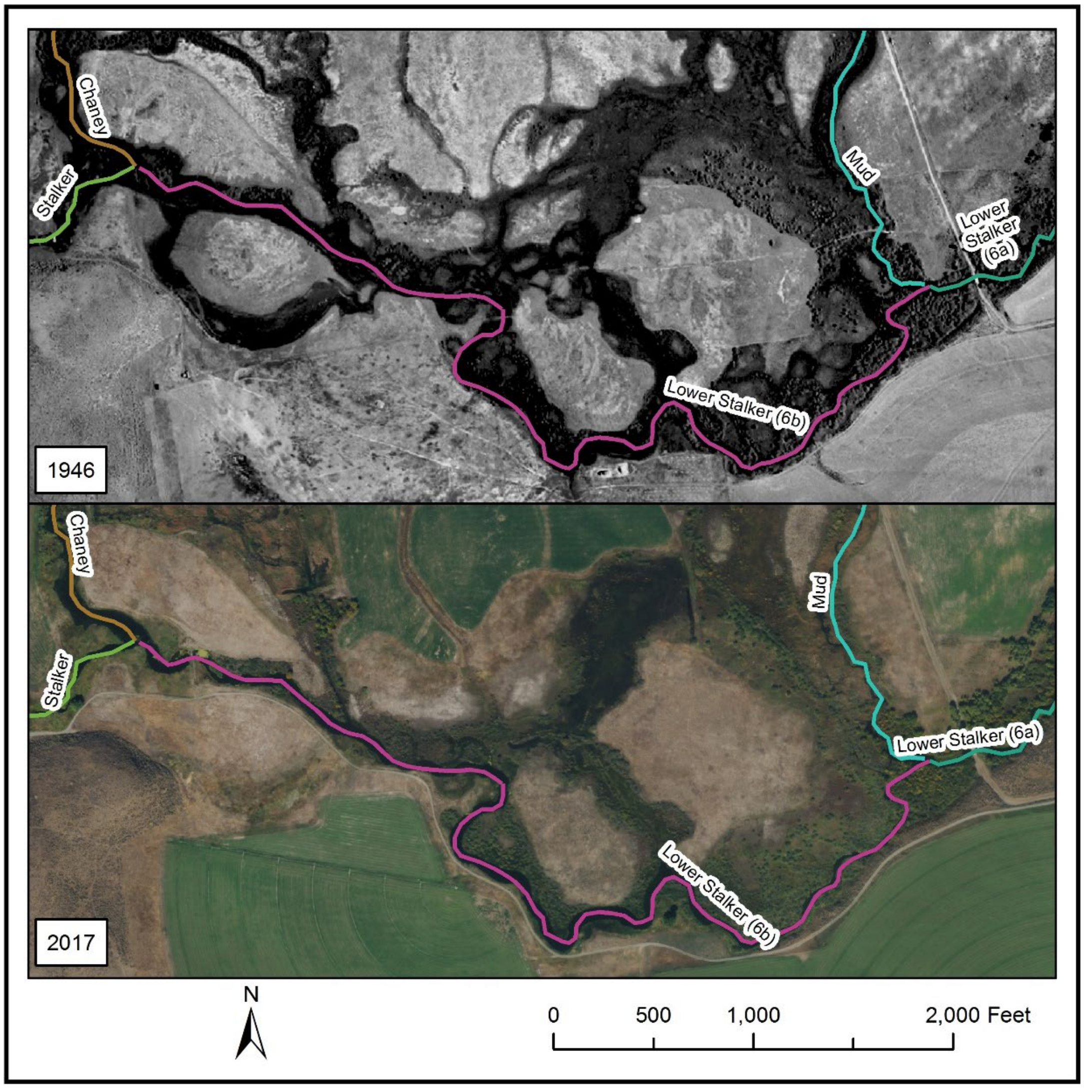
6.2.1 Lower Loving

Trends in lower Loving generally follow the common trends identified above. A comparison of width measurement between aerial images taken in 1946 and 2017 confirm widths have increased (by an average of 48%). Based on comparisons with historical aerial imagery, most of this widening appears to have occurred between the 1940s and the 1990s not to mention any widening that may have occurred prior to 1946. Floodplain extents do not appear to have changed substantially from the 1940s to present day, suggesting pre-1940s land use and stream alterations had already reduced floodplain connection. Similarly, there were few major changes to channel planform observed in the aerial imagery since the 1940s, although measured sinuosity did reduce from roughly 1.35 to 1.15, likely as a result of channel widening and associated simplification.

6.2.2 Lower Stalker/Chaney

Reach-specific trends in lower Stalker/Chaney include substantial alterations to the channel planform. Satellite images from the 1940s show Stalker and Chaney were characterized by a large complex of side channels, wetlands, and vegetated islands, with flow splits of varying sizes and lengths (Figure 6-7). Tributaries such as Chaney and Mud Creeks had historically split and connected with lower Stalker at multiple points. Small islands are not unusual in spring-fed channels (Whiting and Moog 2001), but this reach historically exhibited many large islands that are no longer present. By the 1970s to early 1990s, the channel had been simplified into primarily a single channel, with few remaining side channels connected less frequently and/or with less discharge. Associated with the apparent loss of side channels and consolidation of flows into a single channel is the increased overall wetted width of the mainstem.

Figure 6-7. Comparison of 1946 and 2017 Aerial Photographs of Lower Stalker Creek



1946 black and white aerial photograph of lower Stalker (upper image) shows many side channels and off-channel wetlands. By 2017 (lower image) most side channels had been blocked and the channel had become single-threaded (pink line).

Human-constructed check dams and irrigation ditches have further altered the off-channel habitat and floodplain wetlands. Ditches typically drain wetland areas while check dams backup flow and expand floodplain connection. Floodplain extents have reduced substantially from the earliest aerial images to present day. Observations of recent historical aerial photographs also suggest beaver dams have influenced lower Stalker/Chaney where many riparian shrubs/trees on river left have been recently inundated by higher water and are dead or dying. Beaver activity such as this historically resulted in a mosaic of riparian vegetation with areas of dense woody vegetation, areas of emergent shrub/scrub, and other areas of open water (i.e., beaver ponds). Likewise, avulsions around beaver dams provided increased channel sinuosity.

6.3 Synthesis

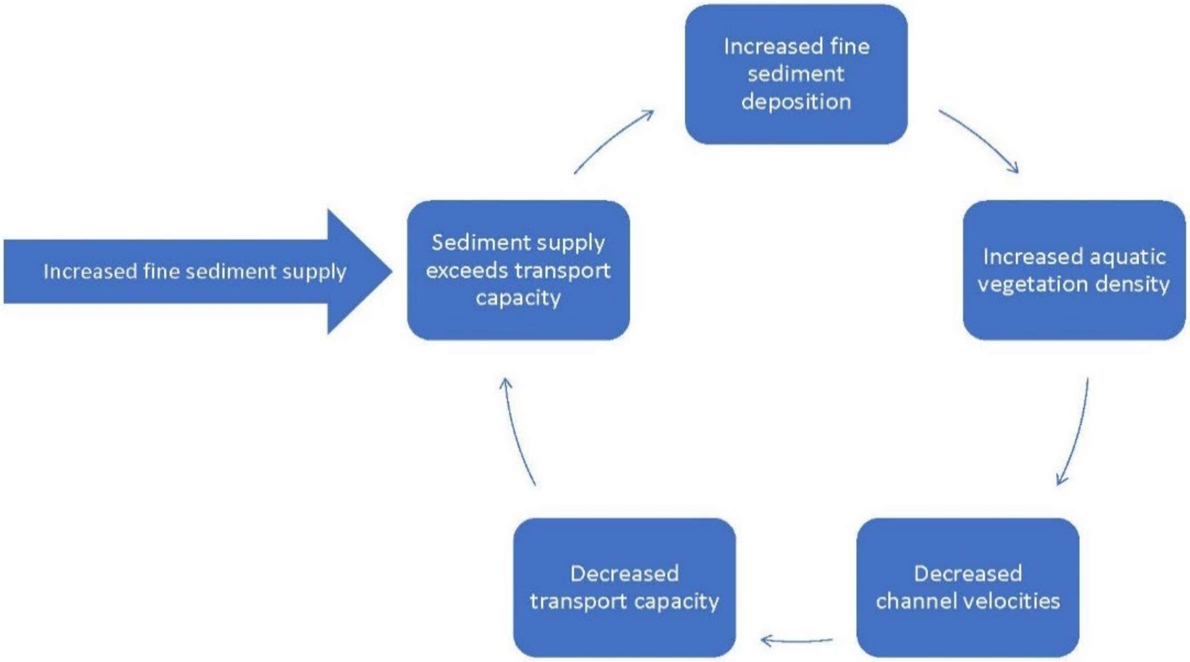
A comparison of historical and current conditions for lower Loving and lower Stalker/Chaney reveals similar changes in both streams:

- Channel widening
- Increased fine sediment deposition
- Reduced woody riparian vegetation and less associated bank structure, cover and shade
- Less in-stream structure forming pools and habitat complexity
- Reduced planform complexity, fewer side channels and less sinuosity

Over-widened channel conditions in lower Loving and lower Stalker/Chaney are likely a result of processes described for the watershed earlier in this report – A lack of riparian vegetation and historical land-use destabilized banks allowing channel widening, which was exacerbated by fine sediment deposition and aquatic vegetation growth raising the water surface. Lower Loving Creek is additionally impacted by backwater conditions from Silver Creek, which further increase water surface elevations and inundate a larger bankfull width, but hydraulic modeling indicates that backwatering only influences the lower-most portion of Loving Creek. Some recent riparian vegetation encroachment has been observed by comparing aerial photographs from the 1990s through present, but field observations confirmed most encroachment is dominated by cattails, rushes, and other aquatic vegetation rather than woody, terrestrial, riparian vegetation (i.e., willows).

Increased fine sediment deposition is most likely connected to greater upland sediment supply (from agriculture and grazing land use) and reduced sediment transport capacity (caused by greater channel width and depth resulting from more aquatic vegetation). This process creates a positive feedback loop (Figure 6-8) whereby land use practices and loss of riparian buffers increase rates of fine sediment supplied to the stream. Increased fine sediment supply more frequently exceeds transport capacity, causing increased fine sediment deposition. Deposited fine sediment provides a substrate for aquatic vegetation to grow in greater densities, which then increases roughness, slowing the water, and increasing channel width and depth. The reduced velocities and greater channel surface area in turn reduce sediment transport capacity, which coupled with the increased sediment supply, further increase sediment deposition providing more substrate for aquatic vegetation. During fieldwork (August 22, 2019), the presence of gravel was qualitatively correlated to less dense aquatic vegetation, greater in-stream structure, and narrower channel widths, so the feedback loop likely exacerbates conditions that reduce in-stream channel complexity and habitat as well.

Figure 6-8. Potential Feedback Loop Between Fine Sediment, Aquatic Vegetation, and In-Stream Hydraulics



With the large amount of fine sediment and aquatic vegetation present in the channel, the positive feedback loop between these elements is likely ongoing and unlikely to naturally reverse within the foreseeable future. Fine sediment contributions from upland sources and from in-stream legacy sources remain prevalent within the watershed. For that reason, restoration efforts on lower Loving and lower Stalker/Chaney need to have the ability to both reduce future inputs from upstream sources and increase transport capacity to scour/remove existing fine sediments.

Riparian vegetation can help buffer fine sediment runoff from entering the stream, and it provides valuable shade. Increased summer stream temperatures are most likely due to a lack of shade resulting from lost riparian vegetation that has been removed to support past land use. Shade is the most important factor affecting in-stream temperatures (Wondzell et al. 2019). Dense riparian vegetation shades the stream reducing summer stream temperatures; conversely, a lack of shade increases temperatures. Additionally, over-widened channel conditions increase the surface area of the stream receiving solar radiation, increasing stream warming. Finally, slower water velocity, in part from increased aquatic vegetation roughness, increases the duration of exposure to solar radiation, which also increases stream temperatures.

Reduced riparian vegetation also affects bank and channel structure. The root mat and roughness of woody riparian vegetation obstructs stream flow near the bank creating hydraulic gradients as well as areas of flow contraction and expansion which can scour pools, mobilize silt, and sort gravel (Figure 6-9). Bank structure from riparian vegetation also reduces rates of bank erosion and channel widening while providing shade and cover (as discussed above). Without dense woody riparian vegetation, in-stream pool and habitat complexity have both decreased.

Figure 6-9. Example of Woody Riparian Vegetation Concentrating Flow

Photograph looking downstream on the upper Lemhi River in central Idaho. The photo shows a channel constriction formed by woody riparian vegetation (willows) encroaching from both banks. The effective width of the channel was reduced by 50% in this location creating a 3-ft-deep scour pool.

Human impacts have also directly altered the stream shape via mechanical straightening, ditching, and disconnecting of side channels. Simplified channel shape (i.e., form) has further simplified in-stream channel complexity and habitat. Similarly, the human-caused removal of beaver has caused channel simplification. Beaver dams historically obstructed flow, created backwater ponds, and trapped sediment forcing channel avulsions around dams through dense woody riparian vegetation creating more channel sinuosity, in-stream structure, and habitat (Figure 6-10). Without many beaver dams and given significant human channel alterations, the overall character and associated habitat of lower Loving and lower Stalker/Chaney has been simplified.

Figure 6-10. Beaver Dam Influenced Reference Reach Example

Aerial photo of beaver dam-influenced stream habitat on Gneiss Creek in Yellowstone National Park. Flow is from right to left in the photo. Many side channels and off-channel areas are connected by backwater conditions resulting from multiple beaver dams. Dense woody riparian vegetation persists throughout the floodplain providing structure and cover for inundated areas. Aerial photo downloaded from Google Earth.

6.4 Target Conditions for Both Reaches

Target conditions include those channel forms that reflect an appropriately restored and therefore improved channel/floodplain condition that will naturally function over the short and long term. Restoration actions should use target conditions as first iteration general guidelines for design criteria to ensure all projects, regardless of implementation timing or team, will work together in a way that supports the natural, long-term function of the stream. Target conditions should be refined with detailed, project-scale analysis prior to final design and construction. Summarized below (Table 6) are recommended target conditions specific to lower Loving and lower Stalker/Chaney reaches.

Table 6. Lower Loving and Lower Stalker/Chaney Creek Target Conditions

Condition	Lower Loving Target (min, avg, max)	Lower Stalker/Chaney Target (min, avg, max)
Bankfull Discharge (cfs)	65.0 (avg)	55.8 (avg)
Width (ft)	15, 25, 35	16, 25, 39
Width/depth ratio	12.5 (avg)	10 (avg)
Sinuosity	1.5	1.8
Planform	Single thread	Single thread
Meander Amplitude (ft)	125 (avg)	125 (avg)
Meander Wavelength (ft)	275 (avg)	272 (avg)
Bend Radius of Curvature (ft)	70 (avg)	54 (avg)
Pool Spacing (ft)	Every meander	Every meander

6.5 Potential Habitat Improvement Concepts

To achieve the target conditions in lower Loving and lower Stalker/Chaney, several potential actions have been selected similar to those restoration actions described for the watershed-scale section earlier in this report. Specific actions are summarized below and have been consolidated into a conceptual plan for the two reaches (Appendix C).

- ▲ Bank Fills
  - Used to narrow over-widened channel segments common throughout both restoration reaches
  - Provide an appropriate floodplain and bank area for new riparian vegetation
  - Increase in-stream velocity to promote fine sediment mobilization and transport
- ▲ Channel Excavation
  - Used to increase channel sinuosity and planform complexity to improve habitat conditions for native trout spawning and rearing
  - Realign the channel adjacent to existing robust, woody, riparian vegetation where possible
  - Create more tortuous meanders (i.e., smaller radius of curvature) to promote bend scour and pool formation
- ▲ Post-Line Willow Weaves
  - Installed along streambanks particularly along the inside of bends and/or in low-energy areas to capture sediment and reduce channel width over the long term while providing in-stream structure and cover over the short term
  - This treatment should be used in conjunction with bank fills to achieve target conditions. If used alone, target conditions will not be achieved for many years.
- ▲ In-Stream Habitat Structures
  - Installed strategically throughout the reach to create channel constrictions and flow contractions enabling pool formation and hydraulic/habitat diversity.
  - Can be used to concentrate flow and define a thalweg in otherwise over-widened and plain bed channel segments (particularly in straight sections) in addition to or as opposed to using bank fill treatments.
- ▲ Removal of Artificial Grade Control (lower Stalker alone)
  - The existing rock grade control structure near the confluence of Stalker and Chaney Creeks has created an unnatural backwater condition upstream, leading to an over-widened channel geometry, fine sediment deposition, shallow stream flow, and plane-bed morphology with poor habitat diversity. Removal of the grade control structure will facilitate the restoration of more natural channel forms and processes within the reach.
- ▲ Riparian Vegetation
  - Riparian vegetation should be planted in all areas lacking appropriate vegetation to meet proposed riparian buffer targets.
  - Areas lacking appropriate vegetation include those with an abundance of noxious weeds, areas lacking the appropriate density of woody vegetation, bare soil, and any area disturbed by the construction of restoration treatments identified above.

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Appendix A. Summary of Existing Literature on Silver Creek Fish Habitat

1 Summary of Pertinent Existing Reports and Data

1.1 Introduction

The following summaries of investigations and reports on the condition of Silver Creek's geomorphology, habitat, sediment, vegetation and fishery provide historical context to the current condition and can inform target conditions. Organized chronologically, they are intended to inform the established issues, restoration targets, justification and reasoning on which the assessment approach is based. Although fisheries information is included in the summaries, the focus on geomorphic and habitat conditions reflects the focus of this assessment. Several fish investigations concentrate on the changing relative abundance of brown trout and rainbow trout within the Silver Creek system. These studies are outside the scope of this assessment and are omitted from the summary. The influence of fish stocking, angler pressure, and fish regulations are also outside of the influence of a geomorphic assessment and restoration concepts, therefore less emphasis is placed on these aspects of fisheries investigations in the summaries below. Similarly, several investigations into the surface and groundwater water quantity and quality of Silver Creek have been performed, especially in the last 20 years. Although critical to ecosystem function, water quantity and quality are generally outside of the scope of this assessment. Certain water quality parameters may be influenced by restoration enhancement efforts, such as temperature, dissolved oxygen, and macro-invertebrate community structure, and are therefore germane to the discussion.

1.2 Chronological Summary of Pertinent Reports and Data

Hauck (1947) noted in an IDFG fishery report that for over thirty years Silver Creek has been considered to be one of the finest trout streams in the West. He notes the clear stream with little turbidity, except in spring high-flow events. He notes that in the fall aquatic vegetation, mainly watercress chokes the stream, and the fish seek pools or "pockets" with gravel substrate free from aquatic vegetation. After the die-back fish must seek cover in undercut banks, instream structure and deeper pools. He noted that production was high in all tributaries to Silver Creek, except for Loving and Stocker Creeks – which had already become silted and little spawning occurred in those creeks. He noted that wherever sufficient gradient and velocity occurred, there were gravels. Brook trout were noted to occur in small numbers. He reported Silver Creek to have an averaged width of 60 feet, 4800 fish per mile. Grove Creek, average width of 30 feet, 2400 fish per mile, all other creeks, width of 10 feet, 800 fish per mile. He recommended the closed upper sections of Silver Creek be opened to fishing. He noted that there was no evidence of large fish migrations, and the Grove had the highest population of any of the tributaries. He recommends taking actions to move silt out of Stocker and Loving Creeks to increase fish populations and uncover the gravel stream bed.

Hauck (1950) investigated if the upper tributaries of Silver Creek should continue to be closed as the theory that larger fish move upstream from the lower sections to spawn in the upper tributaries. Prior to 1948 all tributaries to Silver Creek had been closed to fishing except the lowest mile of Loving Creek. Using tagged fish and angler surveys, he concluded that fish spawn throughout the Silver Creek system and that closing the tributaries was not needed.

Irving (1953) surveyed aquatic vegetation in Grove and Silver Creek between HWY 20 and HWY 93 and reported 50%-90% devoid of aquatic vegetation. Hight turbidity was observed. Spawning was observed to be high in Grove Creek and Silver Creek above Kilpatrick Pond. The rainbow trout population was reported to be healthy and concentrated in deep pools. He suggested an emergency closure of Silver Creek due to concern over the lack of aquatic vegetation.

Simpson (1953) recounts how the fishery was opened in 1953 for a short period, but closed due to concern over the lack of aquatic vegetation restricting the food base for trout.

Gebhards (1963) noted the decline in fishing success between 1959-1962. He summarized observations between 1959-1962 (note this coincided with a period of low flows in Silver Creek). He noted the growth of *Chara*, pondweed, elodea, watercress, and filamentous algae. He noted how aquatic vegetation acts as water barrier and raises water levels. He noted the peak of aquatic vegetation growth is August. Stream flow can then be restricted to gaps in the aquatic vegetation, which can cause the removal of silt and the scouring of pools. He noted that Silver Creek appeared to be mostly sand and silt bottom and that aquatic vegetation is the main source of food, habitat and cover for fish. He noted rainbow trout and brook trout, and that fish abundance and distribution was corelated with aquatic vegetation cover and species composition. Temperatures were recorded at the Point of Rocks location where in 1962, mean temperatures peaked in July at 67.4°F, with a max of 72°F.

Bell (1965) recounts a survey of the property known as Point of Rocks in order to evaluate the viability of a purchase. The stream morphology observations included an average depth of 3 feet. It was also noted that aquatic vegetation growth was high, and that stream flow and aquatic vegetation have been correlated to fish growth. Low flows resulting in low aquatic vegetation and fish growth numbers. Surveys indicated that there was low cover of riparian vegetation, but that undercut banks provided fish cover. Recommendations for riparian plantings for cover and food were made.

Bell (1966) noted heavy aquatic vegetation growth upstream reducing in downstream direction in the creek. He noted very little fish migration in the stream (96% of tagged fish were caught within 2 miles of their release site). Stocking of the creek was common in these years and was found to be highly correlated with abundance. Again, the correlation between stream flow, aquatic vegetation, and water levels was noted. Stream temperatures at the Point of Rocks station were noted to have a maximum of 76°F in in the first week of August 1966. They reported a fishery dominated by rainbow trout.

IDFG (likely 1974) History of Regulations on Silver Creek details many changes in fishing regulations over the years including closures, fly fishing areas, regulation of float tubes, opening and closing date changes, etc. This document demonstrates the concern for the fishery over the years and that its population has fluctuated. Fishing pressure was a concern for many decades.

IDFG (1978) provided the most detailed investigation we found to date, IDFG reported a robust rainbow trout population dominated by two and three-year old rainbow trout, with the highest concentrations in the upper tributaries. IDFG recounts the apparent decline in fish stocks from the 1940s into the 1970s. IDFG noted the loss of pure wild rainbows due to decades of planting hatchery fish. Recommendations included reduction of planting of hatchery fish, especially in the upper reaches of the stream, which were viewed to be more genetically wild populations. Prevention of stream bank vegetation removal promotion of stream bank revegetation are recommended. Continuous monitoring of the stream and a specific management plan with goals for the fishery are called for. They note the beginning of sprinkler irrigation in 1976. They note the bi-modal nature of Silver Creek with the spring peak and then the August irrigation-induced second, smaller peak. Channel morphology and substrate observations note that gravel and silt proportions vary throughout the system. Loving Creek is reported to be heavily silted, while Grove and Stalker Creek are reported to have intermittent gravel areas which support spawning of rainbow trout. In 1977, a temperature logger was placed at confluence of Grove and Stalker Creeks. IDFG reported a maximum water temperature of 72°F in June with a mean maximum temperature of 62.8°F. Water quality samples taken in 1975 and 1976 indicated high ion concentrations in the stream. Again, the close association between aquatic vegetation, invertebrate production and fish production were reported. Sparse vegetation cover, especially in the lower reaches is reported with only the upper reaches having woody vegetation long the streambanks. IDFG reports that the original rainbow trout were stocked from the McCloud River, California in the 19th century. Hatchery and salvage fish from other regions were also stocked in the creek over the years. Brown trout and brook trout are reported to also be in Silver Creek by this time. Large rainbows were most common in the upper section that included Grove, Loving, and the upper part of what is currently the preserve. Juveniles were most abundant in Grove and Wilson Creeks. Fish migration was reported, but like past investigations, most fish were recaptured around a mile of where they were tagged. IDFG reported that reports indicate that large fish (5 lb. to 10lb.) were more common in the 1920s, with declining fish sizes through the decades. The report concludes that hatchery fish have diluted the genetic make-up of the fishery by this time. The hatchery trout are also reported to spawn in the fall. The conversion of natural vegetation cover and pastureland into more wheat and barley production between the 1940s to the 1970s is reported to be associated with wind erosion depositing large amounts of silt into Silver Creek and its tributaries. In winter months, Hayspur hatchery reported 365 tons of silt entering the hatchery per month through its intake on Loving Creek. The lack of historical data makes the degree of naturally occurring silt difficult to quantify. IDFG associated the silt influx with a decline in spawning areas, but recognized that some silt was needed, as *Chara* and *Potamogeton* aquatic macrophyte beds rely on small substrate sizes and can feed the invertebrate population. IDFG noted that a trout grew faster in 1952 in Silver Creek than they did in 1976 and 1977. This could be corelated with the decline in overall production in Silver Creek, however it was noted that the sample sizes were small. The report recommends revegetation of streambanks where cattle grazing has denuded it – especially in the upper tributaries.

Francis and Bjornn (1979) of the University of Idaho conducted an aquatic resources report on the Nature Conservancy section of Silver Creek. They reported maximum temperatures in 1977 to be 22°C (71.6°F). Substrate was composed of silt (including fine sand) and gravel with particle sizes less than 7 cm. Silt was estimated to cover 42 to 56% of the stream bottom during that year. The depth of silt on the gravel bed was found to vary throughout the year, as it was greatest in summer (13.2cm), declined slightly through the summer, before reaching a minimum in October (10.7 cm), before rebounding to 12.9cm in December. Twenty-nine species of aquatic macrohytes were found. Vegetation cover was greatest in August (68% of the stream) and lowest in March (10%). The report noted hat on the preserve, the only gravel areas in late August occurred between aquatic macrophyte beds where *Chara sp.*, *Elodia canadensis*, *Potamogeton pectinatus* and *Veronica angalis-aquatica* were most abundant. Thirty-one genera of algae were also identified. Fifty-three families and seventy-eight genera of aquatic insects were identified. In order of abundance, *Diptera* (true flies), *Tricoptera* (caddisflies), and *Ephemeroptera* (mayflies) were the dominant orders in benthos samples. The order of abundance varied between these orders in drift samples. Ephemeroptera (mayflies) were the most abundant in rainbow trout stomachs, comprising 80% of organisms. Rainbow trout also selected positively for mayflies and negatively for other organisms. While caddisflies were the most abundant in the gravel benthos, true flies and mayflies were most common in the areas covered by vegetation. Mayflies were most common in the drift samples. More specific associations between different invertebrates and specific plan and substrate types. Although silt abundance was high, the report acknowledges that some silt is important, as *Chara* requires silt and this plant in an important host to many invertebrate species. Anecdotal evidence is reported from fisherman that *Chara* in Silver Creek increase and decrease on a 5-7 year cycle, both the authors doubt this cycle to be operating within the Creek. Chlorophyll concentrations indicated that Silver Creek is not very productive compared to other trout streams, most of the production comes from aquatic macrophytes. In contrast to previous work, they reported that trout left the preserve to spawn upstream. The report concludes that the size of fish in Silver Creek has declined and the aquatic vegetation should be monitored twice a year at the maximum and minimum extents.

Manuel at al. (1979) investigated the sources of sediment in Silver Creek. They identified Stalker Creek contributed 63% of the material, Grove Creek 23% and Loving Creek 15%. They estimated that windborne silt was not a major source of sediment. They noted that Stalker Creek had channelization, drainage canals, and extensive areas of exposed fields. They noted that sediment increased in a downstream direction to the Purdy dam, which acts as a sediment trap. Aquatic vegetation was identified as an important factor in the dynamics of sediment deposition and erosion. They note the changes in land use in the prior 20 years paralleled with an increase in sediment load to the creek, which has had a negative effect on the trout fishery. They describe the negative effects of turbidity and sedimentation on primary productivity; dissolved oxygen levels; salmonid habitat and reproduction; among other ecosystem impacts. They detail a lack of historical data on sediment levels, and that local residents' opinions varied. Some said sediment levels had always been high in Silver Creek, others detailed an increase in the preceding years. They assert that the construction of the railroad in the Loving Creek drainage induced sediment increases, especially at the bridges. In addition, several canals in the drainage pre-date 1940. On Stalker Creek, they note the most significant changes were a result of the construction of Patton Drain in 1952-1953. Similarly, the construction of Patterson Drain, in 1945 and Daly Ditch in 1955-1956 were detrimental. Daly ditch is an underground drain that carries water into Loving Creek that originally fed Thompson Creek, a tributary of Grove. They do detail that wind-born sediments have been known to contribute a load to the creek and detail an event in 1974 during a dry spring during planting season coinciding with persistent winds. The result was high sediment loading of the creeks, especially in Loving Creek, which led to the installation of a sediment basin above the hatchery in 1977. They found turbidity to be highest in Stalker Creek (measured just above its confluence with Grove Creek) and lowest in Grove Creek, with the other creeks falling in between. They observed high total sediment loads in late March 1978, with Stalker Creek 6 times higher than Grove Creek. Although they concluded that wind-borne sediments were not a significant source of the sediment load in Silver Creek, they do conclude it undoubtably contributed to the load. They also observed sites with willows had 47-86% reductions in sediment inputs compared to grass-dominated sites. Their observations of sediment depths on the streambed noted that sediment was moving within the channel seasonally and that depths increased in a downstream direction within their study area (roughly the preserve). From core samples and depth measurements, they estimated 5000 metric tons of sediment existed between the confluence of Stalker and Grove Creeks and Kilpatrick Bridge. They observed that the section of Loving Creek on the TNC preserve was blanketed with silt, which they described as aesthetically unpleasant and detrimental to fish habitat. They identified Upper

Loving Creek and Cain Creek as significant sources of sediment, the latter possibly a main source for the sediment at that was measured at the downstream Stalker site.

Bjorn (1980) describes the sampling of vascular aquatic plants at Silver Creek in 1979. In the fall of 1977, 40 to 68% of the area surveyed on Silver Creek was covered by aquatic macrophytes (by dominance: *Chara* (33-50%), Potamogeton (1-20%) and Veronica (6-10%). The annual cycle of growth and recession was recorded, with 10% of the stream covered by vegetation on March 17th, 1978, mostly by *Chara*. In April 3, 1979, vegetation covered more of the stream (23%, 19% *Chara*) than March of 1978, but sampling occurred two weeks later in the year. In the summer of 1977, *Chara* covered 50% of the stream. Following the catch-and-release regulation put in place in 1977, the trout population appeared to have increased.

Griffith et al. (1982a) of Idaho State University performed a baseline biological study on the portions of Chaney and Mud Creeks included in the Stinson Easement (located just north of the existing TNC preserve boundary). They collected data in the fall of 1981 and spring of 1982 on sediment depth; type and height of submerged aquatic vegetation; turbidity and suspended sediment; composition and abundance of aquatic macroinvertebrates; fish composition and riparian vegetation. In Mud Creek, sediment depth accounted for ½ of the total depth, with little to do exposed gravel throughout the reach sampled. Chaney Creek had lower sediment depths, except above the culvert at the road, where a current pond has been created through an enhancement project. Thirty species of invertebrates were collected, with maximum of 25 species on Chaney and 18 on Mud. The heavily silted sections of Mud Creek had very low numbers of insects in the spring, where the bulk of the organisms were worms that could mine the silt. The highest richness occurred in sites with a diversity of substrates, including gravels found on Chaney Creek. The authors conclude that the areas of Mud and Chaney Creek that were silt-laden areas were found to be devoid of important insects valuable as trout food. They documented rainbow and brook trout. The sampling indicated that trout move out the area in winter as the temperatures drop to below 4°C (39°F) and the area lacked deep pools or overhanging banks where trout prefer to overwinter. Riparian vegetation widths ranged from 12 to 42m. The most common were *Poa*, *Juncus*, and *Carex*, which are graminoids and provide little in the form of cover, shade, or airborne sediment reduction. The authors describe that *Potentilla*, *Rosa*, *Betula* and *Salix* species would be preferable for fisheries and stream habitat.

Griffith et al. (1982b) also performed a similar baseline biological study on Grove Creek in the McMahan easement (exact location is unclear for the map provided in the report) to that performed on Mud and Chaney Creeks. Riparian vegetation results were similar to those on Chaney and Mud Creeks with a dominance of graminoids and lack of woody vegetation, although woody species were present in the lower reaches of the sampling area. The fish population was estimated to be 200 fish /hectare, with the majority of the fish dependent on too large, deep holes created by concrete sills in the creek. Riparian vegetation distribution followed a similar pattern to Chaney and Mud Creeks, with 24 genera observed and a lack of woody species in upstream reaches, but a few were present in downstream reaches. The sediment transect contained a limited amount of fine sediment (2-11cms), but built up in the spring as a narrow pocket caused 44cms of deposition on one side of the transect. Riparian vegetation was dominated by *Chara*, with a relatively high proportion of gravel (10-50%) exposed during most of the year.

Parker and Riehle (1987a) of Idaho State University performed a Silver Creek Fish Evaluation for 1986 sampling. The study area extended from just below Stalker Bridge to the confluence with the Little Wood

River. The river was broken into five sections but three sites were used to assess juvenile fish density and growth. The upper site (Stalker) extended from Stalker Bridge to 300m above the confluence with Grove Creek. This section was characterized as having 0.5m depth and a *Chara* and gravel bottom. The Pumphouse section was from immediately below the pumphouse and within the catch-and-release area at that time. *Chara* dominated bottom, deeper and faster water characterized this site. This site contained three 1.5m pools. The Cabin site was below Sullivan Slough and extended to the last island past the TNC visitor Center cabin, and compared other sites it had stronger velocities and only one-third of the channel covered in *Chara*. It also was withing the catch-and-release area at the time. From Loving Creek confluence down to Kilpatrick Bridge was sampled to assess deeper habitat. Downstream of the dam, the Martin bridge site had dense willows. The Point of Rocks section began 500m above Point of rocks Campground and extended to the campground. Its riparian zone was open and grassy. The section from Priest campground to the lower campground was characterized by higher gradient. The effort included electrofishing, snorkeling, angler reports, tower observations, etc. and the locations of each are not clear. Results indicated proportionally higher brown trout populations in lower sections (51-59%), but overall rainbow trout were 81-98% in all sections. Sections above the Purdy dam were estimated to have higher populations than below the dam. Results of the habitat utilization portion of the study found that adult rainbows were elusive and remained close to cover like macrophyte beds, riparian cover, undercut backs, etc. As the summer water elevations increased with macrophyte growth, the authors observed trout holding and hiding in pools. Larger trout (>300mm) particularly exhibited a behavior of holding in pools then moving to shallow riffles to feed and glides to feed roughly within 30m of the holding pool. Fish were observed moving out of the holding pool in August. The authors conclude that rainbow trout in the Silver Creek system prefer water depth, holding pools, and a near-by area with a change in water velocity for feeding areas. Their data indicated an association between depth and area of holding pools and adult rainbow numbers. They concluded that juvenile brown and rainbow trout preferred similar lower velocities (0.15-.02 cm/sec) and depths (57.5-78.9cm) and preferred a gravel substrate.

Riehle and Parker (1987b) summarize their fisheries work on Silver Creek in a short paper that concluded that 10 years (1977-1986) of catch-and-release had resulted in an increase in size and growth rate of rainbow trout on the TNC Silver Creek Preserve. The note the expansion of brown trout upstream in the system. They present that in 1977, brown trout were not known to exist above Picabo, however, by 1986, brown trout made up one-third of the population of trout in the middle section of Silver Creek. They note that their findings indicate that trout seek cover over food in the winter months.

Riehle and Parker (1989) in the Final Report for their multi-year effort (some interim reports were not included in this review as they were exclusively focused on fish density, growth, mortality and angler pressure), the authors performed redd counts from the HWY 20 bridge downstream to the confluence. They found the highest densities (about 44 redds/km) from the HWY 20 bridge downstream to Point of Rocks. From Picabo Bridge downstream had the lowest densities (about 2 redds/km). The authors note that the Preserve was excluded from grazing but much of the rest of the river was heavily grazed and that areas of bulrush were heavily disturbed during the winter months while summer use was light. They note sections of the creek that are eroding and inputting sediment into the stream as a result of cattle damaging the banks. They note that IDFG property is excluded from grazing and other private parcels choose to exclude grazing, and these areas have better bank conditions. They note the lower section of Silver Creek from the HWY 20 bridge east of

Picabo downstream to the Little Wood River was heavily utilized from summer to late fall with no rest. Bank trampling in this area was the most severe of other study sites in the area between upper and Lower Priest Camping Sites, which is administered by the BLM. Pertinent recommendations included revegetation of Lower Silver Creeks Riparian area and better grazing management.

Riehle and Griffith (1993) published a paper on changes habitat use and feeding of juvenile rainbow trout in fall and winter in Silver Creek building on their work over several years on the creek in the Canadian Journal of Fisheries and Aquatic Sciences. The concluded that in late September, fish aggregated briefly during the day, then began to conceal themselves in macrophyte beds, undercut banks, and submerged sedges and grasses along streambanks and temperatures dropped below 8°C in early October. Fish emerged from concealment at night and were most visible and abundant 30-60 min. after sunset and 30 min. before sunrise. Periods of peak feeding changed from afternoon and evening in August and September, when fish were day active to mainly at night in October after then initiated day concealment. Winter diet was mainly of mayflies when water temperatures were between 1-4°C and their stomachs were fullest in in early morning. They concluded that trout in Silver Creek begin a metabolic deficit in September. In their review of pertinent literature (please refer to the paper for relevant citations) they discuss how juvenile salmonids aggregate in open water, especially in thermal refuges (like groundwater inflows), may conceal themselves in woody debris, in interstices of substrate, or under undercut banks. They conceal themselves during the day and emerge at night.

Wolter et al. (1994) reported stream water quality results for the TNC Preserve water monitoring program. Pertinent results include the low-flow year in 1992 resulting in elevated water temperatures, increased aquatic macrophyte growth, and lethal dissolved oxygen levels that summer. On June 23rd, 1992 50 large trout occurred when dissolved oxygen levels reached 2.5 ppm at the Point of Rocks Fish and game access point. In the summer of 1994, dissolved oxygen levels again were a concern, as they reached fluctuated between 3.2 and 15.7 ppm on June 29th at the Stalker Creek Bridge. They reported that Grove and Silver Creeks has the lease sediment build up at their transects while Stalker, Chaney and Loving Creeks had lower velocities and deeper sediments (silt). They describe the 1993 high snow melt year as redistributing sediments in the system – including a change in gravel cover in Grove Creek from 27% in 1992 to 75% in 1993 at their transect.

USDA, NRCS (1996) published a preliminary investigation report on Silver Creek. Focused on water quality, the report identified that Silver Creek as "supported but potentially at risk" for cold water biota, salmonid spawning, and recreational uses. It noted that several farms and ranches had begun conservation measures and that easements had been put in place. At the time, TNC was reported to have 805 acres under ownership, 7,726 acres of land in conservation easements and 987 acres in management agreements. One of the goals was to identify point and non-point sources of pollution within the watershed. They reported the watershed had 35,000 acres of cropland and pastureland, 28,200 acres of rangeland out of the 68,200 acres within the watershed. They also reported that 21,220 of the 35,000 irrigated acres were by sprinkler. They identified the largest water quality problem in Silver Creek to be sediment and other suspended solids. The effects of the sediments on spawning gravels and insect populations were highlighted. They stressed the importance of the sediment issues within the tributaries where they assert most of the spawning occurs. They discuss that the macroinvertebrate population in upper Silver Creek is extremely high for the Rocky Mountains. They attribute this to the clear cold, nutrient rich water with homogenous habitat, deposition substrate and extensive macrophyte beds. They identify agriculture, grazing and wind-blown silt as major causes of the sediment loading within the creek. They attribute the low velocities and high sediment load leading to the deposition of silt and sediment throughout the system. They identify winter and spring as the periods when sediment loading occurs. The causes of the water pollution are identified as loss of riparian vegetation, tillage operations too close to stream banks, improper livestock grazing in riparian and springhead areas, lack of BMPs on to control irrigation return flows, concentrated spring runoff from rangeland, conventional tillage practices and sediment and nutrient loading.

Intermountain Aquatics (2006) investigated the growth and influence of reed canary grass on streamside and instream habitats on and near the TNC Silver Creek Preserve. The investigation focused on Wilson Creek, but also investigated Mud and Stalker Creeks. They concluded that silt and much deposits in in shallow water zones appeared to contribute to the invasion so reed canary grass into aquatic habitats. These silt and muck deposits appeared to have settled in in dense stands of submerged aquatic vegetation. They observed that Stalker Creek had silt, dense aquatic vegetation, and reed canary grass invasions. They suggested that restoration of streams with reed canary grass should attempt to deter invasion into the channel by minimizing areas of exposed, shallow sediment, especially silt or muck. They suggest that the central channel should be deep with relatively high velocities that will limit the accumulation of fine sediment and will maintain adequate depth to thwart reed canary gras colonization. They recommend that shallow, low-velocity areas are vulnerably to reed canary grass invasion should and should be avoided. Soil mixtures with high silt content should be avoided in bank and point bar construction. They recommend aggressive re-vegetation and reed canary grass control following restoration.

Perrigo (2006) examined the historical sedimentation and sediment transport characteristics of Silver Creek for a dissertation. He discusses that excessive sedimentation has been identified as a problem in Silver Creek and that it has the potential to clog spawning grounds, modify stream temperatures and at high levels be lethal to fish. His examination of historical information concluded that there had been an intense removal and destruction of native vegetation coinciding with the introduction of agriculture in the 1880s. He suggested that increased run-off from removed vegetation and flood irrigation likely caused increase sediment supply to the channel. He stated that increased vegetation density within the channel from nutrient run-off also promoted deposition. His analysis of aerial imagery suggested that the channel may have achieved a stable form by the 1950s. He states and cites the Manuel 1979 study as support that in its natural state, Silver Creek was a gravel bed system and therefore the sediment on the channel bed is a disturbance to the system. Remediation techniques examined included dredging and dam removal.

Whitaker (2007) performed a biological assessment of the benthic macroinvertebrates in Silver Creek from his masters thesis from the University of Idaho. Benthic macroinvertebrate samples were collected at ten sites throughout the watershed. Overall, the watershed scored as “good” based on the Idaho Department of Environmental Quality Stream Macroinvertebrate Index. However, some sites scored only “fair” and restoration of those areas and sites with similar characteristics was recommended. Evaluation of restored sites in Upper Grove Creek indicated an apparent increase in water quality. Restored sites narrowed the channel by creating backs with biologs. Planting of woody riparian species and bank restoration where stream banks have been trampled by cattle are recommended. The higher macroinvertebrate assemblages found in gravel-dominated riffles with *Chara* mats was discussed and the focus of the sampling. The lack of riffles within the system was also noted. Notably, the Lower Loving Creek site received “poor” and “fair” ratings.

Further restoration, especially increased water velocities and the creation of riffle and pool habitats was recommended.

Ecosystem Sciences Foundation (2011) provided an ecological enhancement strategy for the Silver Creek watershed. A comparison of landcover mapping from historical aerial imagery from 1943-1946 and from 2009 indicated several changes from the already highly modified system in the 1940s. Over the examined time period, cover of agriculture, developed land and open water increased in acreage while emergent wetland, grassland and shrub/scrub decreased in acreage. A habitat assessment of streams of the TNC preserve concluded that all stream reaches had some critical trout habitat element. Spawning gravels were observed to be distributed throughout the stream. Fish production was observed to be high. Fine sediment deposits were observed to be greatest in the confluence areas. Movement into the creek is attributed to irrigation drains and tributaries. Legacy sediments in Kilpatrick Pond are noted to restrict habitat to adult holding only. Pools on meander bends were found observed to be free of sediments. Reed canary grass was found to be encroaching the stream, and the long-term threat of reed canary grass colonizing the stream in shallow sections is acknowledged. Winter habitat conditions are discussed, with the role of surface ice in eroding streambanks and changing water surface elevations. They performed an analysis of existing data and data gaps. Data gaps included tributary hydrology and temperature data, spring head hydrology and temperature data, pond temperatures, groundwater balance data, fish habitat inventory, land use mapping, muskrat/beaver habitat inventory, channel geometry and icing conditions. Further discussions of thermal loading, stream channel morphology changes (e.g. channel straightening and widening), and sediment loading, and ecological tipping points (e.g. if temperatures reach a certain threshold, trout populations will decline) are included. Additional stressors identified include exotic species invasions, recreation stress, whirling disease, groundwater mining, urbanization and development, land use conversions and herbicide/pesticide accumulation. They provide twenty-nine restoration guidelines. They present techniques to address bank instability, sedimentation, over-widened channels, headcutting, channel alteration, and others. They suggest restoration using buffers and riparian vegetation. They also discuss using natural processes for restoration, but that in some situations, mechanical interventions are needed. Specific restoration actions are prioritized int three tiers. Tier 1 included Kilpatrick Pond Island creation, Loving Creek restoration, establishment of riparian buffer zones, and improvement of riparian buffer quality. Second tier actions included additional island construction to narrow channels, spring protection, surface water flow augmentation, and construction of sediment trap basins. Third tier actions included Kilpatrick dam reconstruction, reduction of pond surface areas, dredging and channel narrowing. Finally, they suggest a robust monitoring and adaptive management program.

Schultz (2012) examined the relative influence of physical and anthropogenic variables on instream habitat in Silver Creek as a masters thesis. She concluded that the higher elevation tributary streams channels have lower slopes, are narrower, are more shallow, contain less sediment and are bordered by higher percentage of riparian vegetation than lower elevation (main stem) steam channels. Anthropogenic variables most correlated with instream habitat variables were percent developed acres, percent riparian acres and structure density. She found natural variable more highly correlated with habitat than anthropogenic variables. She took sediment depth measurements at sites on the preserve and the tributaries above. The main stem of Silver Creek sites averaged 0.85 feet while the tributary sites averaged 0.51 ft. Her average width to depth ratios were between 31 and 33 ft. for both the mainstem and the tributaries.

Ecosystem Sciences Foundation (2015) performed redd counts and habitat surveys in the tributaries to Silver Creek. They found the highest concentrations of redds in Grove Creek. They found a lack of deep pools, and large stretches of silt and fine sediment areas that were devoid of useful fish habitat. The data is unpublished but is available to the public.

MacCoy and Short (2017) performed a USGS evaluation of macroinvertebrate communities prior to and following channel restoration in Silver Creek. Their investigation concluded that there were no significant decreases in macroinvertebrate community assemblages following restoration. In fact, taxa and EPT richness of colonized areas increased post-restoration. Restoration included dredging and creating islands to reduce width-to-depth ratio and increase velocities.

TNC (ongoing) has been performing redd counts on the TNC Preserve. Within the preserve, the most redds generally occur in Silver Creek just downstream of the Grove Creek confluence. Lower Chaney Creek, Lower Loving Creek and Stalker Creek below the Chaney Creek confluence generally had redds absent.

Silver Creek Alliance and Ecosystem Sciences Foundation (2011-2018) have published Annual Reports detailing hydrology, temperature, dissolved oxygen, and sediment monitoring occurring throughout the Silver Creek watershed. Although results vary from year to year, some general patterns include:

- Grove Creek is largest and coldest tributary.
- Upper Stalker Creek, Lower Mud, Loving Creek (especially the North Fork of Loving) and lower reaches of Silver Creek (HWY 20 downstream) have the highest summer temperatures in general.
- In a 2015 analysis of stream temperatures over a five-year period in relation to each other, stream flows, and air temperatures, it was concluded that the volume of water is the most critical component driving stream temperatures. Stream temperatures in the large water year of 2017 verified the relationship.
- An evaluation of the Kilpatrick Pond restoration project (and dam replacement enabling a bottom-release) on stream temperatures within and downstream of the dam revealed a stream temperature benefit within the pond and for a short distance downstream.
- Springheads generally run cold, but the North Fork of Grove and Cain Creek Spring heads are the warmest (just below 60°F).
- Lower Silver, Loving and Stalker Creeks have the highest amounts of sediment measures at silt transects. Grove, Cain and Wilson have the lowest loads.
- Repeated measurement of sediment transects indicate that sediment is being transported through the system as cross-section vary between years.
- Sediment transects measured at the location of a dredging project were performed in in 2015 (before) and 2016 (after), documenting the reduction in sediment at the site and serving to provide a baseline to measure the re-accumulation of sediment in future years.
- Declining groundwater levels are documented through well data.
- The change in irrigation water practices from surface water to groundwater in recent decades is discussed, as less water has come to the Silver Creek watershed from the Big Wood River, and more groundwater has been pumped for irrigation.
- Dissolved oxygen levels are best in Lower Grove and Lower Chaney Creeks. Butte Creek and Lower Silver Creek locations have had the highest fluctuations and lowest Dissolved oxygen numbers.

Generally, these sites reach 5 mg/L in the height of the summer, though is some years, 3 mg/L is occur.

1.3 Summary of Ecosystem Conditions and Restoration Targets

The results of the review of existing literature on Silver Creek are summarized below and represent possible restoration targets for the assessment. They are separated by ecosystem component, though most of the components are interrelated.

- ▲ Submerged Aquatic Vegetation
    - Submerged aquatic vegetation (or aquatic macrophytes) is important for the food base of trout (due to their association with stream macroinvertebrates), but *Chara* beds that grow on gravel substrates with higher velocities are superior to the communities that flourish in slow-moving silty areas. There were conflicting reports of *Chara* being present in silty areas as well.
    - Aquatic vegetation volume in the creek follows a yearly cycle, with lowest densities in the late winter and early spring, and highest densities in August. This affects channel conditions, as water levels and velocity profiles are modified by the vegetation volume. The vegetation also affects dissolved oxygen concentrations, which can vary greatly during summer months.
    - The aquatic vegetation provides cover for trout. When vegetation is absent, trout require cover in the form of deep pools, overhanging streambanks and large wood. Much of Silver Creek lacks deep pools, and fish congregate in those that do exist.
    - Aquatic vegetation can trap fine sediment, covering gravels and changing hydraulics.
- ▲ Silt and Fine Sediment
    - Silver Creek was likely originally a gravel bed system.
    - Silt and fine sediment have been identified as a problem in Silver Creek since at least the 1940s. The origins and historical presence are a subject of some debate, but land use practices, past and present, are most often cited as responsible for the sediment loads, which vary between tributaries and the main stem reaches.
    - Loving Creek, Stalker Creek and portions of Chaney Creek are noted as containing high volumes of silt, while Stalker Creek and Loving Creek have been identified as the largest sources of sediment to Silver Creek.
    - Silt deposition areas free of aquatic vegetation are associated with a community of insects considered undesirable for producing a trout food base.
    - Removal of silt coupled with increased depths and velocities through restoration action have been shown to benefit macroinvertebrate community composition.
    - A diversity of substrates, including multiple gravel sizes as well as areas of fine sediment have been found to have the highest macroinvertebrate species richness.
    - Silt has been attributed to higher increased stream temperatures and a decrease in suitable spawning habitat.
- ▲ Habitat Use by Fish
    - Although fish are known to migrate within the stream, many reports indicate that fish do not move large distances.

  - Having a diversity of habitats where fish can hold, feed, and even spawn in close proximity are desired. Having riffles and pools in close proximity will allow trout to move between holding and feeding areas.
  - Water depth and large hiding pools have been associated with high trout numbers.
  - Winter cover and food are needed in Silver Creek, as they are lacking. Fish go into a metabolic deficit in September. Winter brings reduced swimming abilities. A diversity of habitats with cover throughout the stream is therefore desirable.
  - Additional cover in the form of undercut banks, large wood, and deep pools are desirable.
- ▲ Riparian Vegetation
  - Many investigations noted the need for woody vegetation along streambank margins. They stabilize stream banks, provide food and cover for fish, and reduce airborne sediment inputs to the creek. Species such as Booth's willow (*Salix boothii*), Yellow Willow (*Salix lutea*), Coyote willow (*Salix exigua*) Drummonds willow (*Salix drummondiana*) red-osier dogwood (*Cornous stolonifera*) and water birch (*Betula sp.*)
  - Reed canary grass has invaded the system and has moved into the channel in shallow areas with low velocities, negatively affecting stream morphology. To prevent reed canary grass invasion into the channel, restoration that creates increased depths and velocities is recommended.
  - Other invasive plants such as purple loosestrife (*Lythrum salicaria*) and yellow flag iris (*Iris pseudacorus*) are known to occur within the area and are a threat to the ecosystem's native vegetation. Monitoring for invasive plants and an Early Detection and Rapid Response (EDRR) program is recommended.
- ▲ Temperature and Dissolved Oxygen
  - Temperatures in portions of Silver Creek reach temperatures over 70°F in mid-summer, which is stressful for trout. These conditions most often occur in Upper Stalker Creek, Lower Mud, Loving Creek (especially the North Fork of Loving) and lower reaches of Silver Creek (HWY 20 downstream).
  - Dissolved oxygen levels can fluctuate from super-saturated to very low levels in some reaches of Silver Creek in summer months. Fish kills and closures of the fishery have been attributed to dissolved oxygen levels.

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Appendix B. Individual Reach Characteristics

Technical Memorandum

Applied Science & Engineering

2449 S. Vista Ave. Suite B, Boise, ID 83705

TO:	The Nature Conservancy
FROM:	Rob Richardson, Rio ASE
DATE:	May 2020
FILE:	035-104-001-01
SUBJECT:	Silver Creek Assessment—Final Individual Reach Summaries

The following sections summarize individual reach characteristics and target restoration conditions as part of the Silver Creek Assessment. Target conditions and recommendations were developed based on the quality and quantity of available data per reach. Targets and recommendations for reaches with data gaps and/or a high degree of variability (e.g., multiple channels) are therefore necessarily less detailed and/or qualitative compared to those reaches with more and/or better data. Methods associated with the information provided below are described in the Silver Creek Assessment Report, prepared by Rio ASE and Ecosystem Sciences, of which this is an appendix.

SILVER CREEK REACH 1

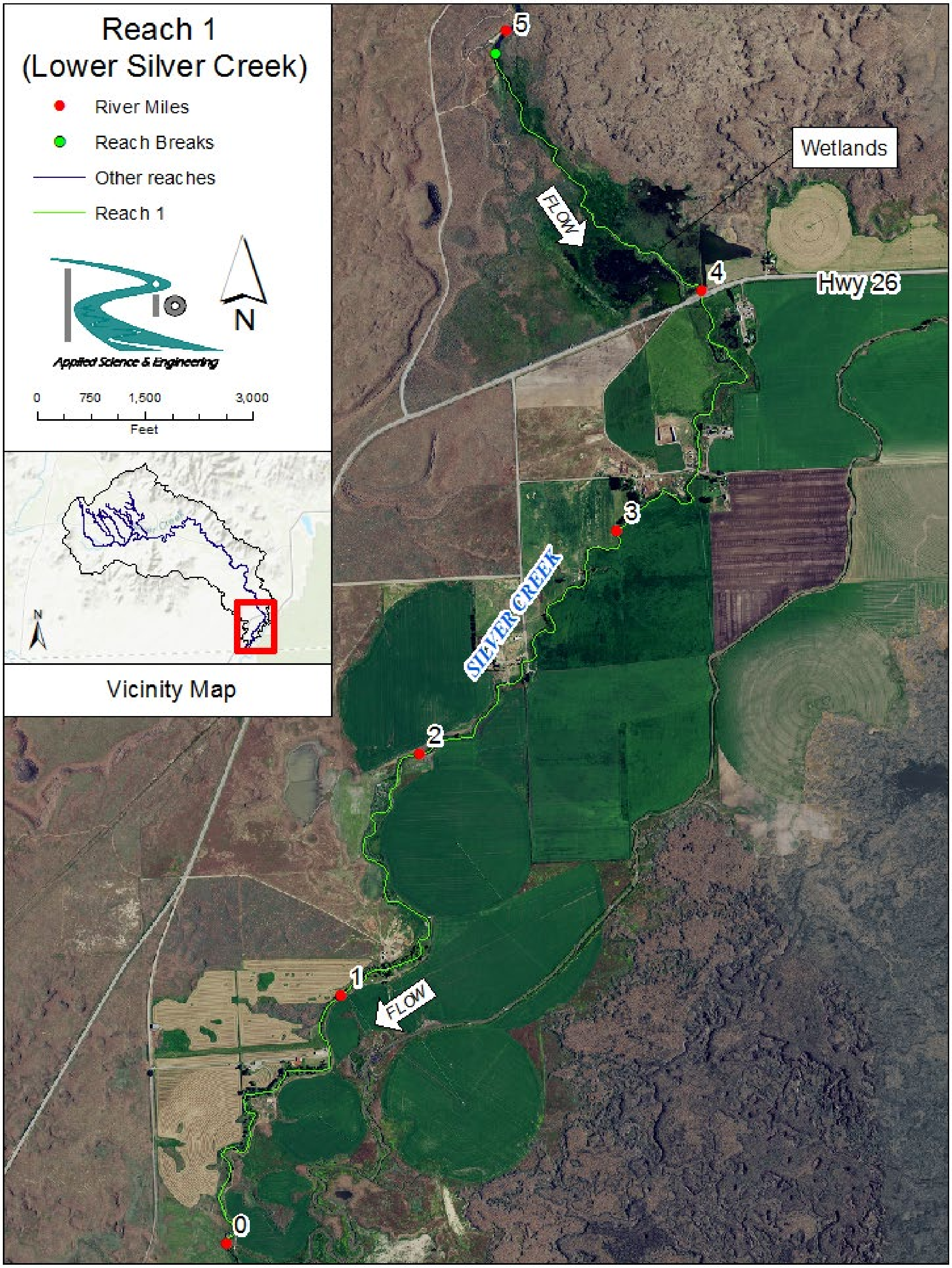
Silver Creek Reach 1 (river mile [RM] 0–4.9) is located at the downstream end of Silver Creek, between its confluence with the Little Wood River and a transition from a valley confined reach (Silver Creek Reach 2). Reach 1 is characterized by human influence from agriculture, irrigation, and roads. Riparian conditions are poor, sedimentation is high, and summer temperatures commonly exceed temperature thresholds for wild trout. One notable feature is a wetland upstream of and potentially impounded by Highway 26.

This reach is not flow-limited, but poor habitat connectivity and temperature characteristics produce low fish use potential overall (Reaches 1–4c all have similar fish use potential for the same reason). While there may be potential restoration actions that can improve the conditions of Reach 1, the constraints of working with many landowners and a highway bridge reduce the restoration feasibility. Reach 1 also exhibits poor habitat uplift potential, because adequately addressing habitat goals for the watershed and providing high-value habitat uplift in the reach at reasonable cost is not considered feasible.

Table 1. Reach 1

Reach Condition	Existing	Target
Sinuosity	1.32	1.6–1.8
Gradient	0.11%	0.08–0.09%
Average Stream Width (ft)	20	20
Hydrology (Changes)	Losing	Losing
Riparian Conditions	Poor	Minimum buffer width: 40 ft
Sedimentation	High	See general target conditions
Human Features	Artificial wetland upstream of Hwy. 26; bridge at Hwy. 26; many pivot irrigation systems	Remove or modify human features most impacting stream form and/or function.
Temperature: Average # of days between 70–78°F (average # of days >78°F)	62 (5) Data Logger: Silver Crk. @ Hwy 93	Reduced
Habitat Connectivity	Poor	High

Figure 1. Reach 1



SILVER CREEK REACH 2

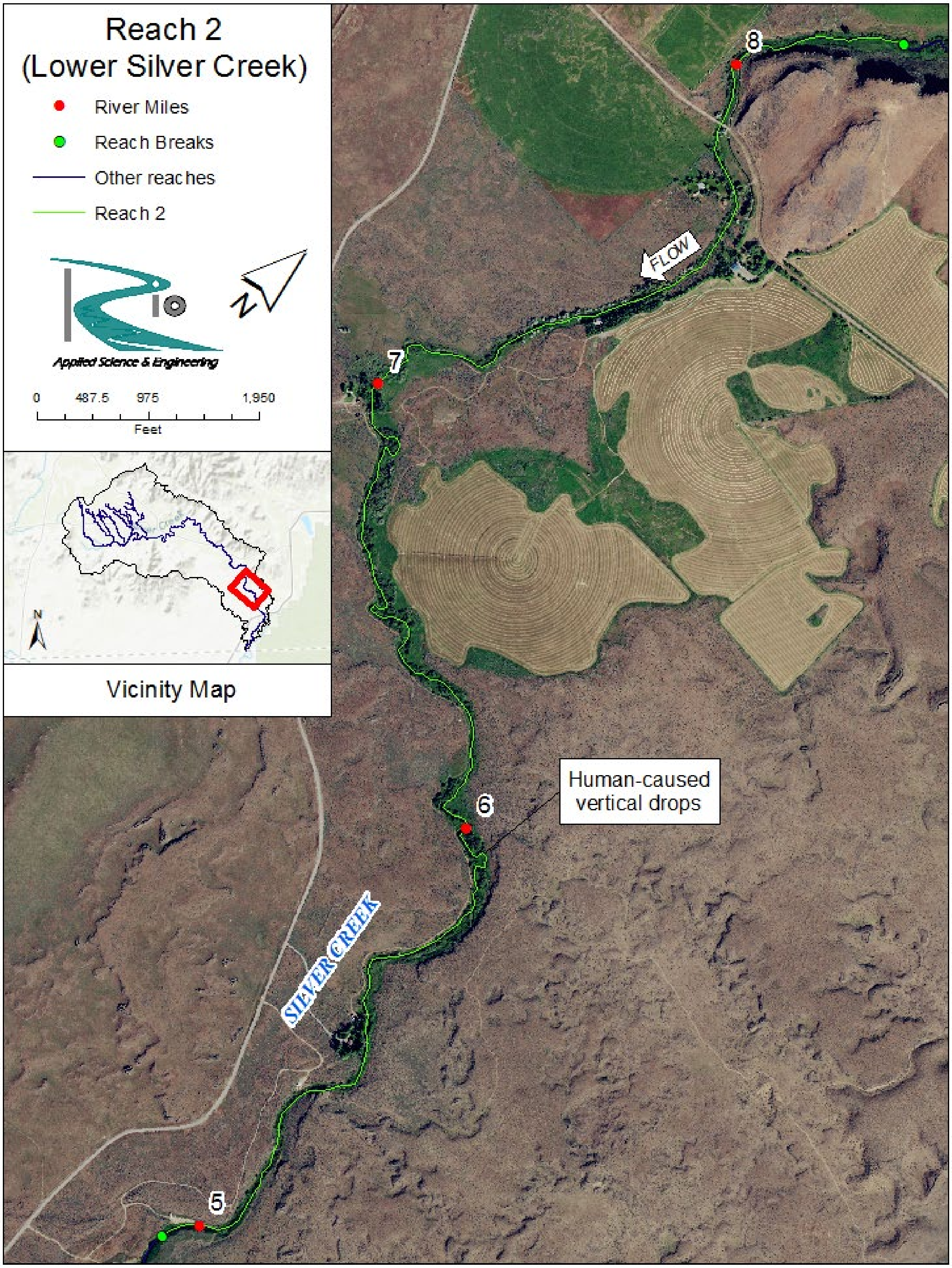
The defining characteristic of Silver Creek Reach 2 (RM 4.9–8.3) is pronounced valley confinement from natural bedrock outcrops throughout the reach; this reach is subject to more valley confinement than most other reaches. Unlike the typical valley-confined stream, this reach still exhibits high sinuosity, though much of the planform has been impacted by human activities. Like most lower Silver Creek reaches, temperature, sedimentation, and habitat connectivity are poor.

Reach 2 exhibits generally poor fish use potential, because despite adequate flow, there are poor temperatures and poor habitat connectivity due to high temperatures disconnecting it from upstream reaches. In short, the reach is believed to be too hot during large parts of the year to support healthy native trout populations. Restoration feasibility is also low, because the potential for geomorphic response is relatively poor given the physical constraints of a valley-confined reach; therefore, restoration that is most feasible (i.e., reasonable cost and regulatory compliance) include working within the existing channel alignment. Similarly, the habitat uplift potential is poor, because most of the feasible restoration actions would not address temperature and habitat connectivity issues stemming from upstream that are limiting fish use in this reach. Additionally, the cost to significantly improve habitat beyond existing conditions (other than the addition of in-stream structure such as large woody debris [LWD] and other treatments described in Section 4.5 of the accompanying main report) in such a confined reach are likely cost-prohibitive relative to higher benefit-to-cost ratio projects in reaches farther upstream.

Table 2. Reach 2

Reach Condition	Existing	Target
Sinuosity	1.32	1.6–1.8
Gradient	0.47%	0.08–0.09%
Average Stream Width (ft)	40	30
Hydrology (Changes)	Losing	Losing
Riparian Conditions	Fair	Minimum buffer width: 60 ft
Sedimentation	High	See general target conditions
Human Features	Series of vertical drops at RM 7.7	Remove/modify human features most impacting the reach including structures creating vertical drops.
Temperature: Average # of days between 70–78°F (average # of days >78°F)	62 (5) Data Logger: Silver Crk. @ Hwy 93	Reduced
Habitat Connectivity	Poor	High

Figure 2. Reach 2



SILVER CREEK REACH 3

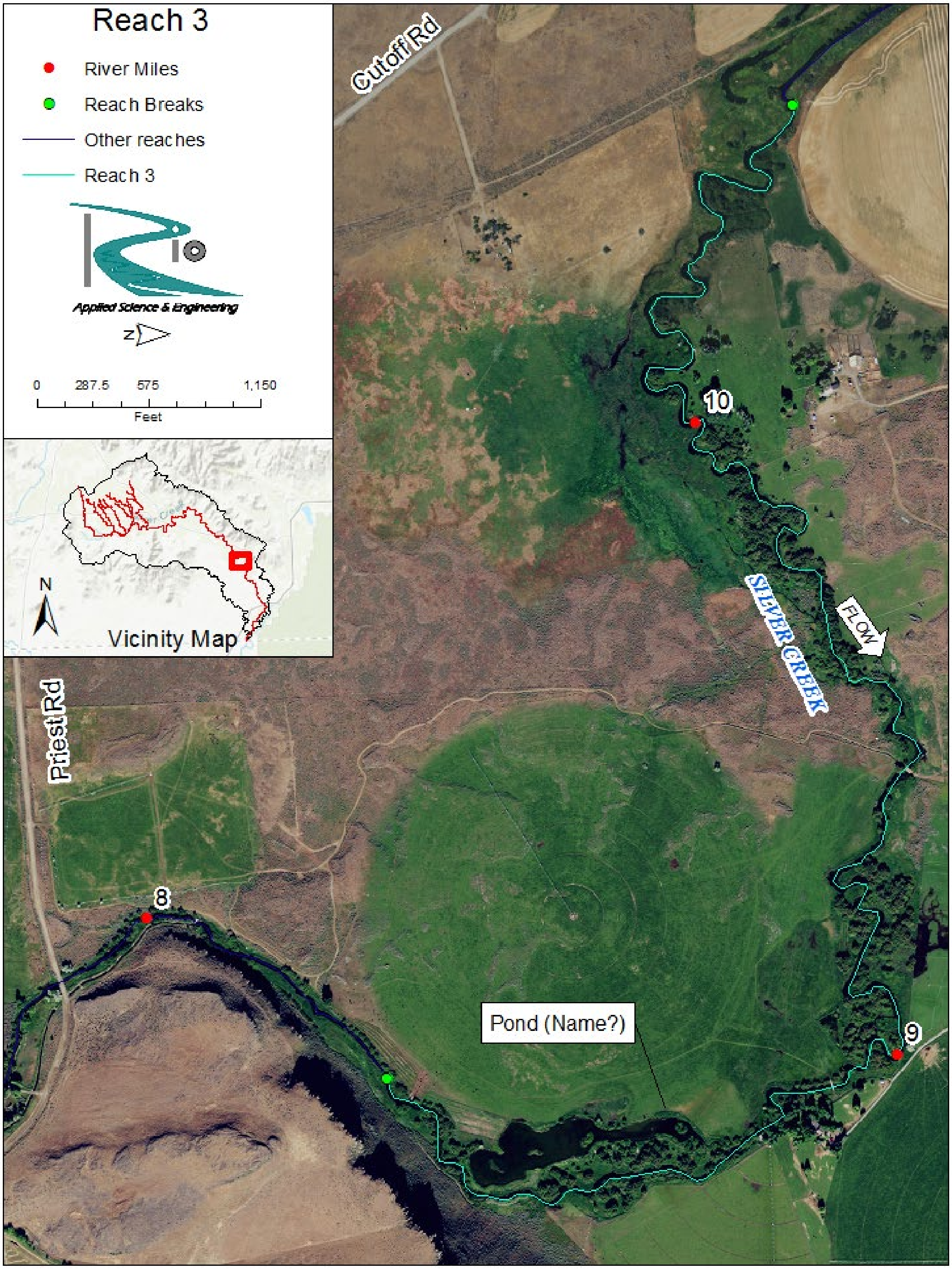
Despite some geomorphic simplification, Silver Creek Reach 3 (RM 8.3–10.6) maintains a higher sinuosity than most other reaches in lower Silver Creek. Reach 3 also appears to exhibit better floodplain connection than most reaches in the area, potentially due to less geomorphic simplification. Water temperatures, habitat connectivity, and sedimentation are all considered poor in this reach.

Reach 3 exhibits poor fish use potential and restoration feasibility metrics based on high summer temperatures and poor habitat connectivity; however, the habitat uplift potential is high given the relatively unaltered form of the channel, unconfined floodplain, and generally low slope providing high geomorphic response potential. Habitat conditions can be improved in a relatively low-cost manner that still addresses habitat uplift goals, although the benefit for fish may be limited by poor temperature and habitat connectivity as noted above. In-stream treatments including the addition of LWD, geomorphically appropriate flow constrictions, and other in-stream structure and/or cover to provide habitat complexity and diversity would likely improve conditions for wild trout. Please refer to Appendix C for more information regarding typical treatments, including flow constructions and several other in-stream structures.

Table 3. Reach 3

Reach Condition	Existing	Target
Sinuosity	1.53	1.6
Gradient	0.15%	0.14%
Average Stream Width (ft)	30	30
Hydrology (Changes)	Losing	Losing
Riparian Conditions	Good	Minimum buffer width: 60 ft
Sedimentation	High	See general target conditions
Human Features	Man-made pond, pivot irrigation systems	Remove/modify human features impacting the reach
Temperature: Average # of days between 70–78°F (average # of days >78°F)	54 (2) Data Logger: Silver Crk. @ Suzie Q	Reduced
Habitat Connectivity	Poor	High

Figure 3. Reach 3



SILVER CREEK REACH 4 (S-TURNS TO SUZIE Q)

Silver Creek Reach 4 (RM 10.6–24.3) is one of the largest and most variable reaches in the system, consisting of four subreaches. While the subreach morphology differs, the underlying geomorphic processes in the reach are similar.

- Subreach 4a [immediately downstream of Suzie Q] is characterized by moderate human disturbance and a lower sinuosity.
- Subreach 4b [Suzie Q] exhibits more natural characteristics than surrounding reaches and may be able to provide a reference for restoration actions.
- Subreach 4c [Purdy Pond and Idaho Fish and Game access] is characterized by extensive human disturbance, especially clearing of riparian vegetation, reduced in-stream flow due to irrigation, and disconnected side channels and off-channel habitat. Subreach 4c has a high sinuosity but is lacking meander bends with a low radius of curvature, which are common in less disturbed subreaches (e.g., 4b and 6a). Purdy Pond has been previously restored to include in-stream structure, deeper pools and channel narrowing. The dam retaining Purdy Pond has also been improved with a bottom release and improved fish passage.
- Subreach 4d [S-turns and Kilpatrick Pond] is substantially different than the other subreaches because of the backwatering produced by the dam at the downstream end. The slower water velocity and expanded channel width result in increased temperatures and sediment deposition within this subreach. Substantial past restoration efforts have significantly narrowed the reach within Kilpatrick Pond and removed relic sediment.

Water temperatures throughout Reach 4 are generally poor, especially lower in the reach, downstream of the ponds and large areas exhibit poor riparian conditions.

Most of the subreaches have poor fish use potential given poor summer temperatures and poor habitat connectivity, although these conditions improve moving upstream. Restoration feasibility is generally high given the channel is not highly confined and habitat restoration actions are likely feasible, although there are many landowners within this long reach, which may complicate restoration implementation. Habitat uplift potential is generally good in Reaches 4a and 4c, but 4b (Suzie Q) is already highly functional from the perspective of channel form/process, so there is less room for improvement, and 4a consists primarily of backwater ponds that have unknown existing habitat benefit and may be difficult to gain stakeholder consensus for a given restoration. General recommendations for restoration include the ongoing use of ponds for sediment retention and periodic removal (i.e., dredging), reduced stream width via bank treatments, connection of relic side channels and/or off-channel habitat visible on the floodplain, addition of in-stream structure, and/or improved riparian vegetation as noted in the general recommendations.

Table 4. Reach 4

Reach Condition	4a (RM 10.6–12.8)	4b (RM 12.8–13.7)	4c (RM 13.7–23.3)	4d (RM 23.3–24.3)	Target
Sinuosity	1.45	1.74	1.81	1.33	1.8
Gradient	0.23%	0.10%	0.05%	0.12%	0.10%
Average Stream Width (ft)	30	28	45	150	20
Hydrology (Changes)	Mixed	Mixed	Mixed	Mixed	Losing
Riparian Conditions	Poor	Good	Poor	Poor	Minimum buffer width: 40 ft

Table 4. Reach 4

Reach Condition	4a (RM 10.6–12.8)	4b (RM 12.8–13.7)	4c (RM 13.7–23.3)	4d (RM 23.3–24.3)	Target
Sedimentation	High	High	High	High	See general target conditions
Human Features	Channel has been straightened, bridge at Hwy. 20	Some straightening, relatively undisturbed	Channel has been extensively reworked, producing geomorphic simplification, channel straightening, and reduced off-channel habitat; large bridges at u/s end of reach	Dam at downstream end of reach produces extensive backwatering and sedimentation	Remove/modify human features most impacting the reach and features straightening channel alignment
Temperature: Average # of days between 70–78°F (average # of days >78°F)	54 (2) Data Logger: Silver Crk. @ Suzie Q	54 (2) Data Logger: Silver Crk. @ Suzie Q	25 (1) Data Logger: Silver Crk. @ Hwy 20	25 (1) Data Logger: Silver Crk. @ Hwy 20	Reduced
Habitat Connectivity	Poor	Poor	Poor	Poor	High

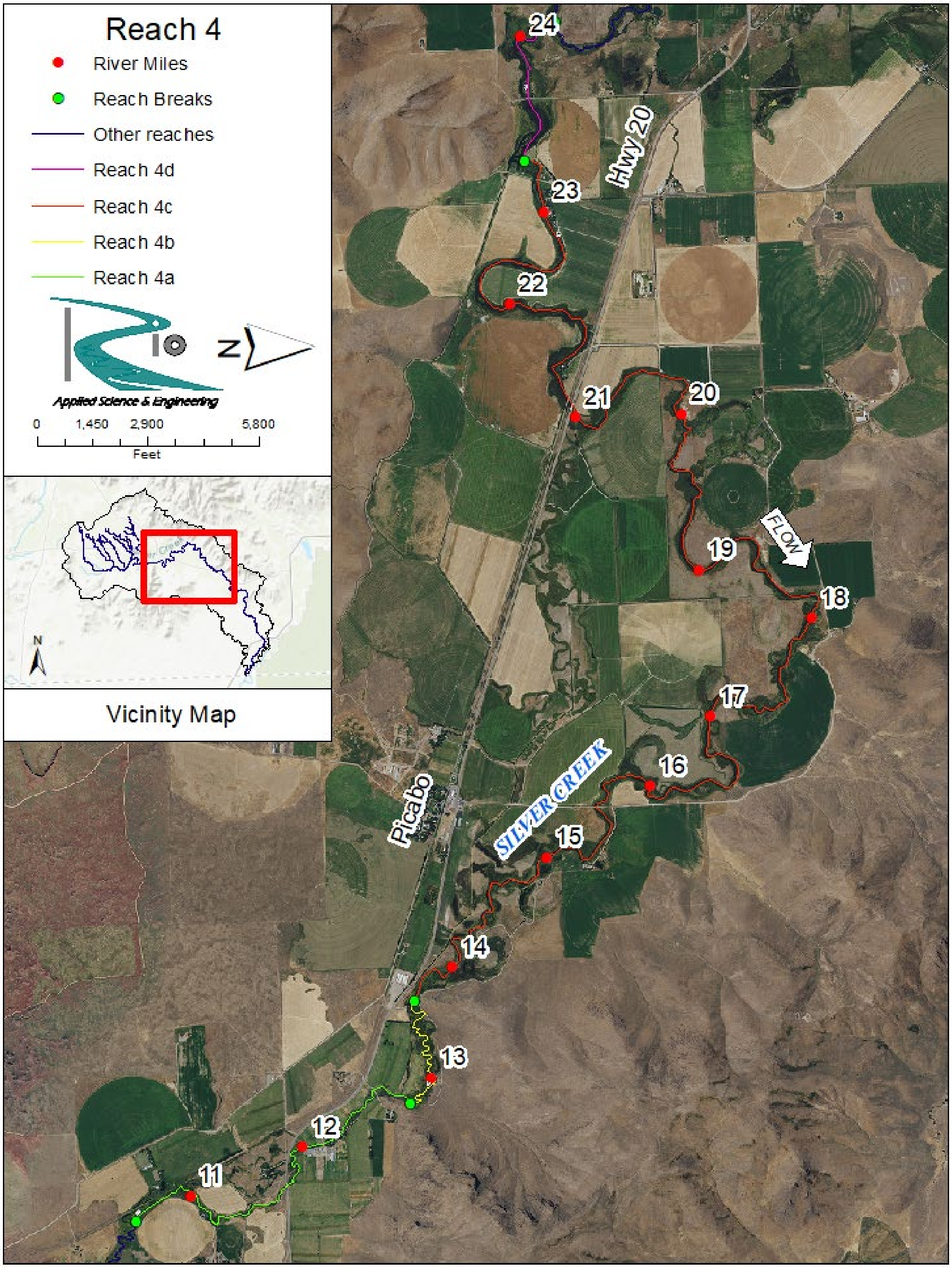


Figure 4. Reach 4 (S-Turns, Kilpatrick Pond, Suzie Q)

SILVER CREEK REACH 5 (UPPER SILVER CREEK AND SULLIVAN'S POND)

Silver Creek Reach 5 (RM 24.3–25.85) exhibits relatively good riparian conditions and favorable water temperatures. Stream width increases sharply in comparison with upstream reaches (i.e., Lower Stalker). Reach 5 exhibits a relatively high sinuosity characterized by several meander bends with a large radius of curvature. Reach 5 lacks many of the small radius bends that characterize potential reference reaches (e.g., 6a and 4b). Sedimentation is high in this reach.

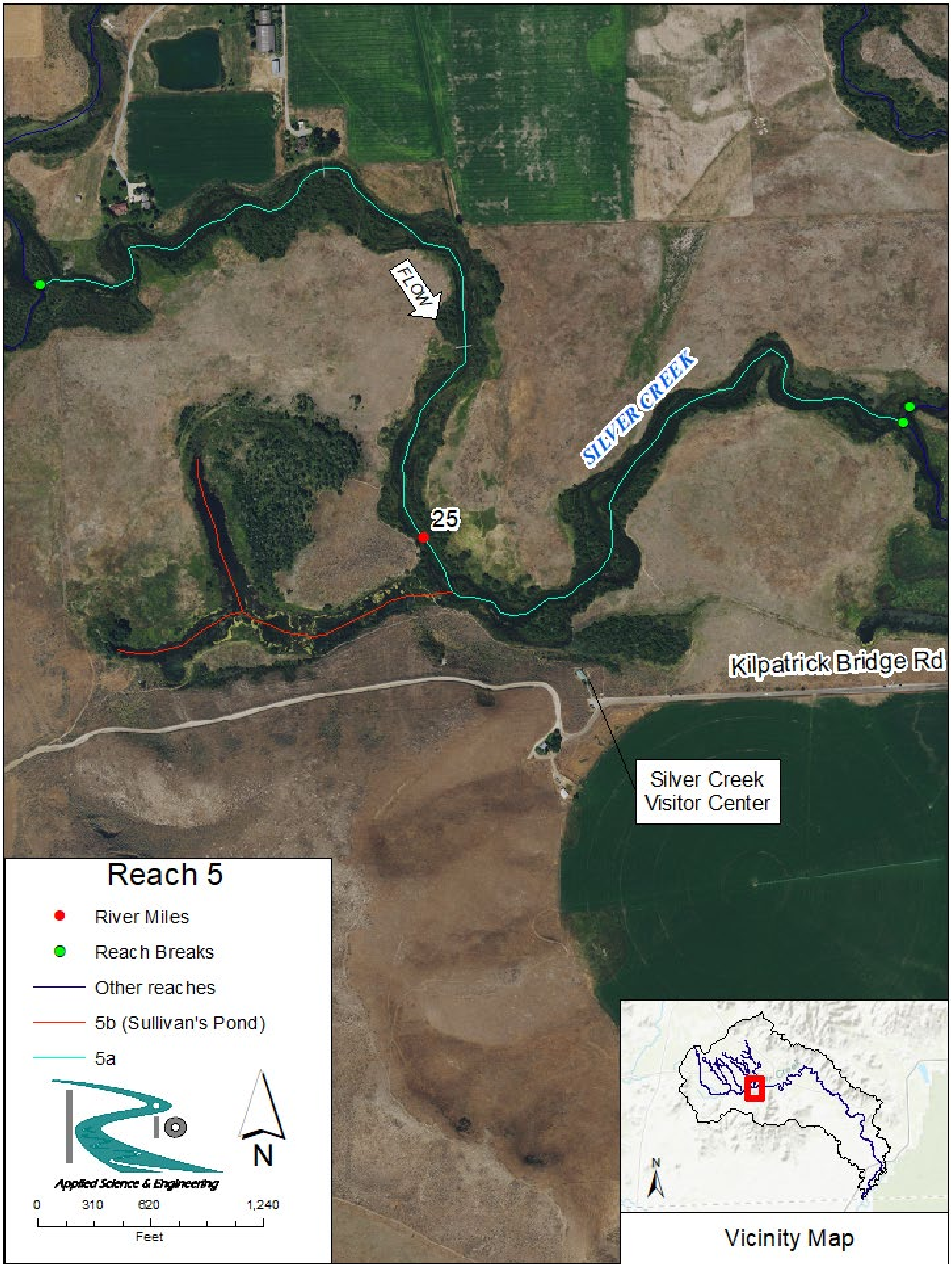
Reach 5 exhibits excellent fish use potential, with good habitat connectivity and stream flow. Summer temperatures commonly fall within the stress band for wild trout, but the potential for geomorphic response is high and there are relatively few major constraints on potential restoration actions. Channel planform and riparian conditions are already generally good (especially in the upper reach) reducing the habitat uplift potential associated with restoration in this reach.The principal impacts in the reach are associated with temperature and sediment from upstream reaches, making restoration somewhat less feasible without addressing upstream conditions first. Otherwise, channel widening (especially in the lower reach) could be addressed along with the addition of in-stream habitat structure and cover.

Sullivan Pond lies within this reach but has low fish use potential due to poor habitat connectivity, anecdotal evidence of poor substrate conditions (silt bed), and low flow despite low stream temperatures. Restoration feasibility is relatively high given the unconfined valley and favorable landowner, but habitat uplift potential is relatively low given the small area. Restoration actions in Sullivan Pond should focus on reducing silt, improving riparian vegetation and improving connection to the mainstem.

Table 5. Reach 5

Reach Condition	Upper Silver Creek (5a)	Sullivan's Pond (5b)	5a Target
Sinuosity	1.76	N/A	1.9
Gradient	0.08%	N/A	0.086%
Average Stream Width (ft)	56	N/A	25
Hydrology (Changes)	Gaining	Mixed	Gaining
Riparian Conditions	Good	Fair	Minimum buffer width: 50ft
Sedimentation	High	Unknown	See General Target Conditions
Human Features	Foot Bridges	Artificial impoundment	N/A
Temperature: Average # of days between 70–78°F (average # of days >78°F)	26 (0) Data Logger: Silver Crk S Turns	14 (2) Data Logger: Sullivan's Pond	Lower
Habitat Connectivity	Good	Good	High

Figure 5. Reach 5



REACH 6 (LOWER STALKER CREEK)

Lower Stalker Creek is divided into two subreaches (6a downstream of Mud Creek and 6b upstream of Mud Creek). In general, 6a exhibits relatively natural (reference-like) conditions, while 6b is over-widened with poor riparian buffer density and width.

Geomorphic simplification is apparent in both subreaches, with larger amounts of simplification in 6b and some simplification due to channel straightening in the upstream portions of 6a. The temperature logger in reach 6a recorded an average of 30 days in the stress band, indicating sub-optimal temperatures below the confluence with Mud Creek. However, whether reach 6b has similarly high temperatures is unclear (see Table 6 notes). The amount of sediment accumulation is high in both reaches. Additionally, increased floodplain activation (possibly resulting from beaver activity) may be altering the riparian conditions from woody shrubs/trees to primarily wetland rushes, sedges, and cattails in the lower river left portions of 6b.

This reach has high fish use potential, with good habitat connectivity and flow, although summer temperatures are relatively high. Restoration feasibility is good in 6a and excellent in 6b, with the difference due to feasibility of potential treatments without impact to existing habitat. This reach has excellent habitat uplift potential; most reach issues can be addressed using feasible actions at a reasonable cost with the potential for good long-term sustainability. Restoration should be focused in 6b with an emphasis on decreasing the width-to-depth ratio and increasing in-stream structure, to add sinuosity and habitat complexity. Additionally, riparian vegetation should be improved by enabling greater abundance of mature woody vegetation (i.e., willow, river birch, etc.) within the targeted buffer width throughout 6b to provide shade, cover, and long-term bank structure.

Table 6. Lower Stalker Creek

Reach Condition	Lower Stalker Creek (6a; RM 25.85-27)	Lower Stalker Creek (6b; RM 27-28.2)	Target (6b)
Sinuosity	1.53	1.52	1.8
Gradient	0.08%	0.06%	0.08%
Average Stream Width (ft)	32	42	25
Hydrology (Changes)	Gaining	Gaining	Gaining
Riparian Conditions	Fair; poor on river right in upper reach	Poor	Minimum buffer width: 50 ft
Sedimentation	High	High	See general target conditions
Human Features	Channel straightening and some simplification associated with land use	Channel simplification and spring head/ side channel simplification associated with land use	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70–78°F (average # of days >78°F)	30 (0) Data Logger: Lower Stalker	Uncertain*; suspected to be lower than 6a	Reduced
Habitat Connectivity	Fair	Poor	High

* Stream temperatures tend to increase from the Lower Chaney temperature logger to the Lower Stalker temperature logger. The Upper Stalker temperature logger (upstream of Stalker-Chaney confluence) recorded 39 days in the stress band and 2 days >78°F, while the Lower Chaney temperature logger recorded zero days in the stress band. The degree of influence on temperature between the mixing of Stalker and Chaney, solar radiation throughout reach 6b, and the addition of Mud Creek isn't clear.

Figure 6. Channel Simplification at Lower Stalker and Downstream Portions of Mud and Chaney Creek

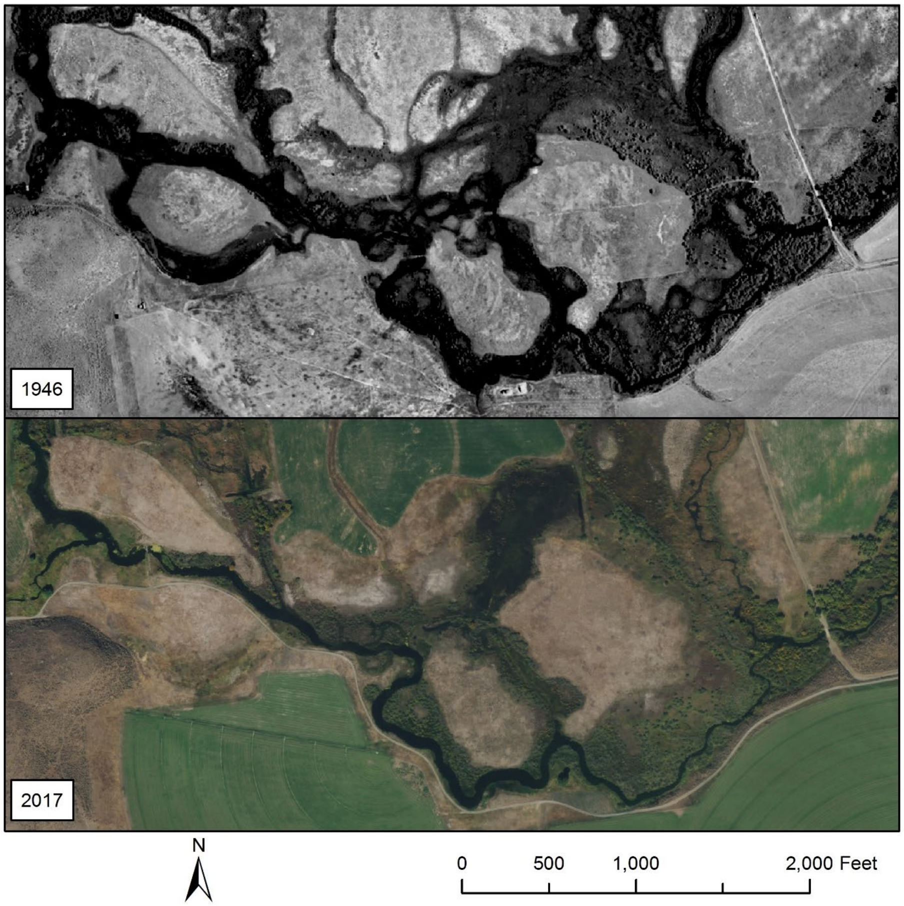
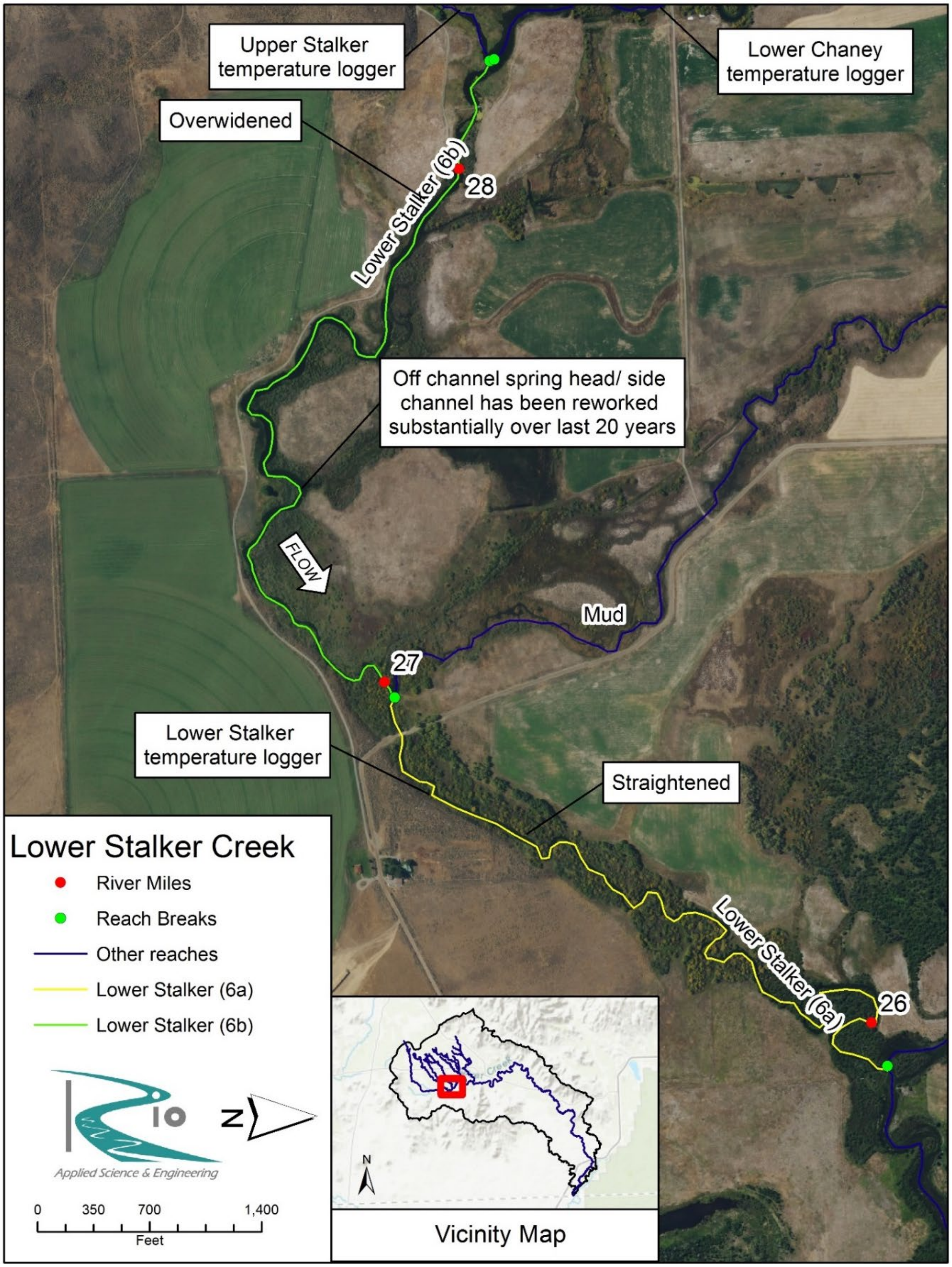


Figure 7. Reach 6 (Lower Stalker Creek)



LOWER LOVING CREEK

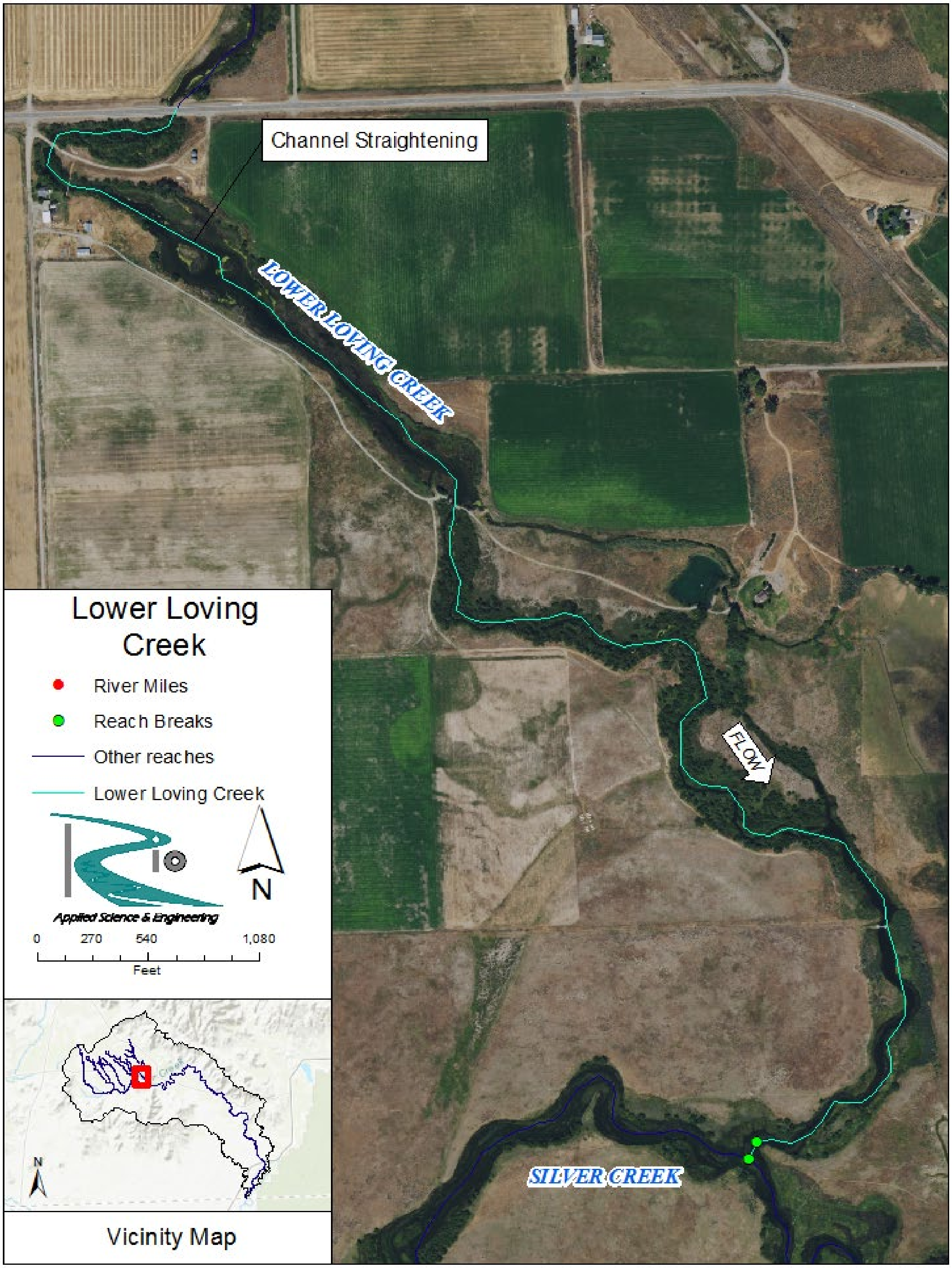
Lower Loving Creek has been straightened and impacted by human activities, leading to relatively low sinuosity, poor riparian conditions, and high sedimentation. Recent restoration in the upper portion of the reach appears have lowered channel widths and increased sinuosity to target levels.This restoration appears to be very effective and may provide a good reference for future restoration in the area. A large, artificial pond, although unnatural and likely contributing to increased temperatures, can potentially be used as an affective sediment retention pond. Habitat connectivity has the potential to be good due to the downstream proximity to Silver Creek. Areas without ponding tend to have better riparian conditions than ponded areas, especially the restored area directly upstream and downstream of the pond.The impact (positive and/or negative) ponds have on fish health and survivability is unknown and beyond the scope of this assessment.

This reach has high fish use potential due to good habitat connectivity and adequate flow, but summer stream temperatures are frequently high. Restoration feasibility is high regarding geomorphic response potential (low gradient and unconfined valley), ability to address impacts to the reach (over-widening, poor riparian vegetation, and lack of in-stream structure), and landowner considerations.The habitat uplift potential is also high as projects in this reach would directly address restoration goals and the uplift potential is high given the relatively low cost to improve the existing lack of habitat (in the lower reach – downstream of existing restoration). Restoration should focus on the lower reach (downstream of existing restoration) including narrowing the width-to-depth ratio, adding in-stream structure, and improving the riparian buffer.

Table 7. Lower Loving Creek

Reach Condition	Existing	Target
Sinuosity	1.2	2
Gradient	0.18%	0.12
Average Stream Width (ft)	58	25
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Fair	Minimum riparian width: 50 feet
Sedimentation	High	See general target conditions
Human Features	Ponds, extensive straightening	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70–78°F (average # of days >78°F)	18 (0) Data Logger: Lower Loving Crk	Reduced
Habitat Connectivity	Fair	High

Figure 8. Lower Loving Creek



UPPER LOVING CREEK

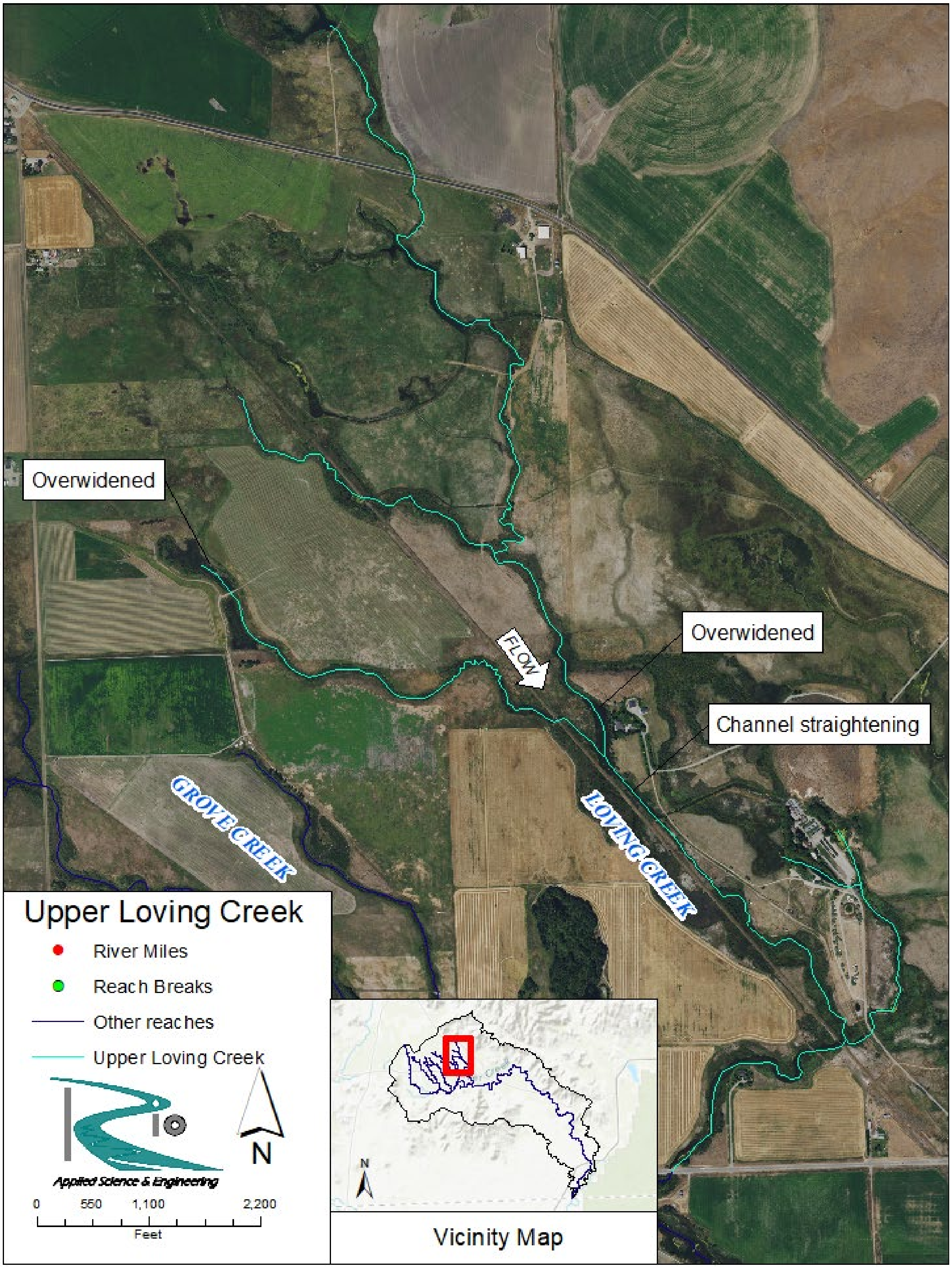
Upper Loving Creek has been heavily impacted by human activity. Many irrigation diversions, artificial ponds, ditches, and legacy effects from a relic railroad grade have significantly altered the natural planform of the reach. Pond impoundments may also block fish passage. Temperatures are high in many portions of the reach, particularly in the North Fork of Loving Creek and dissolved oxygen levels are a concern in Butte Creek. Large portions of the channel are characterized with poor riparian conditions, and much of the reach is significantly over-widened. Loving Creek also has the highest documented sediment accumulation of any measured reach other than lower Silver Creek. It is unclear to what extent these sediments are a result of legacy conditions or ongoing accumulation associated with agriculture, cattle grazing, and/or local roads. Additionally, the Idaho Department of Fish and Game manages a fish hatchery in this reach with unknown effects on the reach and the overall fishery.

High stream temperatures and poor habitat connectivity indicate low fish use potential within this reach, though both restoration feasibility and habitat uplift potential are high. Because much of the temperature increase and fine sediment concerns in this stream are produced within this reach, restoration actions have potential for positive downstream impacts on Lower Loving Creek. Restoration should focus on reducing stream width-to-depth ratio, adding channel sinuosity where previously straightened, improving in-stream habitat and riparian buffers, and eliminating unnecessary stream diversions, ditches, and ponds. Existing ponds, where maintained, can be used to retain sediment to reduce sediment loads in downstream reaches. Any remaining pond impoundments should also be evaluated for fish passage barriers and appropriate passage provided to establish/maintain habitat connectivity.

Table 8. Upper Loving Creek

Reach Condition	Existing	Target
Sinuosity	1 to 1.2	Increased Sinuosity
Gradient	Varies	Reduced according to sinuosity
Average Stream Width (ft)	Varies	Reduced
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Poor	Minimum riparian buffer of 2X the restored stream width
Sedimentation	High	Reduced
Human Features	Channel straightening, road and railroad crossings	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70–78°F (average # of days >78°F)	14 (0) Data Logger: Upper Loving Crk	Reduced
Habitat Connectivity	Poor	High

Figure 9. Upper Loving Creek



LOWER WILSON CREEK AND GROVE CREEK

Where access is available in this reach and observations have been taken, there is generally good habitat. Stream temperatures are low, and habitat connectivity is high. Stream widths are higher than optimal particularly lower in the reach. Channel sinuosity is lower than expected for this reach and less than other similar reaches, though there are no specific locations with readily apparent channel straightening. In general, riparian conditions are very good in the upper part of the reach and relatively poor in the lower part.The downstream portion of this reach has the potential to provide thermal refugia for fish in warmer reaches downstream (i.e., Reaches 5 and 6). However, the lack of habitat in Grove Creek near the confluence with Silver Creek may be reducing the capacity of this reach to provide thermal refugia. Habitat restoration performed in lower Wilson creek appears to be very effective and may provide a good reference for future restoration in the area.

This reach has high fish use potential (low temperature, good habitat connectivity, and adequate flow) and high habitat uplift potential (high likelihood of directly addressing restoration goals with high benefit-to-cost ratio projects). Landowner access is the primary constraint to restoration in this reach. Where access is permissible, restoration should mimic previous efforts by reducing the width-to-depth ratio, increasing the riparian buffer, and adding in-stream structure and cover. Restoration in the lower-most portion of the reach may provide improved habitat connectivity to previously restored reaches upstream and/or thermal refugia for Reaches 5 and 6.

Table 9. Lower Wilson Creek and Grove Creek

Reach Condition	Existing	Target
Sinuosity	1.1	Increased sinuosity in lower reach
Gradient	Varies	Reduced according to sinuosity
Average Stream Width (ft)	Varies (10-200)	Reduced in lower reach
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Good	Minimum riparian buffer width of 2X restored stream width
Sedimentation	Low	Low
Human Features	Overwidened area	Reduce width in overwidened area in lower reach
Temperature: Average # of days between 70-78°F (average # of days >78°F)	6 (0) Data Logger: Lower Grove (TNC)	Maintain or reduce temperatures
Habitat Connectivity	Good	High

Figure 10. Lower Wilson Creek and Lower Grove Creek

UPPER GROVE CREEK AND TRIBUTARIES

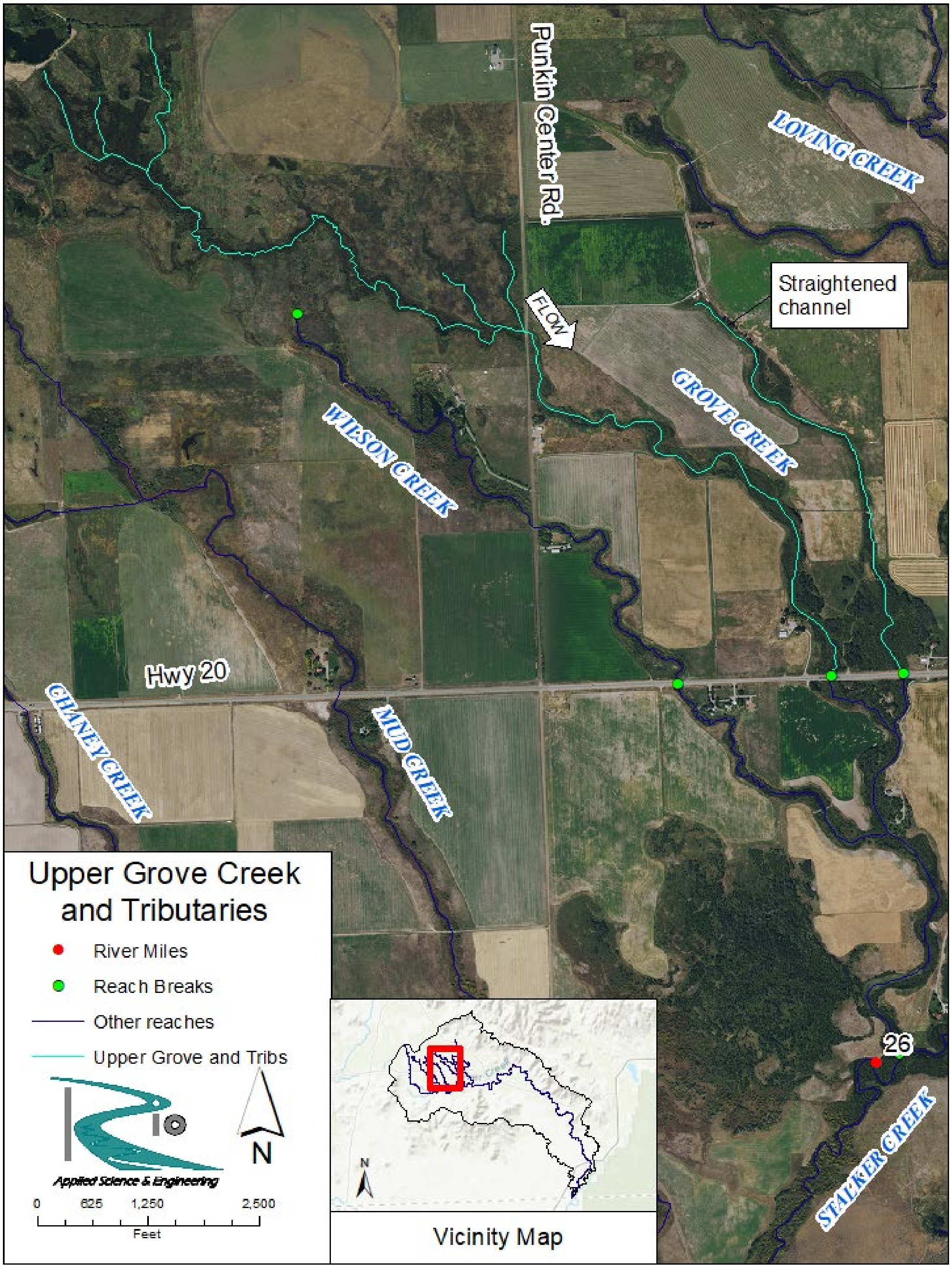
Stream temperatures throughout the reach are relatively low and habitat connectivity is good. Downstream portions of the reach have good riparian conditions, but riparian conditions in much of the upstream portions of the reach are poor. The far upstream end of Upper Grove Creek has been impounded into a roughly 7-acre pond that may impact habitat connectivity and in-stream temperature. Sinuosity in the tributaries is highly variable, some of which is due to channel straightening and some of which is due to highly sinuous restoration. Conditions from past restoration efforts are mixed; favorable restoration has included a reduced width-to-depth ratio and periodic channel constrictions with in-stream hydraulic complexity creating pools and gravel riffles, while less-favorable restoration has included inappropriate meander geometries resulting in over-widened riffles and relatively stagnant, over-widened pools with poor sediment transport capacity.

This reach has high fish use potential (low temperature, good habitat connectivity, and adequate flow), high restoration feasibility (high geomorphic response potential, feasible restoration actions, and relatively few landowner constraints), and high habitat uplift potential (high likelihood of directly addressing restoration goals with high benefit-to-cost ratio projects). Restoration projects in this reach have been shown to improve habitat with potential for improved response, given appropriate channel geometries. Restoration efforts should continue to focus on increased sinuosity, reduced width-to-depth ratio, and increased in-stream structure forcing constrictions and pools with cover.

Table 10. Upper Grove Creek and Tributaries

Reach Condition	Existing	Target
Sinuosity	1 to 1.2	Increased where channel straightening has occurred
Gradient	Varies	Reduced according to sinuosity
Average Stream Width (ft)	Varies	Reduced where over-widened
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Fair	Minimum riparian buffer width of 2X restored stream width
Sedimentation	Low	Low
Human Features	Several small ponds, channel straightening	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70-78°F (average # of days >78°F)	0 (0) Data Logger: Grove Crk. @ Pumpkin Rd.	Reduce or maintain temperatures
Habitat Connectivity	Good	High

Figure 11. Upper Grove Creek and Tributaries



WILSON CREEK

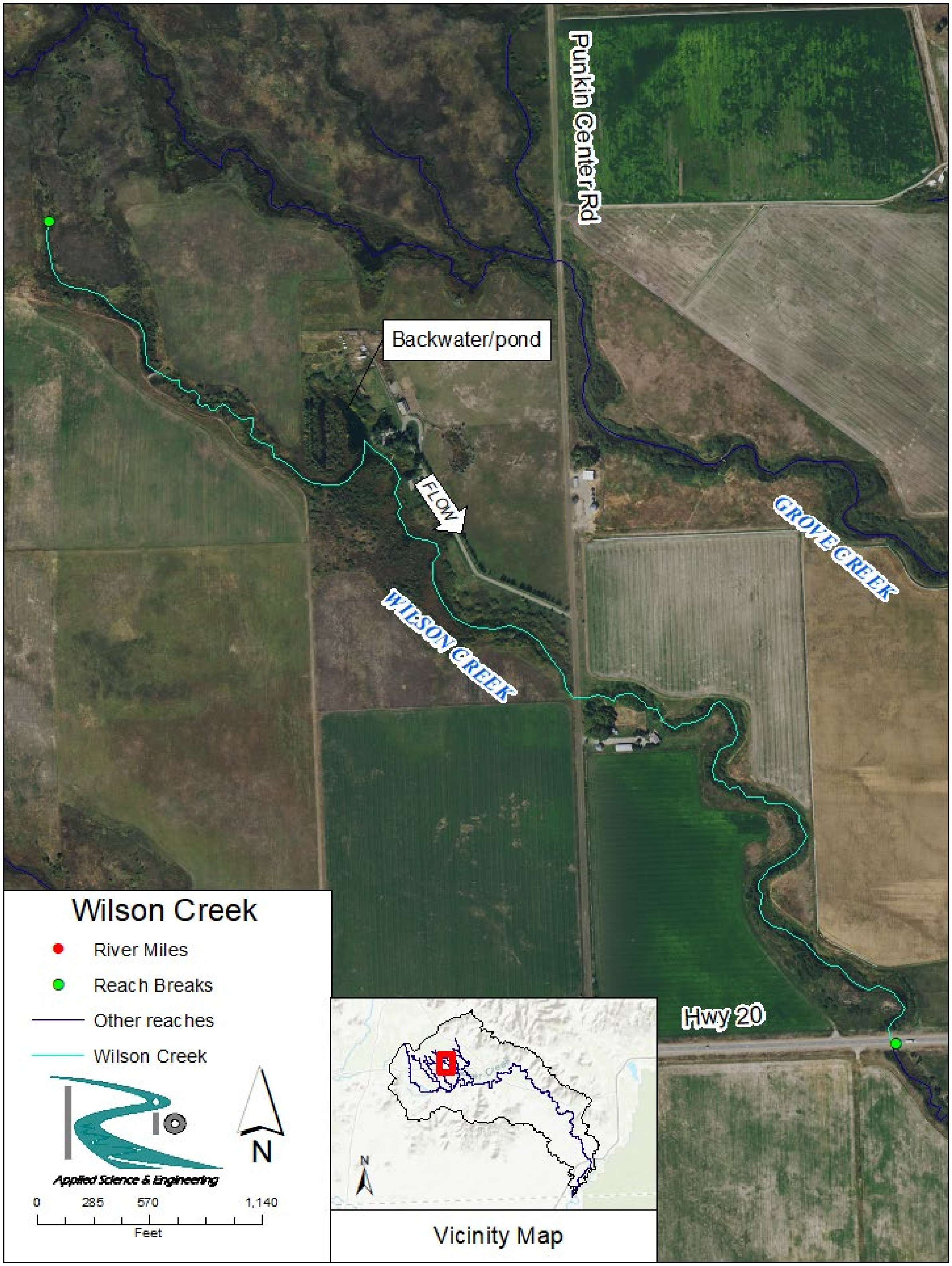
Habitat in Wilson Creek is generally good. Flows in Wilson Creek are less than Grove Creek. Sedimentation has not been measured in Wilson Creek but is assumed to be low based on low measurements from Grove Creek downstream. There are several ponds in this reach that may impact temperature and habitat while also potentially retaining sediment. Riparian conditions are variable with good riparian cover in previously restored areas; otherwise, riparian areas are relatively narrow and/or lacking appropriate vegetation. Landowner access has precluded detailed on-the-ground data collection from much of this reach, but aerial photograph and LiDAR analysis suggest previous restoration has improved conditions. Past restoration downstream of Highway 20 (part of Lower Wilson/Grove Reach) appears more geomorphically appropriate (particularly the width-to-depth ratio and sinuosity) and appears to provide improved geomorphic and habitat conditions compared with restoration upstream of the highway. Restoration in Lower Wilson Creek is a good reference for future restoration upstream and downstream of the highway.

This reach has good fish use potential (low temperature, good fish habitat connectivity, and adequate flows). Because habitat is already in relatively good condition (in large part due to past restoration), uplift potential is lower than many other reaches. Additionally, potential landowner constraints reduce the restoration feasibility, although uplift potential (benefit-to-cost) ratio is considered high as evident by previous, successful restoration actions. Future restoration efforts should mimic past restoration downstream of the highway by reducing the width-to-depth ratio, increasing sinuosity, creating diverse in-channel structure, and improving riparian cover.

Table 11. Wilson Creek

Reach Condition	Existing	Target
Sinuosity	1.4	1.6 to 1.8
Gradient	0.24%	Reduced according to sinuosity
Average Stream Width (ft)	15	Reduced where over-widened
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Fair	Minimum riparian buffer width of 2X restored stream width
Sedimentation	N/A (Low downstream in Grove)	Low
Human Features	Bridge crossing stream; culvert at stream crossing	Increase in-stream structure as described in Section 4.5 of report
Temperature: Average # of days between 70–78°F (average # of days >78°F)	0 (0) Data Logger: Wilson Crk. @ Hwy 20	Reduce or maintain temperatures
Habitat Connectivity	Good	Good

Figure 12. Wilson Creek



MUD CREEK

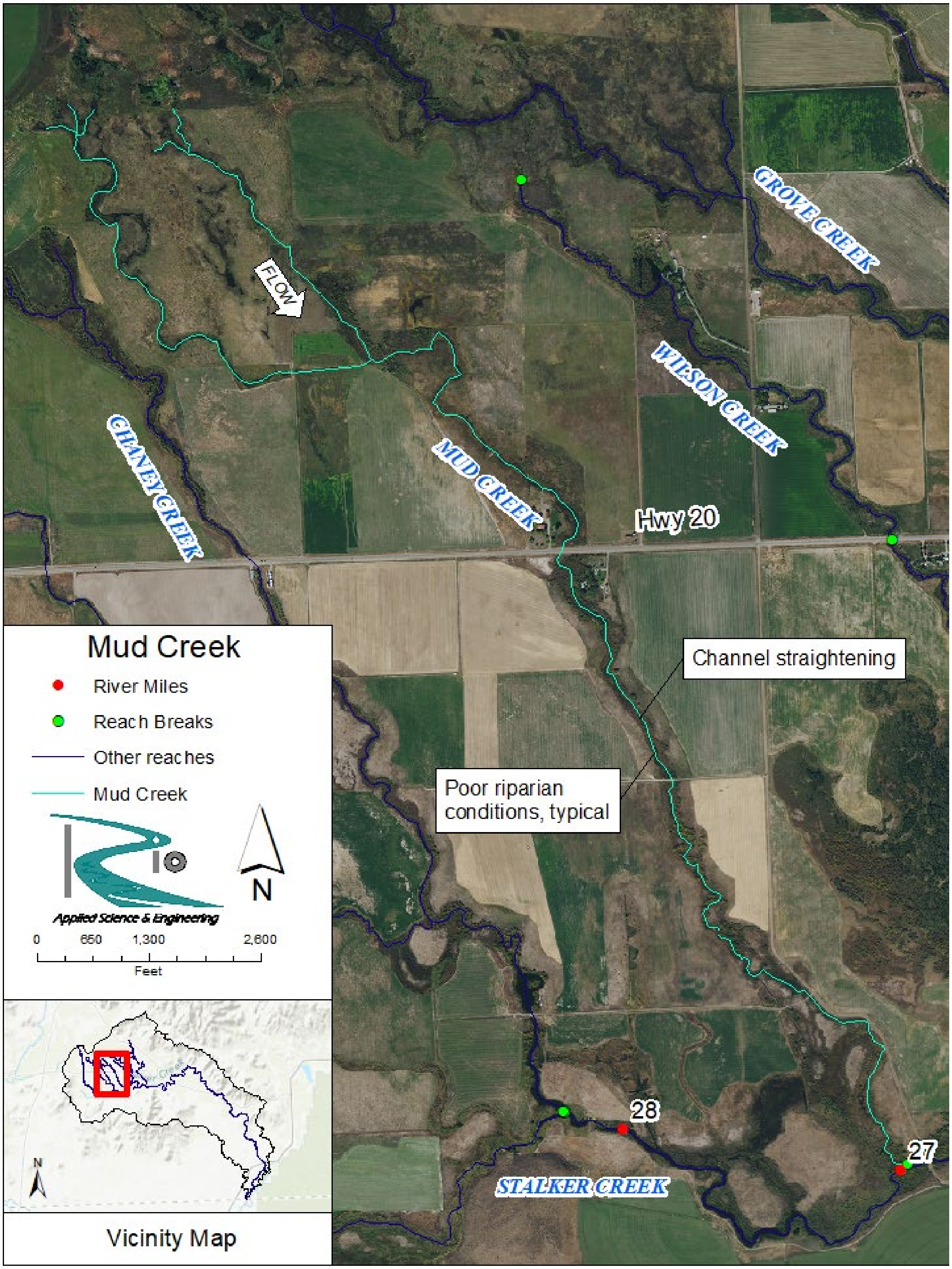
Mud Creek is a relatively small stream with high temperatures, moderate sedimentation, and moderate habitat connectivity. There have been no previously documented restoration actions taken on this creek. Much of the reach upstream of the highway is too small to offer favorable habitat for wild trout, and portions of the downstream reach are simplified and/or straightened (Figure 6). Riparian conditions are relatively poor throughout the creek. There is one small pond located downstream of the highway. Additionally, increased floodplain activation in the lower-most portion of the reach (possibly resulting from beaver activity) may be altering the riparian conditions from woody shrubs/trees to primarily wetland rushes, sedges, and cattails.

Mud Creek has poor fish use potential resulting from high stream temperatures and relatively low stream flow. Habitat connectivity is moderate given its confluence with Lower Stalker Creek is within an area that has been highly manipulated and lacks high-quality habitat. Habitat uplift potential is poor, given restoration actions will not directly address low flow and high temperatures otherwise limiting habitat within this reach. Also, restoration feasibility is good except for potential landowner limitations. Restoration should focus on reducing in-stream temperature and sediment (especially in the upper reach) that affect this reach and contribute to habitat degradation downstream where fish use potential is higher.

Table 12. Mud Creek

Reach Condition	Existing	Target
Sinuosity	1.1 to 1.2	1.25
Gradient	Varies	0.17%
Average Stream Width (ft)	13	13
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Fair	Minimum riparian width of 33 feet
Sedimentation	Moderate	Low
Human Features	Road crossings, straightened channel	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70–78°F (average # of days >78°F)	44 (1) Data Logger: Lower Mud	Reduced
Habitat Connectivity	Fair	High

Figure 13. Mud Creek



CHANEY CREEK

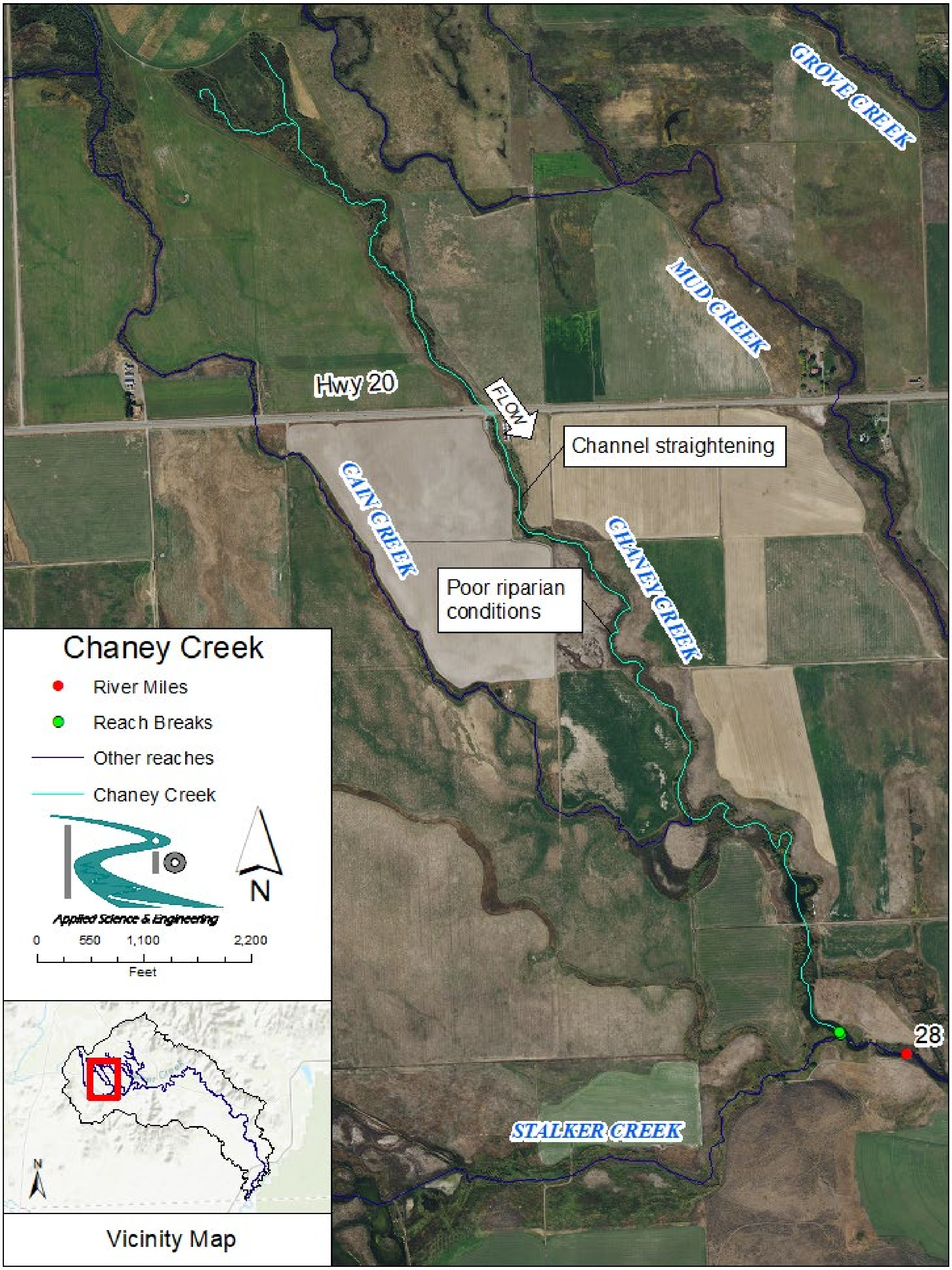
Chaney Creek has relatively poor habitat except for specific areas that have been previously restored. Downstream of Highway 20, this reach is significantly over-widened and lacks adequate riparian vegetation where extensive simplification has occurred (Figure 6). Stream temperatures are generally good despite poor riparian conditions and the associated lack of shade within the reach. Two ponds are present in the lowermost portion of the reach, providing sediment traps and habitat diversity. The lower pond (extending into Lower Stalker Creek) is relatively shallow compared with the upper pond. Confined outlets from both ponds constrict flow, creating high velocity that has scoured a large/deep pool at each location.

While habitat connectivity within most of this reach is relatively poor, temperature and flow are both good, providing overall adequate fish use potential. Restoration feasibility is high given the high geomorphic response potential of the unconfined reach, limited landowner constraints, and high potential to address impacts directly with restoration. Habitat uplift potential is also high with generally poor existing habitat providing ample room for improvement and the potential to address habitat goals directly via relatively high benefit-to-cost ratio projects. Restoration should focus on improving access and connectivity (i.e., improving habitat continuity) within the reach and to neighboring reaches, while reducing stream width-to-depth ratio, improving riparian conditions, and increasing in-stream habitat complexity/diversity (specifically adding constrictions and structure to force/maintain pools and provide cover) including within the pond in lower Chaney Creek (see also Appendix C for detailed restoration concepts within this reach).

Table 13. Chaney Creek

Reach Condition	Existing	Target
Sinuosity	1.3	1.4
Gradient	0.23%	0.21%
Average Stream Width (ft)	14	14
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Poor	Minimum riparian width of 33 feet
Sedimentation	Moderate	Low
Human Features	Road crossings, pond	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70–78°F (average # of days >78°F)	0 (0) Data Logger: Lower Chaney	Maintain or reduce temperatures
Habitat Connectivity	Poor	High

Figure 14. Chaney Creek



CAIN CREEK

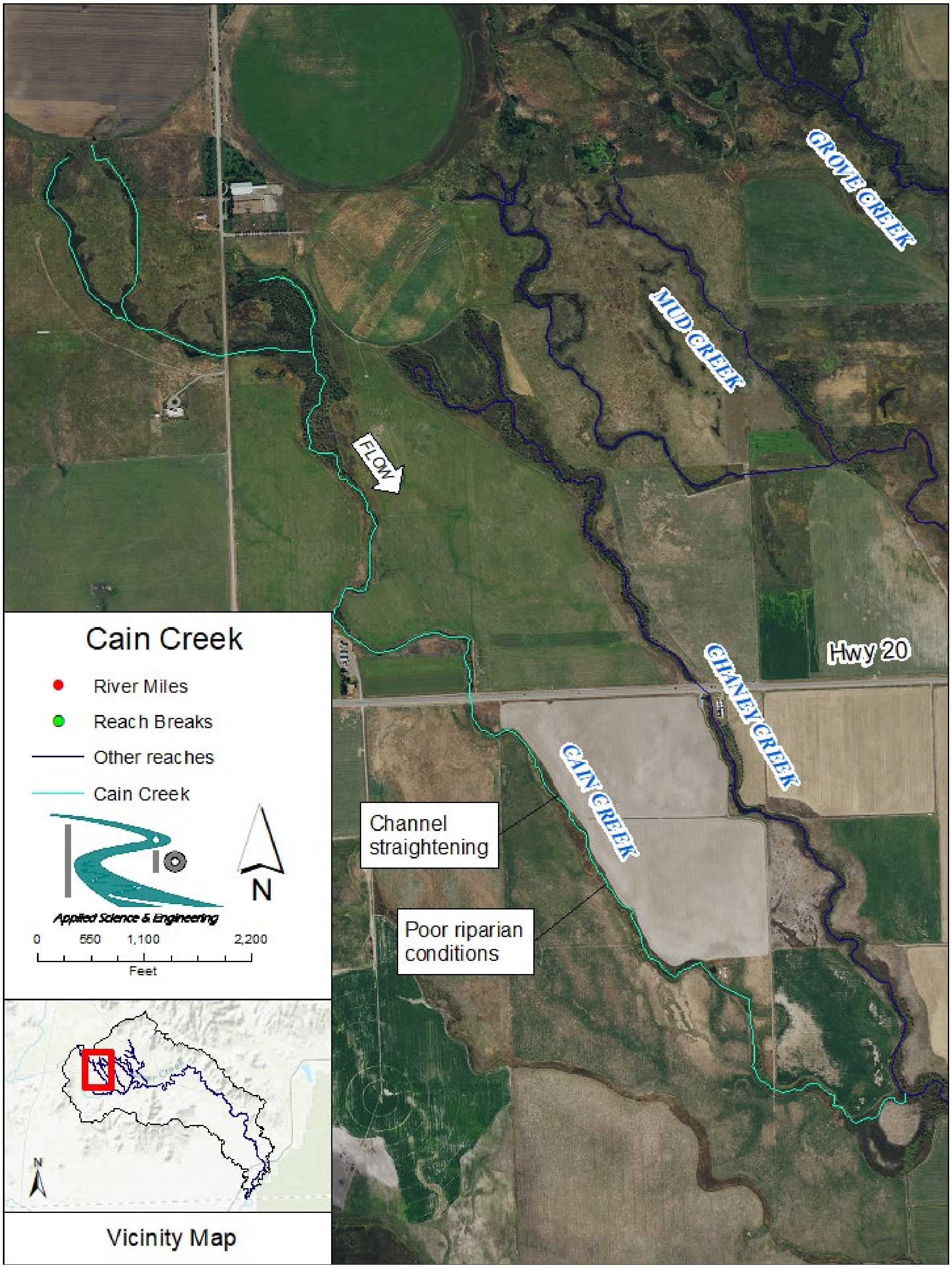
Cain Creek is a relatively small stream with poor temperatures, habitat connectivity, and flow, although fine sediment contribution is believed to be low. The channel geometry is generally over-widened and accompanied by poor riparian conditions. Much of the channel downstream of Highway 20 has been straightened and lacks in-stream structure and habitat diversity. The reach upstream of the highway exhibits better riparian conditions and a lower (more appropriate) channel width than downstream of the highway. The improved conditions upstream of the highway may be partially attributed to past restoration efforts in this portion of the reach.

This reach exhibits poor fish use potential due to poor temperatures and flow as well as large areas of poor habitat, which collectively limit the overall habitat connectivity. Restoration feasibility is also poor given the lack of potential for feasible actions that can address the poor fish use potential within the reach. Additionally, habitat uplift potential is low given the lack of feasible projects that can address uplift goals at a reasonable cost. Restoration in this reach should focus on improving riparian conditions and associated shade to improve conditions within this reach and those reaches farther downstream. Stream channel reconstruction would be appropriate for those reach segments that have been straightened, although channel reconstruction on such a low fish-use stream would likely yield a relatively low benefit-to-cost relative to other potential restoration actions within the watershed. Alternatively, adding in-stream structure to create habitat and hydraulic diversity (channel constrictions, pools, etc.) may provide comparable habitat uplift at a lower cost.

Table 14. Cain Creek

Reach Condition	Existing	Target
Sinuosity	1.15	Increased where channel straightening or over-widened conditions occur
Gradient	0.27%	Reduced according to sinuosity
Average Stream Width (ft)	12	Reduced where over-widened
Hydrology (Changes)	Gaining	Gaining
Riparian Conditions	Poor	Minimum riparian buffer width of 2X restored stream width
Sedimentation	Low	Low
Human Features	Road crossing, channel straightening.	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70–78°F (average # of days >78°F)	38 (6); Data logger: Lower Cain	Reduce temperatures
Habitat Connectivity	Poor	High

Figure 15. Cain Creek



UPPER STALKER CREEK

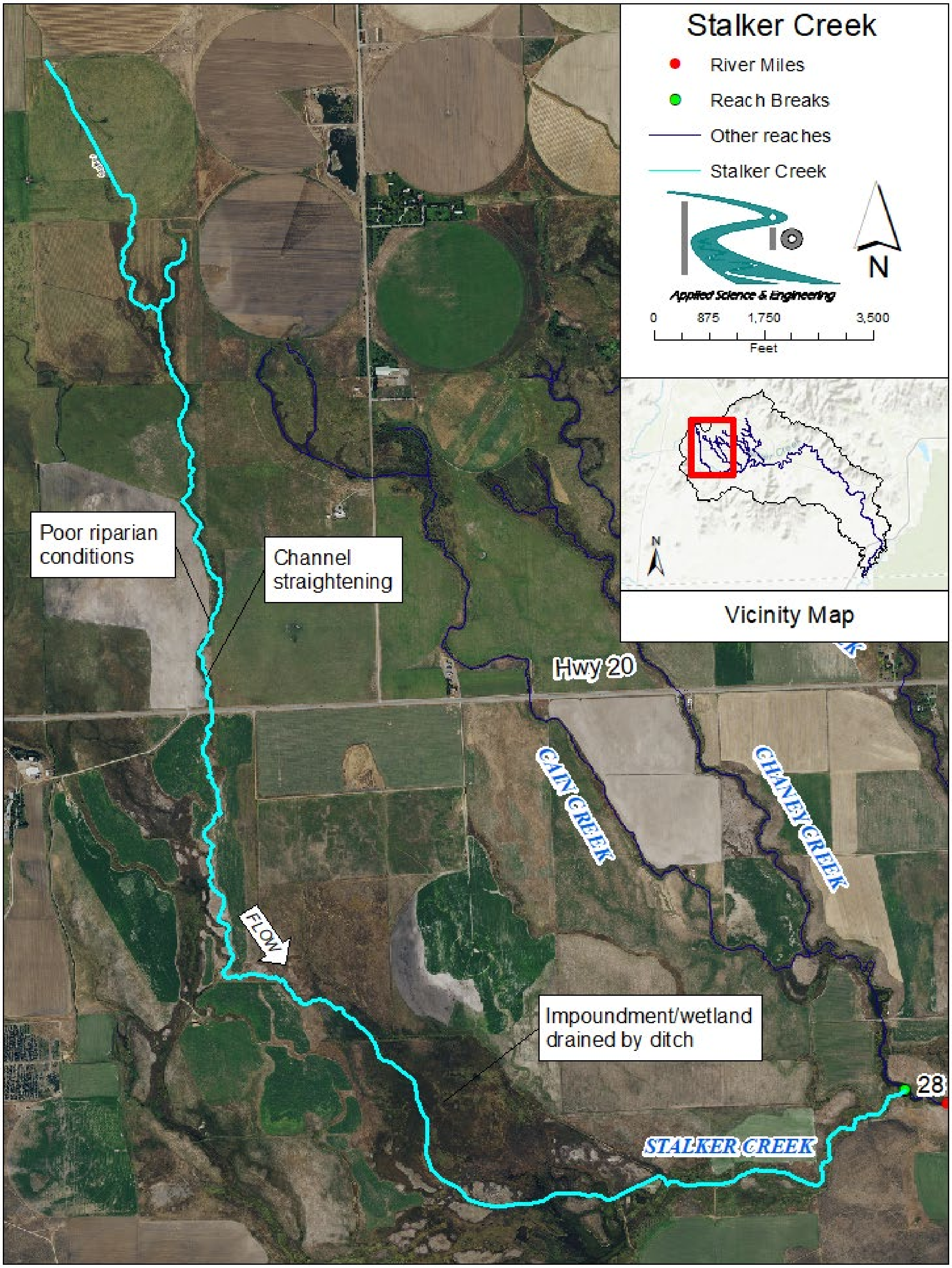
Upper Stalker Creek is small, with poor habitat, and a high degree of sedimentation. Temperatures are high, especially for a headwater tributary. A large wetland/pond dominates the middle of this reach formed by a roughly 1,000-ft-long earthen impoundment drained by a constructed ditch. Downstream of this impoundment, the channel planform and geometry are generally near target conditions, though the channel has been simplified near the confluence with Chaney (Figure 6). Substantial evidence of vehicle/tractor disturbance in the riparian areas of the uppermost headwaters and grazing disturbance in the riparian areas of the large wetland are likely contributing to high sediment production (historical and ongoing).

Fish use potential is poor for Upper Stalker given high temperatures, poor habitat connectivity, and low flows. Restoration feasibility is moderate with high geomorphic response potential and few landowner constraints, but improving the limiting flow, temperature, and habitat connectivity is relatively infeasible compared with actions in other reaches. Similarly, habitat uplift potential is low due to the lack of potential actions that can directly address restoration goals. Restoration would be best focused on reducing sediment sources and improving riparian conditions to improve habitat and temperature conditions within this reach and those reaches farther downstream. These restoration outcomes may be more economical by relocating the stream into an existing relic channel with adequate conditions (channel geometry, substrate, and riparian vegetation) as opposed to creating them within the existing channel.

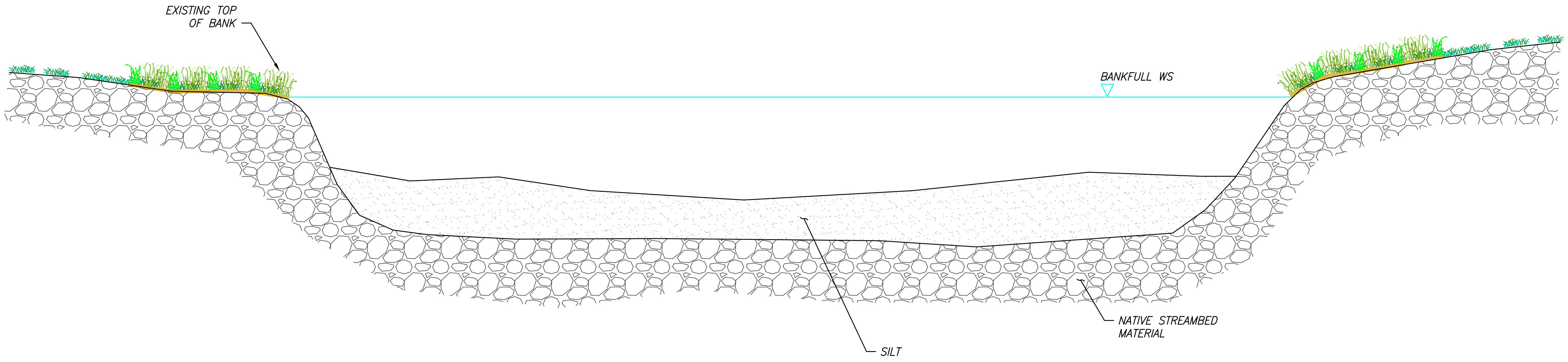
Table 15. Upper Stalker Creek

Reach Condition	Existing	Target
Sinuosity	1.22	1.3
Gradient	0.22%	0.21%
Average stream width (ft)	10	10
Hydrology (changes)	Gaining	Gaining
Riparian conditions	Poor	Minimum riparian width of 33 feet
Sedimentation	High	Low
Human features	Channel straightening	Add sinuosity where previously straightened; increase in-stream structure
Temperature: Average # of days between 70–78°F (average # of days >78°F)	39 (2) -Data Logger: Upper Stalker	Reduced
Habitat Connectivity	Fair	High

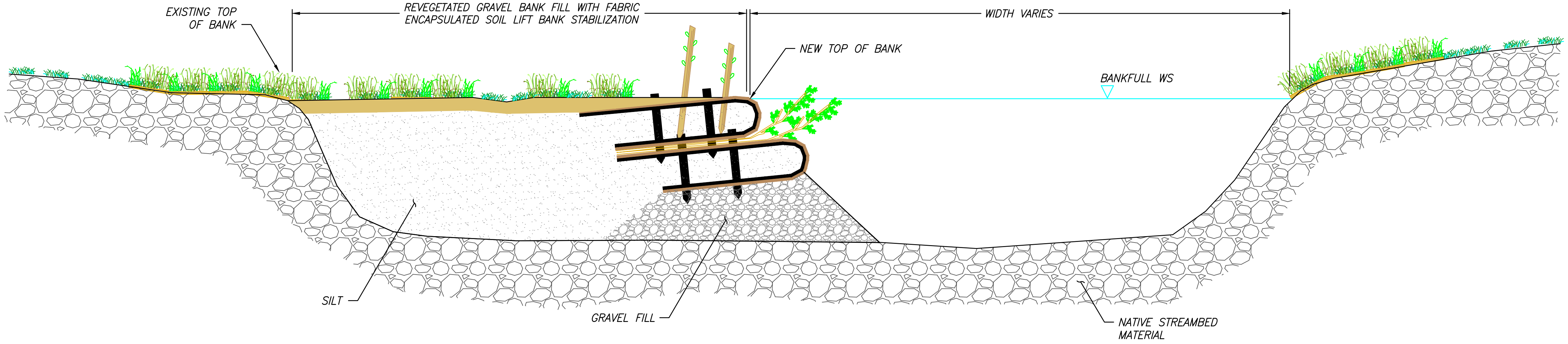
Figure 16. Stalker Creek



Appendix C. Conceptual Designs and Restoration Treatments



EXISTING CHANNEL SECTION



RESTORED CHANNEL SECTION

NOTES:

- BANK STABILIZATION TREATMENT TYPE WILL VARY BY LOCATION AND ARE ONLY PROPOSED FOR BANKS HAVING HIGH VELOCITY AND SHEAR STRESS.
- EXAMPLES OF VARIOUS BANK TREATMENT TYPES ARE PROVIDED IN SUBSEQUENT DRAWINGS.

TYPICAL CHANNEL SECTIONS

LOCATION: R:\PROJECTS\LITTLE_WOOD_HUC104\SILVER_CR_ASSESSMENT\CAD\PRODUCTION\SILVER-CREEK-DETAILS.DWG PLOT DATE:12/2/2019

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SECTIONS

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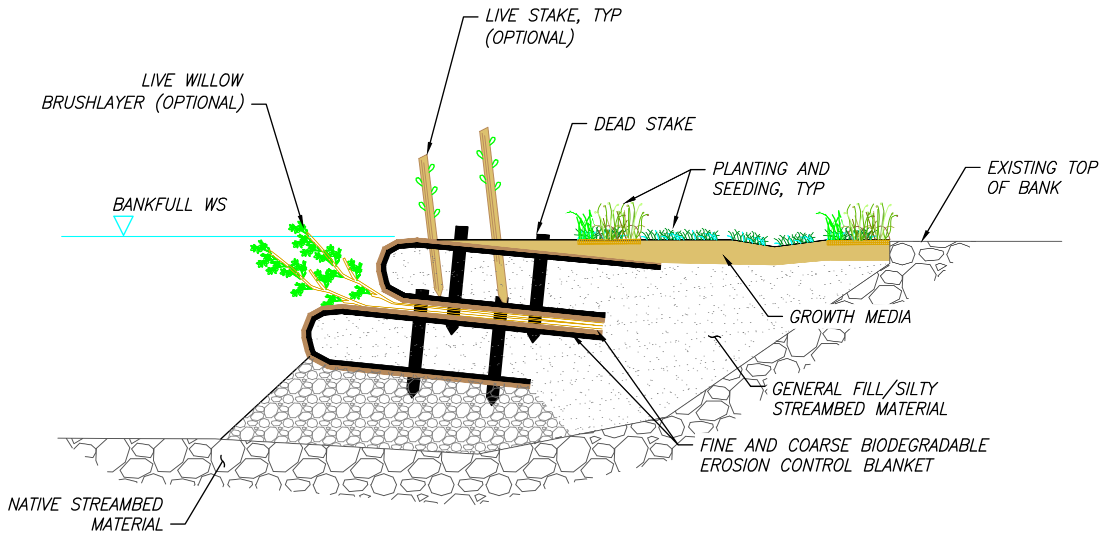

SECTION VIEW

APPLICATIONS AND EFFECTIVENESS:

- USED TO REDUCE CHANNEL WIDTH
- QUICKLY ESTABLISH RIPARIAN VEGETATION
- CAN BE COMPLEX AND EXPENSIVE
- PRODUCE A NEWLY CONSTRUCTED, WELL–REINFORCED STREAMBANK
- USEFUL IN RESTORING OUTSIDE BENDS WHERE EROSION IS PROBLEMATIC
- CAPTURE SEDIMENT AND ENHANCES CONDITIONS FOR COLONIZATION OF NATIVE SPECIES
- SLOPE STABILITY ANALYSES ARE RECOMMENDED
- TYPICALLY REQUIRE A STABLE FOUNDATION

DESIGN INTENT:

- STABILIZE NEW OR EXISTING STREAMBANKS USING BIOENGINEERING TECHNIQUES

DESIGN CONSIDERATIONS:

- UTILIZE NATIVE SPECIES FOR BRUSH LAYER, FASCINES, BRANCH CUTTINGS, AND PLANTINGS
- SELECT APPROPRIATE GEOTEXTILE TO WITHSTAND ANTICIPATED HYDRAULIC FORCES. IF NECESSARY, INCORPORATE LARGE WOODY MATERIAL FOR INCREASED HABITAT VALUE

ABOVE: PRE–CONSTRUCTION; OVER–WIDENED CHANNEL (BIG SPRINGS CREEK, ID).

BELOW: POST–CONSTRUCTION; BANK FILL WITH FESL WITH ALCOVE (BIG SPRINGS CREEK, ID)

ABOVE: FESL CONSTRUCTION WITH LIVE WILLOW BRUSHLAYER (YANKEE FORK, ID).

1 BANK FILL WITH FABRIC ENCAPSULATED SOIL LIFT (FESL)

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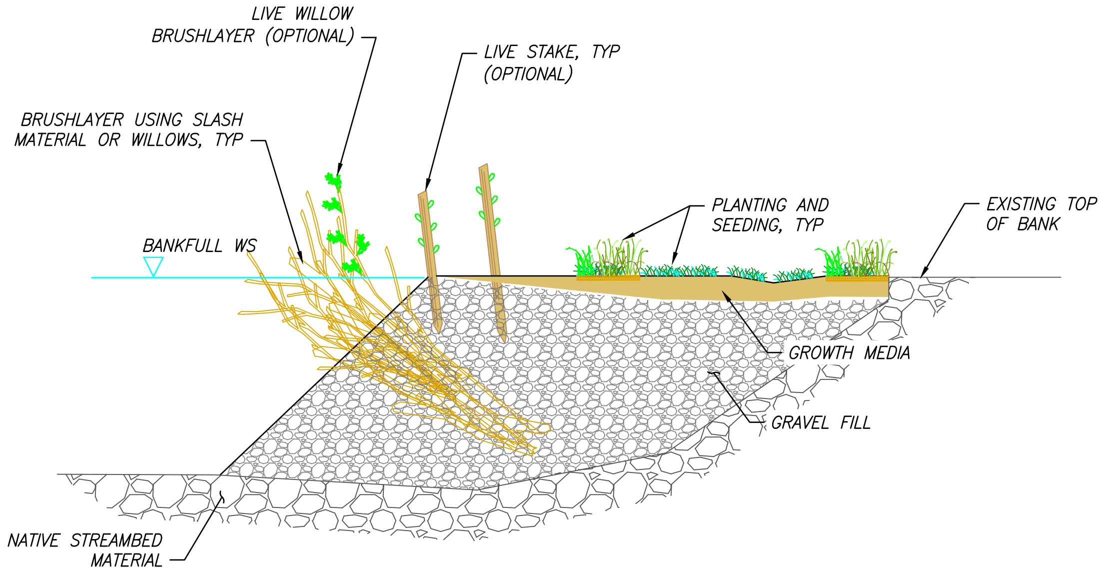

SECTION VIEW

APPLICATIONS AND EFFECTIVENESS:

- USED TO REDUCE CHANNEL WIDTH
- QUICKLY ESTABLISH RIPARIAN VEGETATION
- PRODUCE A NEWLY CONSTRUCTED, WELL–REINFORCED STREAMBANK
- USEFUL IN RESTORING OUTSIDE BENDS WHERE EROSION IS PROBLEMATIC
- CAPTURE SEDIMENT AND ENHANCES CONDITIONS FOR COLONIZATION OF NATIVE SPECIES
- SLOPE STABILITY ANALYSES ARE RECOMMENDED
- TYPICALLY REQUIRE A STABLE FOUNDATION
- HIGH BANK ROUGHNESS

DESIGN INTENT:

- STABILIZE NEW OR EXISTING STREAMBANKS USING BIOENGINEERING TECHNIQUES

DESIGN CONSIDERATIONS:

- UTILIZE NATIVE SPECIES FOR BRUSH LAYER, FASCINES, BRANCH CUTTINGS, AND PLANTINGS
- INCORPORATE LARGE WOODY MATERIAL FOR INCREASED HABITAT VALUE

ABOVE: WILLOW BRUSHLAYER IMMEDIATELY AFTER CONSTRUCTION (LEMHI RIVER, ID).
BELOW: SLASH BRUSHLAYER 1–YEAR POST CONSTRUCTION
(CATHERINE CREEK, OR)

ABOVE: BRUSHLAYER CONSTRUCTION (BIG SPRINGS, ID).

2 BANK FILL WITH BRUSHLAYER

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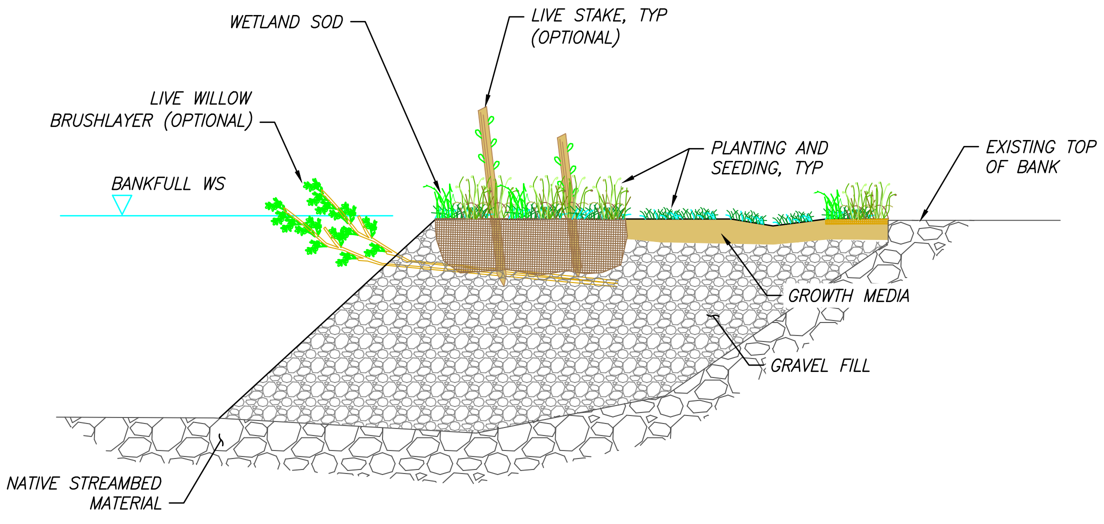

SECTION VIEW

APPLICATIONS AND EFFECTIVENESS:
- USED TO REDUCE CHANNEL WIDTH
- QUICKLY ESTABLISH RIPARIAN VEGETATION
- PRODUCE A NEWLY CONSTRUCTED, WELL-REINFORCED STREAMBANK
- USEFUL IN RESTORING INSIDE BENDS WHERE EROSION IS LESS PROBLEMATIC
- CAPTURE SEDIMENT AND ENHANCES CONDITIONS FOR COLONIZATION OF NATIVE SPECIES
- SLOPE STABILITY ANALYSES ARE RECOMMENDED
- TYPICALLY REQUIRE A STABLE FOUNDATION

DESIGN INTENT:
- STABILIZE NEW OR EXISTING STREAMBANKS USING BIOENGINEERING TECHNIQUES

DESIGN CONSIDERATIONS:
- UTILIZE NATIVE SPECIES FOR BRUSH LAYER, FASCINES, BRANCH CUTTINGS, AND PLANTINGS

ABOVE: WETLAND SOD BANK IMMEDIATELY POST-CONSTRUCTION (BIG SPRINGS CREEK, ID).

BELOW: BANK FILL WITH WETLAND SOD BANK 1-YEAR POST-CONSTRUCTION (LEMHI RIVER, ID)

ABOVE: BANK FILL WITH WETLAND SOD BANK IMMEDIATELY AFTER CONSTRUCTION (BIG SPRINGS CREEK, ID)

③ BANK FILL WITH WETLAND SOD
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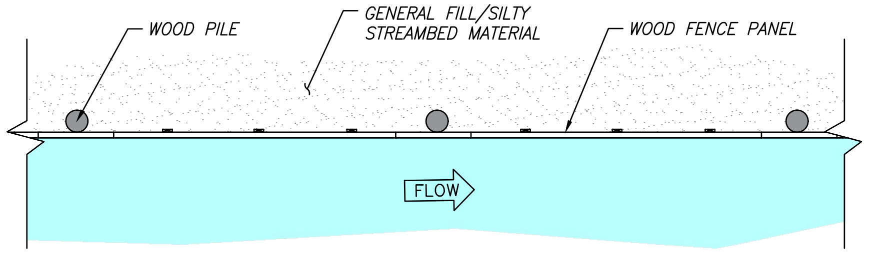
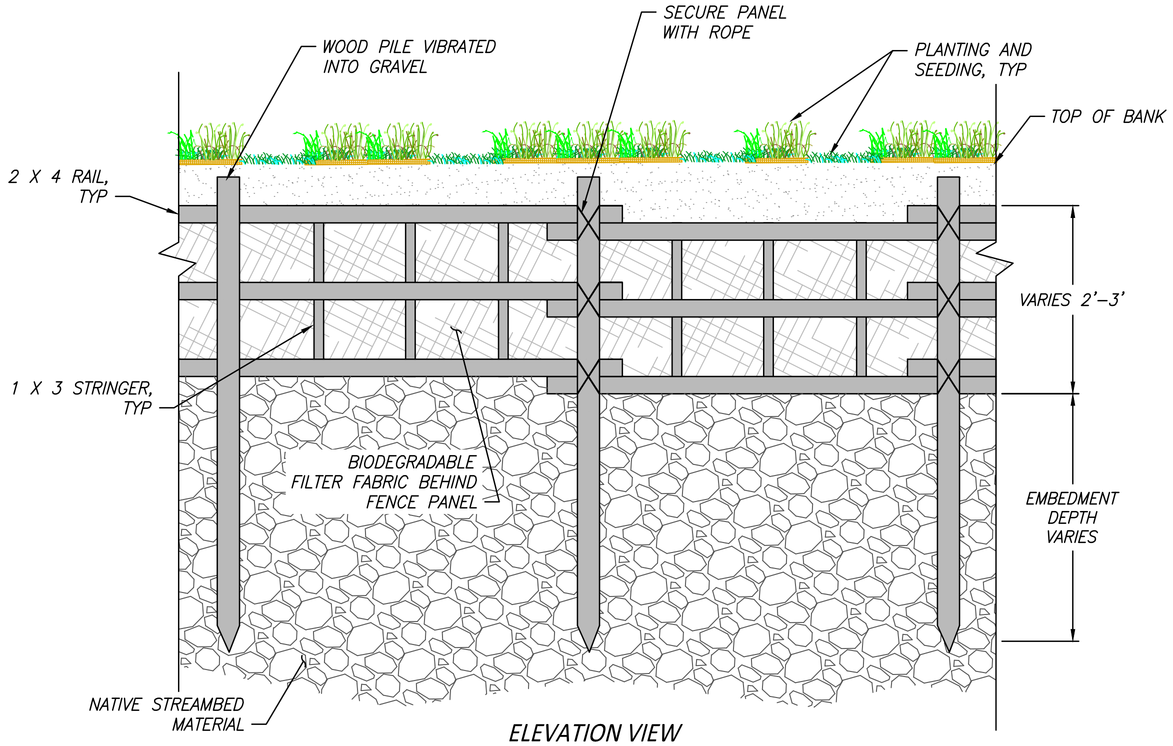
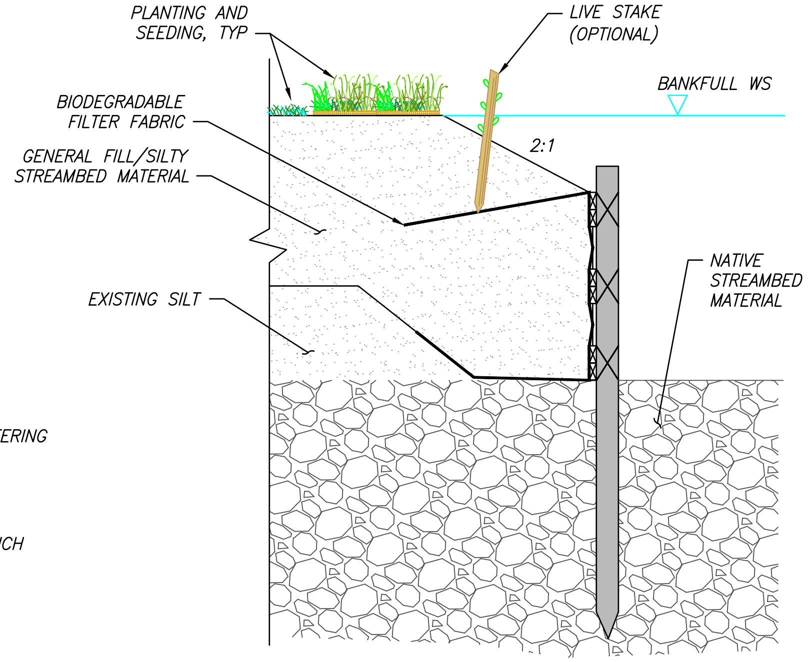


PLAN VIEW



ELEVATION VIEW



SIDE VIEW

APPLICATIONS AND EFFECTIVENESS:
- USED TO REDUCE CHANNEL WIDTH
- PRODUCE A NEWLY CONSTRUCTED, VERTICAL STREAMBANK
- USEFUL IN RESTORING INSIDE AND OUTSIDE BENDS
- SLOPE STABILITY ANALYSES ARE RECOMMENDED
- TYPICALLY REQUIRE A STABLE FOUNDATION

DESIGN INTENT:
- STABILIZE NEW OR EXISTING STREAMBANKS USING BIOENGINEERING TECHNIQUES

DESIGN CONSIDERATIONS:
- UTILIZE NATIVE SPECIES FOR BRUSH LAYER, FASCINES, BRANCH CUTTINGS, AND PLANTINGS

④ BANK FILL WITH RETENTION FENCE
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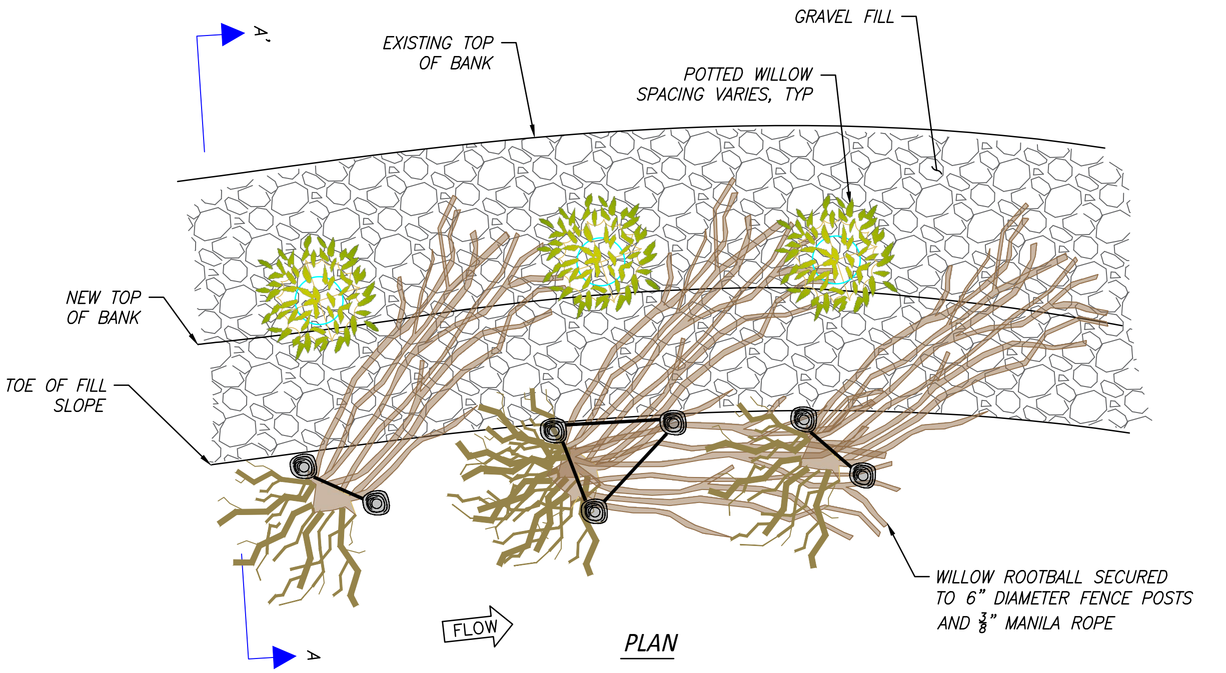

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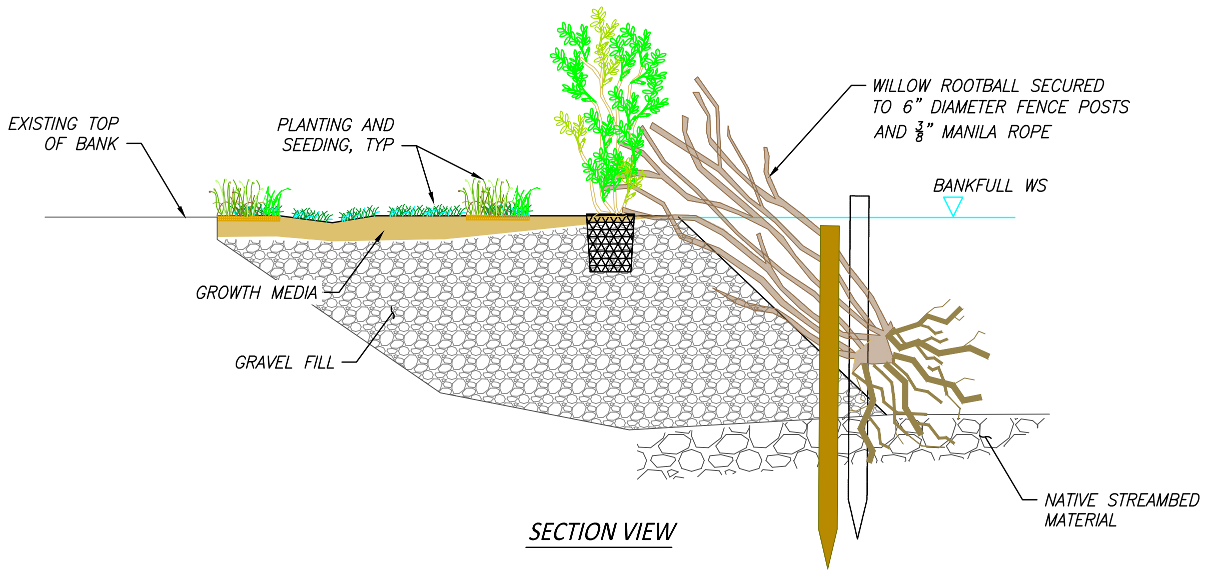

SECTION VIEW

APPLICATIONS AND EFFECTIVENESS:

- USED TO CREATE IN-CHANNEL COMPLEXITY, VELOCITY AND DEPTH VARIABILITY
- PROMOTE GRAVEL SORTING
- CREATE COVER FOR IMPROVED HABITAT
- USED TO CREATE CONSTRICTIONS
- TYPICALLY REQUIRE A STABLE FOUNDATION
- HIGH IN-CHANNEL AND BANK ROUGHNESS

DESIGN INTENT:

- STABILIZE NEW OR EXISTING STREAMBANKS USING BIOENGINEERING TECHNIQUES

DESIGN CONSIDERATIONS:

- UTILIZE NATIVE SPECIES FOR BRUSH LAYER, FASCINES, BRANCH CUTTINGS, AND PLANTINGS
- INCORPORATE LARGE WOODY MATERIAL FOR INCREASED HABITAT VALUE

ABOVE: 2 YEARS POST-CONSTRUCTION; WILLOW CLUMPS (BIG SPRINGS CREEK, ID)

5 BANK FILL WITH WILLOW CLUMPS

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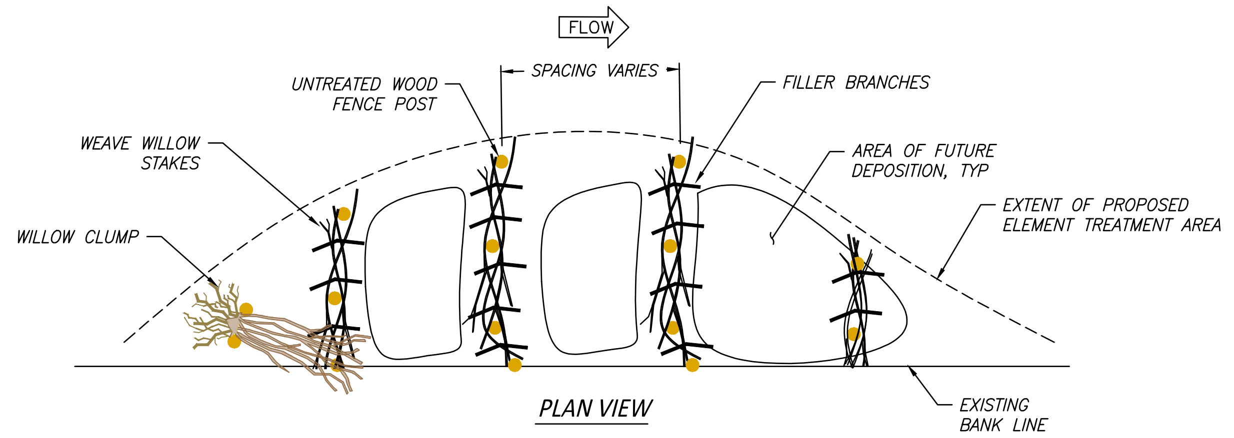
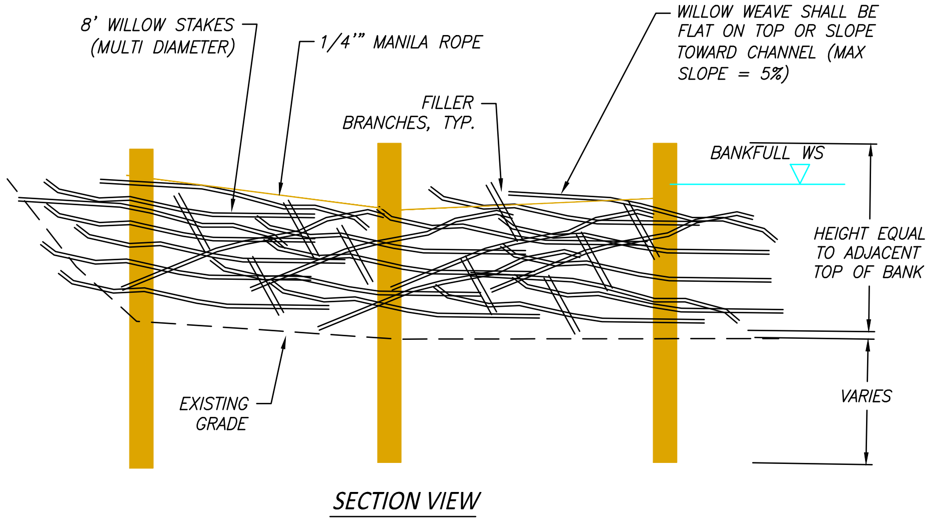


PLAN VIEW

ABOVE: POST LINE WILLOW WEAVE CONSTRUCTION (LEMHI RIVER, ID).



SECTION VIEW

APPLICATIONS AND EFFECTIVENESS:

- USED TO REDUCE CHANNEL WIDTH
- PROVIDES VELOCITY BREAKS
- CAPTURE SEDIMENT AND FORMATION OF POINT BARS
- PRIMARILY USED FOR RESTORING INSIDE BEDS
- LOW IMPACT AND MAY BE INSTALLED IN THE "WET"

DESIGN INTENT:

- CAPTURE AND RETAIN FINE GRAIN SEDIMENT AND ENCOURAGE NATURAL POINT BAR FORMATION

ABOVE: PRE-CONSTRUCTION; OVER-WIDENED CHANNEL (BIG SPRINGS CREEK, ID)

ABOVE: 6 MONTHS POST-CONSTRUCTION; POST LINE WILLOW-WEAVE FENCES WITH FINE SEDIMENT DEPOSITION (BIG SPRINGS CREEK, ID)

DESIGN CONSIDERATIONS:

- UTILIZE NATIVE SPECIES FOR BRUSH LAYER, FASCINES, BRANCH CUTTINGS, AND PLANTINGS. USING LIVE CUTTINGS MAY PROMOTE REVEGETATION
- INSTALL PILES USING HAND-HELD PILE DRIVER, PRESS INTO BED USING EXCAVATOR, OR OTHER MEANS

6 POST LINE WILLOW-WEAVE FENCE (PLWWF)

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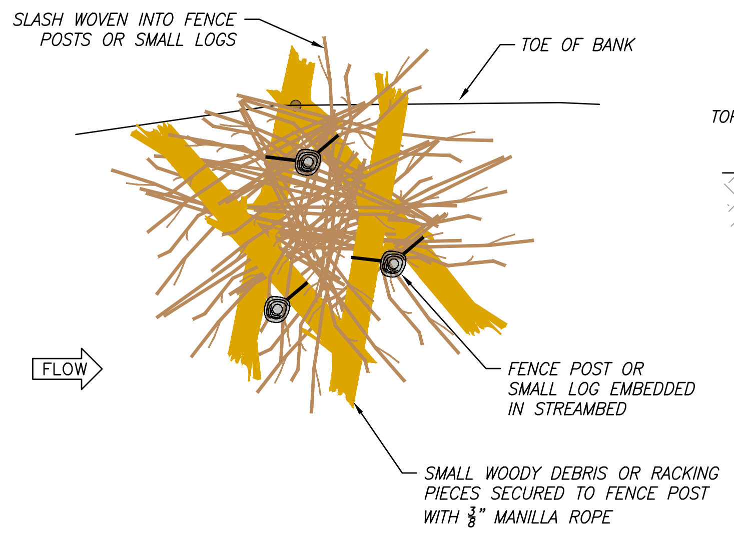
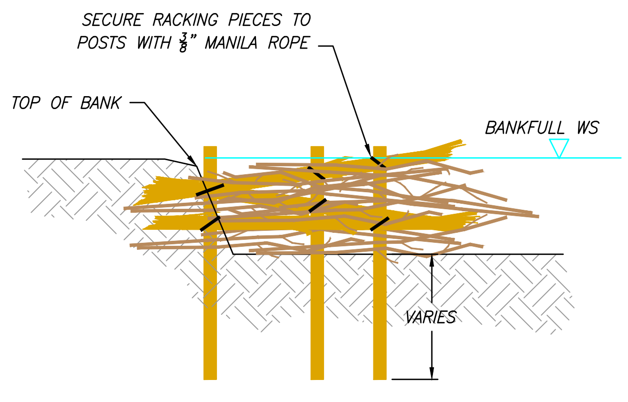


PLAN VIEW



SECTION VIEW

APPLICATIONS AND EFFECTIVENESS:
- USED TO CREATE IN–CHANNEL COMPLEXITY, VELOCITY AND DEPTH VARIABILITY
- PROMOTE SCOUR AND GRAVEL SORTING
- CREATE COVER FOR IMPROVED HABITAT
- USED TO CREATE CONSTRICTIONS
- TYPICALLY REQUIRE A STABLE FOUNDATION
- HIGH IN–CHANNEL ROUGHNESS

DESIGN INTENT:
- CREATE IN–CHANNEL COMPLEXITY, VELOCITY AND DEPTH VARIABILITY, AND COVER WITH THE INTENT TO IMPROVE HABITAT

DESIGN CONSIDERATIONS:
- INCORPORATE EXCAVATED SCOUR POOL
- INCORPORATE LARGE WOODY MATERIAL FOR INCREASED HABITAT VALUE

ABOVE: 1–YEAR POST–CONSTRUCTION; SMALL WOODY DEBRIS STRUCTURES (BIG SPRINGS CREEK, ID)

BELOW: IMMEDIATELY POST–CONSTRUCTION AFTER REWATERING; SMALL WOODY DEBRIS STRUCTURE WITH EXCAVATED SCOUR POOL (BIG SPRINGS CREEK, ID)

ABOVE: IMMEDIATELY POST–CONSTRUCTION; SMALL WOODY DEBRIS STRUCTURE WITH LARGE WOODY MATERIAL INCORPORATED (BIG SPRINGS CREEK, ID)

7 SMALL WOODY DEBRIS HABITAT STRUCTURE
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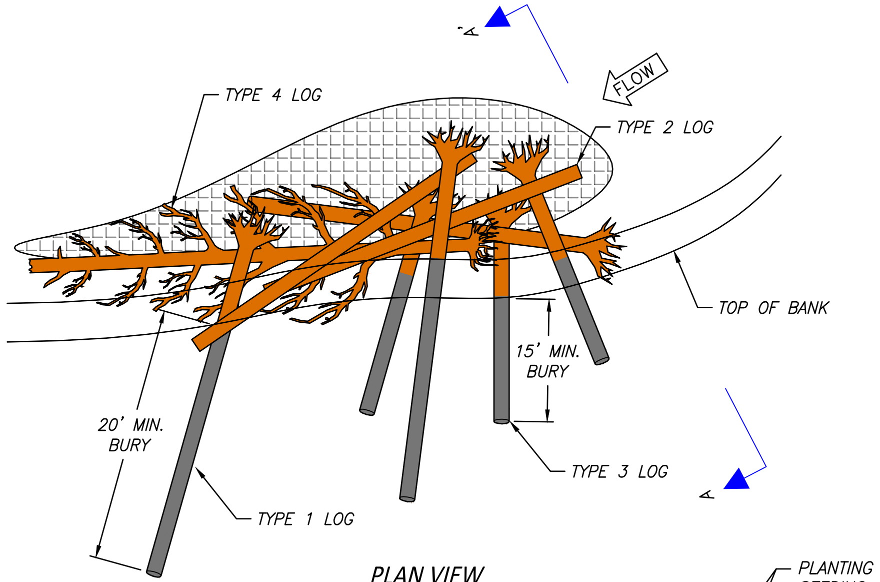
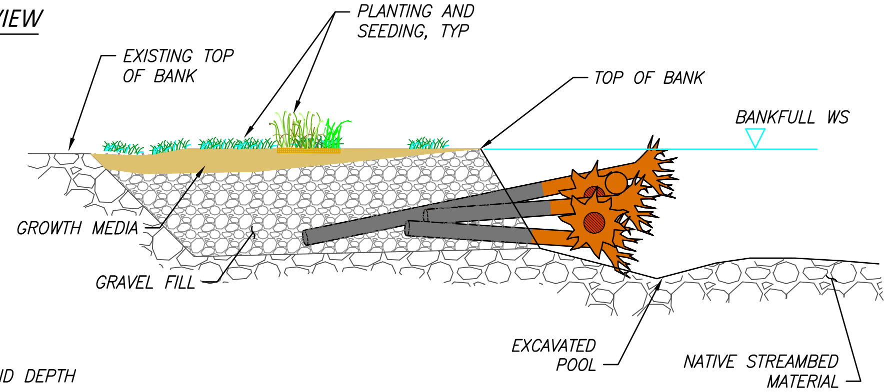


PLAN VIEW

APPLICATIONS AND EFFECTIVENESS:
- USED TO CREATE IN–CHANNEL COMPLEXITY, VELOCITY AND DEPTH VARIABILITY
- PROMOTE SCOUR AND GRAVEL SORTING
- CREATE COVER FOR IMPROVED HABITAT
- USED TO CREATE CONSTRICTIONS
- TYPICALLY REQUIRE A STABLE FOUNDATION
- HIGH IN–CHANNEL ROUGHNESS



SECTION VIEW

DESIGN INTENT:
- CREATE IN–CHANNEL COMPLEXITY, VELOCITY AND DEPTH VARIABILITY, AND COVER WITH THE INTENT TO IMPROVE HABITAT

DESIGN CONSIDERATIONS:
- INCORPORATE EXCAVATED SCOUR POOL
- INCORPORATE LARGE WOODY MATERIAL FOR INCREASED HABITAT VALUE
- WILLOW CLUMPS MAY BE A SUITABLE REPLACEMENT FOR LWD IN CERTAIN ENVIRONMENTS WHERE STREAM SIZE AND POWER ALLOW.

ABOVE: IMMEDIATELY POST–CONSTRUCTION; LARGE WOODY DEBRIS HABITAT STRUCTURE (LEMHI RIVER, ID)

ABOVE: 1–YEAR POST–CONSTRUCTION; LARGE WOODY DEBRIS HABITAT STRUCTURE (BIG SPRINGS CREEK, ID)

8 LARGE WOODY DEBRIS HABITAT STRUCTURE
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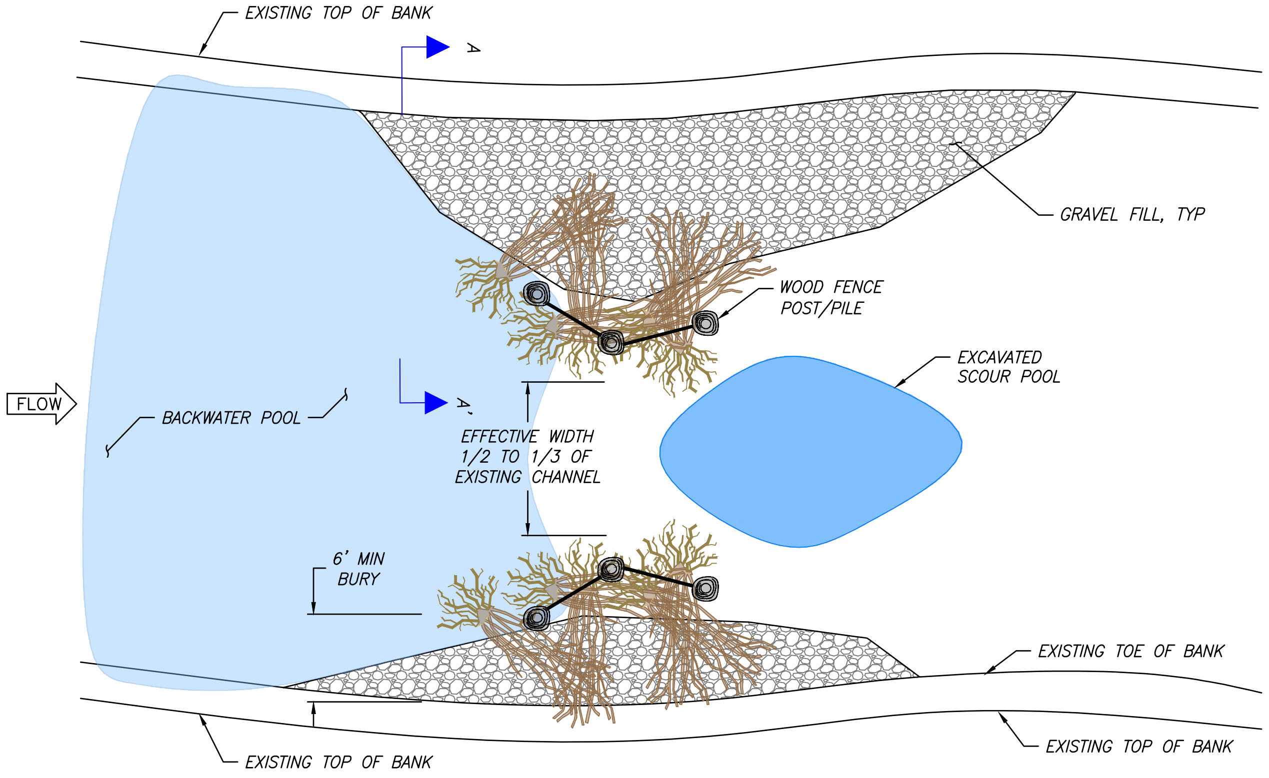

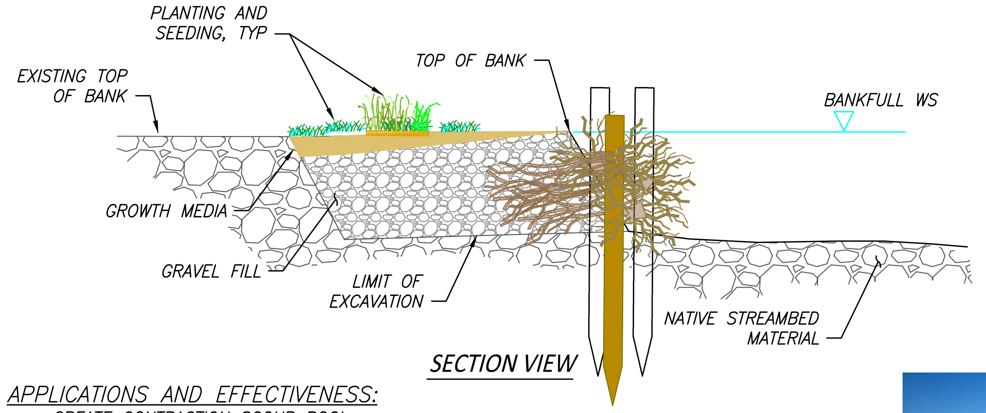

SECTION VIEW

APPLICATIONS AND EFFECTIVENESS:

- CREATE CONTRACTION SCOUR POOL
- REDUCE EFFECTIVE WIDTH OF CHANNEL LOCALLY
- PROMOTE SCOUR AND GRAVEL SORTING
- CREATE IN–CHANNEL COMPLEXITY, VELOCITY, AND DEPTH VARIABILITY
- CREATE COVER FOR IMPROVED HABITAT
- HIGH IN–CHANNEL ROUGHNESS

DESIGN INTENT:

- DESIRED HYDRAULIC RESPONSE INCLUDES UPSTREAM BACKWATER AND DOWNSTREAM CONTRACTION SCOUR WITH MINIMAL OVERTOPPING OF THE STRUCTURE AND NO BANK EROSION
- CREATE IN–CHANNEL COMPLEXITY, VELOCITY AND DEPTH VARIABILITY, AND COVER WITH THE INTENT TO IMPROVE HABITAT

DESIGN CONSIDERATIONS:

- TYPICALLY REQUIRE A STABLE FOUNDATION
- INCORPORATE EXCAVATED SCOUR POOL BELOW CONSTRICTION
- INCORPORATE LARGE WOODY (OR SIMILAR) MATERIAL FOR INCREASED HABITAT VALUE
- WILLOW CLUMPS MAY BE A SUITABLE REPLACEMENT FOR LWD IN CERTAIN ENVIRONMENTS WHERE STREAM DEPTH, SIZE, AND POWER ALLOW.
- TO BE APPLIED ONLY WHERE HYDRAULIC CONDITIONS ARE APPROPRIATE
- STRUCTURE SPACING TO BE SUFFICIENT THAT SCOUR POOL IS NOT INFLUENCED BY BACKWATER POOL OF THE SEQUENTIAL DOWNSTREAM STRUCTURE.
- NUMBER AND SIZE OF INDIVIDUAL LOGS/ WILLOW CLUMPS WILL VARY BASED ON CHANNEL DEPTH, SIZE, AND POWER.

9 DISCRETE CONSTRICTIONS

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ABOVE: BACKWATER POOL ABOVE FLOW CONSTRICTION (BIG SPRINGS CREEK, ID)

ABOVE: FLOW ACCELERATION AND SCOUR POOL BELOW FLOW CONSTRICTION (BIG SPRINGS CREEK, ID)

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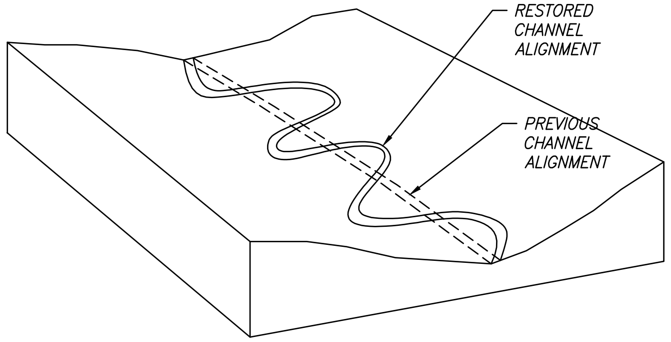


LEFT: TRANSFORMATION OF A STRAIGHTENED STREAM INTO A MEANDERING ONE TO REINTRODUCE NATURAL CHANNEL DYNAMICS, IMPROVE CHANNEL STABILITY, HABITAT QUALITY, AESTHETICS, AND OTHER STREAM CORRIDOR FUNCTIONS OR VALUES. (FISRWG, 2001)

ABOVE: CHANNELIZED RIVER LOCATED AGAINST THE LEFT VALLEY WALL (CATHERINE CREEK, OR)

BELOW: CHANNEL RE-MEANDER/RECONSTRUCTION OCCURRING WITHIN FLOODPLAIN (CATHERINE CREEK, OR)

APPLICATIONS AND EFFECTIVENESS:

- USED TO CREATE A MORE STABLE STREAM WITH MORE HABITAT DIVERSITY.
- USED TO RELOCATE A CHANNEL AWAY FROM NEGATIVE RESPONSE AREAS SUCH AS LATERAL MIGRATION TOWARD A HIGHWAY.
- REQUIRES ADEQUATE AREA WHERE ADJACENT LAND USERS MAY CONSTRAIN LOCATIONS.
- REQUIRES A HIGH LEVEL OF ANALYSIS.
- CAN INCREASE OR DECREASE LOCAL FLOOD ELEVATIONS AND GROUNDWATER ELEVATIONS TO BENEFIT RIPARIAN PRODUCTIVITY.
- CAN INCREASE FREQUENCY OF SELF-SUSTAINING POOLS AT MEANDER BENDS TO IMPROVE HABITAT.

DESIGN INTENT:

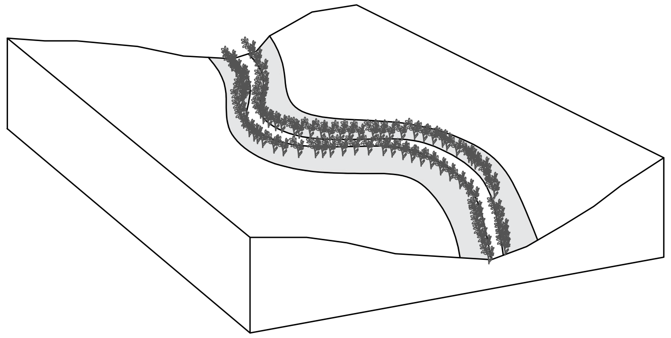
- RELOCATE AND DEVELOP A NEW CHANNEL NETWORK TO IMPROVE CHANNEL FORM, STABILITY, HABITAT QUALITY, OR OTHER STREAM AND RIPARIAN CORRIDOR FUNCTION.

DESIGN CONSIDERATIONS:

- POTENTIAL INCREASE IN GROUNDWATER AND FLOOD ELEVATIONS.
- NEED APPROPRIATE ROOM TO EXECUTE SUCCESSFULLY

(10) CHANNEL RE-MEANDER- CHANNEL REALIGNMENT

NTS



LEFT: STREAMSIDE VEGETATION TO LOWER WATER TEMPERATURES, PROVIDE A SOURCE OF DETRITUS AND LARGE WOODY DEBRIS, IMPROVE HABITAT, AND TO REDUCE SEDIMENT, ORGANIC MATERIAL, NUTRIENTS, PESTICIDES, AND OTHER POLLUTANTS MIGRATING TO THE STREAM (FISRWG, 2001)

ABOVE: RIPARIAN PLANTING STRIPS DURING CONSTRUCTION IN YEAR 2001 (WALLA WALLA RIVER, OR)

BELOW: RIPARIAN PLANTING STRIPS POST-CONSTRUCTION IN YEAR 2006 (WALLA WALLA RIVER, OR)

APPLICATIONS AND EFFECTIVENESS:

- APPLICABLE ON STABLE AREAS ADJACENT TO PERMANENT OR INTERMITTENT STREAMS, WETLANDS AND AREAS WITH GROUND WATER RECHARGE.
- UNSTABLE AREAS SUCH AS THOSE WITH HIGH SURFACE EROSION RATES, MASS SOIL MOVEMENT OR ACTIVE GULLIES WILL REQUIRE STABILIZATION PRIOR TO ESTABLISHMENT OF RIPARIAN BUFFERS.
- TOLERANT PLANT SPECIES AND SUPPLEMENTAL WATERING MAY BE NEEDED IN SOME AREAS.
- SITES IN ARID AND SEMI-ARID REGIONS MAY NOT HAVE SUFFICIENT SOIL MOISTURE THROUGHOUT THE GROWING SEASON TO SUPPORT WOODY PLANTS.
- CONCENTRATED FLOW EROSION, EXCESSIVE SHEET AND RILL EROSION, OR MASS SOIL MOVEMENT MUST BE CONTROLLED IN UPLAND AREAS PRIOR TO ESTABLISHMENT OF RIPARIAN BUFFERS.

DESIGN INTENT:

- INCREASES RATE OF COLONIZATION OF NATIVE SPECIES, REDUCES NON-NATIVE SPECIES.
- CREATE LONG TERM BANK STABILITY AND STREAM SHADE THROUGH ROOT STRUCTURE AND OVERHEAD CANOPY.

DESIGN CONSIDERATIONS:

- UTILIZE NATIVE SPECIES AND ENSURE ACCESS TO WATER.

(11) REVEGETATION - RIPARIAN PLANTING

NTS

Applied Science & Engineering
2449 S. Vista Ave. Suite B
Boise, Idaho 83705

Lower Stalker and Loving Creek
Restoration and Habitat Improvement
Conceptual Design
for The Nature Conservancy
Little Wood Basin
Blaine County, Idaho

Not For Construction

Date: NOV 2019
Designed: JY, JF
Drawn: JY
Checked: --
Approved: --

Drawing Name

DETAILS - 6

Drawing No.
D6

Sheet 18 of 18

LOCATION: R:\PROJECTS\LITTLE_WOOD_HUC104\SILVER_CR_ASSESSMENT\CAD\PRODUCTION\SILVER-CREEK-DETAILS.DWG PLOT DATE:12/2/2019

Appendix D. Report Limitations and Guidelines

The information in this appendix is provided by Rio ASE and Ecosystem Sciences (together “us” or “we”) to help The Nature Conservancy and Silver Creek Alliance (“Client”) manage their risks with respect to the use of this report associated with the Silver Creek Restoration Planning and Coordination Assessment (“Project”) and in accordance with the Subconsultant Agreement (“Agreement”) signed July 15, 2019, by Rio ASE and Ecosystem Sciences, and with Ecosystem Sciences Professional Services Agreement with Client dated January 16, 2019.

Read These Provisions Closely

Some clients, design professionals, and contractors may not recognize that stream and river engineering analysis and design practices are less exact than other engineering and natural science disciplines. Such misunderstanding can create unrealistic expectations, sometimes leading to disappointments, claims, and disputes. We include these explanatory “limitations” provisions in our reports to help reduce such risks. Please confer with us if you are unclear how these Report Limitations and Guidelines apply to your project or site.

Stream and River Design Engineering Services Are Performed for Specific Purposes, Persons, and Projects

This report has been prepared for the Client and their authorized agents and regulatory agencies for use on the Project(s) specifically identified in the report. The information contained herein is not applicable to any other sites or projects and cannot be relied upon for any such purpose.

We structure our services to meet the specific needs of our clients. No party other than the Client may rely on the product of our services unless we agree to such reliance in advance and in writing. Within the limitations of the agreed scope of services for the Project, and its schedule and budget, our services have been executed in accordance with our Agreement and generally accepted practices in this area at the time this report was prepared. We do not authorize and will not be responsible for the use of this report for any purposes or projects other than those specifically identified in the report.

A Stream or River Design Engineering Report Is Based on a Unique Set of Project-Specific Factors

This report has been prepared solely for this Project and Client. We considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless we specifically indicate otherwise, it is important not to rely on this report if it was:

- not prepared for you
- not prepared for your project
- not prepared for the specific site
- completed before project changes were made

For example, changes that can affect the applicability of this report include those that affect the following:

- the function of the proposed design and/or structure
- elevation, configuration, location, or orientation of the proposed structures
- composition of the design team
- project ownership

If changes occur after the date of this report we cannot be responsible for any consequences of such changes in relation to this report unless we have been given the opportunity to review our interpretations and recommendations in the context of such changes and make modifications or confirmations as appropriate. Based on that review, we can provide written modifications or confirmation, as appropriate and subject to a separate Services Agreement.

Conditions Can Change

This report is based on conditions that existed at the time the study/design was performed. The findings and conclusions of this report may be affected by the passage of time, by human-made impacts such as construction on or adjacent to the site, new information or technology that becomes available subsequent to the report date, or by natural events such as floods, earthquakes, slope instability, stream flow fluctuations, or stream channel fluctuations. If more than a few months have passed since issuance of our report or work product, or if any of the events described above may have occurred, please contact us before applying this report for its intended purpose so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

Any designs associated with this report may need to be adjusted in the field during construction in order to meet the specific site conditions and intended function. We cannot assume responsibility for the recommendations in this report if unexpected conditions are encountered during construction. We recommend you allow sufficient monitoring and consultation by us during construction to confirm the conditions encountered are consistent with those indicated in the report, to provide recommendations for design changes if the conditions revealed during the work differ from those anticipated, and to evaluate whether construction activities are completed in accordance with our recommendations.

Report Could Be Subject to Misinterpretation

Misinterpretation of this report can result in costly problems. We can help reduce the risks of misinterpretation by conferring with appropriate stakeholders after submitting the report, participating in pre-bid and preconstruction conferences, and providing construction observation.

To help reduce the risk of problems, we recommend giving contractors the complete report, including these Report Limitations and Guidelines. When providing the report, we suggest you preface it with a clearly written letter of transmittal that does the following:

- Advises contractors that the report was not prepared for purposes of bid development and that its accuracy is limited

- Encourages contractors to confer with us and/or to conduct additional study to obtain the specific types of information they need or prefer

Hazards of Instream Habitat Structures

Instream habitat structures ("Structures") create potential hazards, including, but not limited to the following:

- Persons falling from the Structures and associated injury or death
- Collisions of recreational users and their watercraft with the Structures, and associated risk of injury, and damage of the watercraft
- Mobilization of a portion of or all the Structures during high water flow conditions and related damage to downstream persons and property
- Flooding
- Erosion
- Channel avulsion

In some cases, instream habitat structures are only intended to be temporary, providing temporary stabilization while riparian vegetation becomes established or while stream/river processes stabilize. This gradual deterioration with age and vulnerability to major flood events makes the risks with temporary Structures inherently greater with their increasing age.

We strongly recommend the Client appropriately address safety concerns, including but not limited to warning construction workers of hazards associated with working in or near deep and fast water and on steep, slippery, and unstable slopes. In addition, signs should be placed along the enhanced stream reaches in prominent locations to warn third parties, such as nearby residents and recreational users, of the potential hazards noted above.

Channel Response is Unpredictable

In general, rivers and streams are dynamic and unpredictable. Any predictions regarding future channel evolution and/or response either stated or implied in this report or associated design(s) shall be considered an estimate based on professional judgement given the data available and conditions that existed at the time the study/design was performed. Channel evolution and/or response may include but is not limited to erosion, deposition, channel migration, avulsion, flooding, and sediment and debris transport. Channel evolution and/or response is inevitable, and it should not be assumed that any condition whether natural or constructed will persist unchanged indefinitely in a riverine environment.

Importance of Monitoring and Maintenance

In some designs, we may have excluded piles, anchors, chains, cables, reinforcing bars, bolts, and similar fasteners from woody habitat structures with the intent of mimicking naturally occurring instream wood structures. While we design Structures to be relatively stable during flood events, some movement of these Structures is expected. We recommend the Client implement appropriate monitoring and maintenance procedures to minimize potential adverse impacts at or near areas of concern, and consider replacing, adjusting, and/or removing damaged, malfunctioning, or deteriorated components of Structures.

Construction Contractors are Responsible for Site Safety on Their Projects

Our recommendations are not intended to direct the construction contractor's procedures, means, methods, schedule, or management of the work site during construction of any project associated with this report. The construction contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and adjacent properties.