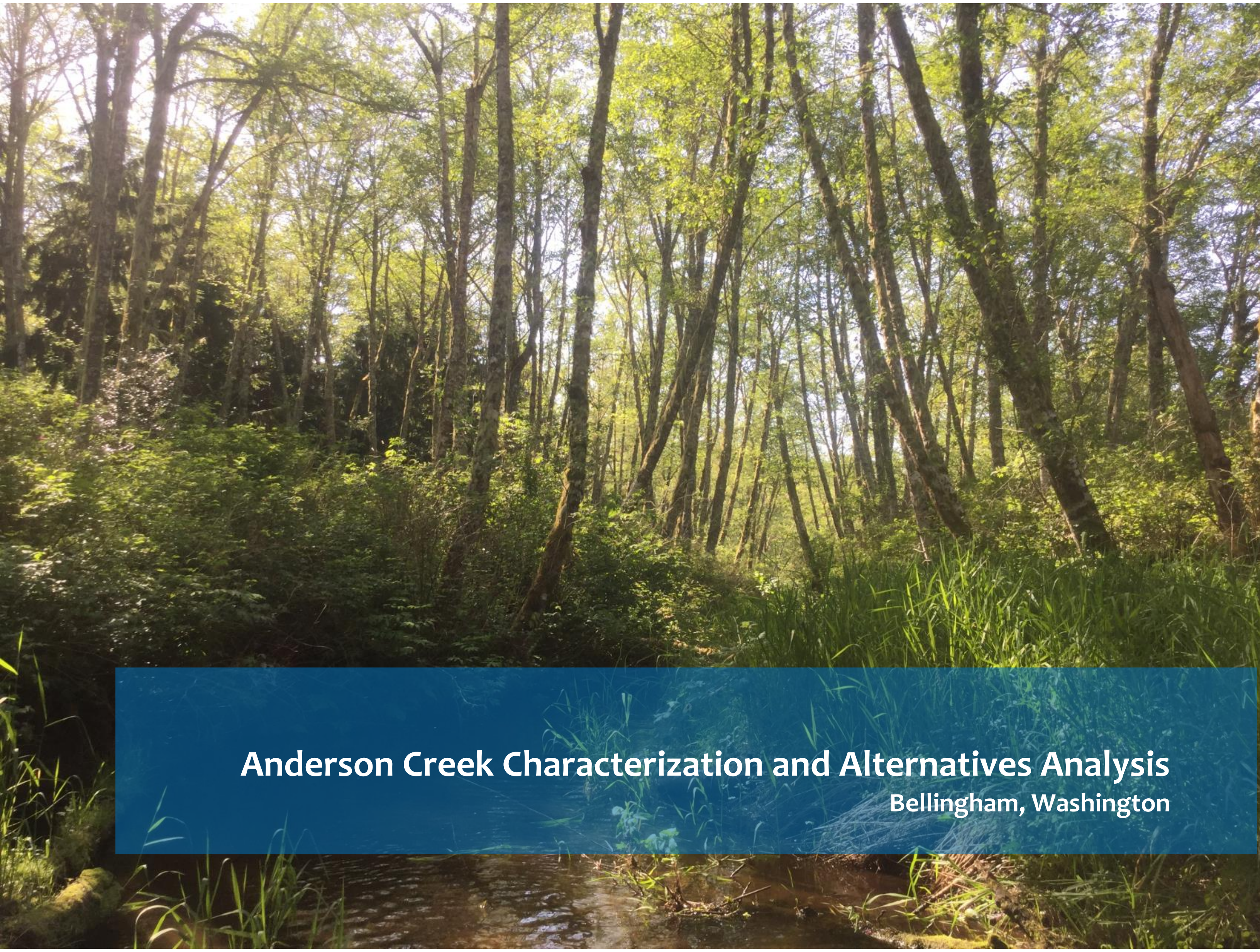

Anderson Creek Characterization and Alternatives Analysis

Bellingham, Washington

City of Bellingham
Public Works Department
Natural Resources Division

August 2019

Natural Systems Design

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Seattle, WA 98103

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1. INTRODUCTION

Natural Systems Design Inc. (NSD) is supporting the City of Bellingham to better understand ongoing physical and habitat processes in Anderson Creek, a tributary to Lake Whatcom. Anderson Creek supports spawning of Lake Whatcom Kokanee (a form of land-locked sockeye salmon that never leave fresh water, and spawn in the tributaries of their home lake), as well as a genetically distinct, adfluvial coastal cutthroat trout population native to Lake Whatcom. Anderson Creek has also played a key role in the City of Bellingham's municipal water supply system. Water from the City's diversion on the Middle Fork Nooksack River is conveyed to Anderson Creek's headwaters in Mirror Lake through 2.5 miles of open stream channel to Lake Whatcom.

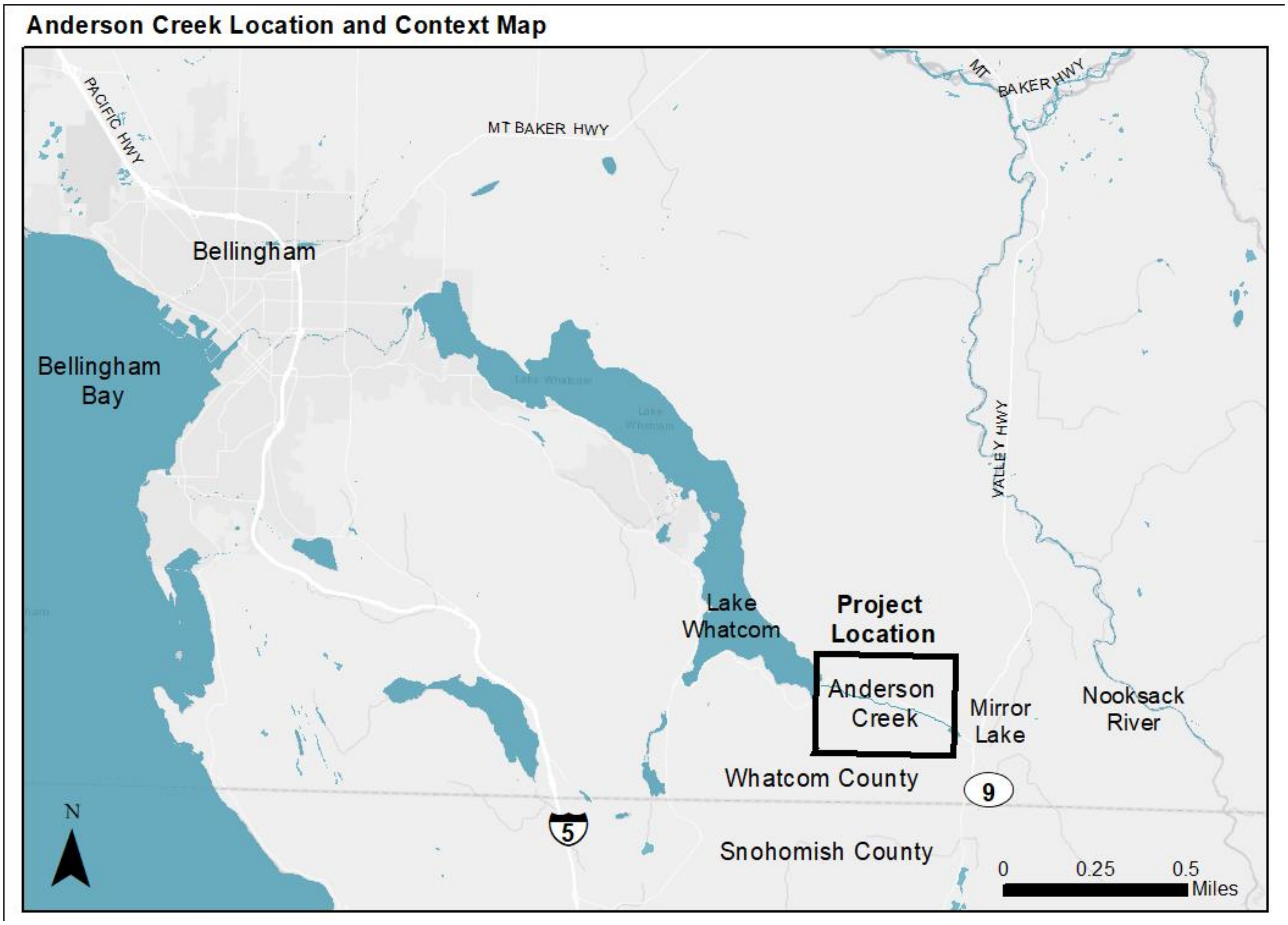


Figure 1 Anderson Creek location map.

The water diversion was installed in 1962 and can convey approximately 116 cubic feet per second (cfs), which is similar to the natural annual natural flood from the Anderson Creek watershed. The diversion has been operated since the 1960s; management has varied over time, in response to environmental concerns associated with Lake Whatcom and changing needs for water with the closure of the Georgia Pacific Mill in 2007. Management in the 1960s appears to have consisted of full capacity flow for most of the summer. When used more recently, the diversion has operated with moderation.

The diversion has influenced many aspects of Anderson Creek including the channel form, water quality, and habitat characteristics. In addition to the water diversion, the Anderson Creek valley has been modified through the installation of a railroad by 1902, logging of the watershed, and channelization associated with agricultural land use conversion (Tracy, 2001).

Goal: The City of Bellingham has initiated this effort to identify existing conditions and processes within the Anderson Creek corridor, as well as identify opportunities to improve salmonid habitat and water quality. The project will include preliminary design of a selected alternative(s) as developed by the project team.

To support this work, Natural Systems Design (NSD) and Brown and Caldwell (B&C) developed a broad characterization of Anderson Creek focusing on:

1. Geology/Geomorphology
2. Hydrology and Hydraulics
3. Water Quality
4. Riparian Habitat
5. Instream Habitat

To support the analysis, NSD performed field assessments in the Spring/Summer of 2018 to collect data on instream habitat, riparian community trends, bank erosion, and fish passage barriers. NSD also developed a hydraulic model and synthesized information on the geology and hydrology of Anderson Creek. B&C reviewed the watershed and leveraged their previous water quality monitoring efforts from the Tributary Monitoring campaigns and new field reconnaissance to develop their assessment of water quality status and trends.

A workshop was held with the City of Bellingham on July 19, 2018 to develop a conceptual model of the current status and trends of the watershed. This report was prepared to provide a summary of key findings, present restoration alternatives, and provide the information needed to select a path forward in the management of Anderson Creek.

This report summarizes the results of the characterization, develops goals and objectives, and provides preliminary project elements. The characterization is supported with a map folio (Appendix A) depicting our findings on maps of the creek corridor and data are provided in .kmz format for use with Google Earth.

Middle Fork Nooksack Diversion

The use of the City's diversion from the Middle Fork Nooksack River to Lake Whatcom has occurred since the 1960s. For the purposes of this report, we assume that the City will maintain its water right and will continue to utilize the diversion. No specific future diversion flow regime is assumed in our analysis or recommendations. The City has taken steps to reduce the impacts of the diversion to Anderson Creek over time, and we understand the City will continue to avoid and minimize impacts where possible. In general terms, the impacts of the diversion on Anderson Creek scale with the magnitude and duration of the diversion. If the full diversion capacity is utilized for extended lengths of time (as was typical from the 1960s through the 1980s) the diversion will have greater influence on Anderson Creek.

2. ANDERSON CREEK CHARACTERIZATION

2.1 Overview

The Anderson Creek watershed drains 4.1 square miles of steep forested slopes to a broad valley bottom then to the southeastern shore of Lake Whatcom. Second growth conifer forest covers approximately 85% of the watershed and there has been limited development in the valley bottom. A railroad constructed on a berm runs parallel to Anderson Creek, with a crossing approximately 1,200 feet upstream of the mouth at Lake Whatcom. Anderson Creek is crossed by South Bay Drive approximately 450 feet from the mouth and Park Road parallels the creek channel on the north side of the valley.

Anderson Creek flows 2.5 miles from Mirror Lake west to Lake Whatcom. At the headwaters of the stream, Mirror Lake is a natural lake at the low divide to the Samish River. Lake Whatcom is a drinking water supply for both the City of Bellingham and Whatcom County and Anderson Creek is a part of that water supply system that includes a diversion from the Middle Fork Nooksack River (MF diversion). The City of Bellingham has acquired much of the Anderson Creek corridor dating back to the start of the MF diversion (Figure 2).

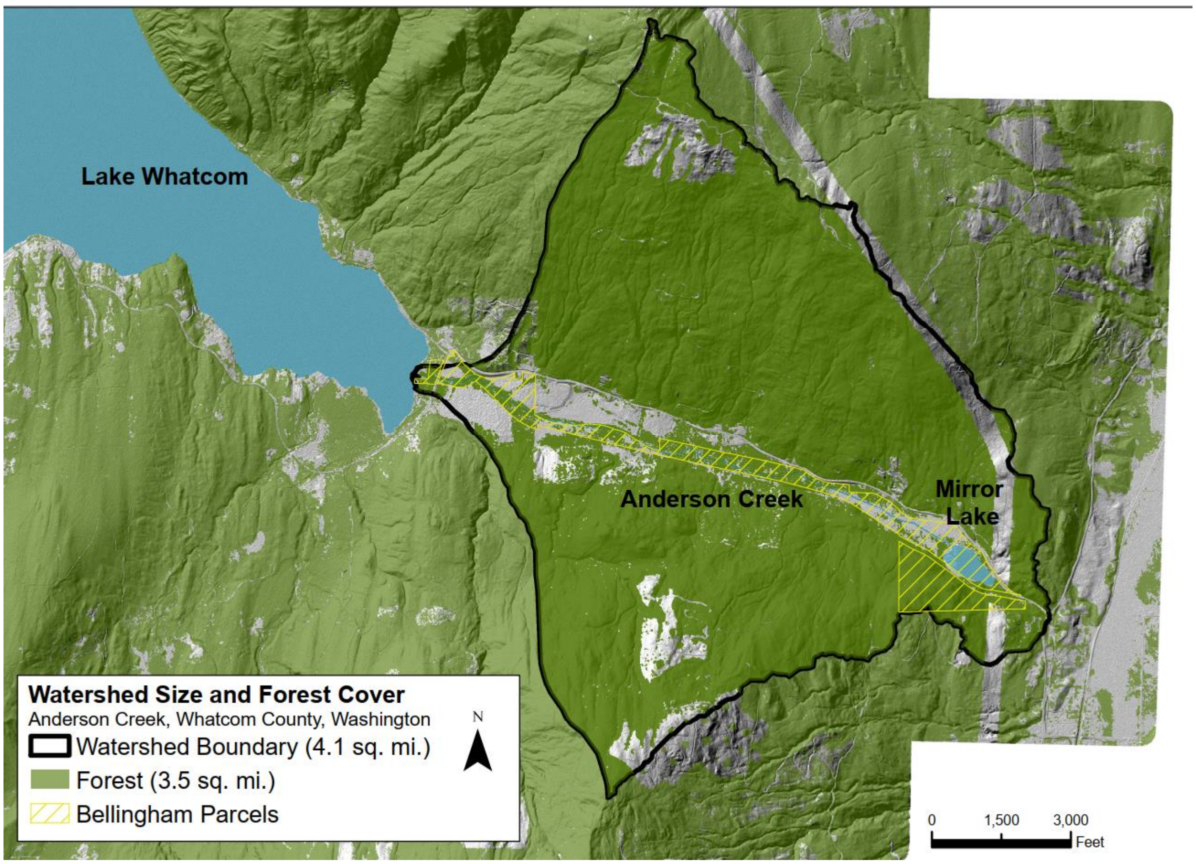


Figure 2. Anderson Creek watershed overview.

Anderson Creek provides habitat for Kokanee, resident cutthroat trout, prickly sculpin, coastrange sculpin, three-spined stickleback, and Pacific lamprey (Edwards 2016). The Washington Department of Natural Resources reports that the following fish species have been documented as present in the Lake Whatcom basin: resident cutthroat trout, Kokanee, rainbow trout, peamouth, brook trout, lake trout, yellow perch, brown bullhead, largemouth bass, smallmouth bass, other trout subspecies.

Historical surveys for the General Land Office (GLO) mapped Anderson Creek from 1883 to 1885. The GLO survey notes record large beaver dams and extensive cranberry bogs in the valley bottom (Figure 3).

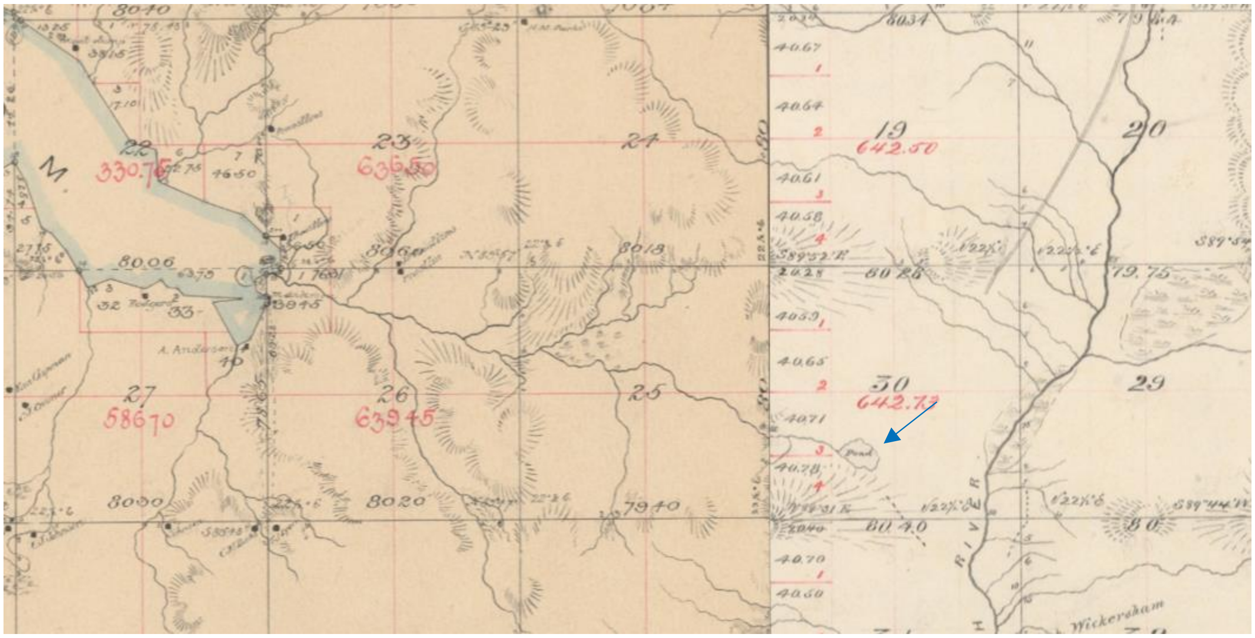


Figure 3. 1884 and 1885 GLO Maps showing Anderson Creek. Note that Mirror Lake is labeled as "Pond" indicated with the blue arrow

Based on photos georeferenced by the Whatcom Conservation District, valley bottom conversion to agriculture, the railroad, and straightening of Anderson Creek are apparent by 1943 (Figure 4).

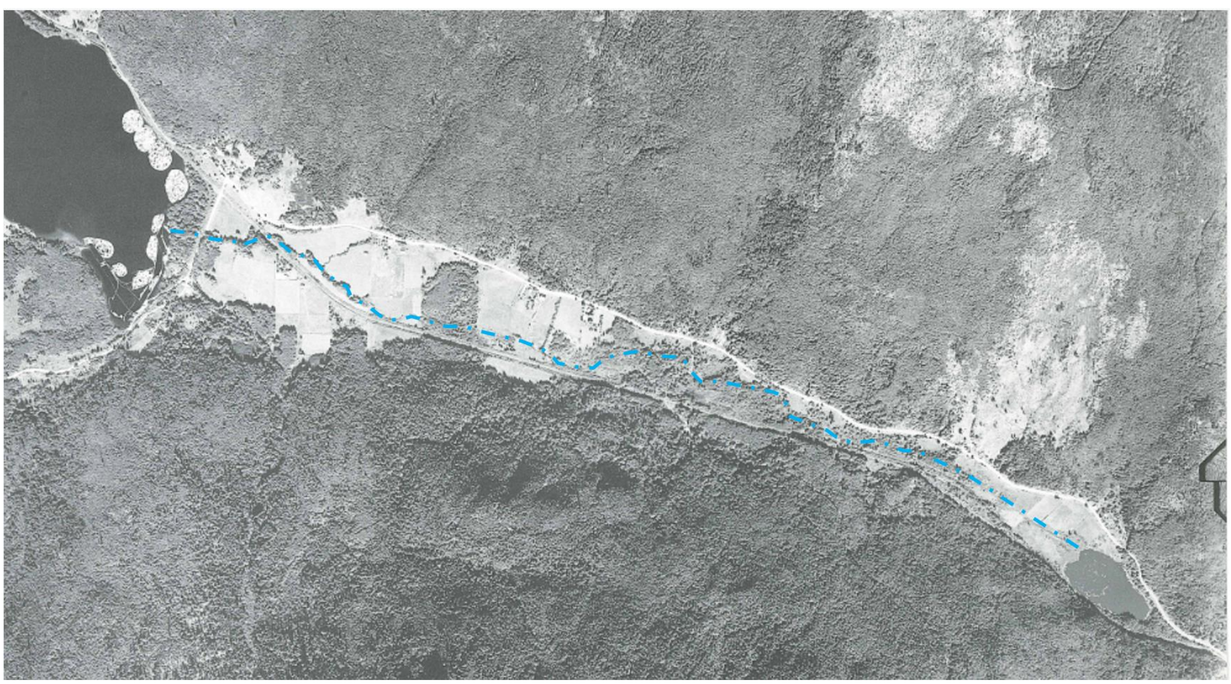


Figure 4. 1943 Aerial view of the Anderson Creek Valley. Aerial obtained from the Whatcom County Conservation District.

2.2 Geology and Geomorphology

Anderson Creek drains a small, steep valley left after glaciers scoured bedrock leaving what is now Anderson Mountain. The valley bottom is geologically-mapped as undifferentiated glacial sediments (see Qgd label in Figure 5). Anderson Creek is small in comparison to the valley width suggesting that the valley was formed during glacial episodes, rather than through fluvial processes alone. Also, the creek has not re-worked all of the glacial deposits on the valley bottom, indicating that the glacial sediments are generally larger than those which can be transported or mobilized by the creek, even though the lower half of the creek receives significantly more surface water contribution than the upper half due to the overall watershed shape.

Anderson Creek is a small alluvial channel that has been modified with past channelization and accelerated erosion due to water supply diversion flows. The channel is shorter than it has been previously, but it is unlikely that the channel ever meandered over the width of the valley under the current climatic regime.

LiDAR topography (2013, Figure 6) also shows alluvial fans forming at each tributary inflow into the lower gradient valley bottom. These alluvial fans control the overall Anderson Creek channel plan form. Anderson Creek itself has formed a delta of coarse sediment into Lake Whatcom. This delta has been modified with the construction of the South Bay Drive bridge. Because of this bridge, the delta has likely narrowed from its historical expanse of over 1,200 feet wide, to an active delta of closer to 500 feet wide today. The focusing of the channel under this bridge has also likely resulted in delta progradation farther into Lake Whatcom over time. A low flow channel has formed through the delta, so it is unlikely that fish access is being blocked with the current delta configuration.

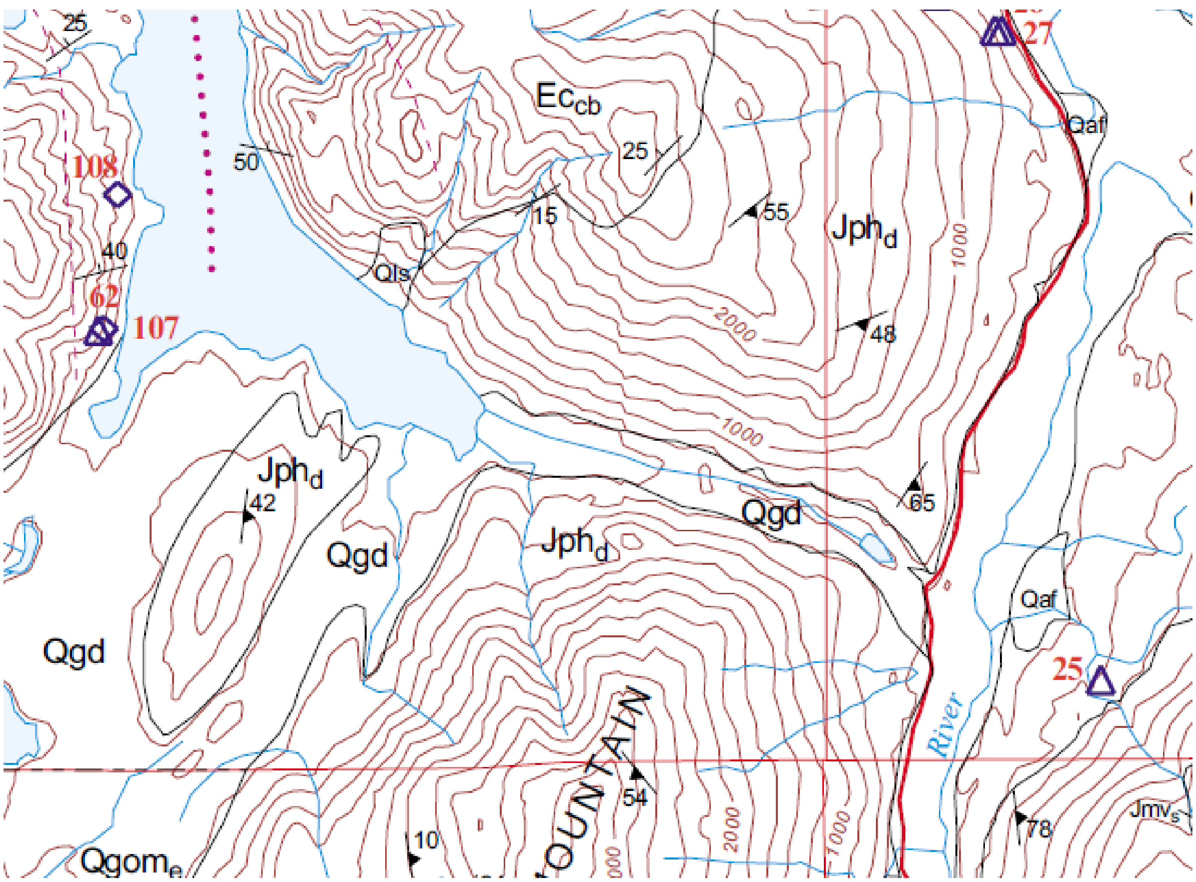


Figure 5 Geologic map of Anderson Creek with Anderson Mountain along the bottom and Lake Whatcom along the left side (Bellingham 1:100,000 Quadrangle, WA DNR)

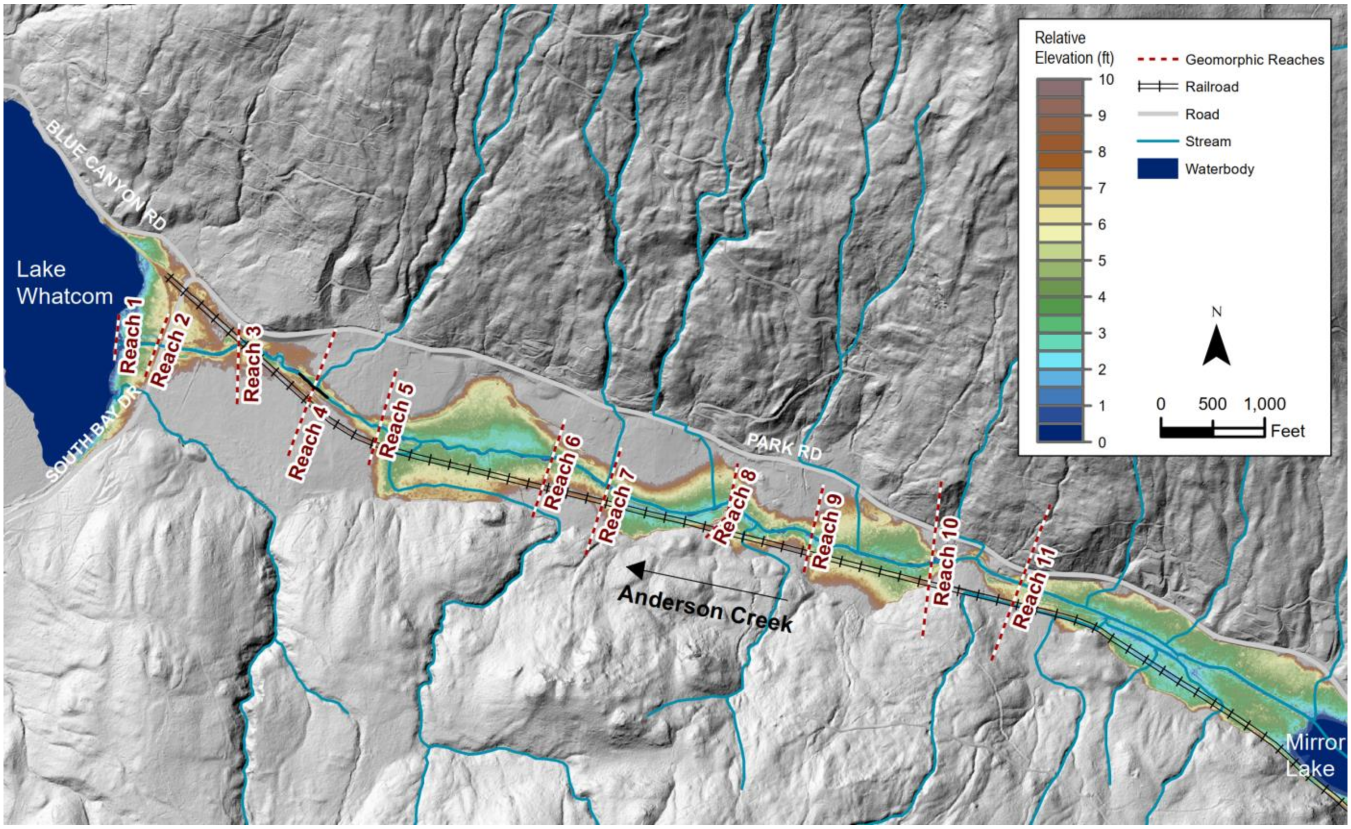


Figure 6. Relative Elevation Map of the Anderson Creek Valley. **Relative elevations are based on the apparent water surface during the 2013 LiDAR data acquisition so the color ramp represents the floodplain elevation compared to the closest channel location.**

Figure 6 depicts all the areas within 10 vertical feet of the Anderson Creek channel. Our hydraulic analysis indicates that this would be the maximum extent of the floodplain inundation. The width of alluvial sediments and creek processes varies through the valley, often controlled by alluvial fans from the steep tributaries. Anderson Creek covers a wide low gradient area downstream of Mirror Lake then is alternately wide then confined between fans in the downstream direction. The railroad berm also limits the extent of the floodplain in Reaches 3 and 4. A longitudinal profile of Anderson Creek is shown below in Figure 7.

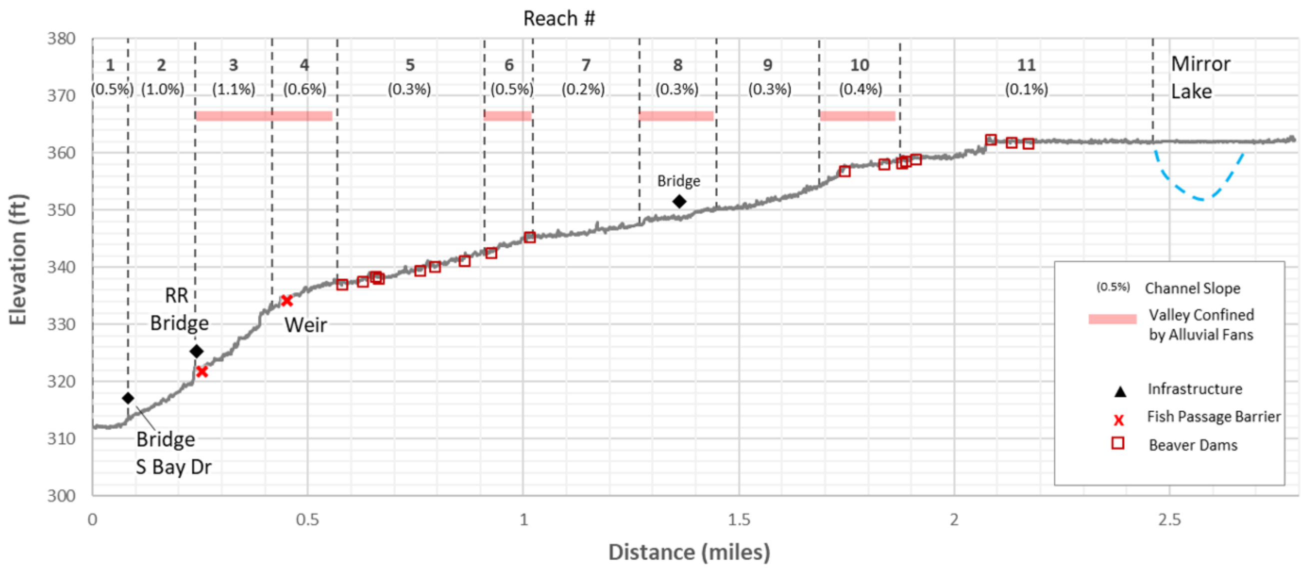


Figure 7. Anderson Creek Longitudinal profile from 2013 LiDAR showing the 11 geomorphic reaches.

As noted in Figure 7, beavers are active throughout the watershed, and have an enduring influence in Reaches 5, 10, and 11. The most active beaver colonies are in Reach 11 below Mirror Lake. Many of the lower dams are not active as of 2018.

2.2.1 Channel Alterations

We recorded a number of direct and indirect channel alterations throughout the watershed. In reaches 1 and 2, fill for old roads and current South Bay Road constrain the floodplain and delta reach. In reaches 3 and 4, fill for the railroad and the railroad bridge and associated rock weir constrain and alter channel morphology. In reaches 5-10 there are old log weirs and two private driveways with old failed bridges. In reach 11, the channel was straightened during the early phases of land conversion on the valley bottom.

Channel incision has occurred in Anderson Creek, resulting in nearly vertical bank angles in places. Channel alterations are greater in the lower three reaches where the active channel is partially confined by the railroad berm.

Only two significant areas of bank erosion were observed during the 2018 surveys, both in geomorphic reach 3 (Figure 8 and Figure 9). In these locations, bank erosion was 3 meters (9 feet) and 7 meters (21 feet) long, respectively. Reach 3 is where the channel is most influenced by the railroad grade, so the channel is likely responding to a combination of past confinement and incision.

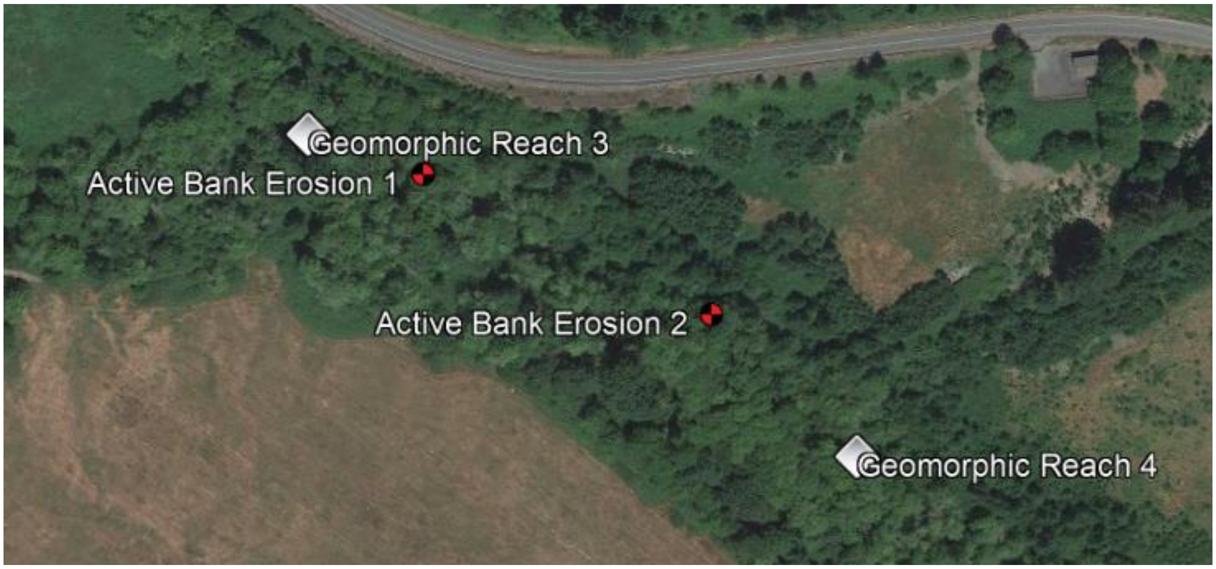


Figure 8 Active bank erosion locations in Anderson Creek geomorphic reach 3.

Figure 9 Photo of one of the active bank erosion locations in Anderson Creek reach 3.

The South Bay Drive bridge over Anderson Creek and downstream channelization have changed the form of the delta, where Lake Whatcom water level management of lowering the lake in the winter and raising it in the summer, allows for delta progradation during the winter low lake stand that is then inundated in the summer.

2.2.2 Future Bank Erosion

Areas of existing bank erosion likely to contribute sediment to Lake Whatcom are limited as noted above. However, the last significant high flow occurred in 2014 so many of the banks have revegetated since the last high flow, and thus the current survey may suggest a higher level of stability than actually exists. As the creek continues to adjust to past incision, additional bank erosion and widening is likely to occur over the coming decades. Bank erosion may also result in proportionally large downstream flux of phosphorus based on the relatively high total phosphorus to total suspended solids relationship reported by Beeler and Mitchell (2017).

To assess the potential magnitude of bank erosion that exceeds a natural background, we used the HEC RAS hydraulic model to evaluate how hydraulics (shear stress versus water depth) will change if the channel were to widen. The intent of the analysis was to determine if the channel is likely to exhibit significant bank erosion due to systemic widening and, if so, identify a reasonably likely eventual channel morphology where additional lateral erosion would return to natural levels.

As part of this analysis, we found that the overall stream power in Anderson Creek is very low in the current condition, so we did not observe a significant change in the flow to shear stress relationship with progressively wider channels. Therefore, while Anderson Creek will continue to naturally erode its banks as it is an alluvial channel, it does not appear that the channel will exhibit accelerated erosion due to widening as it continues to evolve. There will continue to be localized bank erosion, as is evident in Reach 3 (Figure 10), approximately 200 feet upstream of the railroad bridge.

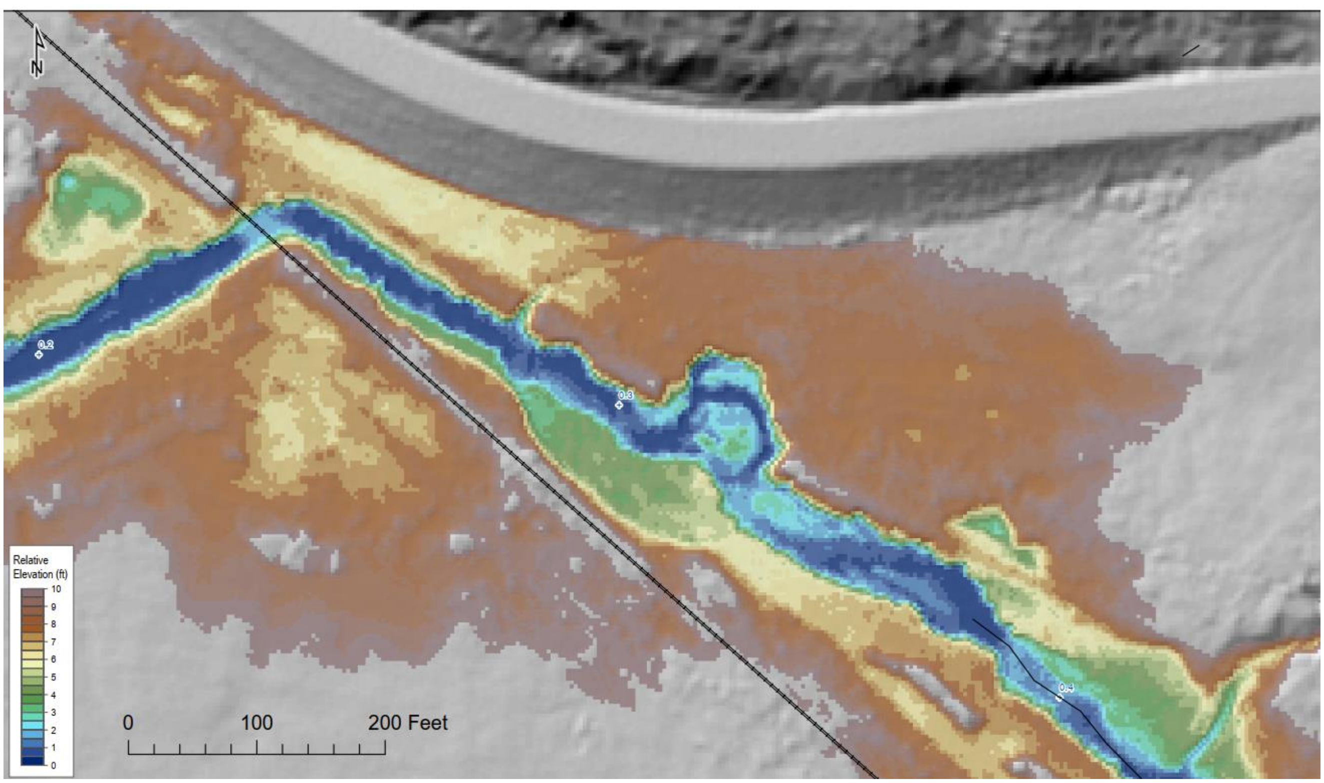


Figure 10. Relative elevation map showing new meander in Reach 3 formed due to erosion of the alluvial fan.

To estimate potential annual erosion volumes, we reviewed the reaches that are more likely to adjust (e.g. steeper slope, narrower existing channel), and estimated rates of retreat based on available historical aerials. Using this approach, we estimate that 15 to 60 CY/year of sediments generated from bank erosions will reach Lake Whatcom. This calculation is likely conservative on the high side, as it assumes that 75 percent of eroded bank sediments will reach the lake.

Using the range of bank erosion volumes, and typical phosphorus concentrations within the soil (see Section 2.5, below), we estimate that an ongoing background level of bank erosion would result in phosphorus loading of between less than 1 percent to 8 percent of the annual phosphorus load from Anderson Creek to Lake Whatcom, depending on the magnitude of the operation of the MF Nooksack diversion.

The influence of the MF Diversion on future bank erosion is anticipated to be limited. The maximum diversion rate is near the natural one year annual peak flow, and, historically, the diversion often occurred during natural low flow periods. Therefore, the diversion does not exacerbate larger (50% annual chance or above) peak flow events that are likely to result in the most bank erosion.

Therefore, phosphorus loading from ongoing bank erosion in Anderson Creek is a minor component of the overall phosphorus loading to Lake Whatcom from Anderson Creek. As such, while overall roughening of the channel with large wood would have other geomorphic and habitat benefits, its effectiveness at reducing phosphorus loading to the lake would be limited.

2.2.3 Geomorphology Summary

1. Anderson Creek's channel has formed within a glacially formed valley and is highly influenced by hillslope inputs and alluvial fans formed along the valley margins.
2. Tributary alluvial fans dominate the alignment of the mainstem Anderson Creek, and tributaries are now intersected by either the railroad or Park Road prior to flowing into the mainstem.
3. We identified 11 geomorphic reaches along Anderson Creek that vary in terms of channel slope, confinement, and channel bed materials.
    a. Reaches that are lower slope and less confined typically have channel forms dominated by beavers.
    b. Steeper sections in the lower third of the watershed have gravel beds.
4. Past channel and floodplain alterations include:
    a. Fill associated with the railroad and South Bay Road
    b. Fill associated with an old road immediately west of South Bay Road
    c. Channel excavation and straightening of the reach below Mirror Pond
    d. Routing of Fir Creek against the southern valley wall and away from the mainstem
    e. Installation of the culvert at South Bay Drive
    f. Log Weirs and pedestrian bridge in Reach 4
    g. RR Bridge and weir at Reach 3

5. Anderson Creek appears to have incised vertically into the valley due to both past manipulations and changed hydrology associated with past the MF Nooksack diversion and land use changes. Therefore, the channel is likely to widen slowly over time, with some evidence that this process is occurring in Reaches 2 and 3.

2.3 Watershed Hydrology and Hydraulics

2.3.1 Streamflows

Flow in Anderson Creek is influenced by both direct rainfall and snowmelt from higher elevations. Rain events drive high flows from November to January, and snowmelt peaks drive high flows in June and July as captured in monthly average flows (Figure 11). Flows in Anderson Creek have been gauged by the USGS. The gauge at the South Bay Road crossing has operated by the USGS from 1969 to 1977 and then from 2007 to present. For 1992 to 2007, Western Washington University's Institute for Watershed Studies operated the gauge.

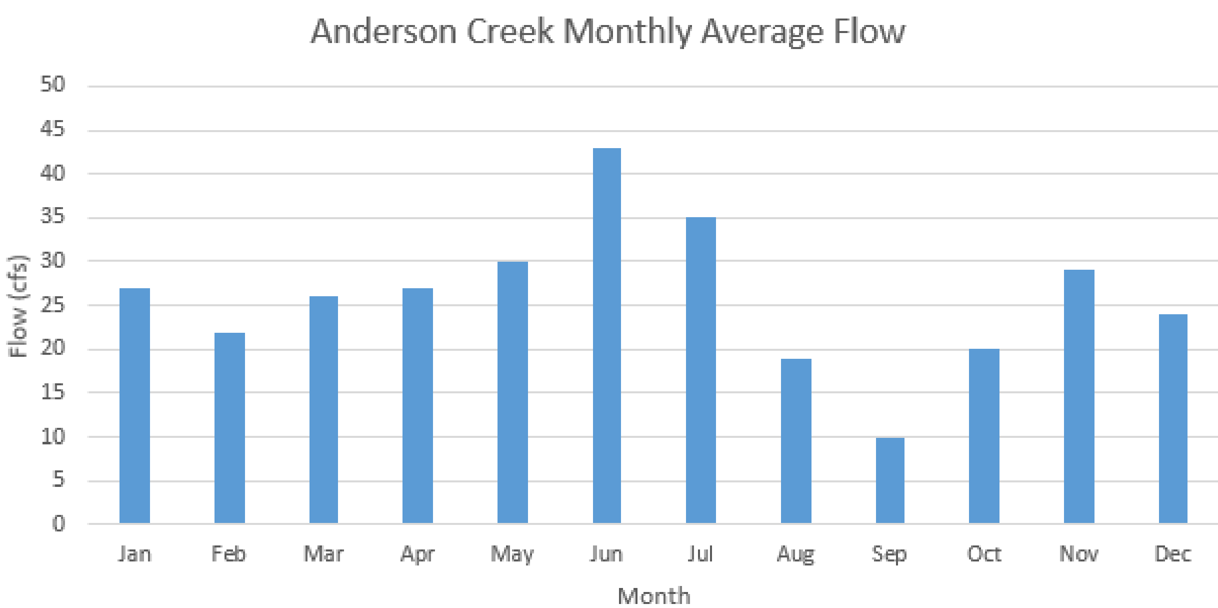


Figure 11 Anderson Creek hydrology shown as average monthly creek flow in cubic feet per second (cfs). Please note that these long-term statistics include diversion flows

For the periods gauged by the USGS, annual peak flows (the highest recorded flow in each year) in Anderson Creek range from about 80 to 400 cfs. These peak flows result from watershed runoff with no or very limited diversion influence. To summarize annual peak flows, we developed a Log-Pearson Type 3 analysis of flood recurrence intervals (Figure 12):

- Annual flood = 100 cfs
- 2-year flood = approx. 150 cfs
- 10-year flood = approx. 275 cfs
- 100-year flood = approx. 500 cfs.

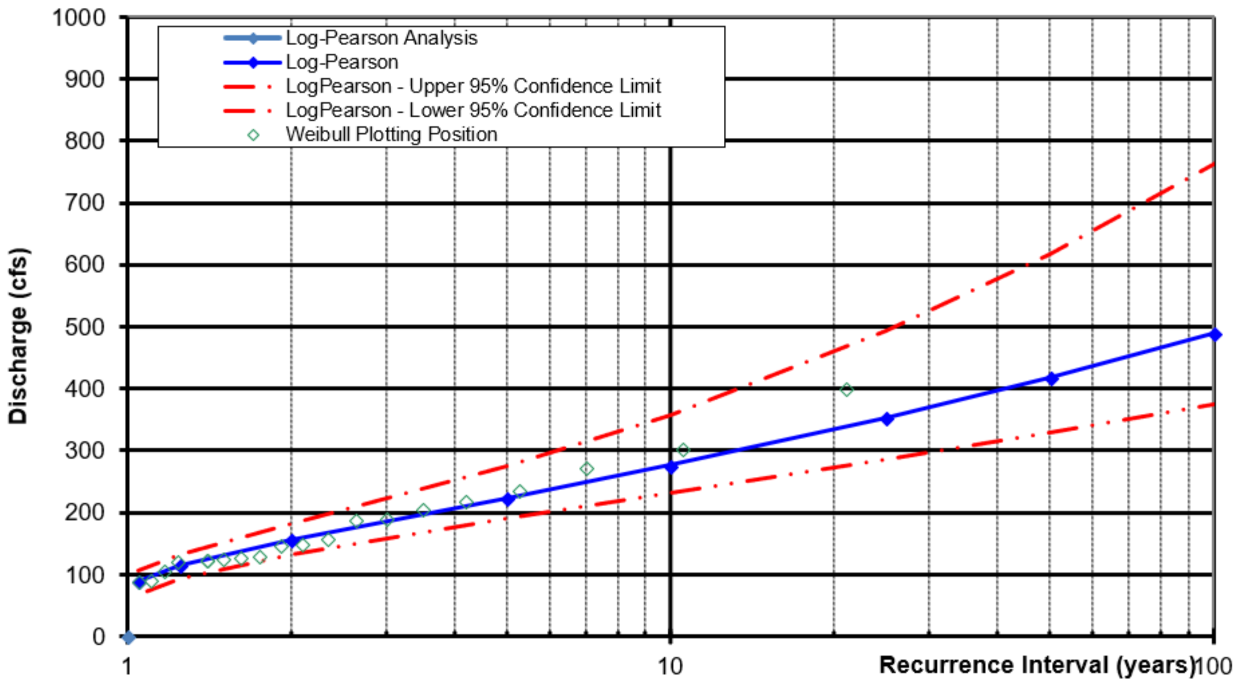


Figure 12 Log-Pearson analysis of flood recurrence intervals for Anderson Creek.

2.3.2 Tributaries

There are 18 mapped tributaries to Anderson Creek using the City's GIS Streams layer (City of Bellingham 2018). Eight of those tributaries on the north side of the valley and six on the south side. A larger named tributary (Fir Creek) now flows directly to Lake Whatcom, but based on the shape and extend of the alluvial fan, historically flowed directly into Anderson Creek in Reach 2 or 3.

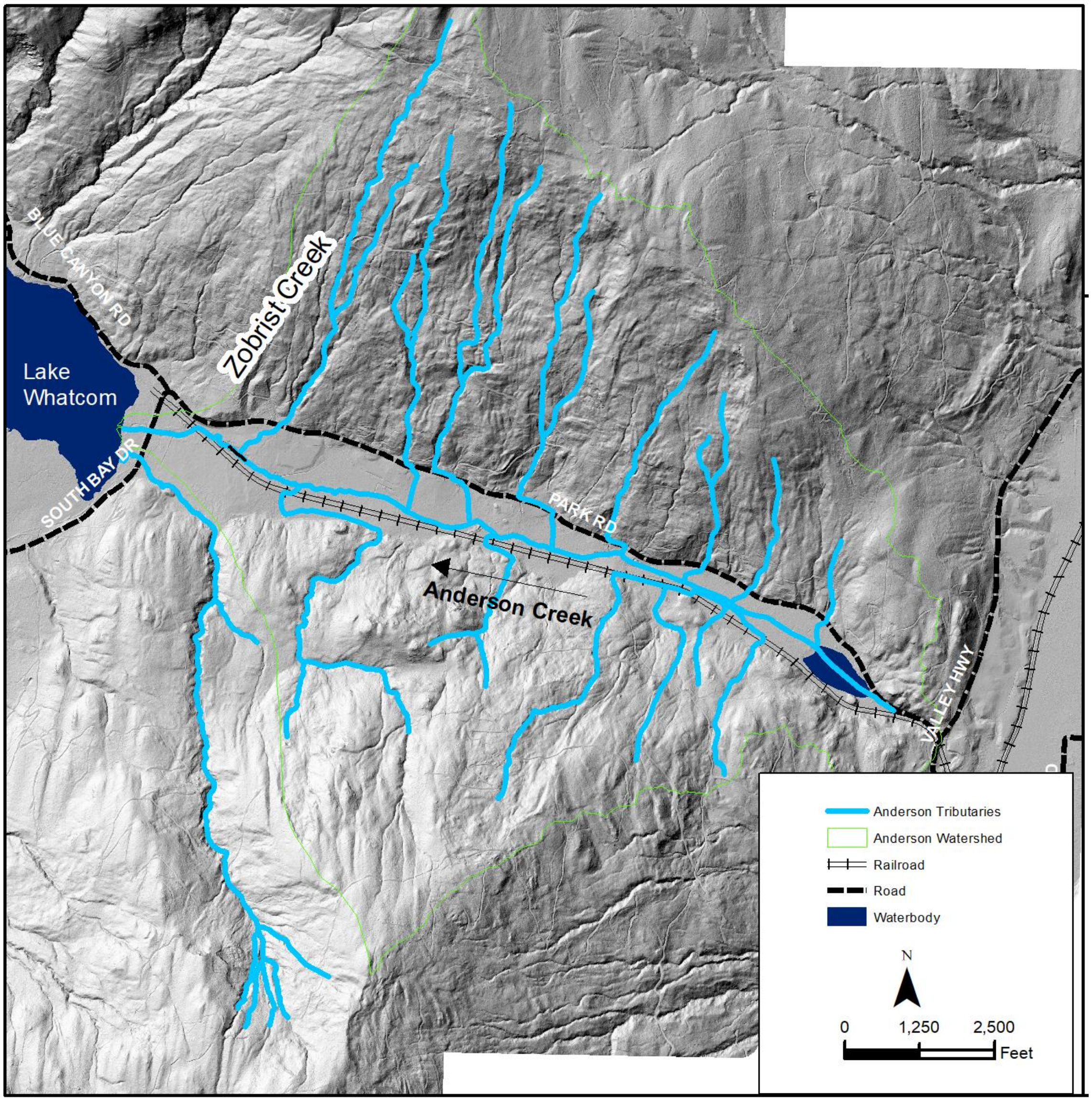


Figure 13. Anderson Creek watershed with mapped tributaries

Tributaries from the north side all pass below Park Road, so drain points are focused at road culverts which then influence how water moves into the floodplain, sometimes redirecting flows along the roadside ditch to new drain points. For example, Zobrist Creek (the most downstream tributary from the north that flows into Reach 3) flows west along Park Road to a culvert, but recently jumped back to a historical channel path, resulting in erosion within the tributary.

2.3.3 Hydraulics

Existing FEMA maps do not depict any regulated floodplain around Anderson Creek. However, they do identify a limited "A" Zone, or 100-year floodplain zone, around Mirror Lake. To further understand the hydraulics of Anderson Creek, we developed a 1D HEC RAS model based on 2013 LiDAR and limited survey data collection. The hydraulic model results suggest that the channel is confined within the banks of the creek, with just a few areas of broad inundation at the 100-year flow. The figures below (Figure 14 and Figure 15) illustrate the variance between confined reaches and reaches with broader inundation at high flows.

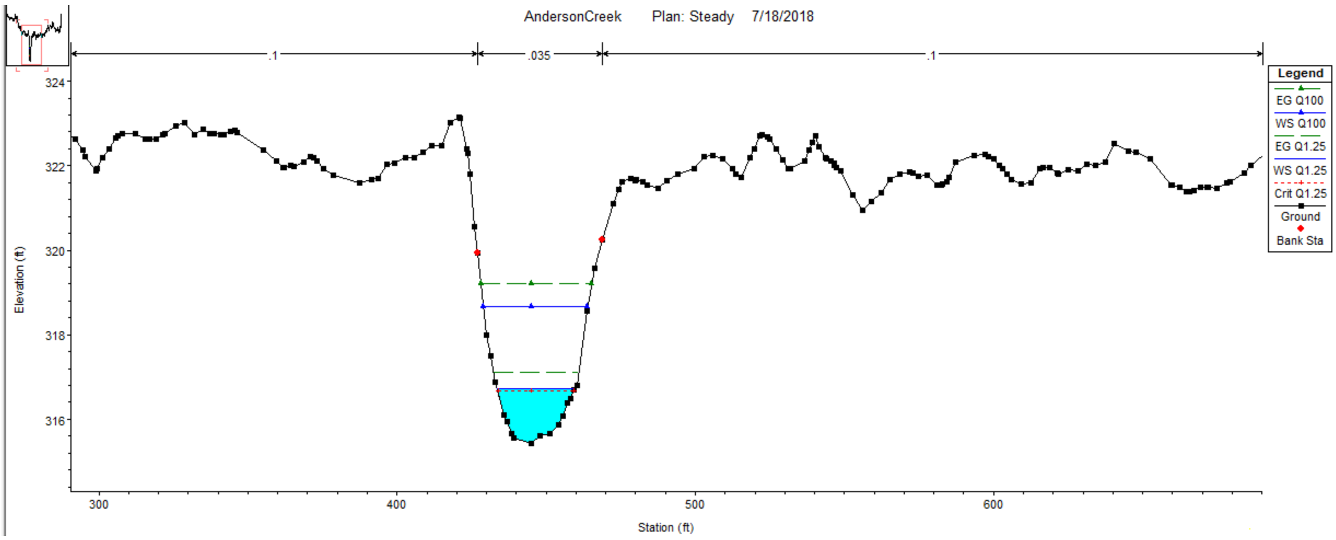


Figure 14. HEC-RAS results in Reach 2 showing the 1.25 year recurrence interval flow (Q1.25) in blue shading and the 100 year recurrence interval flow (Q100) stage in dark blue with triangles. Note that EG = Energy Grade, Crit = Depth at critical flow.

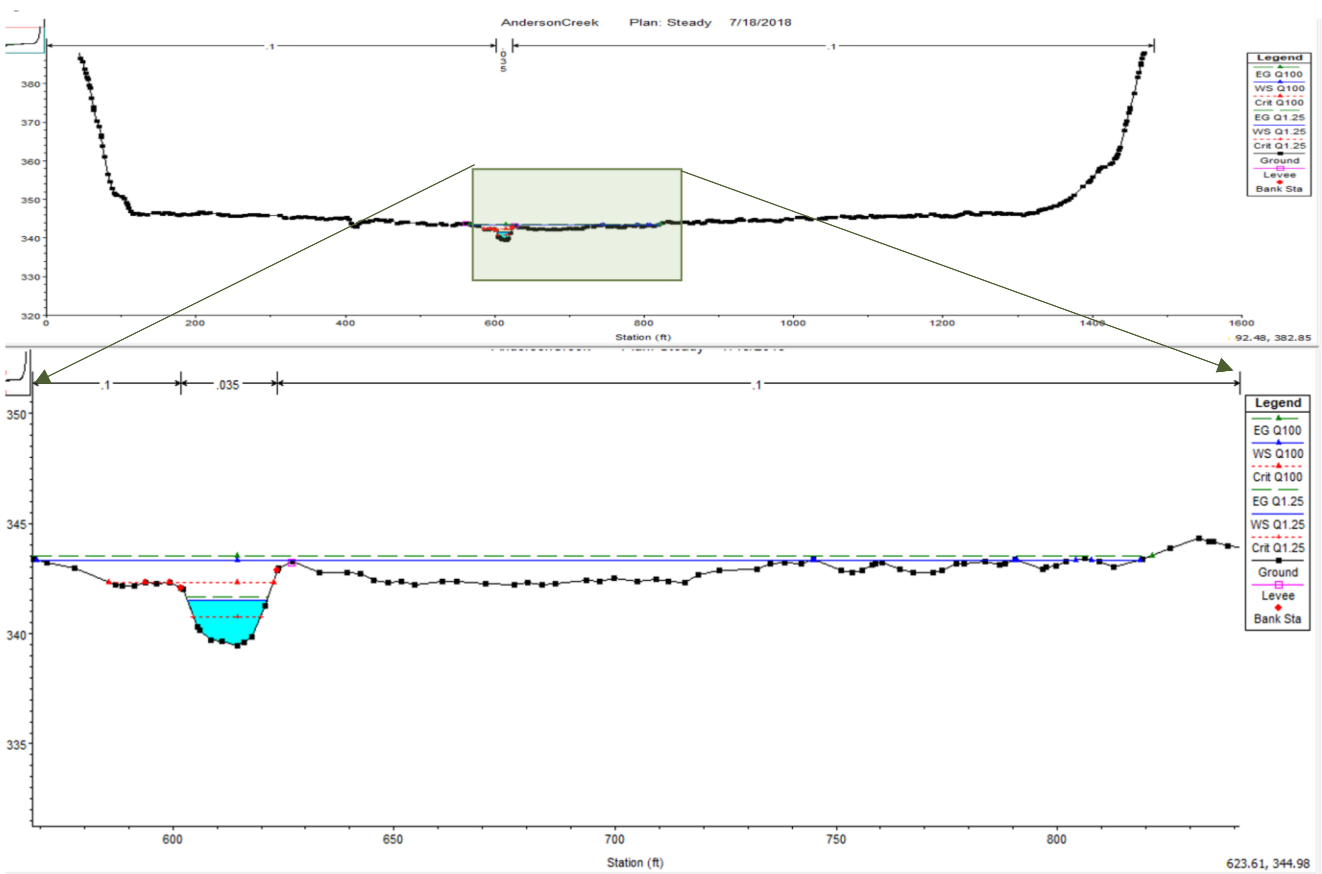


Figure 15. HEC-RAS results in Reach 5 showing broader inundation at the Q100 event.

2.4 Diversion Hydrology

The City of Bellingham has water rights and a diversion system to move water from the Middle Fork Nooksack River (MF Nooksack) to Lake Whatcom via Mirror Lake and Anderson Creek. When operated, the Middle Fork Nooksack River Diversion changes the annual hydrograph of Anderson Creek.

Under the higher diversion operation regime prior to the 1990s, the creek flowed at nearly 100 cfs all summer which is nearly the annual peak flow based on natural watershed hydrology. Therefore, during the full diversion period, the creek was flowing at close to geomorphically significant flows for a long duration. The influence of the diversion appears to have rarely influenced annual peak flows. Although diversion practices prior to the 1990s likely had significant influence on channel form, this influence has reduced with changes in diversion management.

2.4.1 Hydrology and Hydraulics Summary

1. Anderson Creek is a rain on snow and snow dominated system with modest annual peak flows.
2. The shape of the watershed is such that the drainage area substantially increases approximately half way down the channel length; the upper reaches have limited local inflow.
3. Anderson Creek's relatively small size in relation to the glacially carved valley means that floodplain widths are smaller than the overall valley width.
4. The MF Nooksack diversion has the ability to divert a flow to Anderson Creek that is similar to an annual flood event. The early use of the diversion (1960s to 1990s) likely had significant influence on channel form, but this influence has reduced with changes in diversion management.
5. The diversion appears to not have had a significant influence on annual peak flows.

2.5 Anderson Creek Water Quality Overview

Anderson Creek is a major tributary to Lake Whatcom, providing about 10 percent of the average annual inflow to the lake (Greenberg and Crawford 2016). Lake Whatcom is the source of potable water for nearly 100,000 people (Ecology 2016a). About 91 percent of the 2,600-acre Anderson Creek watershed is forested and 5 percent is open space, water, or wetlands. Rural residential land uses cover about 3.5 percent of the watershed (Ecology 2016a).

Anderson Creek water quality has been monitored by the City, Whatcom County, Western Washington University (WWU), and the Washington State Department of Ecology (Ecology). Water quality concerns include phosphorus, fecal coliform bacteria, and temperature. Dissolved oxygen (DO) has been identified as a potential concern based on limited monitoring in 2003 and 2005 (Ecology 2016b).

2.5.1 Phosphorus

Long-term monitoring by WWU found that DO concentrations in Lake Whatcom were declining over time. Ecology determined that excess algae growth triggered by phosphorus loading is the main cause for declining DO in the lake. In 2014, Ecology established a Total Maximum Daily Load (TMDL) for DO in Lake Whatcom. The DO TMDL requires reductions in total phosphorus loads from all tributaries including Anderson Creek.

The TMDL study estimated that the Anderson Creek watershed contributed about 585 pounds of total phosphorus load to Lake Whatcom during 2003, the base year for the TMDL study. Ecology estimated that about 7 percent of the total phosphorus load to Lake Whatcom during 2003 came from the Anderson Creek watershed. The TMDL study determined that the phosphorus load from the developed portion of the Anderson Creek watershed needs to be reduced by about 66 lbs/year, assuming base year (2003) hydrologic conditions (Ecology 2016a).

Figure 17 shows the total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations in stormwater and baseflow samples collected from Anderson Creek by the City, Whatcom County, and WWU collected stormwater and baseflow samples between June 2007 and May 2018. As shown in the figure, total phosphorus concentrations were much higher than soluble reactive phosphorus concentrations, indicating that most of the phosphorus is in particulate form. This is consistent with other recent studies that found most of the phosphorus load to Lake Whatcom enters the lake adsorbed to suspended sediments from creeks (e.g., Beeler and Mitchell 2017).

Figure 17 also shows that total phosphorus concentrations were considerably higher in stormflow as compared to baseflow samples, while soluble reactive phosphorus concentrations in stormflow samples were similar to baseflow concentrations. This pattern indicates that the increase in total phosphorus during storm events is attributable to particulate rather than dissolved phosphorus.

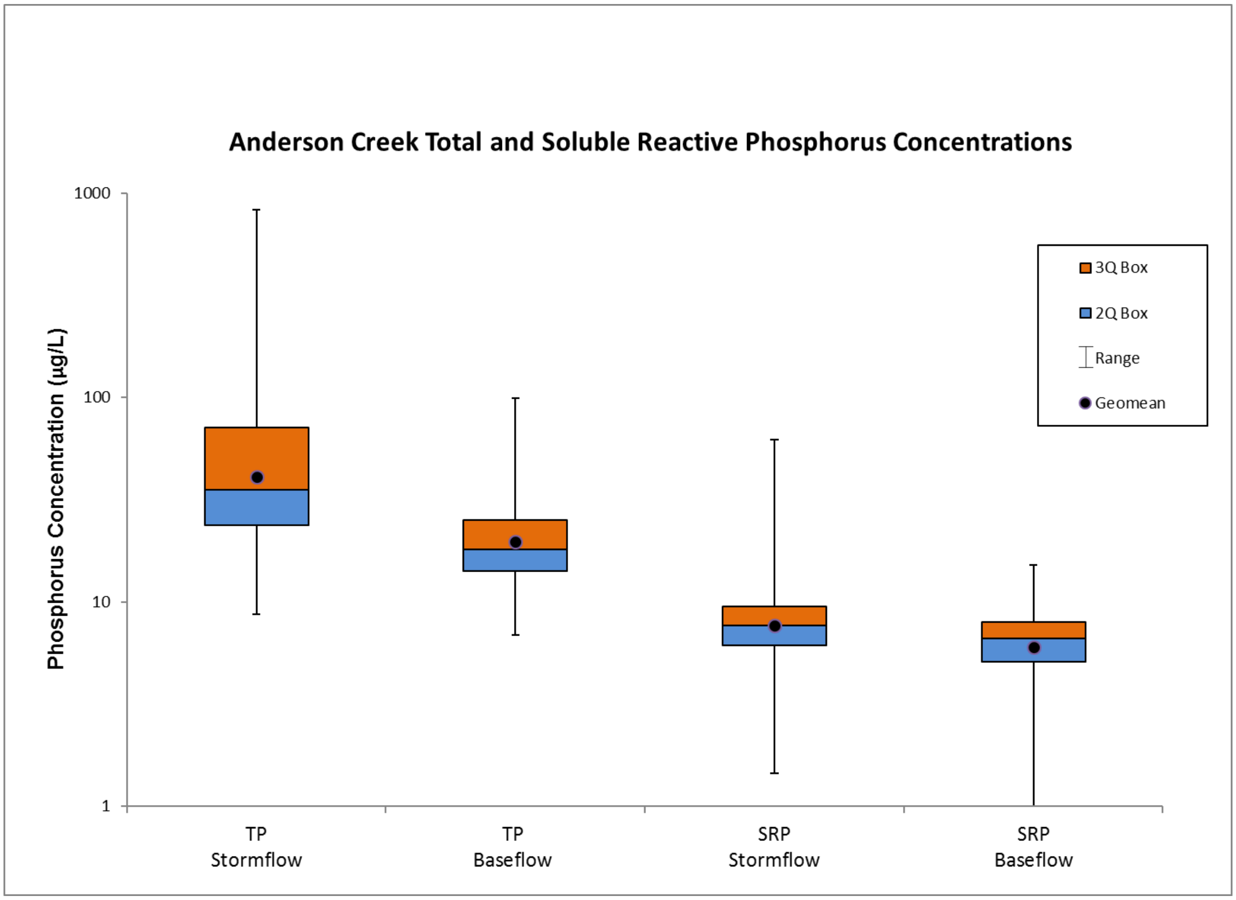


Figure 16. Phosphorus Concentrations in Anderson Creek (*note log scale*)

The available land use/land cover data and field observations indicate that the elevated phosphorus load in Anderson Creek is related to non-point sources. Potential anthropogenic phosphorus sources include accelerated soil erosion, domestic animals, septic systems, and bank erosion, as discussed below.

- Soil Erosion. As noted above, most of the phosphorus observed in creek water samples is in particulate form, and concentrations increase substantially during storm events. Ecology's TMDL study estimated that most of the phosphorus load in Anderson Creek is from the forest lands that cover more than 90 percent of the watershed. However, Ecology estimated that the developed areas contribute more phosphorus per acre than the forested areas of the watershed. Development often increases soil erosion rates/sediment yields as compared to pre-developed conditions due to loss of tree canopy and forest floor, soil disturbance by landscaping and construction activities, soil compaction, increased surface runoff, and other factors.

  A 2011 study of phosphorus in the Lake Whatcom watershed soils (including the Anderson Creek basin) found median TP concentrations ranging from 619 to 959 mg/kg (or ppm) (Groce 2011). Beeler and Mitchell (2017) found relatively high ratios of total phosphorus to total suspended solids in Anderson Creek, which they suggested could be attributable to lateral erosion of stream channels in lower relief pasturelands and wetlands.

- Domestic Animals. Domestic animals can contribute phosphorus to creeks by increasing soil disturbance and erosion. If they have direct access to the creek, they can also contribute phosphorus through fecal contamination and bank erosion.
  The valley portion of the Anderson Creek watershed is zoned rural residential, which allows up to nine domestic animal units per five-acre lot. Direct access to the creek is limited because the City owns the riparian corridor, but domestic animals could contribute to erosion of small tributary channels. No domestic animals were observed during the site visits conducted for this study.

- Septic Systems. The Anderson Creek watershed contains a small number of septic systems. Septic systems can be phosphorus sources in some situations, such as surface failure of a system located near a water body or man-made conveyance structure (e.g., storm drain). Subsurface transport from septic systems is typically quite limited because phosphorus is strongly retained in the soil. The septic systems in the Anderson Creek watershed are located well away from the creek, so they are unlikely to contribute appreciable phosphorus to the creek.

- Bank erosion. Bank erosion along Anderson Creek is estimated to contribute 15 to 60 cubic yards of sediment to Lake Whatcom each year (see Sec. 2.4 above). Assuming the eroded sediment contains the average soil phosphorus concentration measured by Groce (2011), bank erosion could contribute 21 to 84 pounds of phosphorus to the annual load at the mouth of the creek. To put this in perspective, Ecology's TMDL study estimated that the Anderson Creek watershed contributed about 585 pounds of phosphorus to Lake Whatcom during the 2003 base year (Ecology 2016a).

In summary, the available data suggest that erosion is the predominant source of phosphorus loading in the Anderson Creek watershed. Most of the load is from the forested areas that cover more than 90 percent of the watershed, but the developed areas contribute more phosphorus per acre.

2.5.2 Fecal Coliform Bacteria

During development of the DO TMDL, Ecology found that fecal coliform concentrations in Anderson Creek and several other tributaries exceeded state water quality criteria for protection of recreational uses. Therefore, Ecology established a TMDL to reduce fecal coliform concentrations in these creeks (Ecology 2016a).

Figure 18 shows the fecal coliform concentrations in storm event and baseflow samples collected from Anderson Creek by the City, Whatcom County, and WWU during 2007–2018. Table 1 below compares the results to the TMDL targets. As shown in the table, fecal coliform concentrations exceeded the TMDL targets.

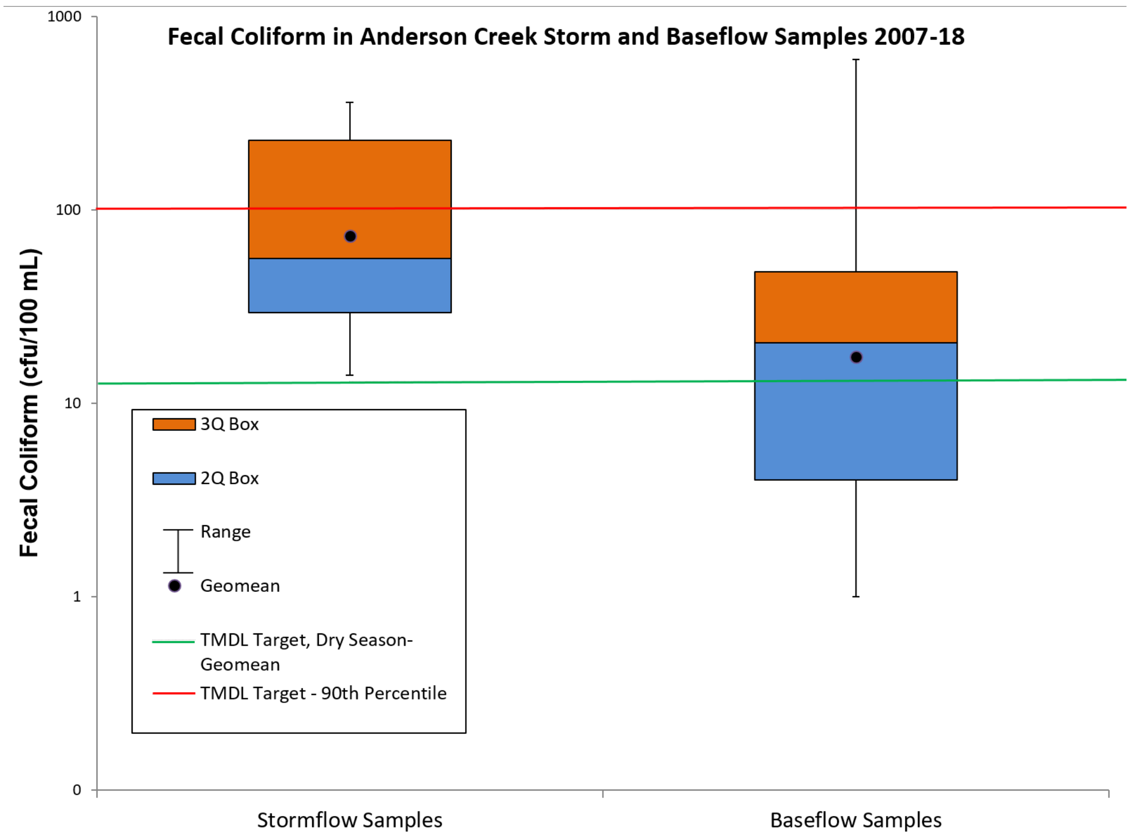


Figure 17. Fecal Coliform Bacteria in Anderson Creek Storm Event and Baseflow samples (2007–2018)

Table 1. Bacteria TMDL Targets and 2007–2018 Sampling Results for Anderson Creek

TMDL Targets for Fecal Coliform				2007–2018 Fecal Coliform Sampling Results			
Wet season targets		Dry season targets		Storm sample results		Baseflow sample results	
Geometric mean (cfu/100 mL)	90th Percentile (cfu/100 mL)	Geometric mean (cfu/100 mL)	90th Percentile (cfu/100 mL)	Geometric mean (cfu/100 mL)	90th percentile (cfu/100 mL)	Geometric mean (cfu/100 mL)	90th Percentile (cfu/100 mL))
50	100	13	100	73	312	19	123

cfu = colony forming units; mL = milliliter

In January 2019, the State of Washington revised the water quality criteria for protection of recreation uses to be consistent with EPA guidelines. The revised criteria use *E. coli* as the indicator bacteria for fresh water recreational uses, instead of fecal coliform. Under the revised criteria, all fresh water bodies are designated for primary contact recreation, so one set of *E. coli* criteria applies to all fresh water bodies in the state. The new *E. coli* criteria call for a geometric mean concentration less than 100 colony forming units per 100 milliliters (cfu/100 mL) and no more than 10 percent of samples above 320 cfu/100 mL (Washington Administrative Code [WAC] 173-201A). Considering that *E. coli* is a type of fecal coliform bacteria, the new criteria appear to be less stringent than the criteria in effect when Ecology developed the TMDL for Anderson Creek and other tributaries to Lake Whatcom.

Potential fecal bacteria sources include septic systems, domestic animals, and wildlife, as described below.

- Septic systems. Fecal coliform bacteria from properly functioning septic systems rarely travel very far in the subsurface. For example, a recent study of the Spanaway watershed of Pierce County estimated a maximum horizontal travel distance of 350 feet in an area with highly permeable soils and shallow groundwater (Pierce County and Brown and Caldwell 2017). Discharges from failed septic systems (i.e., systems where the drainfield is clogged such that untreated sewage is present on the ground surface) are a potential source because such discharges can contain high concentrations of fecal bacteria. Septic systems are unlikely to be a significant source to Anderson Creek, however, because the septic systems are widely dispersed and located well away from the creek.
- Domestic animals. Fecal matter from domestic animals is another potential source of fecal coliform to the creek. Direct contamination of the mainstem is unlikely because access is limited by fences and dense riparian vegetation. However, tributaries flowing through pasture lands could contain elevated fecal bacteria concentrations due to domestic animals.
- Wildlife. Wildlife is a likely source of the observed fecal bacteria in Anderson Creek. The creek and adjacent riparian area provide habitat for beavers, birds, and other wildlife species.

In summary, the available water quality and land use/land cover data suggest that wildlife is probably the main source of fecal coliform in Anderson Creek. Based on the existing fecal coliform data, it is possible that Anderson Creek meets the recently revised state water quality criteria for recreational waters.

2.5.3 Temperature

Anderson Creek is designated as core summer salmonid habitat. The state water quality criterion (WAC 173-201A-200) for core summer salmonid habitat requires that the 7-day average of daily maximum temperatures (7-DADMax) cannot exceed 16 degrees Celsius (°C).

Ecology's 2016 Water Quality Assessment listed Anderson Creek as "Impaired" (Category 5) for temperature. The listing is based on elevated water temperatures measured during 2004 and 2005 (Ecology 2016b).

Warming in Mirror Lake can increase the water temperature in Anderson Creek downstream of the lake. Lake water temperatures can exceed the numerical criteria due to natural conditions (e.g., long hydraulic residence time and large unshaded surface area). Therefore, the state water quality criteria require that human actions considered cumulatively may not increase the 7-DADMax by more than 0.3°C above natural conditions. Modeling is often required to estimate water temperature increases attributable to human actions.

Immediately downstream of Mirror Lake, Anderson Creek flows through reed canarygrass with little shade. Downstream of the reed canarygrass reach, most of the Anderson Creek riparian corridor is forested, providing valuable shade for the creek. As described in Section 2.7 below, much of the riparian forest canopy is comprised of red alder trees that are nearing the end of their life spans. The understory is dominated by dense shrubs with few young trees. Creek temperatures could rise after the alders die if the shrubs out-compete the young trees, resulting in less shade for the creek.

2.5.4 Dissolved Oxygen

Ecology's 2016 Water Quality Assessment listed Anderson Creek as a "Water of Concern" (Category 2) for dissolved oxygen (DO). The Category 2 listing is based on limited monitoring conducted during 2002–2005, which found two of 35 samples with DO concentrations less than 9.5 mg/L (Ecology 2016b).

DO in Anderson Creek could be affected by a number of factors including water temperature, turbulence, aquatic plants, and sediment oxygen demand. Elevated water temperature can reduce DO concentrations because warm water cannot hold as much oxygen as cold water. Turbulence increases DO by bringing more water into contact with air. Aquatic plants and algae can increase DO during the day when photosynthesis is occurring and reduce DO at night when respiration is occurring. Decomposition of plant detritus and other organic matter in bottom sediments can reduce DO in the water column.

Additional monitoring would be needed to determine whether Anderson Creek is meeting the state water quality criterion for DO. Water quality modeling would be needed to evaluate the factors affecting DO in the creek. Based on the limited existing information, elevated water temperature and lack of turbulence could be important factors affecting DO in Anderson Creek.

2.5.5 Water Quality Summary

1. The relatively limited amount of land use conversion and low density of land use result in a modest increase in phosphorous and bacteria loading to Anderson Creek compared to predeveloped conditions.
2. The county roads within the valley bottom do not include stormwater treatment. The road's typical distance to the main channel and relatively low traffic volumes suggest that the overall loading from the road is low to moderate. Further, pollutants generated from roads are not typically phosphorus or bacteria.
3. For temperature and dissolved oxygen – current conditions are good, primarily due to consistent riparian cover. Therefore, maintaining cover and shade should be a high priority. Warmer temperatures and lower dissolved oxygen occur in Mirror Lake and could be exacerbated at least temporarily with the use of the MF diversion.
4. For Phosphorus – the general background sources of phosphorus appear to be low, consistent with the TMDL findings. Erosion from the watershed, in the tributaries, and along channel banks are and will continue to be sources, but avoiding excess erosion due to hydrologic alterations (e.g. stormwater in tributaries) would reduce overall loading.
5. For fecal coliform - levels are generally low, and the current primary source (with the reduction in livestock over the years) is likely wildlife.

2.6 Instream Habitat

Anderson Creek and Lake Whatcom support a variety of fish and wildlife including native populations of Kokanee salmon (*Oncorhynchus nerka*) and cutthroat trout (*Oncorhynchus clarki*). Kokanee spawning occurs in Anderson Creek and five other tributaries to Lake Whatcom (http://salmonwria1.org/webfm_send/15), although numbers declined from 20,000 in 1974 to only 100 spawners in 1998. Lakeshore spawning also occurs in Lake Whatcom in isolated areas where gravel is sufficient (http://salmonwria1.org/webfm_send/15).

A 1998 Lake Whatcom watershed analysis performed by the Washington Department of Natural Resources reported that shoreline spawning occurred near the South Bay hatchery, but had not been observed elsewhere (WADNR 1998). Native Kokanee salmon from Lake Whatcom serve a broodstock for the Washington State Brannian Creek Hatchery, which has been functioning for over 100 years, and is one of the oldest operating hatcheries in Washington State.

A genetically distinct, adfluvial coastal cutthroat trout population native to Lake Whatcom are believed to have evolved from post-glacially isolated sea-run cutthroat populations. 50,000 Lake Chelan cutthroat fry were stocked in Lake Whatcom in 1901 and may have hybridized with native populations. Adfluvial populations spawn and rear in rivers/streams and then migrate to lakes for their adult years. Cutthroat are known to spawn in the lower reaches of Anderson Creek, although the most significant cutthroat producing tributaries in the Lake Whatcom watershed are Austin, Beaver, Carpenter, Olsen and Smith Creek (WADNR 1998). The cutthroat trout fishery in Lake Whatcom is managed by the Washington Department of Fish and Wildlife. Fishing for cutthroat is currently closed. WDFW attributes the decline in cutthroat abundance and subsequent fishing closure to siltation from logging and urban activities in spawning tributaries (https://wdfw.wa.gov/fishing/washington/128/).

Adfluvial coastal cutthroat trout juveniles typically rear for one to two years in tributary habitats before outmigrating to lakes or mainstem rivers (Johnston 2001 a). Pools provide critical rearing habitat for cutthroat juveniles in winter months and serve as low flow refugia in the summer (WADNR 1998).

Spawning activities for both Kokanee and adfluvial cutthroat trout largely occur in the lower reaches of tributary streams. Therefore, concerns surrounding spawning gravel availability and embeddedness are of particular importance for pool tail crests in the lower, unimpounded reaches.

Spawning lamprey observed during field reconnaissance

Example of Anderson Creek pool currently in poor to fair condition, from reach 5.

We collected physical habitat data in the free-flowing (e.g. not impounded by beaver dams) portions of Anderson Creek. We developed the sampling to focus on instream habitat that will influence fish use, specifically pools and spawning gravels available to Kokanee and cutthroat trout.

Individual pools were identified and categorized by geomorphic reach:

- There are approximately 90 pools in Anderson Creek. Approximately a third of the pools are in good condition based on having clean spawning gravels over 50 percent of the tailout.
- Pools forced by beaver dams are the most common form.
- Pools are most common in Geomorphic Reaches 3 and 5, notably upstream of the railroad bridge. In Reach 3, pool formation is related to higher channel slope and in Reach 5, pools are typically forced by beaver dams.
- Pool tail outs include appropriate spawning gravel, particularly in the higher gradient reaches.

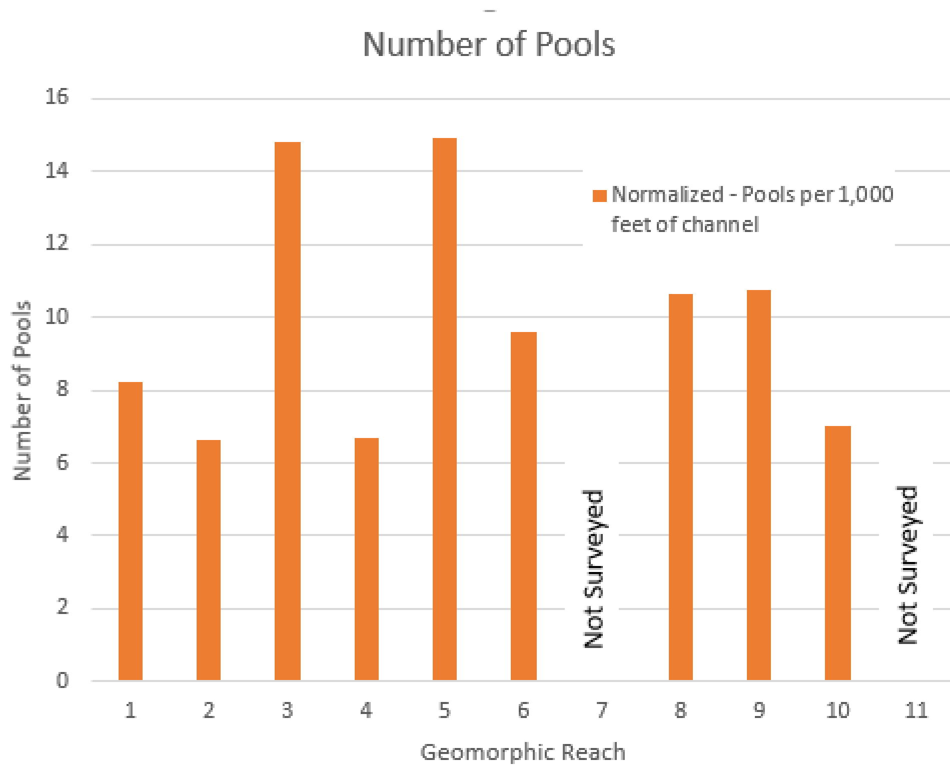


Figure 18. Normalized number of pools/1,000 feet of channel in Anderson Creek

Spawning gravel availability survey identified:

- 0.5 acre of clean spawning gravels, which is less than presumed reference conditions
- 0.3 acre of 30% or more embedded gravels.
- Approximately 46% of clean spawning areas and 60% of embedded gravels were located above the railroad bridge.

In-channel large wood survey found:

- Abundant small wood in the channel, typically >0.2 meters in diameter and less than 10 meters long, was found throughout the upper reaches, all of which appeared to be alder.
- Only two small alder wood jams, one of which was likely part of a relict beaver dam.
- No key pieces of wood and no conifer large wood pieces.

Full results of the instream data collection are illustrated in Appendix A and with data characterization presented in Appendix B.

2.6.1 Habitat Alterations and Fish Passage

A lack of Large Woody Debris (LWD) components has been documented in most Lake Whatcom Tributary stream segments in both high and low gradient stream reaches. Quality pool habitat in the upper reaches of Anderson Creek would most notably benefit cutthroat populations, as Kokanee fry out-migrate within days of emergence and do not use the upper reaches of Anderson Creek for rearing. Our surveys did not encounter any key pieces of wood, and very limited instream wood in general.

The loss of stable and complex spawning areas has been partially attributed to low large wood abundance in spawning tributaries, and has been called out as a primary reason for Kokanee decline in Lake Whatcom, as well as premature displacement of year-class cutthroat into the lake (WDNR 1998). Cementation of spawning gravel by fine sediments in low gradient reaches is of particular concern for small bodied salmonids such as Kokanee and cutthroat trout, who have to expend greater effort to excavate redds in embedded substrate (WDNR 1998). The Washington Department of Fish and Wildlife lists “siltation from logging and urban activities in…spawning tributaries" as the primary reason for the current fishing closure for resident coastal cutthroat trout in Lake Whatcom (https://wdfw.wa.gov/fishing/washington/128/). Increased complexity, cover, access to, and spatial extent of clean spawning gravels in the lower reaches of Anderson Creek would improve instream conditions for spawning.

We noted the following features that limit fish passage in Anderson Creek:

- The South Bay Drive bridge is narrow, so influences velocity and channel form. It is only a partial barrier to fish passage, likely for velocities at higher flows.
- The railroad bridge is a partial barrier, primarily due to a rock weir that has a greater than 0.8-foot drop which will limit juvenile fish migration.
- Log weirs in Geomorphic Reach 4 also limit fish passage; one of the weirs has a greater than 0.8-foot drop so will limit juvenile fish migration.
- Other relict access points including small bridges occur that present minor barriers to passage.

2.6.2 Diversion Flow and Effect on Fish Use and Instream Habitat

We also assessed how potential diversion practices relate to fish usage, in particular Kokanee. As context, the following is a summary of Kokanee periodicity in Anderson Creek:

- **August to January** Kokanee spawn in Anderson Creek.
  - Historically, Kokanee spawned as late as February in Lake Whatcom tributaries. However, intense selection for early run fish by the hatchery drastically reduced late-run Kokanee in the 1950’s. According to the 1998 watershed analysis performed by the Washington Department of Natural Resources, spawning occurs August-January, with peak spawning occurring October-early December (WDNR 1998). A more recent document produced by the WRIA 1 Salmon Recovery Program describes spawning as occurring between August and November (https://www.cob.org/Documents/pw/lw/FactsAboutLakeWhatcomKokanee.pdf) Kokanee eggs develop in the gravel from December through February. If possible, diverting water at flows that could scour the bed should be avoided during this critical time. The risk of redd scouring naturally remains significant during these months due to storms.
  - **March to April:** Kokanee fry emerge from the gravel and outmigrate to Lake Whatcom.
    - Diversion operations during this time present a lower risk to Kokanee, although slow ramp ups remain preferable over high intensity pulses.
  - **May to July:** Kokanee are not utilizing the stream and this is the lowest risk timeframe to divert water to Anderson Creek.

For Coastal Cutthroat Trout, the periodicity within Anderson Creek includes:

- **January to May**: Cutthroat spawn in Lake Whatcom tributaries (Figure 19)
- **March to July**: Cutthroat fry emerge from the gravel
- **Year round**: Cutthroat rear in freshwater tributaries for 1-2 years before outmigrating to lake or staying in Anderson Creek.

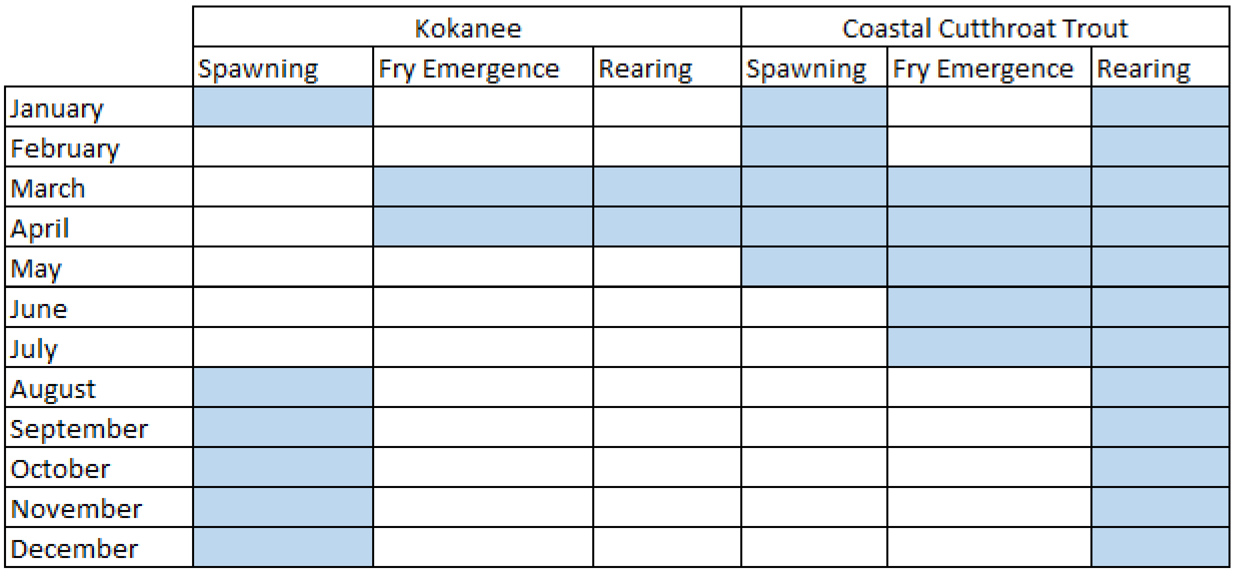


Figure 19. Fish use periodicity chart for Kokanee and Coastal Cutthroat Trout

If flow rates are significant enough to mobilize the streambed, then redds (salmon spawning nests in the channel bed) could be disrupted. Our hydraulic model indicates that D50 sediment (22mm) can be mobilized at 18 cfs, a flow that occurs throughout the year. Kokanee utilize 13-102 mm gravels while spawning. The MF Nooksack diversion has the potential to increase flows to a point that will mobilize the bed and increasing the risk of redd scour.

Bed mobilization is exacerbated with the lack of large wood in the system. The presence of large wood partitions shear stress, meaning that some of the energy that would have gone into transporting bed sediments is diffused by the large roughness elements (Manga and Kirchner, 2000).

2.6.3 Instream Habitat Summary

1. Existing instream habitat provides suitable fish habitat, particularly for Kokanee in Reaches 1-4. Spawning gravels are suitable for Kokanee and cutthroat trout and these areas are more prevalent in the lower reaches of the stream where greater stream power helps maintain clean gravels.
2. The type of instream habitat varies with gradient and degree of impoundment by beavers. Beavers are highly effective at impounding the upper reach below Mirror Lake. Therefore, conditions for salmonid spawning are more favorable lower in the watershed.

3. Redd scour is likely a limiting factor for salmonids in Anderson Creek given the fine streambed sediments. Redd scour could occur either during natural peak flow events or from MF Diversion flows, or a combination thereof.

4. A number of partial barriers to fish passage exist generally in Lower Anderson Creek. The railroad berm and old log weirs may present an upstream passage barrier for juvenile fish, and occur downstream of almost half of the suitable spawning gravels in Anderson Creek. The culvert on S. Bay Road constricts the channel, so presents at least a velocity barrier at times, but is not a full fish passage barrier.

2.7 Riparian Habitat Overview

2.7.1 Existing Riparian Conditions

As a part of the field reconnaissance to develop restorative actions for Anderson Creek, we reviewed the composition of the riparian forest for 150 feet to either side of the creek centerline, visually inspecting about 131 acres adjacent to the creek.

To further understand the ecological condition of the riparian area, we classified it into five distinct vegetation types, based on the US National Vegetation Classification (USNVC.org) framework:

1. Red Alder / Salmonberry Riparian Forest (55 ac, 42%)
2. Red Alder / Big Leaf Maple Forest (42 ac, 32%)
3. Red Alder / Willow / Spirea Wet Shrubland (28 ac, 21%)
4. Red Alder / Bigleaf Maple / Conifer Forest (5 ac, 4%)
5. Reed canarygrass dominated (0.8 ac, 0.6%)

Red Alder / Salmonberry Forest at Anderson Creek (2018)

Red Alder – Bigleaf Maple Forest at Anderson Creek (2018)

Red Alder / Willow / Spirea Wet Shrubland

Western red cedar along Anderson Creek (2018)

For the majority of its length, Anderson Creek's riparian corridor is fairly high-functioning and forested, providing valuable shade for the creek. We found that this riparian corridor area is 78% native deciduous or mixed forest, 21% scrub-shrub wetland, and about 0.6% invasive reed canarygrass (Appendix C). Himalayan blackberry was also noted throughout the corridor.

Approximately 5.4 acres of red alder / bigleaf maple / conifer forest was mapped in the Anderson creek corridor. These areas likely represent reference conditions for the mixed coniferous and deciduous forests that the current red alder riparian forests have replaced. Red alder tends to be the dominant broadleaf species, although bigleaf maple is codominant in some areas. Western red cedar and Sitka spruce are the main conifers comprising the canopy layer. Understory shrub density is reduced in comparison to the two broadleaf dominated forest types, with a more prevalent herb layer. Understory shrub species include salmonberry, thimbleberry, red elderberry, Indian plum and red osier dogwood.

Despite the current high level of functioning of the riparian corridor, the deciduous forest is aging and generally does not include establishing conifers. Much of the canopy is currently comprised of red alder trees, which are senescing and reaching the end of their lifespan. The source of coniferous seed has largely been extirpated from the valley bottom, due to logging. Aside from a 2-acre red alder / bigleaf maple/conifer reference site, the riparian forest will require active management to avoid loss of mature coniferous trees over time and the beneficial canopy cover and source of large wood/key pieces they provide. Conifers will need to be manually re-established through plantings, in order to facilitate natural forest succession and to provide a future source of in-channel wood (see Section 2.6). In much of the riparian corridor there are also dense shrubs, typically salmonberry, in the understory which can outcompete tree species. Therefore, due to a lack of diverse tree-seed sources, and natural competition with shrub-species, there is a risk of losing the valuable forest and shade in the stream corridor over time.

2.7.2 Recent Land Management History

The City of Bellingham has owned most of the riparian corridor between Mirror Lake and Lake Whatcom since 1960. Since then, the City has planted and maintained portions of the corridor. In order to further develop appropriate riparian restoration actions, we collected and summarized all available data that pertained to City planting efforts (Appendix C).

City planting operations have been focused primarily on 1.5 miles of riparian buffer near the downstream end of Anderson Creek. Overall, approximately 30,900 native plants have been installed from 2011 to 2019. The majority of the plants (approximately 27,470) have been installed on the Zobrist property, which was acquired by the City in 2010 (Figure 20). Trees are the majority of species planted, with shrubs representing approximately 8,300 of the total plants.

Washington Conservation Corps crews plant and mow annually. On the whole, monitoring efforts in planted areas have been limited.

2.7.3 Riparian Habitat Summary

Anderson Creek today includes substantial native riparian cover – over 90% is predominantly native, and more than 75% is forested. However, much of the existing riparian forest is on a trajectory to shift to scrub-shrub dominated vegetation communities in the coming decades and lacks sufficient coniferous species to support the large wood cycle and supply key pieces to the stream channel.

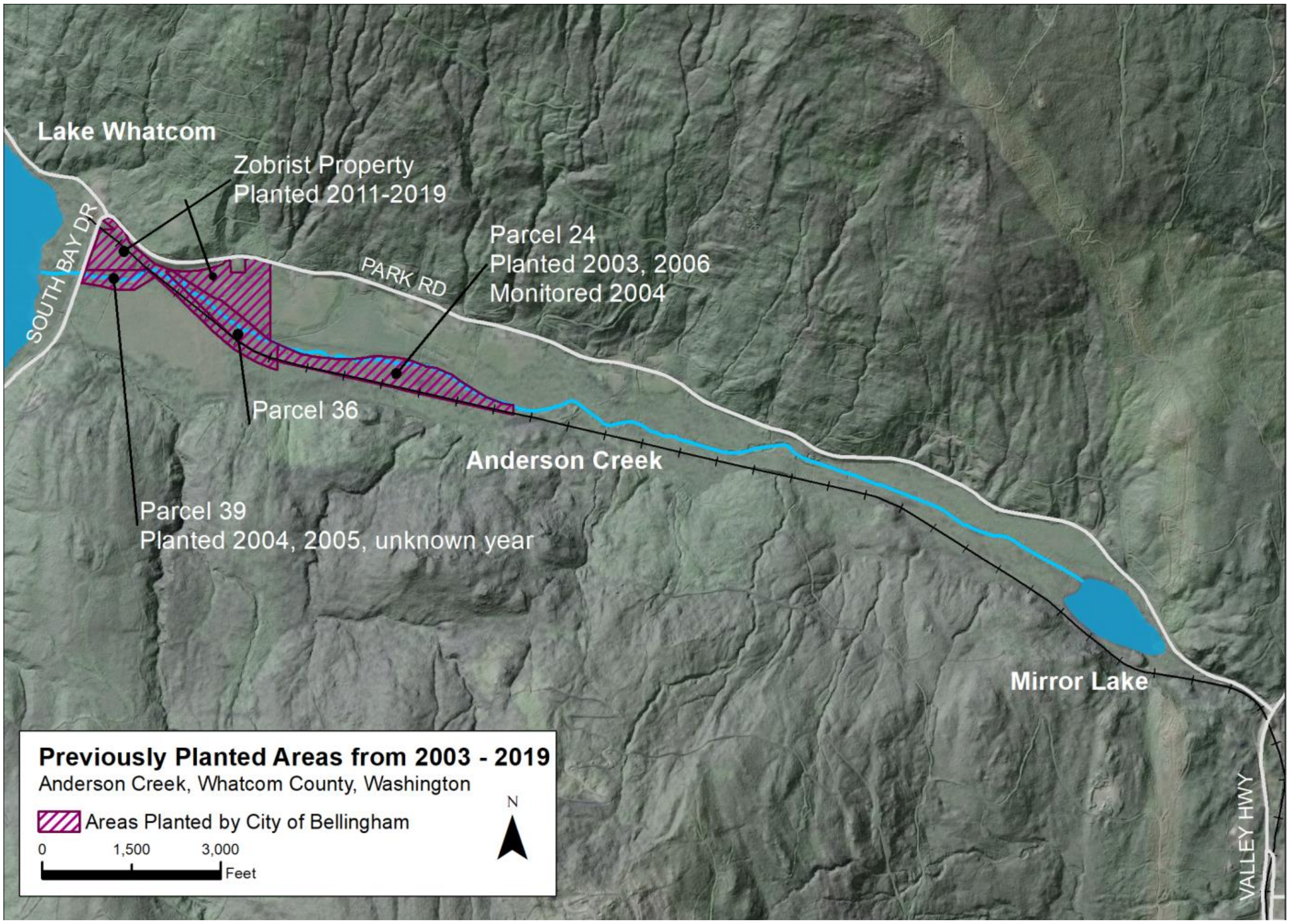


Figure 20. Riparian areas around Anderson Creek that have had plants installed by City of Bellingham from 2003 – 2013.

2.8 Implications for Restoration

As noted in the characterization, the overall level of impairment for Anderson Creek is relatively low. There are few acute alterations, the channel provides suitable in-stream habitat for Kokanee and cutthroat trout, and the riparian corridor is predominantly native forest. Anderson Creek's current and anticipated future contributions to water quality impairments is low, assuming continued optimization of the MF diversion. Anderson Creek is small compared to its valley, so while it appears that the stream corridor is dramatically altered, the stream's alignment was always influenced by hillslope processes.

Therefore, the restoration focus can be on protecting and enhancing the existing level of functioning for habitat and water quality for Anderson Creek. The City has obtained property along the creek and partnered with Whatcom County and the Whatcom County Land Trust to protect the vast majority of the creek corridor, which is an excellent start.

Improvements to gravel retention and embeddedness in pool tail crests would benefit both Kokanee and cutthroat trout. Kokanee juveniles do not utilize tributary habitat for rearing and thus would likely see fewer benefits from wood placement/pool enhancement in the upper reaches. However, improved conditions in tributary habitats directly affect food sources and water quality of downstream lake habitats (WADNR 1998).

To enhance Anderson Creek, the characterization results suggest the following as overarching objectives for restoration, keyed to the City's guidance to consider both habitat and water quality goals.

For Habitat:

1. **Improve Fish Passage** Past land uses have confined the channel in places and resulted in partial fish passage barriers so removal of these partial barriers will maximize accessible habitat.
2. **Enhance instream habitat**. In particular increasing hydraulic diversity to maintain and increase the areas of spawning gravels, adding cover on existing pools, and increasing floodplain connection (e.g. improving off-channel habitats as recommended in the WRIA 1 Salmon Recovery Plan). Adding large wood to the system is a sustainable way to achieve these objectives as the forest continues to mature.
3. **Preserve shade by managing riparian forest**. The existing riparian forest corridor is broadly in good shape today. However, the forest is recovering from past clearing and is not on a trajectory towards a mature mixed conifer-deciduous forest. The current trajectory is for the aging deciduous forest to shift to dense shrubs over time, so active management could change this trajectory and restore a mixed coniferous and deciduous riparian forest. Note that preserving shade is also critical from a water quality standpoint.

For Water Quality:

1. **Increase floodplain water storage.** Improving channel-floodplain connectivity will provide opportunities for sediment storage in the floodplain, and reduce the frequency of bed scouring flows in the mainstem. Removing portions of the railroad berm, for example, will reconnect floodplain storage.
2. **Reduce sediment load to lake**. Tributaries deliver sediment to the valley floor, so allowing deposition (and avoiding erosion) on the alluvial fans will reduce the overall sediment load to the lake. While bank erosion is a relatively small contribution of phosphorus to Lake Whatcom, past channel changes and alterations mean that there is the potential for ongoing erosion and transport of phosphorus during erosional events. Channel stabilization efforts can reduce the potential sediment export, and provide low areas to retain sediment over time.

3. POTENTIAL RESTORATION ACTIONS

The watershed characterization results discussed above were used to develop a range of action alternatives to address habitat, and water quality elements of Anderson Creek. A suite of potential restoration actions keyed to global goals and objectives for habitat and water quality is summarized below in Table 2 and are spatially depicted in Appendix D.

Table 2. Anderson Creek Potential Restoration Actions

Goal	Objective	Intervention	Notes
Habitat	Remove artificial fill	Earthwork to remove artificial fill within the floodplain	Fill associated with an old road in Reach 1, the current South Bay Road in Reach 1, and the railroad berm. Full or partial removal is possible. Partial removal can be beneficial to reconnect hydrologic pathways and limit costs.
Habitat	Remove partial fish passage barriers	Removal of barriers with associated channel restoration	Barriers include the rock weir associated with the RR bridge and low log weirs in Reach 4 The South Bay Drive culvert is also a partial barrier.
Habitat	Increase quantity and quality of spawning gravels	Increase key piece wood loading in higher gradient reaches Log placements ranging from machine engineered log jams where access is feasible to helicopter placed logs to avoid impacts to existing riparian areas	Large wood will influence instream habitats by providing more diverse instream hydraulic conditions to support greater areas of appropriate spawning materials.
Habitat and Water Quality	Preserve and enhance existing riparian forest	Targeted thinning of aging deciduous stands Underplanting with conifers Weed control and native revegetation	Water quality benefits are tightly linked to shade and water retention within alluvial soils. Habitat benefits accrue from vertical vegetative structure and large wood loading over time.
Habitat and Water Quality	Increase sediment retention in floodplain to reduce phosphorus loading to Lake Whatcom	Opportunistic grading to engage low areas of the floodplain to allow for sediment retention over time.	Most effective in conjunction with wood placements for roughness to increase inundation frequency. Floodplain sediment storage is not permanent.

Goal	Objective	Intervention	Notes
Habitat and Water Quality	Enhance wetland area to reduce surface water temperatures and increase habitat diversity	Focus on weed control and native shrub development in Reach 11 downstream of Mirror Lake	Full eradication of reed canarygrass is highly unlikely, but establishing shrub and tree cover will substantially reduce dominance.
Habitat and Water Quality	Reduce sediment and associated nutrient (including phosphorus) loading from tributary channels	Stabilize tributaries with minor grading and channel stabilization at headcuts	Largest head cut is at Zobrist Creek in Reach 3; review drainage influence of Park Road
Habitat	Reduce impacts to fish redds	Maintain and refine operations to minimize diversion flows in periods of fish egg incubation.	In general, the City has already made these changes, but efforts could be made with real time monitoring to refine the current operating rules.

Using these general restoration actions, we developed a range of restoration approaches tailored to each reach of Anderson Creek. The alternatives are summarized below in Table 3 and span a level of intervention range from:

1. High level of intervention for instream habitat and High level of intervention for riparian habitat.

2. Minimum level of intervention for instream habitat (remove potential blockages) and moderate level for riparian habitat.

Table 3. Anderson Creek Restoration Alternatives Organized by Reach

Reach – Alternative	Instream Intervention	Riparian Intervention	Water Quality Intervention
1-1	Excavation to create multiple channels and create more complex (longer) shoreline that inundates at the summer high water level to increase edge habitat and potential lacustrine spawning. Remove portion of remnant berm immediately downstream of S. Bay Road. Replace S. Bay Road culvert with larger span. Install machine built Engineered Log Jams (ELJ)s to disperse flow paths and provide near-lake cover.	Weed control with conifer underplanting. Expand planting in current grass area.	Provide low areas near channels for sediment accumulation; maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading. Design ELJs to encourage hyporheic flow
1-2	No action	Weed control with conifer under planting.	Maintain sustainable riparian cover for shade
2-1	Add key wood pieces as ELJS to avoid wood movement to culvert	Weed control with conifer underplanting.	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading. Design ELJs to encourage hyporheic flow.
2-2	No action	Weed control with conifer under planting.	Maintain sustainable riparian cover for shade
3-1	Remove RR bridge Expand floodplain Key log placements via helicopter	More intensive revegetation in new stream corridor Weed control with conifer under planting.	Maintain sustainable riparian cover for shade.
3-2	Remove RR Bridge with limited grading	Weed control with conifer under planting.	Maintain sustainable riparian cover for shade
4-1	Remove Weirs ELJs at weir locations	Weed control with conifer under planting.	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading. Design ELJs to encourage hyporheic flow.
4-2	Remove weirs	Weed control with conifer under planting.	Maintain sustainable riparian cover for shade

Reach – Alternative	Instream Intervention	Riparian Intervention	Water Quality Intervention
5-1	Roughen toe ditch Breach RR berm at two locations to engage tributaries and floodplain low area	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading.
5-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade
6-1	Helicopter wood placements	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading.
6-2	No action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade
7-1	Helicopter wood placements Breach RR berm	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading.
7-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade
8-1	Helicopter wood placements Berm removal	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading.
8-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade
9-1	Helicopter wood placements Breach RR Berm	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading.
9-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade
10-1	Helicopter wood placements	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; increase potential wetland area with targeted grading.
10-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade
11-1	Breach RR berm	Focused livestake installations in reed canarygrass dominated areas	Maintain sustainable riparian cover for shade
11-2	No action	Focused livestake installations in reed canarygrass dominated areas	Maintain sustainable riparian cover for shade

To provide a comparative ranking of these alternatives, we reviewed each alternative to provide a relative ranking of influence on key ecosystem attributes (summarized below) that influence overall functioning, and have estimated an associated cost range. Each item discussed in the bullets below is summarized by Reach in Table 3:

Anderson Creek Alternative Ranking Criteria:

- Addresses Fish Passage – Yes/No for addressing a known passage barrier in the mainstem, or in the railroad berm
- Increases Floodplain Water Storage – Yes/No. Floodplain storage increased by either direct excavation, roughening channel to promote more floodplain engagement, or removing blockage (e.g. railroad berm).
- Reduces Sediment Load To Lake. Yes/No. Addresses known erosion point (e.g. Zobrist Creek) or roughens mainstem in a way that will reduce likelihood for bank erosion.
- Enhances Instream Habitat. Yes/No. Addition of key pieces of wood or conversion of herbaceous weeds to shrub/forest over time (e.g. Reach 11)
- Preserves Shade. Yes/No
- Cost. High / Medium / Low. High >$100,000, Medium $25,000 to $100,000, Low <$25,000. More detailed cost estimates are included in Appendix E.

Table 4. Anderson Creek Restoration Alternatives Comparison Matrix by Reach

Reach – Alternative	Addresses Fish Passage	Increases floodplain water storage	Reduces sediment load to lake	Enhances Instream Habitat	Preserves shade	Cost	Tier
1-1	N	Y	Y	Y	Y	M	2
1-2	N	N	N	N	Y	L	1*
2-1	N	Y	Y	Y	Y	M	3
2-2	N	N	N	N	Y	L	1*
3-1	Y	Y	Y	Y	Y	H	1
3-2	Y	N	Y	Y	Y	H	1*
4-1	Y	Y	N	Y	Y	H	2
4-2	Y	N	N	N	Y	M	1*
5-1	Y	Y	N	Y	Y	M	2
5-2	N	N	N	N	Y	L	1*
6-1	N	Y	N	Y	Y	M	3
6-2	N	N	N	N	Y	L	1*
7-1	Y	Y	Y	Y	Y	M	3
7-2	N	N	N	N	Y	L	1*
8-1	N	Y	Y	Y	Y	M	2
8-2	N	N	N	N	Y	M	1*
9-1	Y	Y	Y	Y	Y	M	3
9-2	N	N	N	N	Y	L	1*
10-1	N	Y	Y	Y	Y	M	2
10-2	N	N	N	N	Y	L	1*
11-1	N	Y	Y	Y	Y	L	1
11-2	N	N	N	N	Y	L	1*

*Vegetation management recommended in all reaches if feasible

4. PREFERRED ALTERNATIVE

Our preliminary recommendations are to implement the Tier 1 projects then as many of the Tier 2 projects that project budget can support that meet the most benefits. The following list the Tier 1 and 2 projects that should be considered

Tier 1

1. Implement 3-1. This is the only project to hit all the boxes, despite the highest cost
2. Implement 11-1 as providing all benefits but fish passage at a relatively low cost and addresses largest weed infestation
3. Implement forest management (Alt 2 in reach reach) in as many reaches as is feasible – big gain for modest cost.

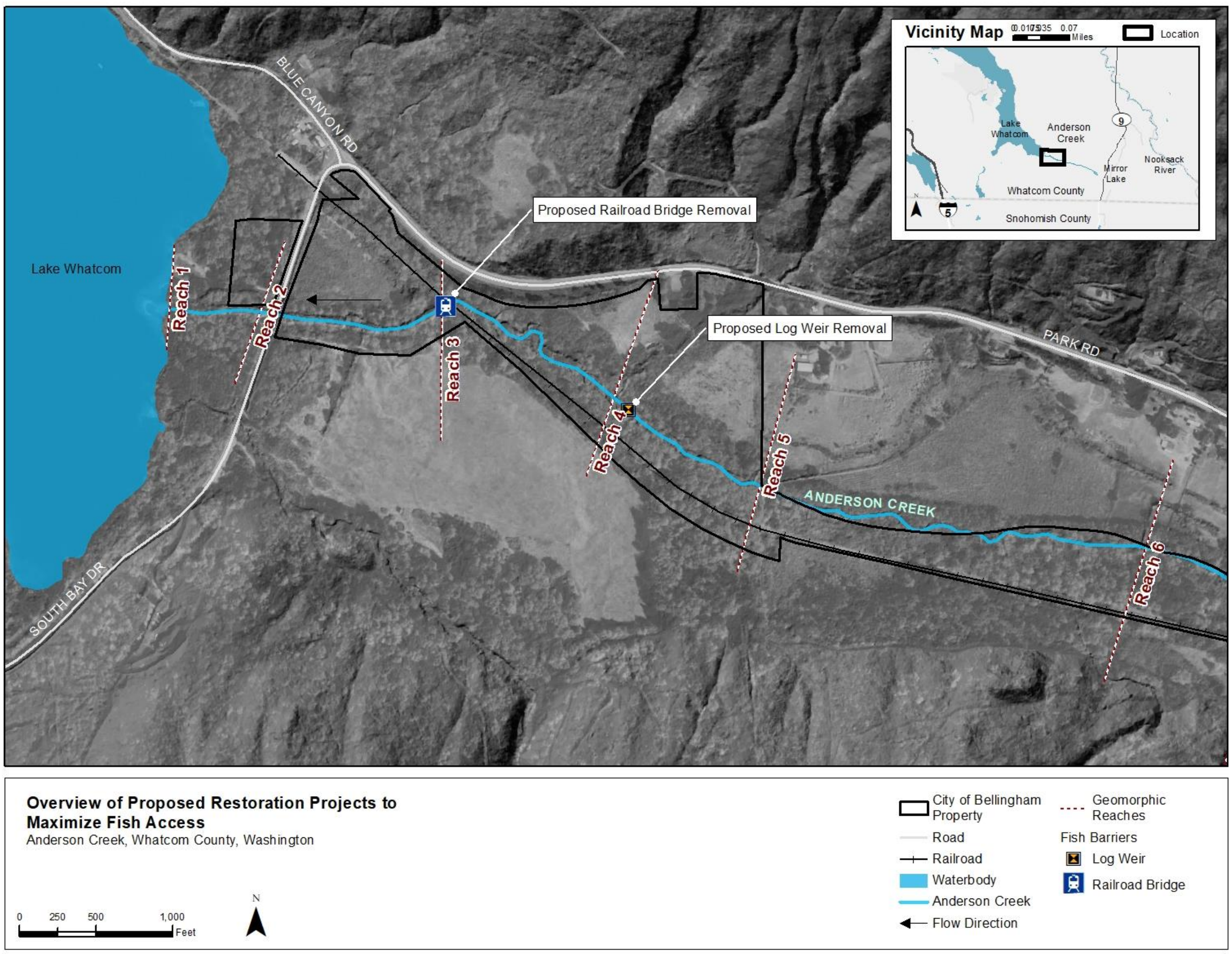
Tier 2

1. Implement 1-1 Delta restoration (ideally couple with culvert replacement in the future).
2. Implement 5-1
3. Implement 7-1
4. Implement 8-1
5. Implement 10-1
6. Implement 4-1

5. RESTORATION CONCEPTS

We have developed initial restoration concepts for two of the restoration actions: removal of railroad bridge, a partial fish passage barrier, and active enhancement and maintenance of the riparian corridor.

5.1 Remove Fish Passage Barriers



Locations of proposed railroad bridge and log weir removal projects

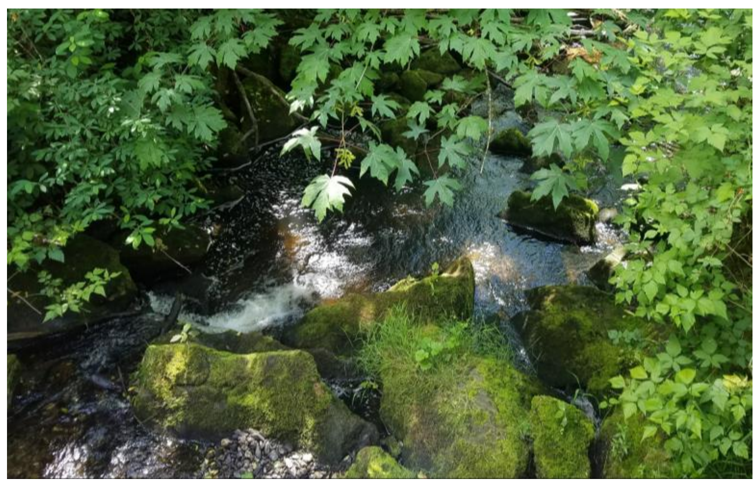
Remove Railroad Bridge

Location: The abandoned railroad bridge at RM 0.25 serves as the reach break between reaches 2 and 3. A conceptual figure of a restored railroad bridge reach is included in Appendix F.

Railroad bridge infrastructure:

- 15 vertical 14” diameter piers
- 55’ x 17’ bridge deck (approximate dimensions), and
- a wooden retaining wall
- lumber appears to be treated with creosote
- Riprap was placed along the stream banks both upstream and downstream of the railroad bridge to prevent channel erosion from impacting bridge stability, however this has resulted in a fish passage barrier and a reduction in instream habitat (see photo).
- The riprap exists along the right bank of the channel from 30 ft upstream of the bridge to 50 ft downstream of the bridge and along the left bank for 115 feet downstream of the bridge.
- Approximately 10 ft downstream of the bridge, riprap within the channel has created a 2 ft drop over large riprap (see top image).

Railroad bridge and riprap



Riprap fish passage barrier downstream of bridge

Approach: The restoration approach in this location includes:

- Removing all bridge infrastructure including fill for railroad berm extending south approximately 250 feet;
- Installing logjams on alternating banks, upstream and downstream of the existing fish passage barrier, to encourage channel sinuosity and provide increased channel roughness, as well as provide instream cover and refuge, and assist with local sediment deposition as the channel regrades in the vicinity of the existing fish passage barrier;
- Remove approximately 250 linear feet (and 550 CY) of the railroad embankment on the south side of the channel. The embankment filled the lower floodplain, so removing will expand the active floodplain in this location.
- Removing and disposing all riprap and debris within the channel, estimated at 130 cubic yards;
- Installing a corner pool logjam structure into the bank at the current location of the wooden retaining wall under the bridge, to increase pool formation, instream cover and refuge.

5.2 Manage Riparian Forest

Why is Forest Management and Restoration Necessary along Anderson Creek?

Red alder has a **life span** of about **80 years**.

The alders in this area are **ALL** about **40 years old and will likely senesce at about the same time**

To create a **self-sustaining riparian forest,** we must **restore pre-logging conifer populations**

How Long Does it Need to be Maintained?

At least 5 years…

Rationale for significant riparian forest restoration actions: Red alder has a life span of about 80 years. The alders in this area are about 40 years old and they are all the same approximate age. Where present, invasive species such as reed canarygrass and Himalayan blackberry pose threats to natural succession as the maturing red alder canopy begins to senesce. However, in areas lacking sufficient recruitment of long-lived tree species such as big leaf maple and western red cedar, the existing salmonberry understory will likely outcompete tree seedlings following the senescence of red alder.

Forest planting is necessary to create a self-sustaining riparian forest by restoring conifer populations to regain a natural forest successional trajectory.

The riparian corridor along Anderson Creek will benefit from planting long lived species such as Sitka spruce, Douglas fir, western red cedar, and bigleaf maple to succeed senescing red alder stands. Such plantings have occurred in the lower portions of Anderson Creek, but monitoring data are limited. We recommend that an inventory of surviving plantings be taken prior to planting efforts in these areas.

Invasive species: Himalayan blackberry and reed canary grass are problematic throughout the stream corridor.

Reed canarygrass is growing ubiquitously on mid channel gravel bars and at stream margins. To avoid using chemical agents to control reed canarygrass, we recommend taking the long-term approach of gradually shading it out through riparian forest restoration.

Reed canarygrass also dominates much of the overbank north of the channel within Geomorphic Reach 11 where more intensive plantings will be necessary to establish a dense shrub layer.

Himalayan blackberry is growing sporadically throughout the stream corridor, but is less prevalent than reed canarygrass. We recommend removal efforts throughout the stream corridor, focused first on riparian planting areas.

Maintenance: Follow up maintenance on the riparian forest areas should be maintained over time to:

- remove invasive species,
- add more plants, and
- thin alder and shrubs as needed.

Western red cedar should be protected from deer browse with plastic protective cylinders. The other conifers species are not as susceptible to herbivory and can be planted without covers. Beaver proof fencing may be necessary in some reaches.

In areas where alders or shrubs have been thinned, maintain a cleared 10- to 15-foot diameter area for 5 years, or until the conifers are 6 feet tall.

Global Riparian Management Goals:

- For the majority of the riparian corridor, establish a conifer overstory with approximately 200 stems/acre
- Establish Bigleaf Maple as a dominant tree species on the upper terrace transition to the higher alluvial fans
- Reduce invasive weed cover over time through clearing and aggressive replanting.
- In wet, scrub-shrub dominated locations, target 90% canopy cover of native willows

Specific treatments keyed to existing vegetation are summarized in Table 4. These treatments have been developed to provide overall targets that can be applied throughout the existing corridor with refinements to incorporate existing conditions and level of conifer establishment.

Table 5 Proposed riparian forest management treatments

Treatment	Existing Vegetation Community	Goal	Description	Notes
1	Deciduous Tree Canopy with existing openings	Remove weeds and establish conifer densities of 200 to 400 stems/acre.	• Clear shrubs from 0.05 to 0.01 acre openings • Underplant Conifers to meet ~200 stems per acre (~15 feet on center) • Group plantings into cleared areas • Remove non-native blackberry from clearing areas at least double the area. • Maintain plantings until conifers are more than 2 meters tall	Conifers to be apportioned by site hydrology In the wettest areas focus on Western redcedar and Sitka spruce In drier areas within the lower terrace focus on Douglas fir In the driest areas and on the transition to the upper terrace focus on Douglas fir and Big Leaf Maple.
2	Deciduous Tree Canopy with closed canopy	Create canopy openings, remove weeds, and establish conifer densities of 200 to 400 stems/acre	Apply Treatment 1 with the addition of thinning trees in the 0.05 to 0.01 acre openings. Again, target a total of ~200 stems/acre conifers	Species selection consistent with Treatment 1
3	Wet Forest/Shrub	Establish >90% cover by shrubs and trees	If current cover is less than 90% shrub and tree, then plant native willow species.	Focus on taller willow species.
4	Reed canarygrass mid channel islands	Shade out canarygrass infestations in active channel	Install tall willow livestakes and use string trimmers or similar for annual maintenance	Willow live stakes to be min. 6 ft tall and at least 0.5 inches diameter,

Treatment	Existing Vegetation Community	Goal	Description	Notes
				ideally 0.75 inches to 1.5 inches (Hartema et al) Density at 3 feet on-center
5	Reed canarygrass dominated floodplain (Geomorphic Reach 11)	Shade out significant canarygrass infestation	Install tall willow livestakes and use string trimmers or similar for annual maintenance	Willow live stakes to be min. 6 ft tall and at least 0.5 inches diameter, ideally 0.75 inches to 1.5 inches (Hartema et al) Density at 3 feet on-center
6	Himalayan blackberry	Reduce or eliminate non-native blackberry	If Himalayan blackberry is present, clear, paint stems	Will require ongoing management

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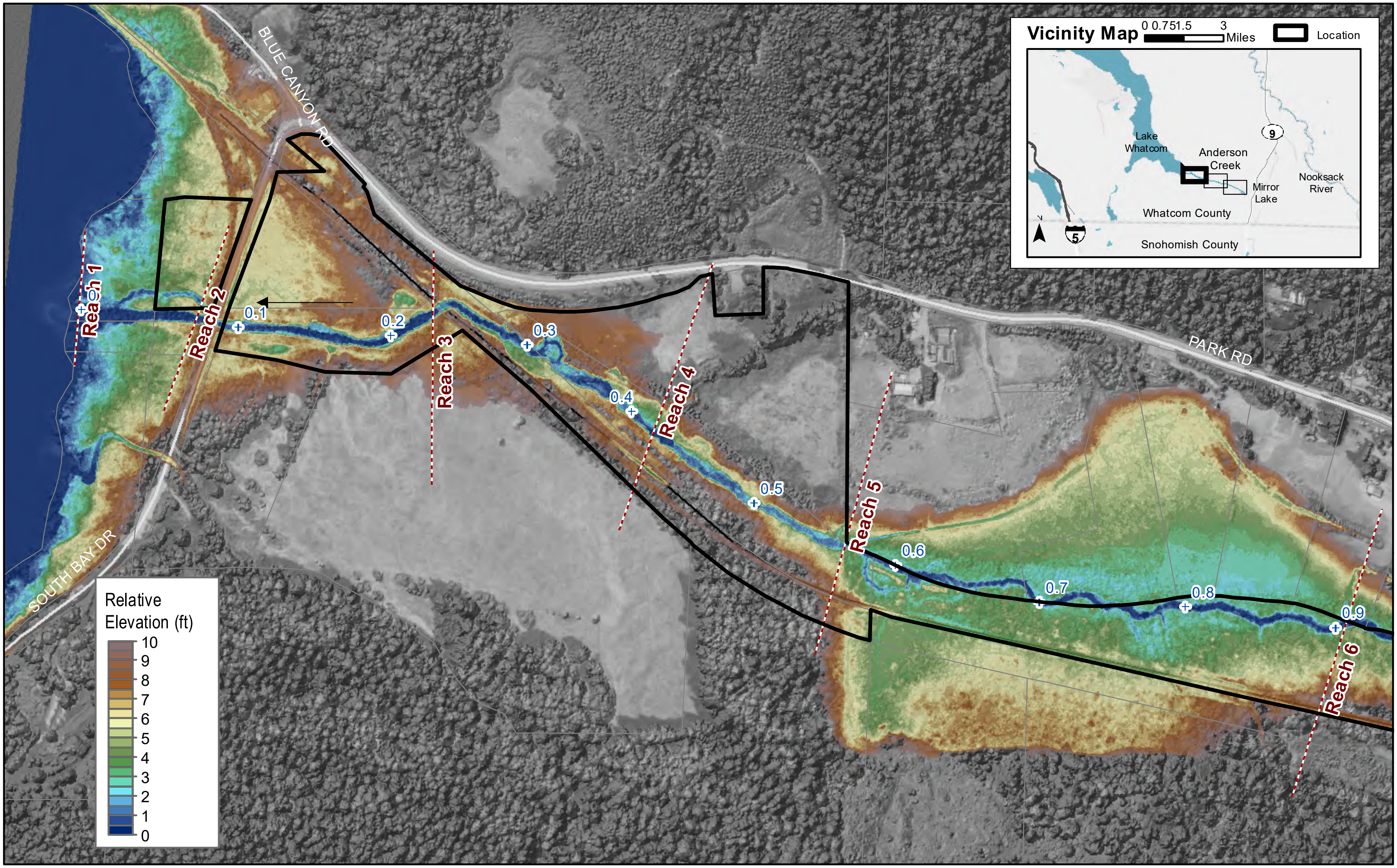
APPENDIX A: ANDERSON CREEK MAP FOLIO

- Relative Elevations within Creek Corridor, Pages 1-3
- Instream Habitat Features, Pages 1-3
- Existing Vegetation Types, Pages 1-3



Relative Elevations Within Creek Corridor

Anderson Creek, Whatcom County, Washington

Page 1

City of Bellingham Property

Parcel Boundary

Road

Railroad

Flow Direction

Geomorphic Reaches

River Mile

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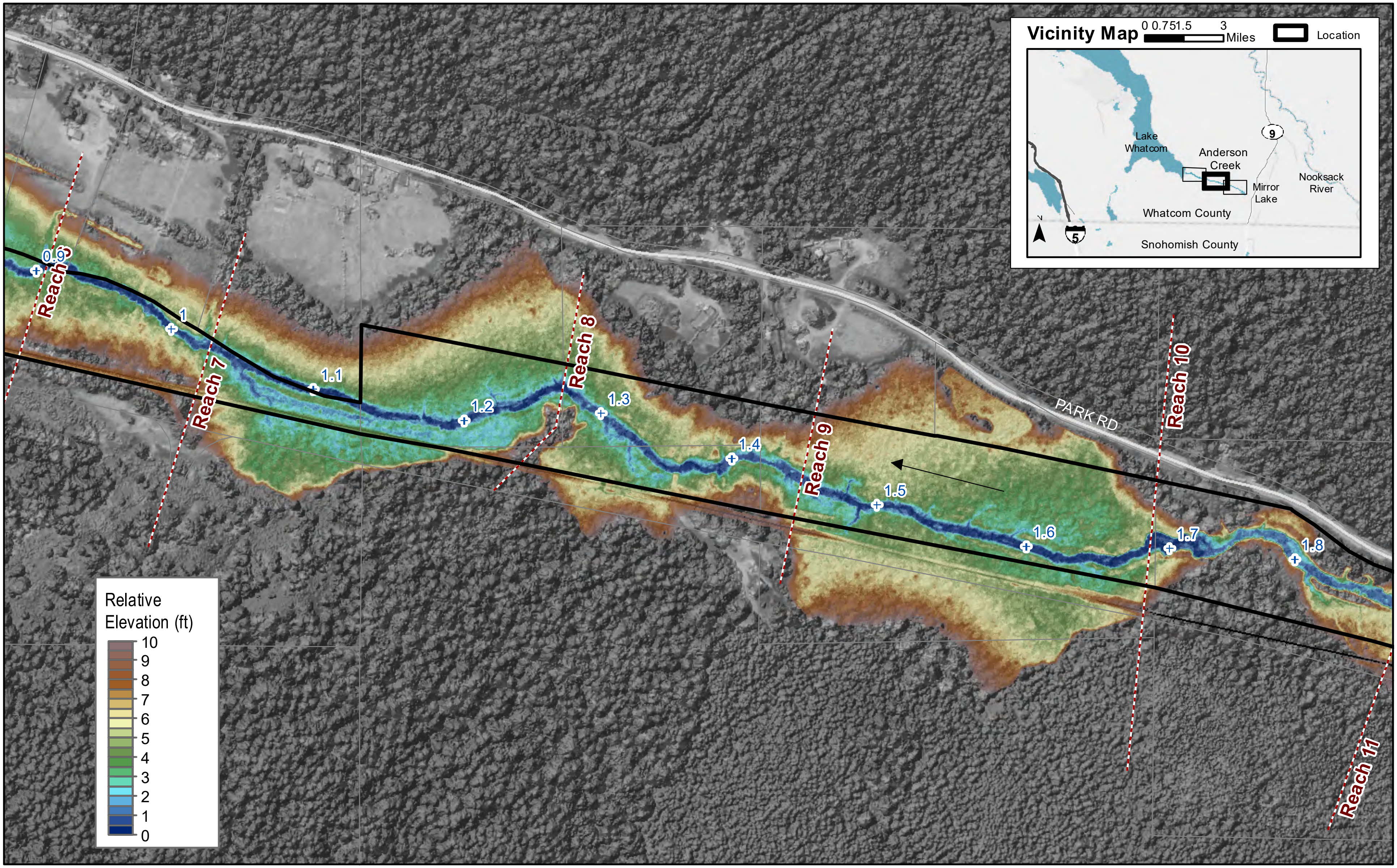

Relative Elevations Within Creek Corridor

Anderson Creek, Whatcom County, Washington

Page 2

0 250 500 1,000 Feet

N

City of Bellingham Property

Parcel Boundary

Road

Railroad

Flow Direction

Geomorphic Reaches

River Mile

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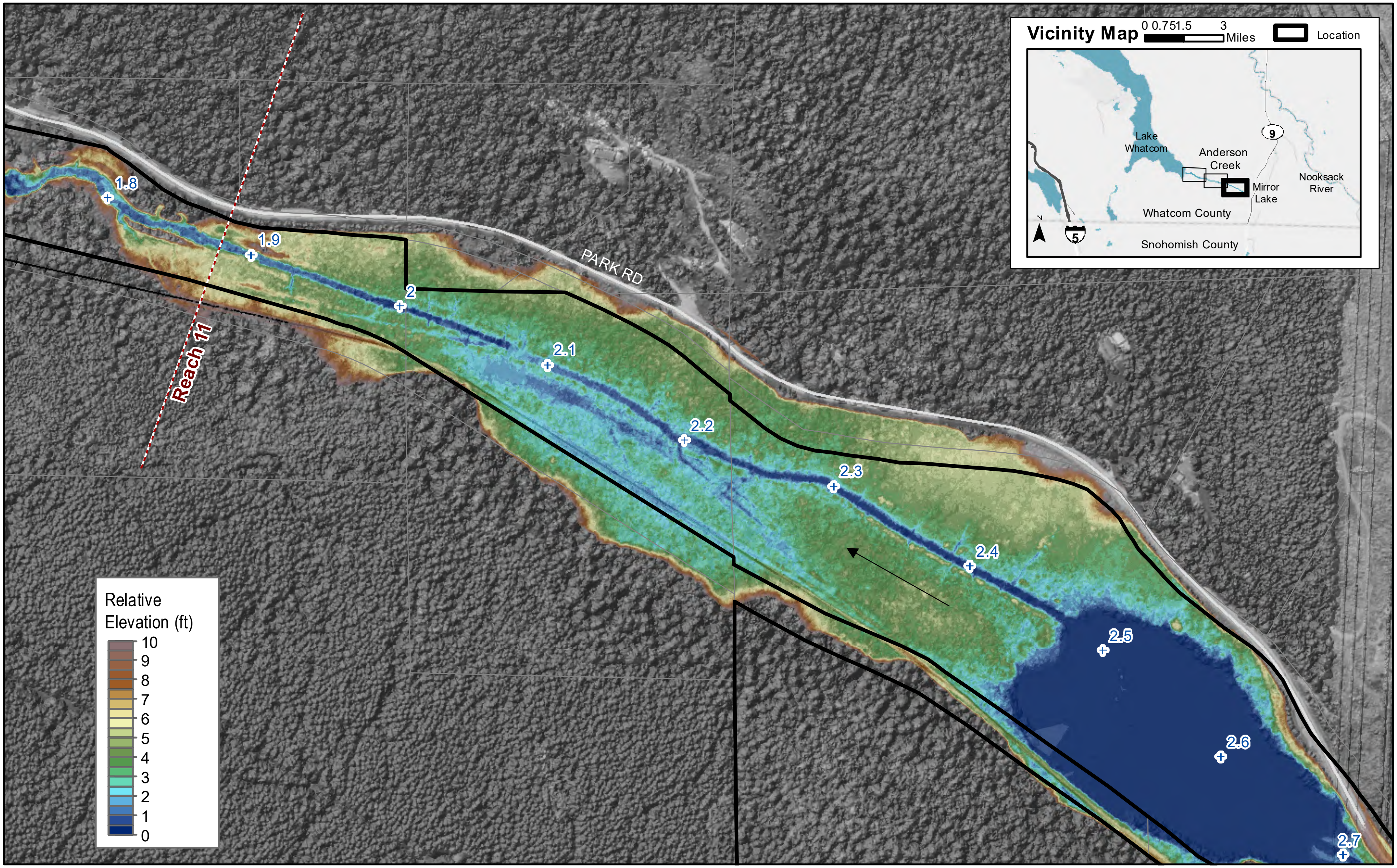

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Relative Elevations Within Creek Corridor

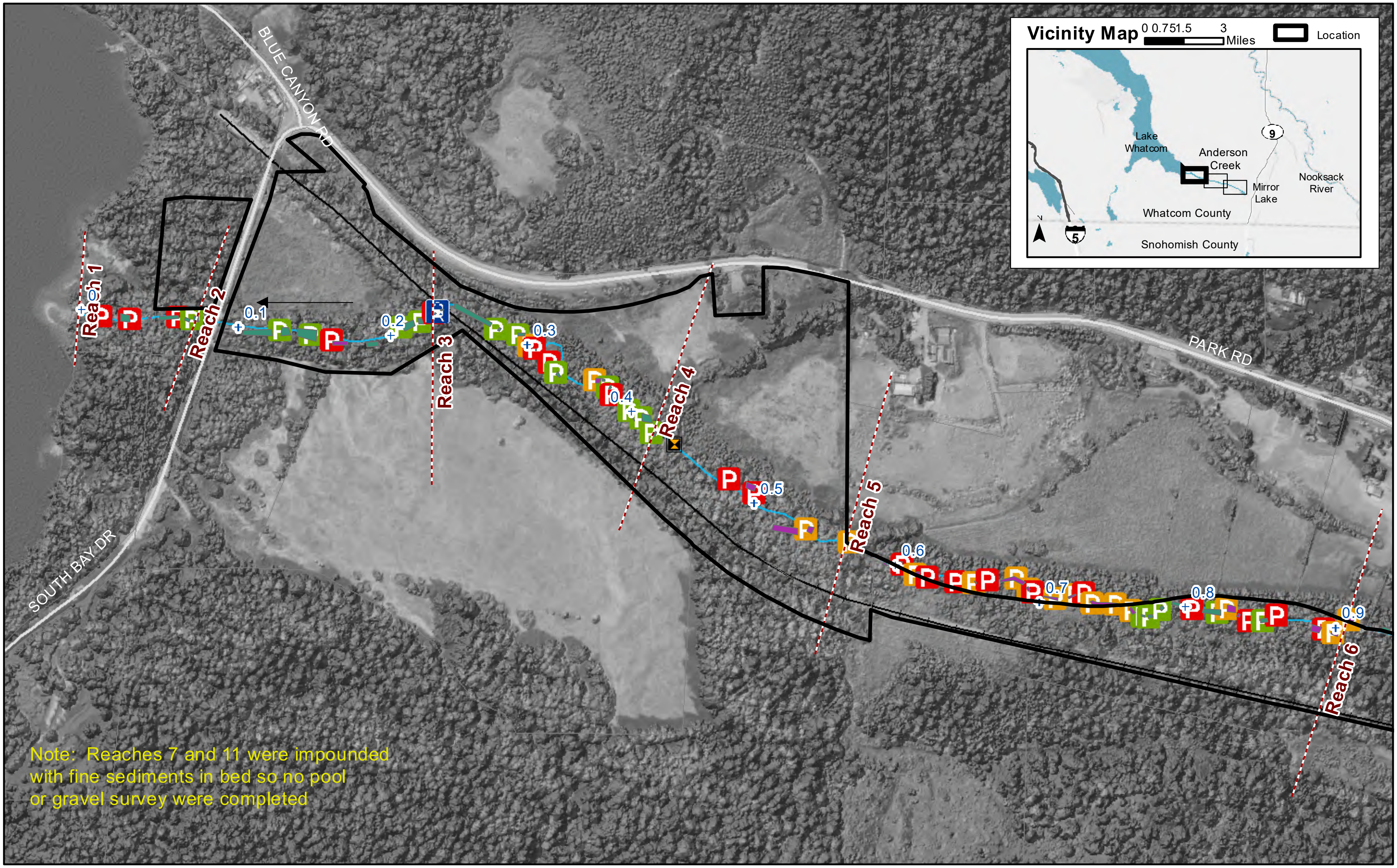
Anderson Creek, Whatcom County, Washington

Page 3

0 250 500 1,000 Feet

N

City of Bellingham Property
Parcel Boundary
Road
Railroad
Flow Direction
Geomorphic Reaches
River Mile



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Instream Habitat Features

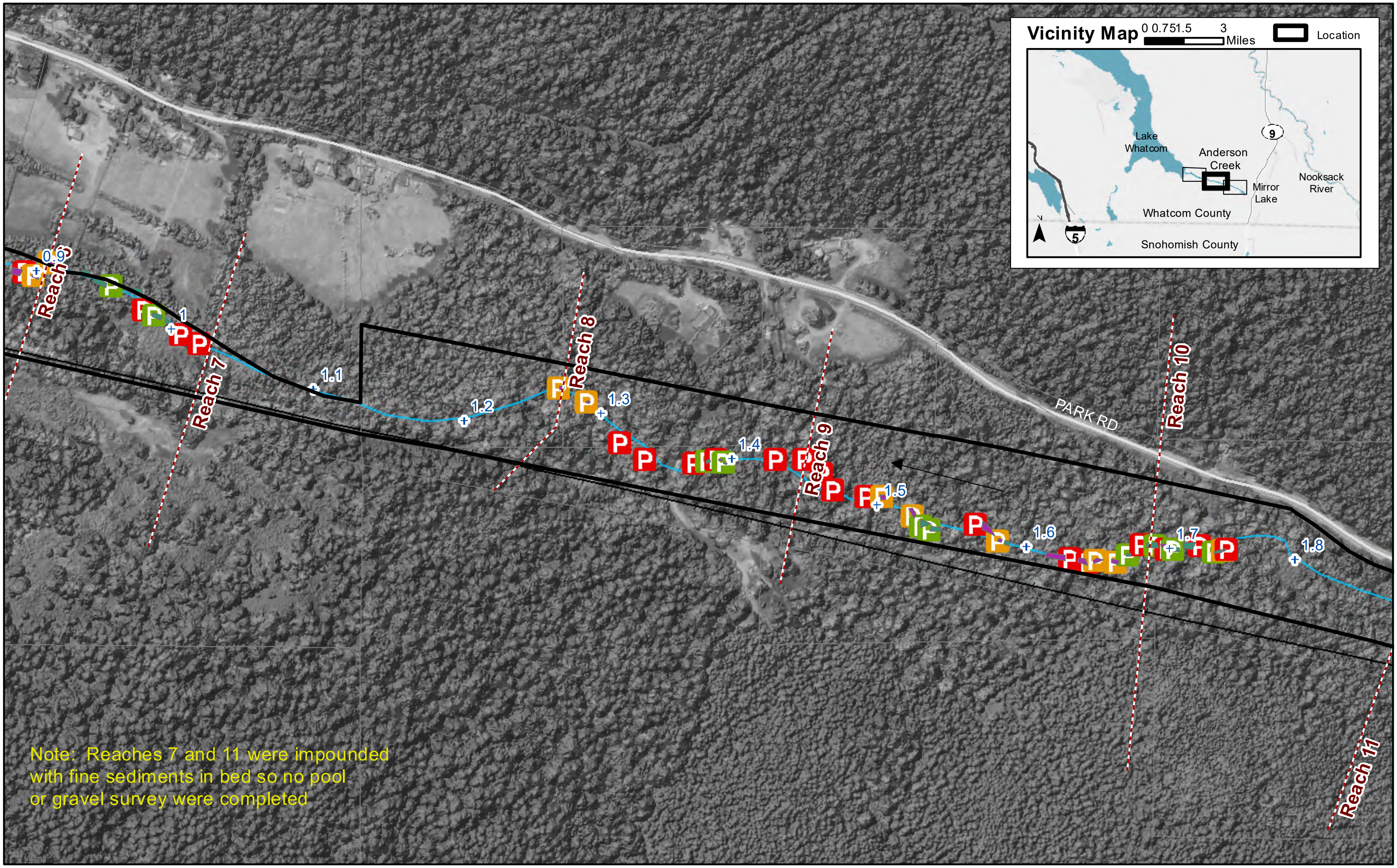
Anderson Creek, Whatcom County, Washington

Page 1

Each P symbol represents a poll individual pool, with color key to quality with
green = good
orange = moderate
red = poor

City of Bellingham Property
Parcel Boundary
Road
Railroad
River Mile
Anderson Creek
Flow Direction
Geomorphic Reaches
Fish Barriers
Log Weir
Railroad Bridge

0 250 500 1,000 Feet



Instream Habitat Features
Anderson Creek, Whatcom County, Washington

Page 2

0 250 500 1,000
Feet

Each P symbol represents a poll individual pool, with color key to quality with
green = good
orange = moderate
red = poor

City of Bellingham Property
Parcel Boundary
Road
Railroad
River Mile
Anderson Creek
Flow Direction
Geomorphic Reaches

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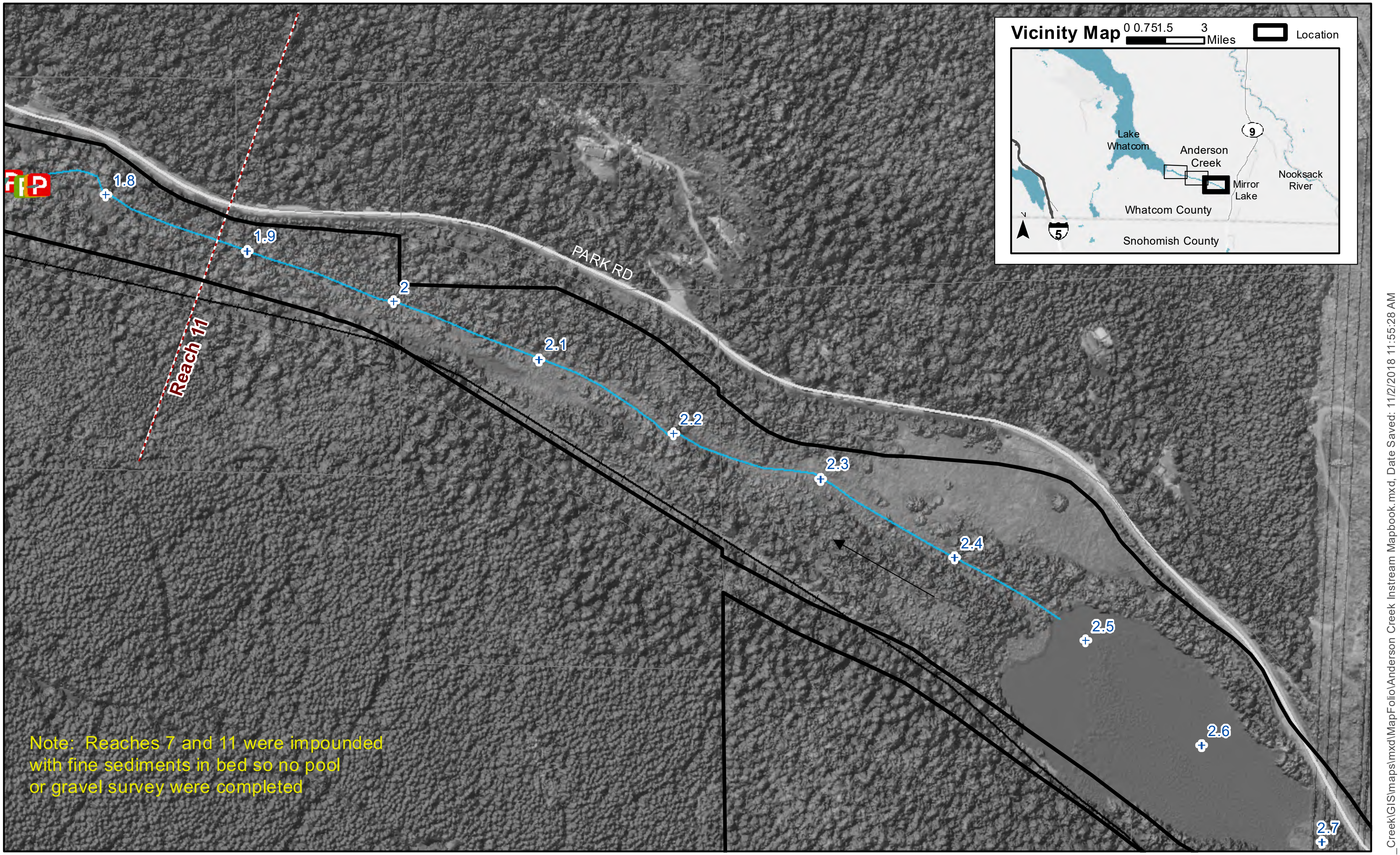


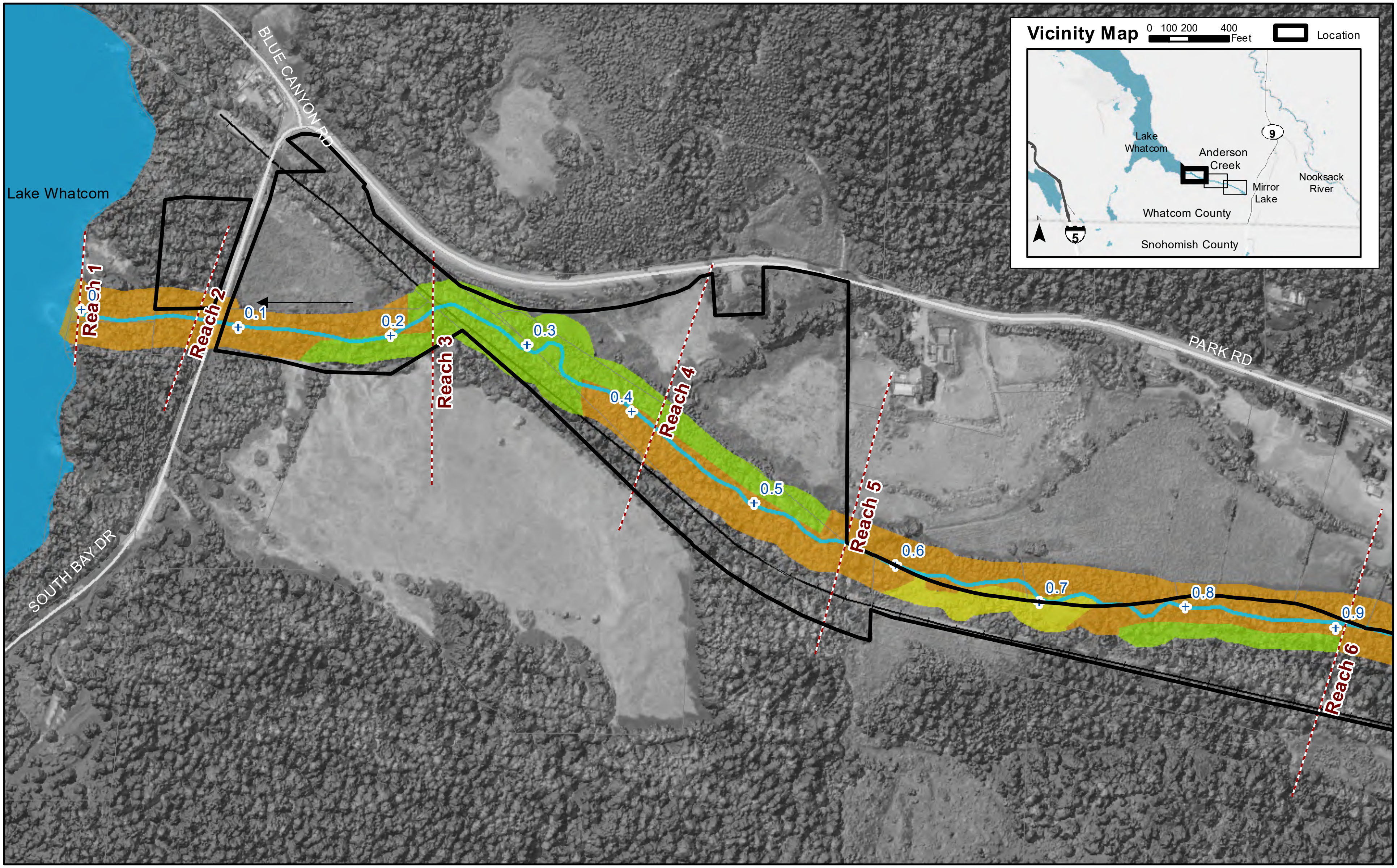
Instream Habitat Features

Anderson Creek, Whatcom County, Washington

Page 3

Each P symbol represents a poll individual pool, with color key to quality with
green = good
orange = moderate
red = poor

- City of Bellingham Property
- Parcel Boundary
- Road
- Railroad
- River Mile
- Anderson Creek
- Flow Direction
- Geomorphic Reaches



Existing Forest and Shrubland Types

Anderson Creek, Whatcom County, Washington

Page 1

0 250 500 1,000 Feet

City of Bellingham Property
Parcel Boundary
Road
Railroad
Waterbody
Anderson Creek
Flow Direction
Geomorphic Reaches

Existing Forest and Shrubland Types
Red Alder - Willow - Spiraea Wet Shrubland
Red Alder - Bigleaf Maple
Red Alder / Salmonberry Riparian Forest

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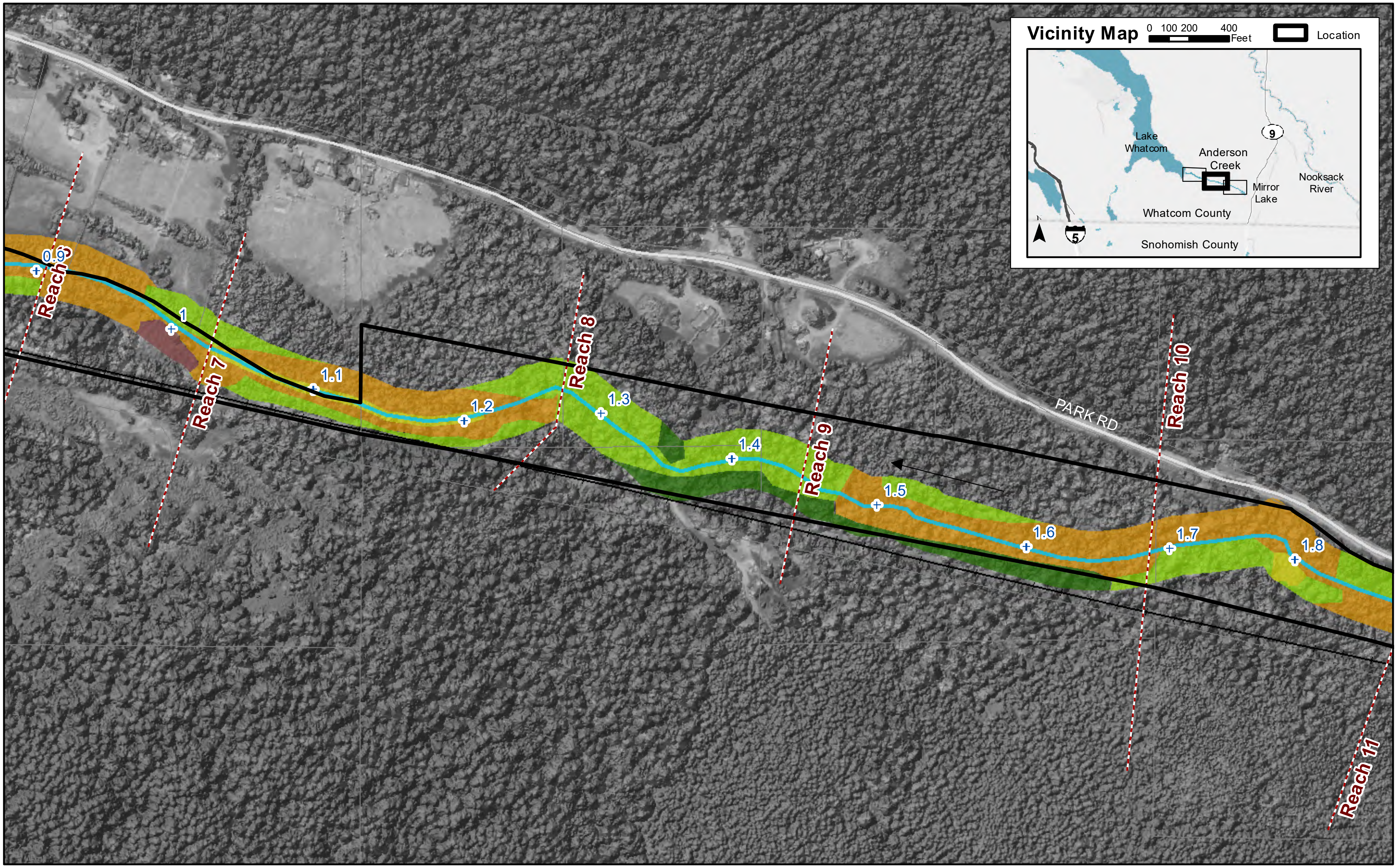

Existing Forest and Shrubland Types

Anderson Creek, Whatcom County, Washington

Page 2

0 250 500 1,000 Feet

City of Bellingham Property
Parcel Boundary
Road
Railroad
Anderson Creek
Flow Direction
Geomorphic Reaches

Existing Forest and Shrubland Types

Dominated by Reedcanary Grass
Red Alder - Willow - Spiraea Wet Shrubland
Red Alder - Bigleaf Maple
Red Alder / Salmonberry Riparian Forest
Red Alder - Bigleaf Maple - Conifer Forest

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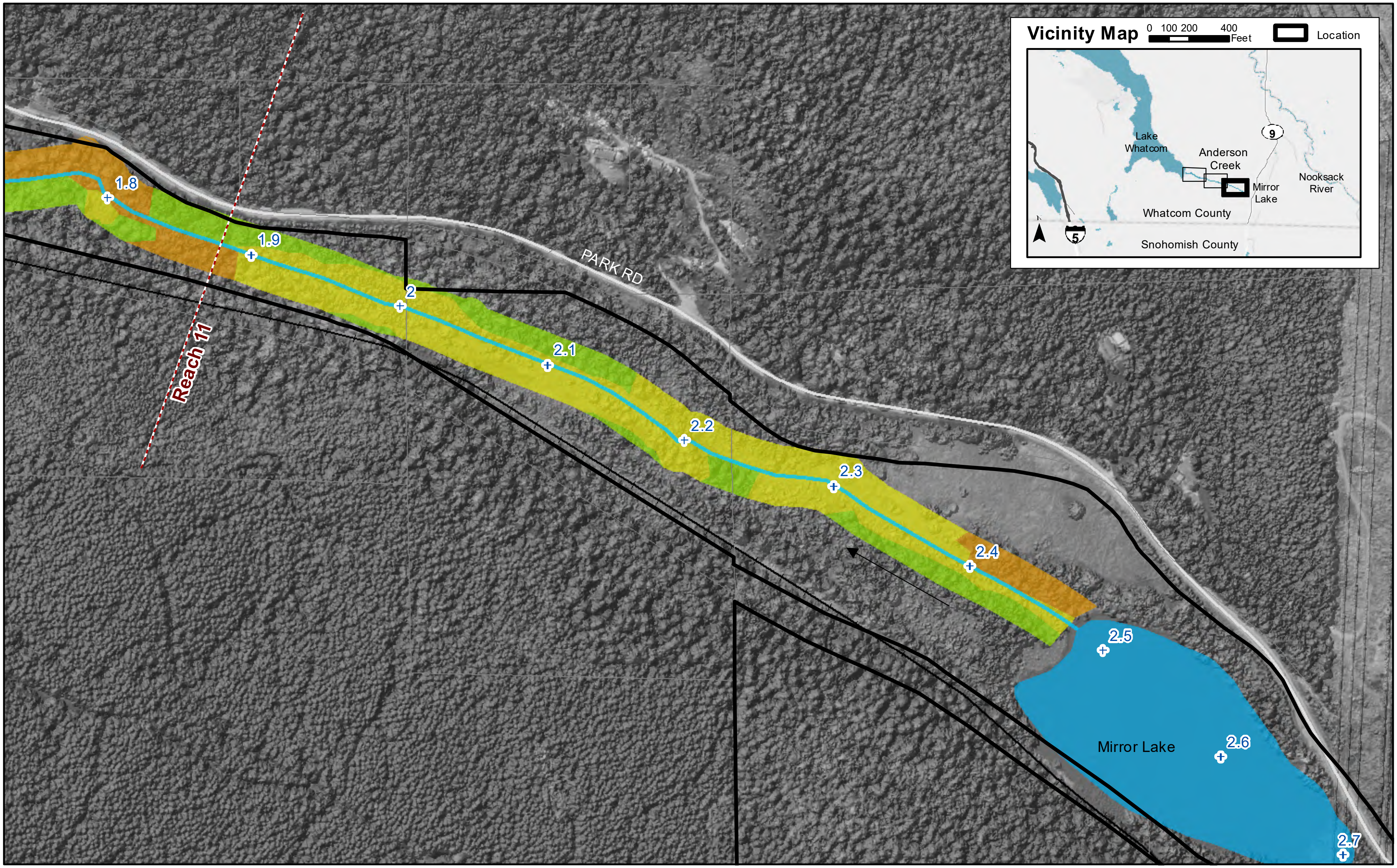

Existing Forest and Shrubland Types

Anderson Creek, Whatcom County, Washington

Page 3

0 250 500 1,000 Feet

City of Bellingham Property

Parcel Boundary

Road

Railroad

Waterbody

Anderson Creek

Flow Direction

Geomorphic Reaches

Existing Forest and Shrubland Types

Red Alder - Willow - Spiraea Wet Shrubland

Red Alder - Bigleaf Maple

Red Alder / Salmonberry Riparian Forest

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APPENDIX B: ANDERSON CREEK INSTREAM HABITAT CHARACTERIZATION DATA

Note: See Appendix A for Maps

Pool Classifications by Geomorphic Reach

GEOMORPHIC REACH	TOTAL POOLS	POOLS BELOW ALL BARRIERS	POOLS ABOVE RAILROAD BRIDGE	POOLS ABOVE LOG WEIRS	TOTAL POOLS GOOD	TOTAL POOLS FAIR	TOTAL POOLS POOR	DAM POOLS
1	4	4	0	0	1	0	3	0
2	6	6	0	0	4	0	2	0
3	12	0	12	0	7	2	3	0
4	5	0	5	5	0	1	2	2
5	25	0	25	25	5	11	9	0
6	8	0	8	8	2	2	4	0
8	9	0	9	9	2	2	5	0
9	19	0	19	19	5	5	9	0
10	4	0	4	4	1	1	2	0

Large Wood Characteristics by Geomorphic Reach

REACH NUMBER	COUNT OF LARGE WOOD > 0.1 / ESTIMATED AVG. LENGTH	COUNT OF LARGE WOOD >0.3 / ESTIMATED AVG LENGTH	COUNT OF LARGE WOOD>0.4/ ESTIMATED AVG LENGTH	NO. OF SMALL JAMS	NO. OF LARGE JAMS	NO. OF KEY PIECES
5	42/ 2.5	6 / 5	0/0	1	0	0
6	50/2.5	2/5	0/0	0	0	0
8	45/4	1/7	1/9	0	0	0
9	108/4	9/5	2/12	1	0	0

APPENDIX C: ANDERSON CREEK VEGETATION CLASSIFICATION DATA

Red Alder / Salmonberry Riparian Forest

Approximately 55 acres of red alder / salmonberry riparian forest was delineated in the Anderson Creek Corridor. These areas are characterized by a mature canopy of red alder growing over a dense salmonberry-dominated understory. Other species in the canopy include a few relict black cottonwood and big leaf maple. Understory plants also include red elderberry, red osier dogwood, thimbleberry, Nootka rose, twinberry, stink currant, and Indian plum. Red alder trees in these areas ranged from 20-60 cm dbh. As the red alders continue to mature and senesce over the next 30 years, it is likely the forest will transition to a salmonberry shrub thicket.

Figure **21**. Photo of existing Red Alder / Salmonberry Forest at Anderson Creek (2018)

Red Alder / Big Leaf Maple Forest

Approximately 42 acres of red alder / big leaf maple forest were delineated in the Anderson Creek corridor. The canopy in these areas is dominated by mature broadleaf trees. Red alder is largely dominant, although big leaf maple is co dominant in small areas. Both mature and emergent conifers exist in these areas, although they account for and estimated 10-20 percent or less of the forest canopy. Conifer species are primarily western red cedar and Sitka spruce. The understory is dominated by salmonberry, but also contains Nootka rose, thimble berry, twinberry, red elderberry and red osier dogwood. In areas where red alder is the dominant canopy species, there is potential for the forest to transition into a salmonberry shrub thicket.

Figure **22**. Photo of existing Red Alder / Bigleaf Maple Forest at Anderson Creek (2018)

Red Alder / Willow / Spiraea Wet Shrubland

Approximately 28 acres of red alder / willow / spiraea wet shrubland were delineated in the Anderson Creek corridor. Vegetation in these areas is dominated by a dense spiraea, willow, and reed canary grass understory. In many areas directly adjacent to the stream bed, reed canary grass is outcompeting native vegetation. Twin berry and cascara are present as well, but are never dominant or codominant in the understory. These areas often include sparse mature to senescent red alders.

Figure 23 Photo of existing Red Alder / Willow / Spirea Wet Shrubland at Anderson Creek (2018)

Red Alder / Bigleaf Maple / Conifer Forest

Approximately 5 acres of red alder / bigleaf maple / conifer forest was mapped in the Anderson creek corridor. Vegetation in these areas is characterized by mixed broadleaf and conifer tree communities. Red alder tends to be the dominant broadleaf species, although bigleaf maple is codominant in some areas. Western red cedar and Sitka spruce are the main conifers comprising the canopy layer. Understory shrubs are reduced in comparison to the two broadleaf dominated forest types described previously, with a more prevalent herb layer. Understory species include salmonberry, thimble berry, red elderberry, Indian plum and red osier dogwood.

Figure 24. Photo of existing Red Alder / Bigleaf Maple / Conifer Forest at Anderson Creek (2018)

City of Bellingham Plantings

The city of Bellingham has owned the riparian corridor between Mirror Lake and Lake Whatcom since 1960, and has planted and maintained portions of the corridor. Operations have occurred primarily on 1.5 miles of riparian buffer near the downstream end of Anderson creek (Figure 1). Planting years, species, and stem numbers are provided below. Note that parcel 36 was planted in 2006, but there does not appear to be a record of stems per acre or species planted. The Zobrist property in particular has received intensive maintenance. WCC crews plant and mow annually. On the whole, monitoring efforts in planted areas have been limited.

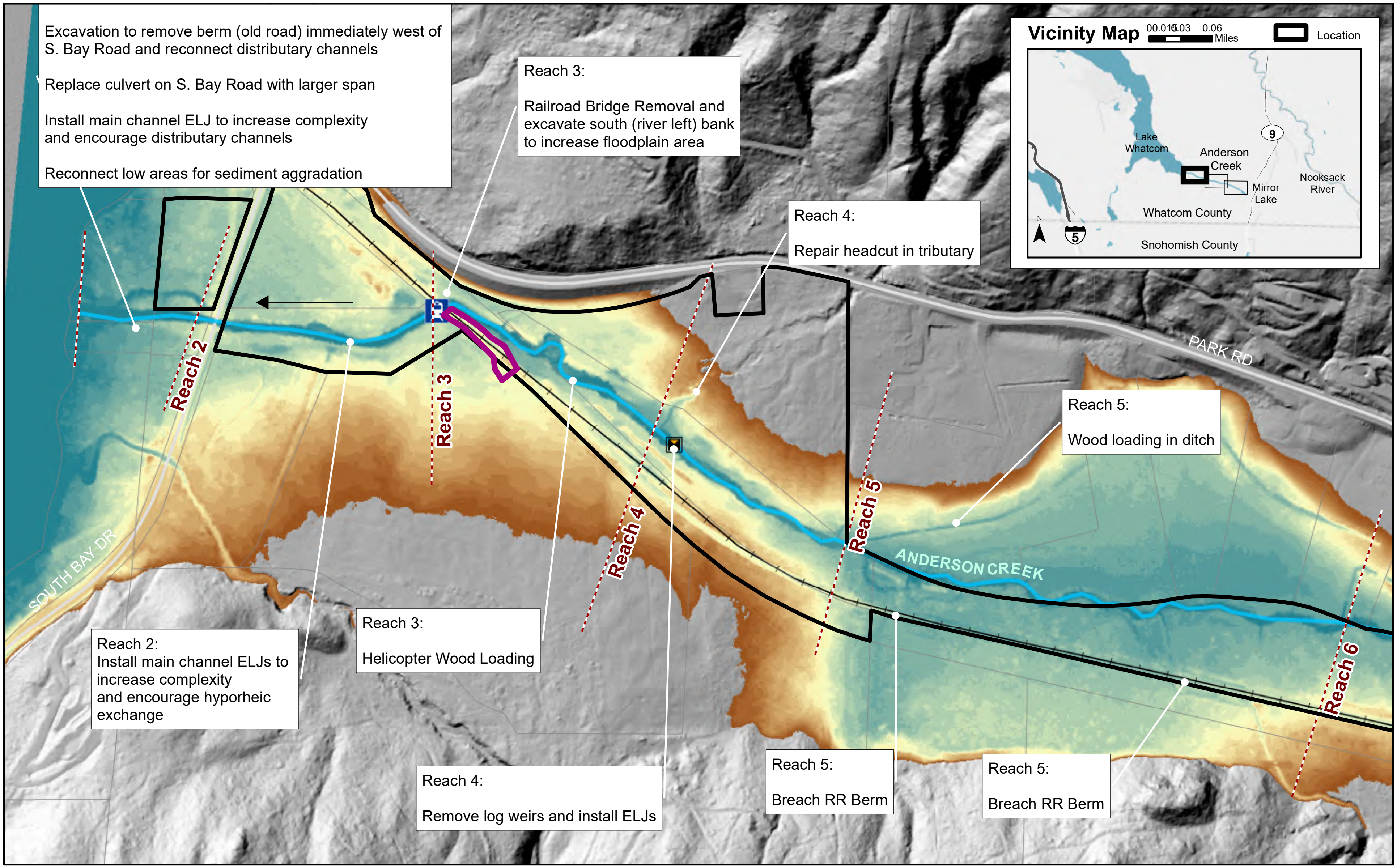
Anderson Creek Plant Species List

Anderson Creek plant species list with notes from local Agate Pond Preserve species list by Washington Native Plant Society (WNPS). Based on lists provided by City of Bellingham of planted species (*) and summer 2018 field observations by Natural Systems Design (NSD).

ANDERSON CREEK PLANT SPECIES LIST			
Trees			
Botanical Name	**Common Name**	**Native (Yes/No)**	**Notes from Local Washington Native Plant Society (WNPS) List**
Abies grandis*	Grand Fir	Yes	WNPS - Agate Pond Preserve
Alnus rubra	Red Alder	Yes	WNPS - Agate Pond Preserve
Malus fusca*	Oregon Crabapple	Yes	WNPS - Agate Pond Preserve
Picea sitchensis	Sitka Spruce	Yes	WNPS - Agate Pond Preserve
Pinus contorta var. contorta*	Shore Pine	Yes	Not on list
Populus tremula*	Aspen	Yes	WNPS - Agate Pond Preserve
Populus trichocarpa	Black Cottonwood	Yes	WNPS - Agate Pond Preserve
Prunus serotina (only one specimen observed)	Black Cherry	Yes	Not on list
Quercus garryana*	White Oak	Yes	WNPS - Agate Pond Preserve - Planted
Fraxinus latifolia*	Oregon Ash	Yes	WNPS - Agate Pond Preserve - Planted
Ilex aquifolium	English Holly	No	WNPS - Agate Pond Preserve - Introduced
Shrubs			
Botanical Name	**Common Name**	**Native (Yes/No)**	**Notes from Local Washington Native Plant Society (WNPS) List**
Acer circinatum	Vine Maple	Yes	WNPS - Agate Pond Preserve
Cornus sericea	Redosier Dogwood	Yes	WNPS - Agate Pond Preserve
Fallopia japonica	Bindweed	No	Not on list
Holodiscus discolor	Ocean Spray	Yes	WNPS - Agate Pond Preserve
Lonicera involucrate	Black Twinberry	Yes	WNPS - Agate Pond Preserve
Oemleria cerasiformis	Indian Plum	Yes	WNPS - Agate Pond Preserve
Frangula purshiana	Cascara	Yes	WNPS - Agate Pond Preserve
Ribes bracteosum	Stinkcurrant	Yes	WNPS - Agate Pond Preserve
Ribes sanguineum	Red-flowered currant	Yes	WNPS - Agate Pond Preserve
Rosa nutkana	Nootka Rose	Yes	WNPS - Agate Pond Preserve
Rubus armeniacus aka Rubus bifrons	Himalayan Blackberry	No	WNPS - Agate Pond Preserve
Rubus parviflorus	Thimbleberry	Yes	Not on list
Rubus spectabilis	Salmonberry	Yes	WNPS - Agate Pond Preserve
Rubus ursinus	Wild blackberry	Yes	WNPS - Agate Pond Preserve

Salix sitchensis or Salix Scoulerii	Sitka Willow or Scouler Willow	Yes	WNPS - Agate Pond Preserve
Ferns			
Botanical Name	**Common Name**	**Native (Yes/No)**	**Notes from Local Washington Native Plant Society (WNPS) List**
Athyrium filix-femina	Lady Fern	Yes	WNPS - Agate Pond Preserve
Blechnum spicant	Deer Fern	Yes	WNPS - Agate Pond Preserve
Polypodium glycyrrhiza	Licorice Fern	Yes	WNPS - Agate Pond Preserve
Polystichum munitum	Western Sword Fern	yes	WNPS - Agate Pond Preserve
Pteridium aquilinum	Bracken Fern	Yes	WNPS - Agate Pond Preserve
Herbs			
Botanical Name	**Common Name**	**Native (Yes/No)**	**Notes from Local Washington Native Plant Society (WNPS) List**
Arctium minus	Common burdock	No	Not on list.
Aianthemum dilatatum	False Lily-of-the-valley	Yes	WNPS - Agate Pond Preserve
Gallium aparine	Cleavers	Yes	WNPS - Agate Pond Preserve
Geum macrophyllum	Large-leaved Avens	Yes	WNPS - Agate Pond Preserve
Hydrophyllum fendleri	Fendler's Waterleaf	Yes	Not on list.
Impatiens capensis	Jewelweed	No	Not on list.
Lysichiton americanus	Skunk Cabbage	yes	WNPS - Agate Pond Preserve
Mentha arvensis	Wild Mint	yes	WNPS - Agate Pond Preserve
Phalaris arundinacea	Reedcanary Grass	No	WNPS - Agate Pond Preserve
Scirupus microcarpus	Small-flowered Bulrush	yes	WNPS - Agate Pond Preserve
Tellima grandiflora	Fringecup	yes	WNPS - Agate Pond Preserve
Tolmei mensezii	Youth-On-Age	yes	WNPS - Agate Pond Preserve
Urtica diota	Stinging Nettle	Yes	WNPS - Agate Pond Preserve

Appendix D: Restoration Alternatives Figures



Proposed More Intensive Instream Restoration Projects

Anderson Creek, Whatcom County, Washington

0 250 500 1,000 Feet

N

- City of Bellingham Property
- Parcel Boundary
- Road
- Railroad
- Anderson Creek
- Flow Direction
- Geomorphic Reaches
- Fish Barriers
  - Log Weir
  - Railroad Bridge

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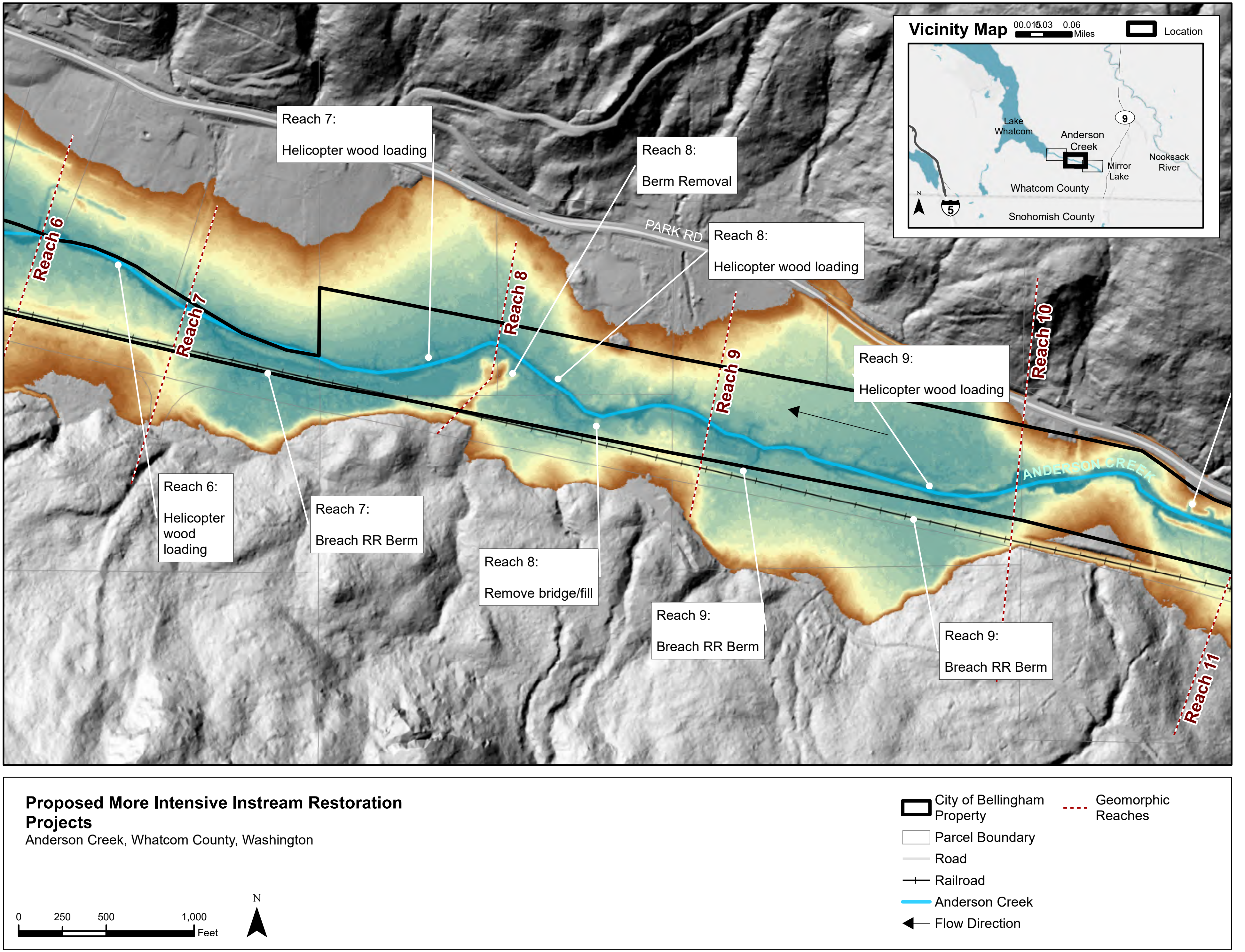
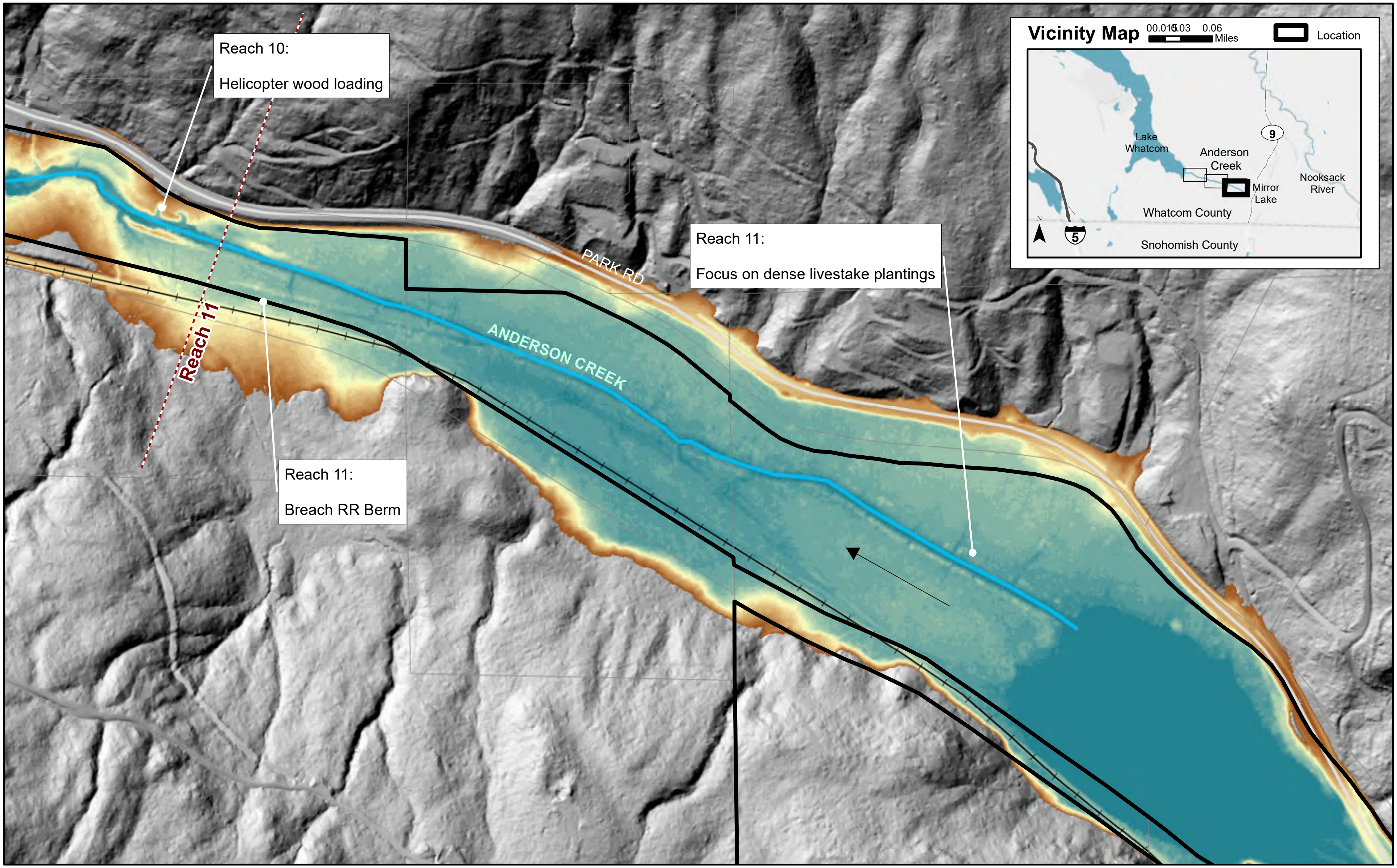


Proposed More Intensive Instream Restoration Projects

Anderson Creek, Whatcom County, Washington



Proposed More Intensive Instream Restoration Projects

Anderson Creek, Whatcom County, Washington

0 250 500 1,000 Feet

N

City of Bellingham Property

Parcel Boundary

Road

Railroad

Anderson Creek

Flow Direction

Geomorphic Reaches

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Appendix E: Preliminary Cost Estimates for Concept Alternatives

Reach – Alternative	Instream Intervention	Riparian Intervention	Water Quality Intervention	Notes	Cost
1-1	Excavation to create multiple channels and create more complex (longer) shoreline that inundates at the summer high water level to increase wetland area Remove portion of remnant road berm Install machine built ELJs to disperse flow paths and provide near-lake cover	Weed control with conifer underplanting. Expand planting in current grass area	Provide low areas near channels for sediment accumulation; maintain sustainable riparian cover for shade; maximize wetland area. Design ELJs to encourage hyporheic flow	May require trail installation to formalize existing informal paths and protect new plantings.	$125,000 (assumes 2 ELJs)
1-2	No action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$5,000
2-1	Add key wood pieces as ELJS to avoid wood movement to culvert	Weed control with conifer underplanting.	Maintain sustainable riparian cover for shade; maximize wetland area Design ELJs to encourage hyporheic flow		$60,000 (assumes 2 ELJs)
2-2	No action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$5,000
3-1	Remove RR bridge Expand floodplain Key log placements via helicopter	More intensive revegetation in new stream corridor Weed control with conifer under planting	Maintain sustainable riparian cover for shade;		$485,000 (assumes 1500 CY of floodplain grading, and 20 helicopter logs)
3-2	Remove RR Bridge with limited grading	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$285,000
4-1	Remove Weirs ELJs at weir locations	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area Design ELJs to encourage hyporheic flow		$130,000 (assumes 4 ELJs)
4-2	Remove weirs	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$20,000
5-1	Roughen toe ditch Breach RR berm at two locations to engage tributaries and floodplain low area	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$90,000
5-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$10,000
6-1	Helicopter wood placements	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$58,000 (assumes 20 wood placements)

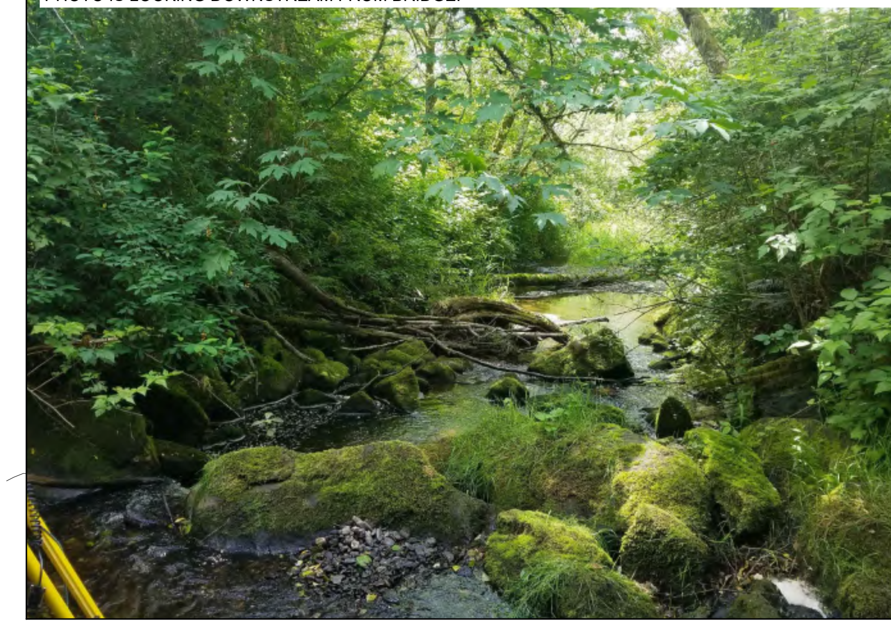
Reach – Alternative	Instream Intervention	Riparian Intervention	Water Quality Intervention	Notes	Cost
6-2	No action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$5,000
7-1	Helicopter wood placements Breach RR berm	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$70,000 (assumes 20 wood placements)
7-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$8,000
8-1	Helicopter wood placements Driveway removal	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$77,000 (assumes 20 wood placements)
8-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$65,000
9-1	Helicopter wood placements Breach RR Berm	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$71,000 (assumes 20 wood placements)
9-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$8,400
10-1	Helicopter wood placements	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$62,000 (assumes 20 wood placements)
10-2	No Action	Weed control with conifer under planting	Maintain sustainable riparian cover for shade; maximize wetland area		$6,300
11-1	Breach RR berm	Focused livestake installations in reed canarygrass dominated areas	Maintain sustainable riparian cover for shade; maximize wetland area		$25,000
11-2	No action	Focused livestake installations in reed canarygrass dominated areas	Maintain sustainable riparian cover for shade; maximize wetland area		$20,000

Primary cost basis assumptions:

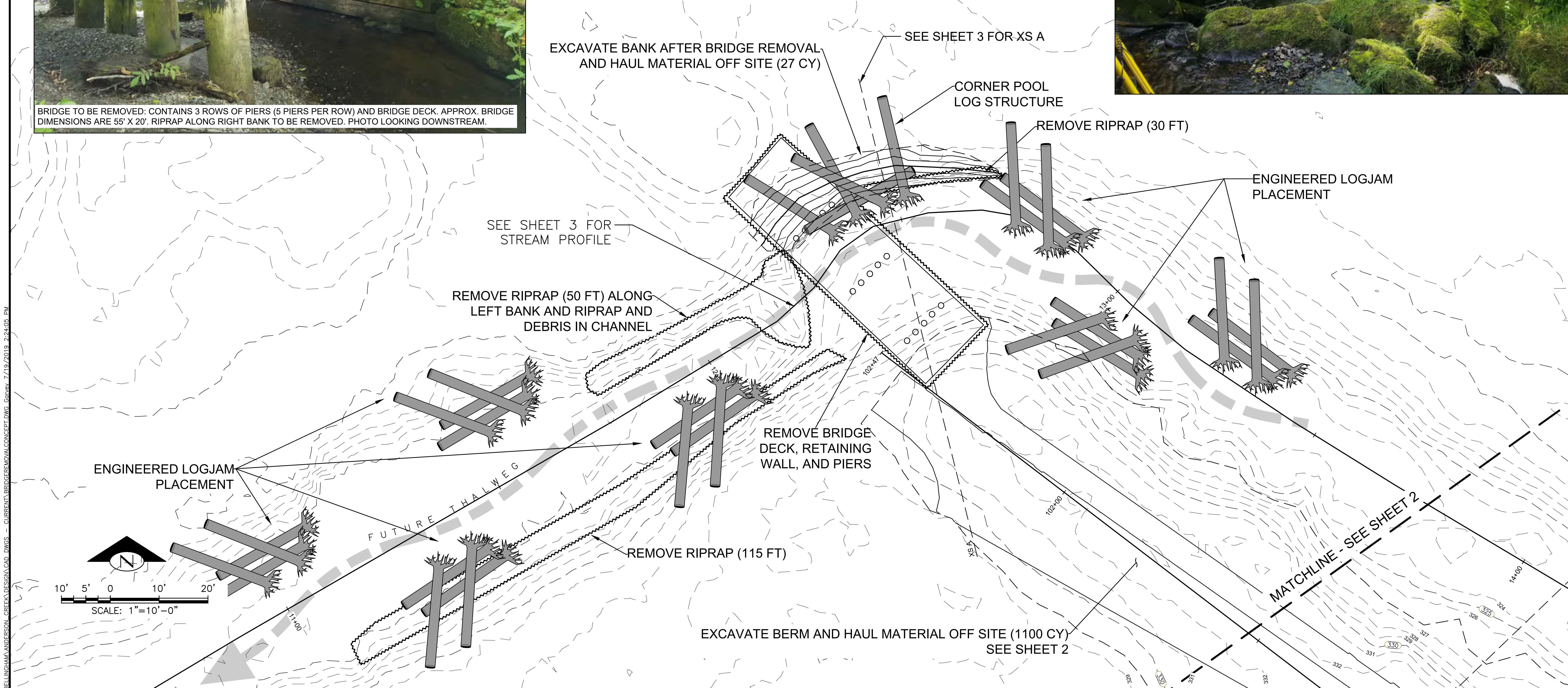
- Rootwad logs = $1,000/ea
- Helicopter log placements based on one day (8 hours) flying time for Vertol aircraft at $7,750/hr
- Grading with disposal at $60/CY
- Engineered log jams/machine placed at $15,000/ea installed
- Forest stand management (includes thinning, weed control, planting) at $42,100/acre
- Planting only at $3,024/acre
- Costs include 30% (planting elements) 50% (civil elements) allowance for indeterminants.

Appendix F: Railroad Bridge Conceptual Restoration Plan

BRIDGE TO BE REMOVED: CONTAINS 3 ROWS OF PIERS (5 PIERS PER ROW) AND BRIDGE DECK. APPROX. BRIDGE DIMENSIONS ARE 55' X 20'. RIPRAP ALONG RIGHT BANK TO BE REMOVED. PHOTO LOOKING DOWNSTREAM.



RIPRAP ON BOTH BANKS AND LARGE ROCK AND DEBRIS IN CENTER OF CHANNEL TO BE REMOVED. PHOTO IS LOOKING DOWNSTREAM FROM BRIDGE.



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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	GD
CHECKED	SW
DRAWN	GD
CHECKED	SW

GEOGRAPHIC INFORMATION	
LATITUDE	48°40'24"N
LONGITUDE	122°15'53"W
TN/SC/RG	T37N/S26/R4E
DATE	7/19/2019

ANDERSON CREEK

BRIDGE REMOVAL

1

SHEET 1 OF 3

Jul 19, 2019 30% DRAWINGS PRELIMINARY

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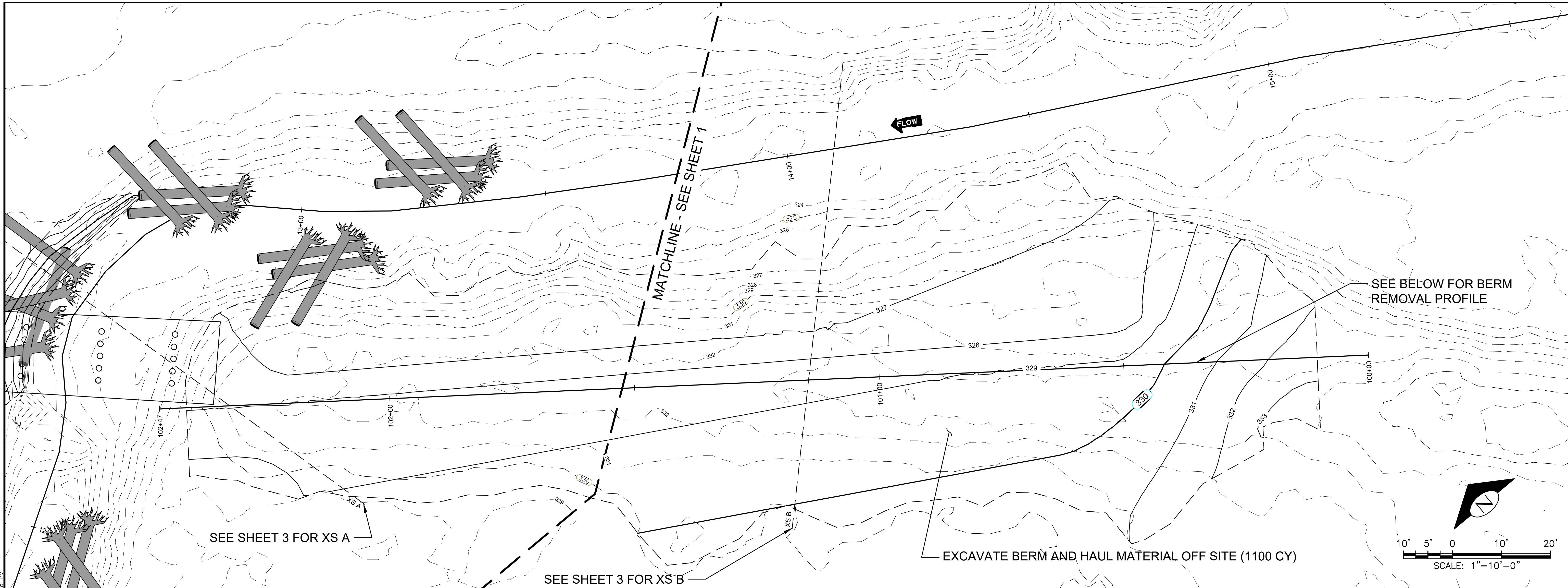

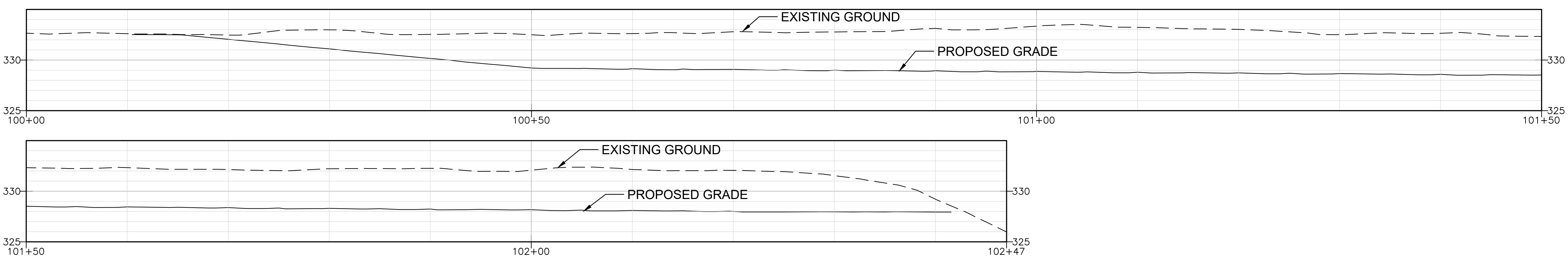

BERM REMOVAL PROFILE

Jul 19, 2019 30% DRAWINGS PRELIMINARY

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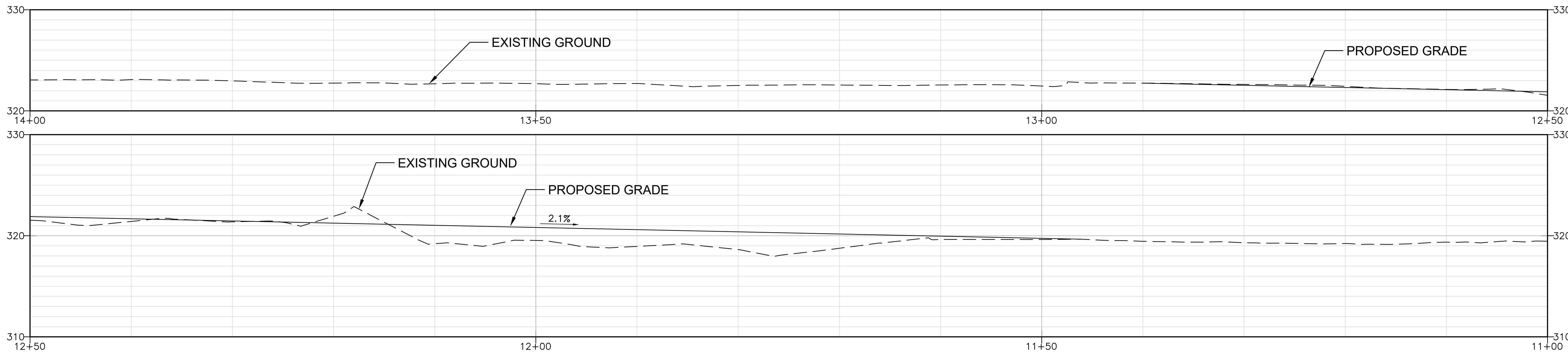
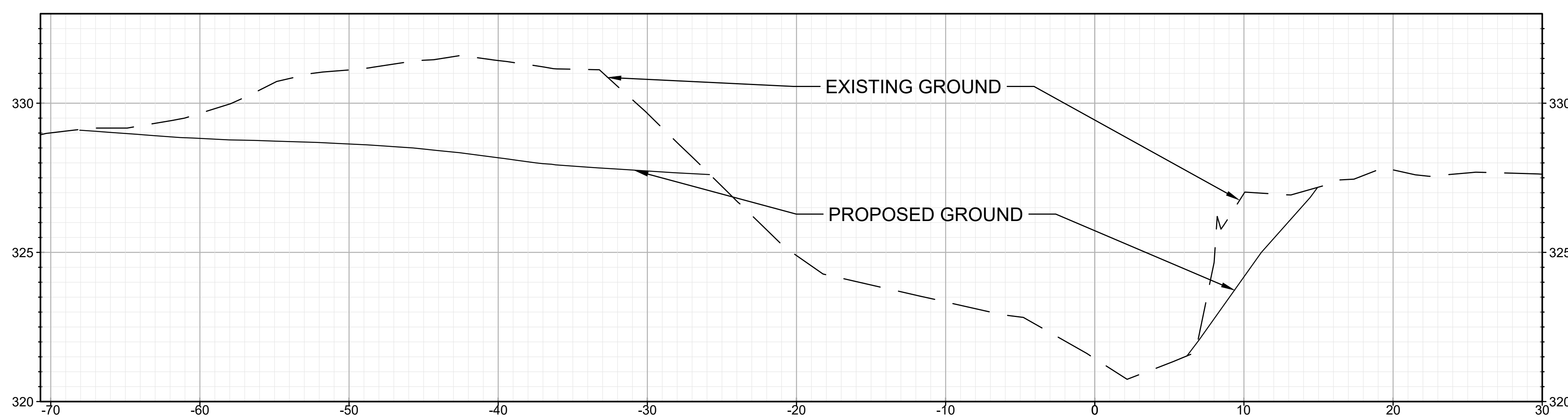
0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.	Natural Systems Design	NAME OR INITIALS AND DATE DESIGNED GD CHECKED SW DRAWN GD CHECKED SW	GEOGRAPHIC INFORMATION LATITUDE 48°40'24"N LONGITUDE 122°15'53"W TN/SC/RG T37N/S26/R4E DATE 7/19/2019	ANDERSON CREEK	BERM REMOVAL

2

SHEET 2 OF 3

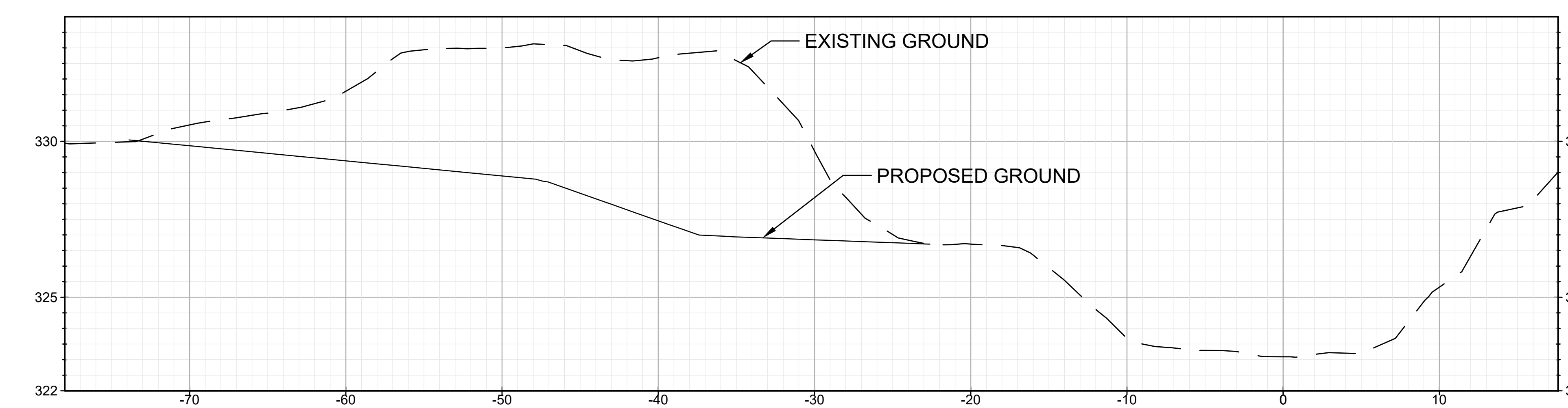


ANDERSON CREEK PROFILE



CROSS SECTION A

10' 5' 0 10' 20'
SCALE: 1"=10'-0"



CROSS SECTION B

0 Ø 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT PLOTTED TO ORIGINAL SCALE.

Natural Systems Design

NAME OR INITIALS AND DATE	
DESIGNED	GD
CHECKED	SW
DRAWN	GD
CHECKED	SW

GEOGRAPHIC INFORMATION	
LATITUDE	48°40'24"N
LONGITUDE	122°15'53"W
TN/SC/RG	T37N/S26/R4E
DATE	7/19/2019

ANDERSON CREEK

DETAILS, PROFILE, CROSS SECTION

3

SHEET 3 OF 3

Jul 19, 2019 30% DRAWINGS PRELIMINARY

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